SHARKFEST '12

Wireshark Developer and User Conference

IPv6 Addressing

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Agenda

- IPv6 addressing models and types
  - unicast,
  - multicast,
  - anycast,
  - global,
  - site local,
  - link local,
  - IPv4 mapped IPv6

Let's Look at Some Addresses

What is this?

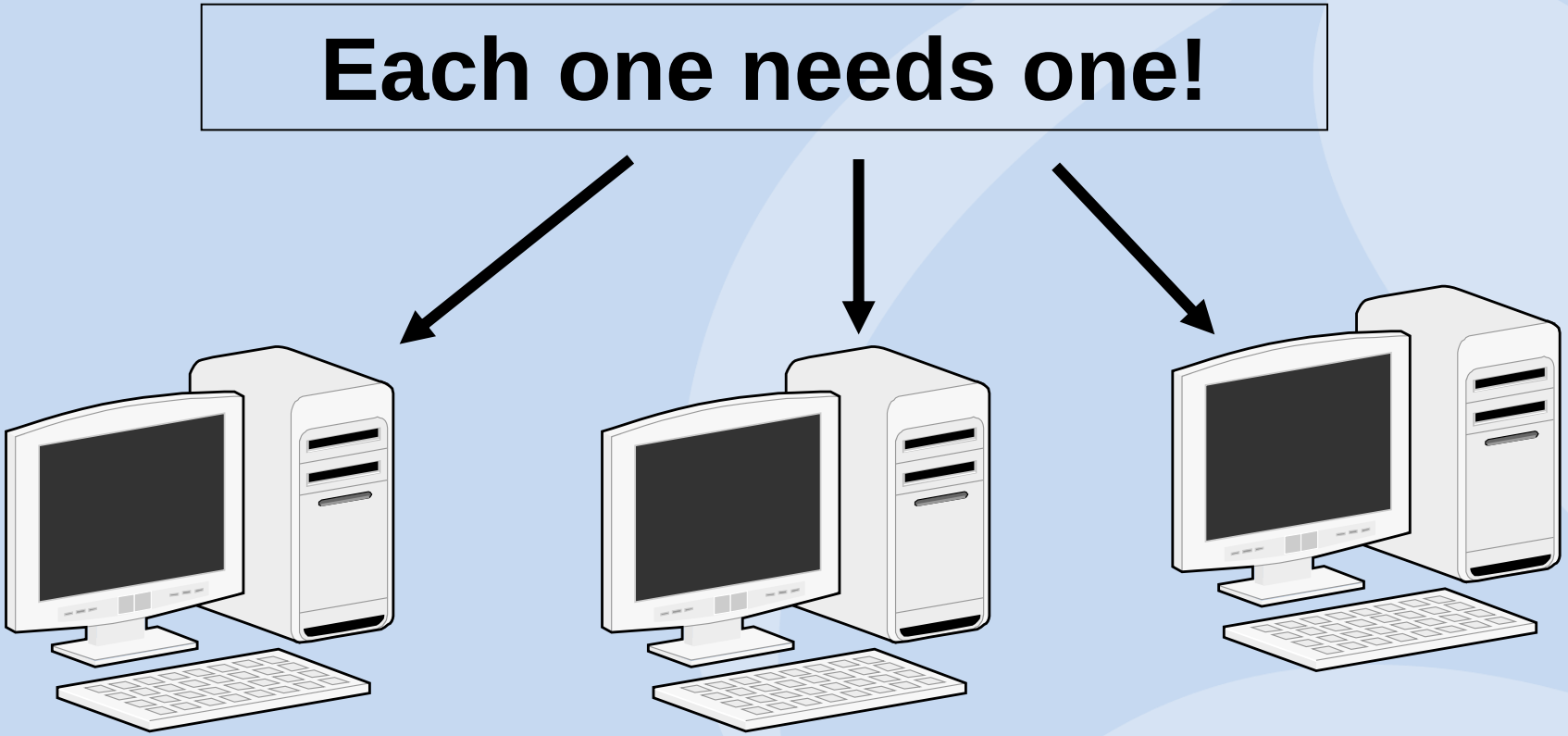
2601 Warring Street
Berkeley, CA

What if you had to change it to:

XX78:&5;; B78gu E#S

CVTY, MB

Network Addresses



What is this?

192.168.1.1

What is this?

192.168.1.1

- IPv4
- Private

What is this?

10.12.15.201

What is this?

10.12.15.201

- IPv4
- Private

What is this?

201.23.5.104

What is this?

201.23.5.104

- IPv4
- Public

Private vs. Public

Public: 2601 Warring Street
Berkeley, CA

Private: P.O. Box 2345,
Berkeley, CA

What is this?

FE80:1234::1

What is this?

2001::2:ABC:123

What is this?

FF01::2

IPv6 Address Basics

- 128 bits
- Can be zero compressed
- Prefixes are important

IPv6 Address Representation

- Addresses are shown as 8 sections of 4 hex digits (16 bits) separated by colons
  - 11:22:33:44:55:66:77:88

- For example:

  2001:DB8:1:0::2

  FE80:208:345:78:123:333::3

  2620:345:123:FACE:B00C::3

IPv6 Prefix

- The prefix length (in bits) can be indicated after a slash at the end. For example:
  - 2001:122:0:0:55:66:77:88 /64
  - The prefix above is:
    - 2001:122:0:0
  - A prefix alone is represented as if the interface ID bits are all zero. For example:
    - 2620:333:ABCD:D0D /64

Important IPv6 Prefix Notations

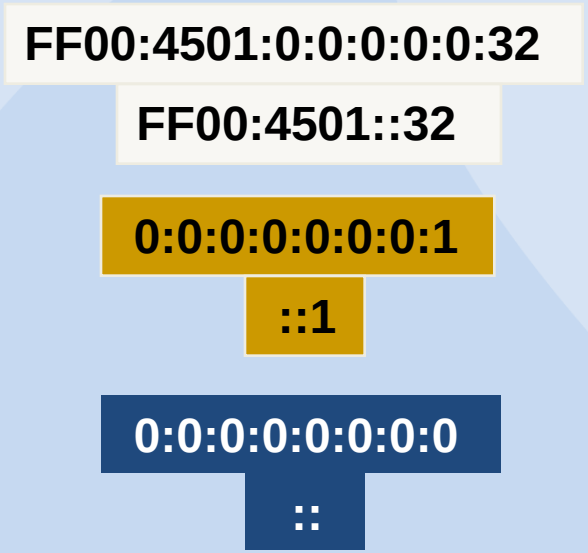
/8	11111111xxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	00xx:: FFxx::
/16	1111111111111111.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:: 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::

Zero Compression

- An IPv6 address can be zero compressed (saves room!)
- A section of zeros can be replaced by a :: (double colon).
- The double-colon can appear only once in any IP address, because if it appeared more than once we could not tell how many zeroes were replaced in each instance.
- So, if our example address were 805B:2D9D:DC28:0:0:FC57:0:0, we could replace either the first pair of zeroes or the second, but not both.

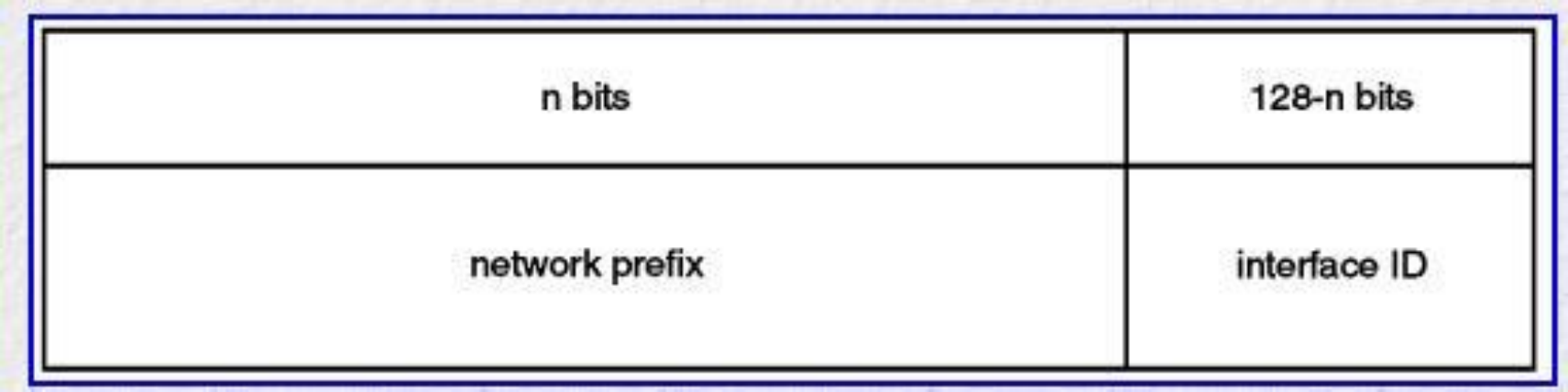
Special Addresses

- Zero compression doesn't make our example much shorter, but due to how IPv6 addresses are structured, long strings of zeroes are common.
- It works even better on special addresses. One special address is: 0:0:0:0:0:0:0:1. With compression, this is simply ::1
- Consider the IPv6 address: 0:0:0:0:0:0:0:0. Apply zero compression to an address that is all zeroes, and what do you get? ::



IPv6 Unicast Address

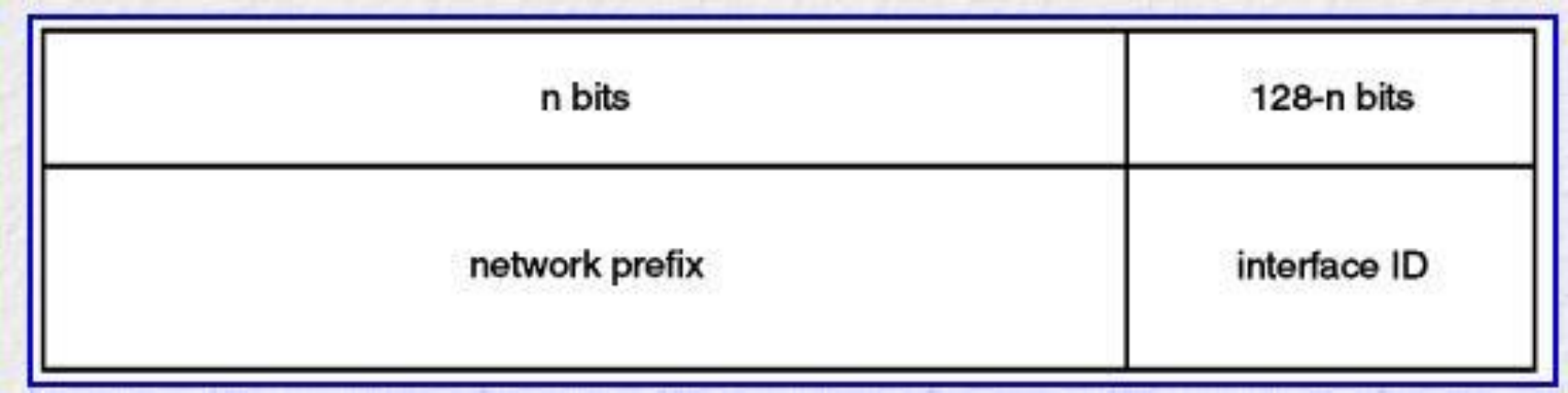
- This is the address for a specific interface.
- A unicast address has the following format:



There are several types of unicast addresses in IPv6:
- global unicast,
- site-local unicast, and
- link-local unicast.

Unicast Address Interface ID

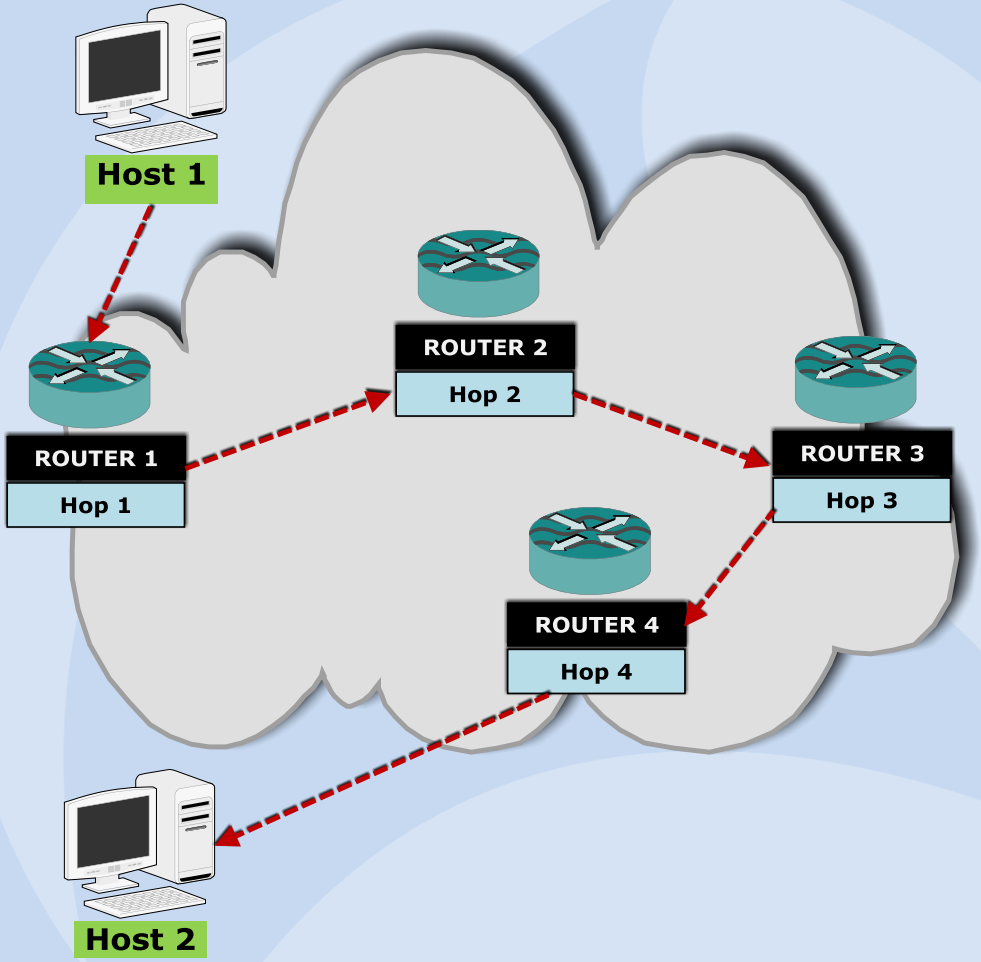
- Interface identifiers in a IPv6 unicast address are used to identify the interfaces on a link.
- Interface identifiers are required to be unique on that link.
- The link is generally identified by the subnet prefix.



IID is derived from IEEE identifier (for example: MAC address)

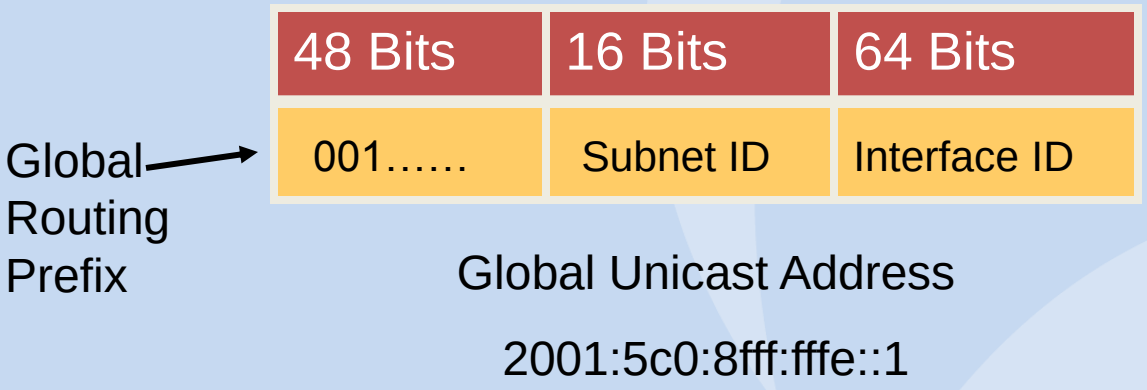
IPv6 Global Unicast Address

- The IPv6 global unicast address is the equivalent of the IPv4 global unicast address.
- Global unicast addresses are supposed to be used in a hierarchy.
- This should limit the number of routing table entries in the global routing table.



IPv6 Global Unicast Address

- The global unicast address typically consists of a 48-bit global routing prefix and a 16-bit subnet ID
- The current global unicast address allocation uses the range of addresses that start with binary value 001 (2000::/3). This is subject to change.
- 2000::/3 is the global unicast address range and uses one-eighth of the total IPv6 address space. It is the largest block of assigned block addresses



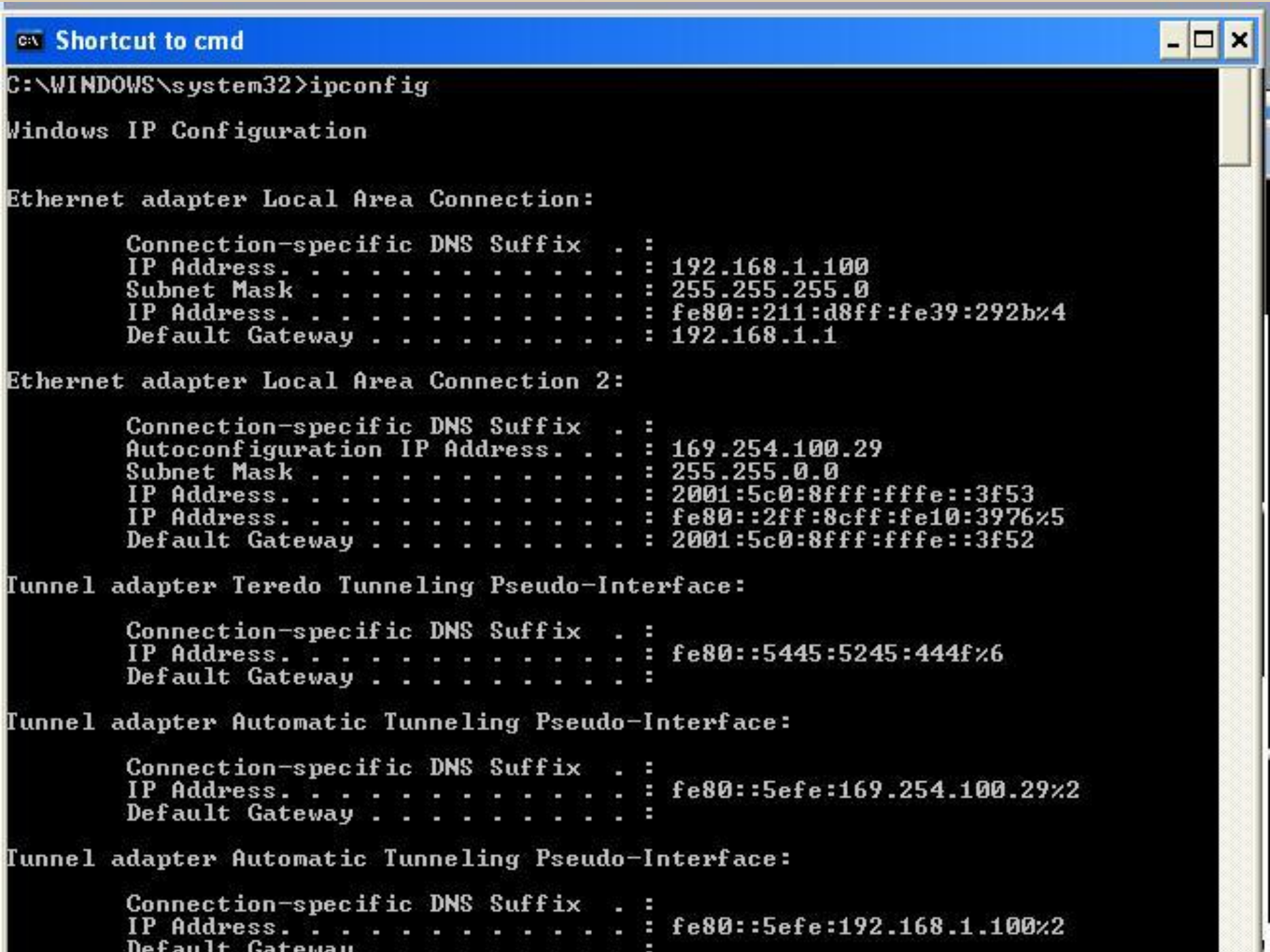
The 16-bit subnet ID can be used to create a local addressing hierarchy and to identify subnets. This field allows an organization to use up to 65,535 individual subnets.

Interface Identifier

- The 64-bit interface identifier in an IPv6 address is used to identify a unique interface on a link.
- In many cases, an interface identifier will be the same as or based on the link-layer (MAC) address of an interface.
- Interface identifiers used in global unicast and other IPv6 address types must be 64 bits long and constructed in the EUI-64 format.
- The EUI-64 format interface ID is derived from the 48-bit link-layer (MAC) address by inserting the hex number FFFE between the upper three bytes (OUI field) and the lower 3 bytes (serial number) of the link layer address.

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


Shortcut to cmd
C:\WINDOWS\system32>ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
Connection-specific DNS Suffix . :
IP Address. . . . . : 192.168.1.100
Subnet Mask . . . . . : 255.255.255.0
IP Address. . . . . : fe80::211:d8ff:fe39:292b%4
Default Gateway . . . . . : 192.168.1.1
Ethernet adapter Local Area Connection 2:
Connection-specific DNS Suffix . :
Autoconfiguration IP Address. . . : 169.254.100.29
Subnet Mask . . . . . : 255.255.0.0
IP Address. . . . . : 2001:5c0:8fff:fffe::3f53
IP Address. . . . . : fe80::2ff:8cff:fe10:3976%5
Default Gateway . . . . . : 2001:5c0:8fff:fffe::3f52
Tunnel adapter Teredo Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5445:5245:444f%6
Default Gateway . . . . . :
Tunnel adapter Automatic Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5efe:169.254.100.29%2
Default Gateway . . . . . :
Tunnel adapter Automatic Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5efe:192.168.1.100%2

IPv6 Prefix Importance

- IPv4 Address : 32 bits
- IPv6 address : 128 bits

- To start getting familiar with IPv6 addresses, look at what they start with.

- This will tell you what kind of an address it is.
  - Can you go out on the internet with it,
  - Can you talk to other devices with it,
  - Is it “special”, etc.

FE80 = Link Local

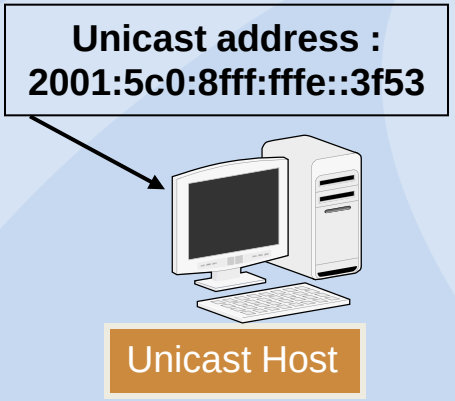
FF02 = Multicast

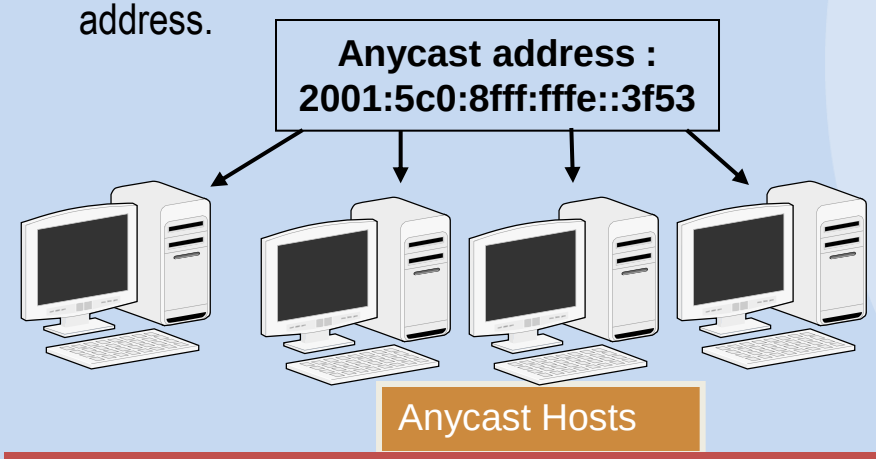
2001 = Global Unicast

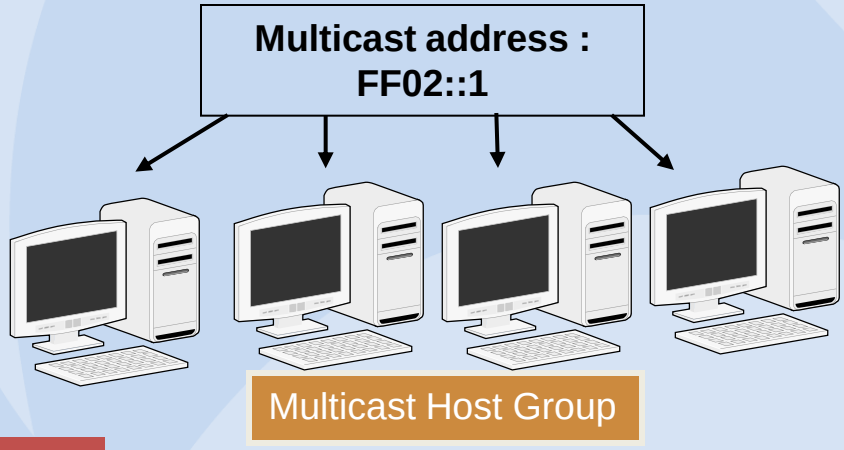
0000 = Special

IPv6 Address Types

- Unicast: An address for a single interface. A packet sent to a unicast address is delivered to the interface identified by that address.
- Anycast: An address for a set of interfaces. A packet sent to an anycast address is delivered to one of these interfaces identified by the address. Many implementations do not support Anycast.
- Multicast: An address for a set of interfaces (typically belonging to different nodes). A packet sent to a multicast address will be delivered to all interfaces identified by that address.



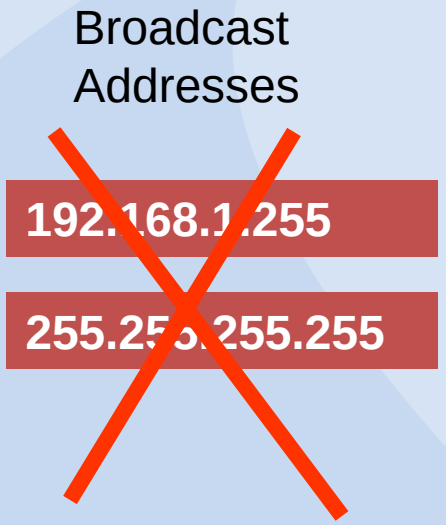




Anycast addresses appear the same as unicast addresses

More Addressing Changes

- Broadcast addressing does not exist in IPv6.
- Broadcast functionality is implemented using multicast addressing to groups of devices. A multicast group to which all nodes belong can be used for broadcasting in a network, for example.
- This changes everything!
- The way that address planning is done in IPv4 can no longer be done!!!
- In IPv4, we designed subnets by having the first address in the range as a network address and the last as the broadcast. No more!



IPv6 Special Unicast Addresses

- Just as in IPv4, a small part of the IPv6 address space is set aside for special addresses.
- There are four basic types of "special" IPv6 addresses:
  - Reserved,
  - Unspecified,
  - Loopback and
  - Private

IPv6 Reserved Unicast Addresses

- A portion of the address space is set aside as reserved for various uses by the IETF, both present and future.
- Unlike IPv4, which has many small reserved blocks in various locations in the address space, in IPv6 the reserved block is at the “top” of the address space: the ones starting with “0000 0000” (or 00 for the first hexadecimal octet).
- This represents 1/256th of the total address space.
- Some of the other special addresses below come from this block.
- IPv4 address embedding is also done within this reserved address area.

0000 = Reserved

IPv4 Addresses in IPv6

- The IPv6 transition mechanisms use a technique for tunneling IPv6 packets over the existing IPv4 infrastructure.
- IPv6 nodes that support such mechanisms use a special kind of IPv6 addresses that carry IPv4 addresses in their lower order 32-bits.
- These addresses are called IPv4 Compatible IPv6 addresses.
- This is deprecated!

0000 = Reserved

80 Bits	16 Bits	32 Bits
zeroes	zeroes	IPv4 Address

IPv4 Compatible IPv6 Address

::192.168.0.1

- There is a special type of IPv6 address that holds an embedded IPv4 address.
- This address is used to represent the addresses of IPv4-only nodes as IPv6 addresses.
- These addresses are used especially by applications that support both IPv6 and IPv4.
- These addresses are called IPv4 Mapped IPv6 Addresses.

0000 = Reserved

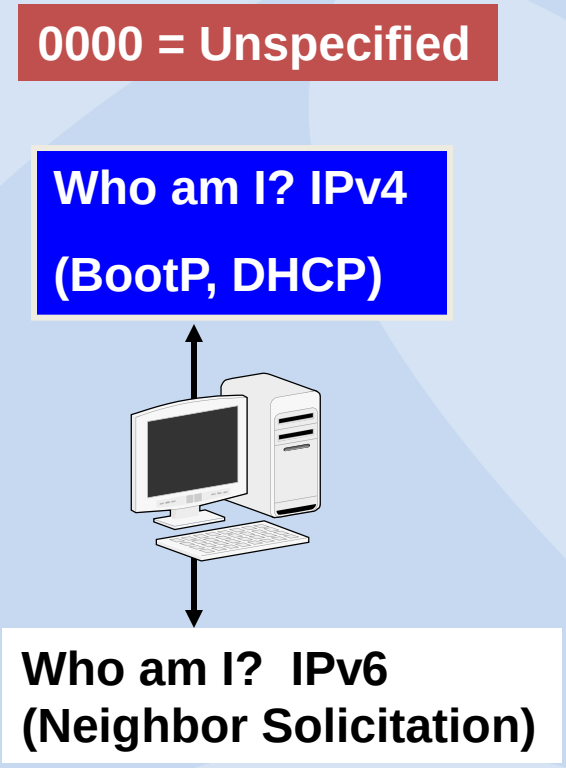
80 Bits	16 Bits	32 Bits
zeroes	FFFF	IPv4 Address

IPv4 Embedded IPv6 Address

::ffff:192.168.0.1

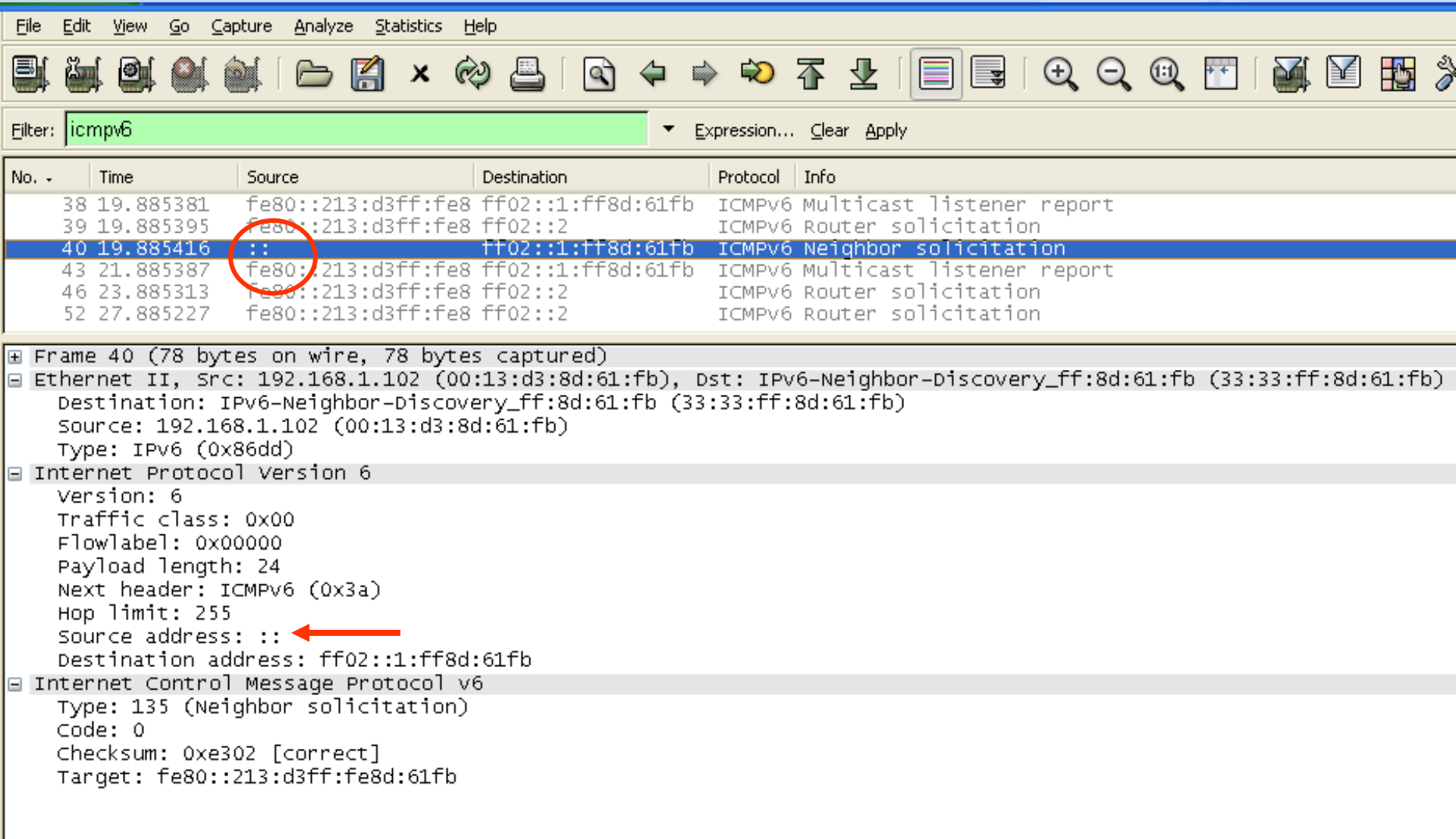
IPv6 Unspecified Address

- In IPv4, an IP address of all zeroes has a special meaning - it refers to the host itself, and is used when a device doesn't know its own address.
- In IPv6 this concept has been formalized, and the all-zeroes address (0:0:0:0:0:0:0:0) is named the *unspecified address*.
- It is typically used in the source field of a datagram sent by a device seeking to have its IP address configured.
- A unicast address is called an unspecified address if all the bits in the address are zero. Textually it is represented as "::".



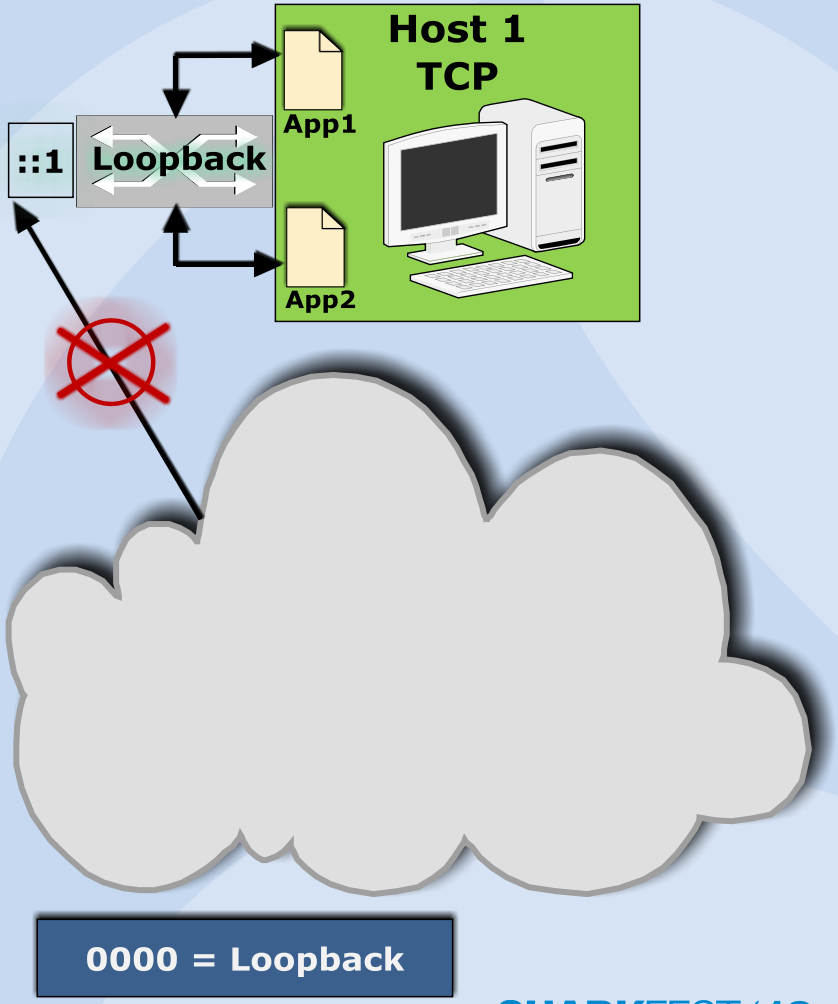
```
164 ADCD     PACKET   00000004 08:14:04.416323 Packet Trace
  From Interface    : ETH1              Device: LCS Ethernet     Full=342
   Tod Clock        : 2006/01/06 08:14:04.416317                 Intfx: 4
   Sequence #       : 0                 Flags: Pkt
  IpHeader: Version : 4                 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     : 638253633501033D07010013D38D61FB3204C0A801650C0C42617272792D636
    Vendor Info     : 6D706171511000000042617272792D636F6D7061712E3C084D53465420352E3
     DHCPMSG        : DhcpREQUEST
     CLIENTID       : 7 010013D38D61FB
     REQIPADDR      : 192.168.1.101
```

IPv6 Neighbor Solicitation



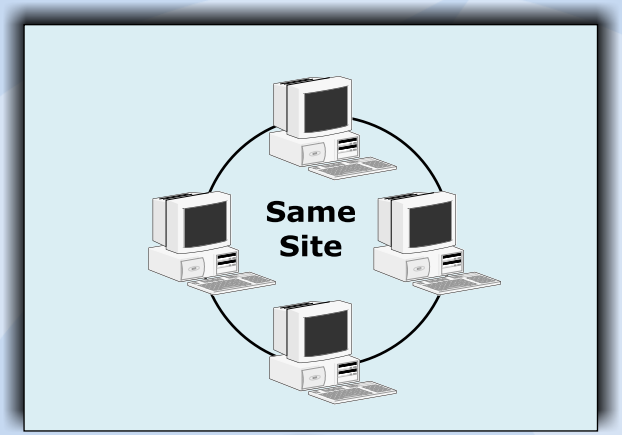
Loopback Address

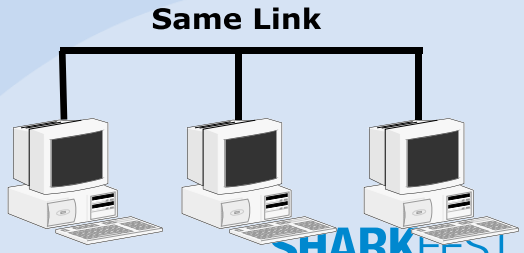
- The loopback address is a reserved address.
- The address 0:0:0:0:0:0:0:1 is called the loopback address. It cannot be assigned to any physical interface. It allows local applications to send messages to each other.
- The loopback address cannot be used as the source address in IPv6 packets that are sent outside of a node. An IPv6 packet with a destination address of loopback cannot be sent outside of a node and be forwarded by an IPv6 router.
- A packet received on an interface with destination address of loopback will be dropped.



IPv6 Private Addresses

- A block of addresses is set aside for private addresses, just as in IPv4.
- These private addresses are local only to a particular link or site and are therefore never routed outside a particular company's network.
- Private addresses are indicated by the address having "1111 1110 1" for the first nine bits.
- So, private addresses have a first octet value of “FE” in hexadecimal, with the next hex digit being from “8” to “F”.
- These addresses are further divided into two types based on their scope, described next.



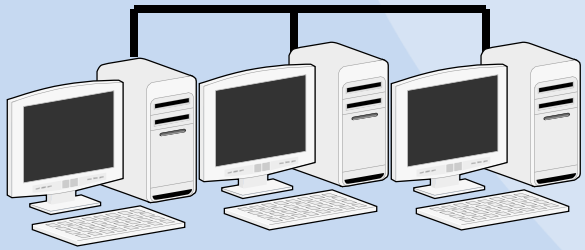


FE8n – FEFn = Private Addresses

Link Local Address

- A link-local unicast address is an IPv6 unicast address that is automatically configured on an IPv6 node interface by using the link-local prefix FE80::/10 (1111 1110 11) and the interface ID in the EUI-64 format.
- Link-local addresses are used in the neighbor discovery protocol and the stateless autoconfiguration process.
- Link-local addresses are typically used to connect devices on the same local link network without the need for global addresses. Hence, link-local addresses are useful only in the context of the local link network.

Who am I? IPv6 (Neighbor Solicitation)



FE8n - FEBn = Link Local

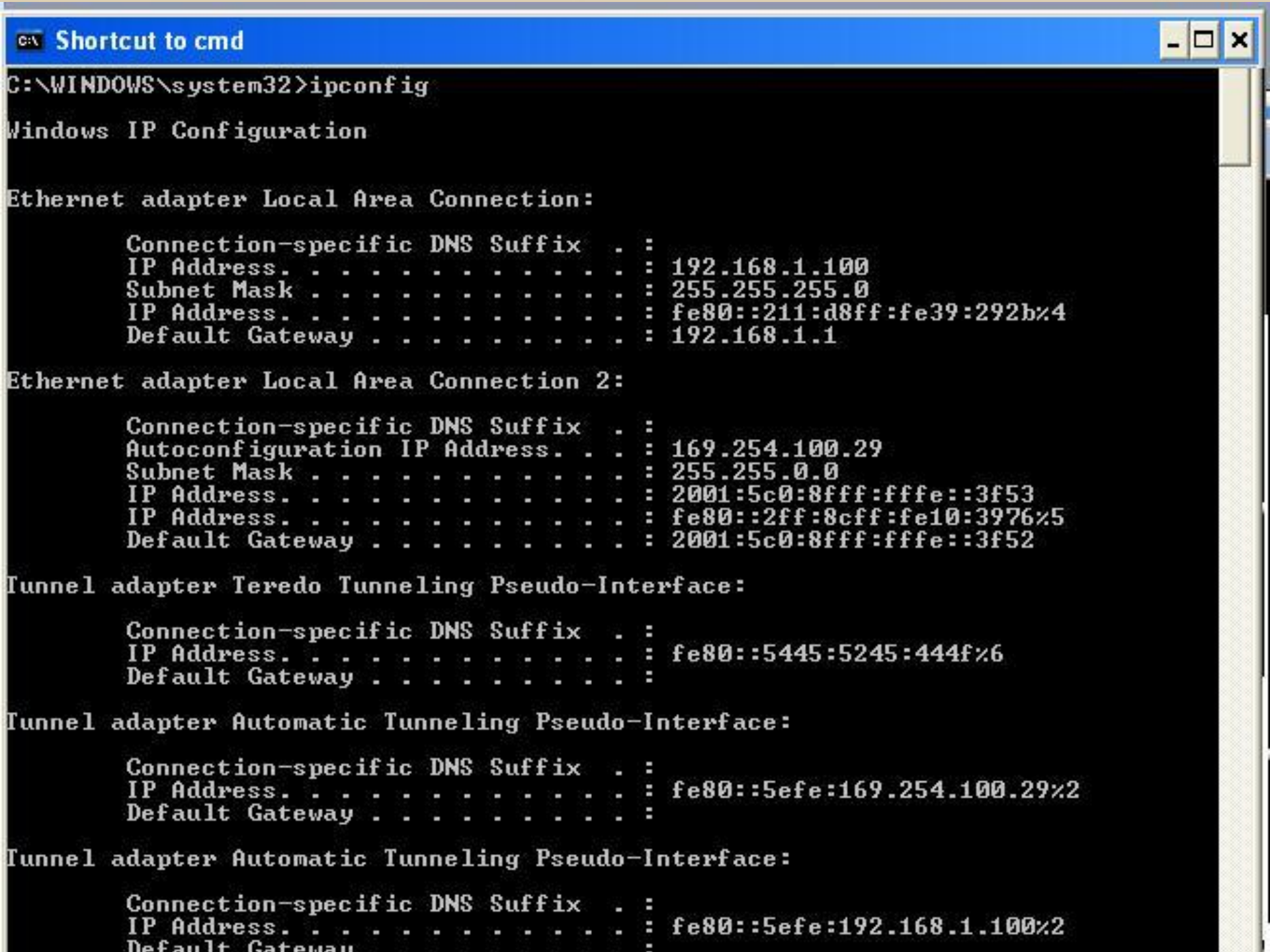
Link Local Address

- Nodes on a local link can use link-local addresses to communicate with each other without the need for a router.
- IPv6 nodes do not need site-local or globally unique addresses to communicate.
- IPv6 routers must not forward to other links packets that have link-local source or destination addresses.
- FE80::/10 is the link-local unicast address range and uses 1/1024 of the IPv6 address space.
- Let's look again at the Link Local addresses generated on the Windows PC.

10 Bits	54 Bits	64 Bits
1111111010	zeroes	Interface ID

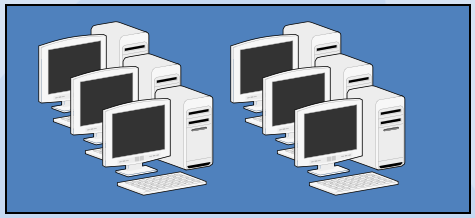
Sample Link Local Address

Fe80:211:d8ff:fe39:292b


Shortcut to cmd
C:\WINDOWS\system32>ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
Connection-specific DNS Suffix . :
IP Address. . . . . : 192.168.1.100
Subnet Mask . . . . . : 255.255.255.0
IP Address. . . . . : fe80::211:d8ff:fe39:292b%4
Default Gateway . . . . . : 192.168.1.1
Ethernet adapter Local Area Connection 2:
Connection-specific DNS Suffix . :
Autoconfiguration IP Address. . . : 169.254.100.29
Subnet Mask . . . . . : 255.255.0.0
IP Address. . . . . : 2001:5c0:8fff:fffe::3f53
IP Address. . . . . : fe80::2ff:8cff:fe10:3976%5
Default Gateway . . . . . : 2001:5c0:8fff:fffe::3f52
Tunnel adapter Teredo Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5445:5245:444f%6
Default Gateway . . . . . :
Tunnel adapter Automatic Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5efe:169.254.100.29%2
Default Gateway . . . . . :
Tunnel adapter Automatic Tunneling Pseudo-Interface:
Connection-specific DNS Suffix . :
IP Address. . . . . : fe80::5efe:192.168.1.100%2

Site Local Addresses

- Site-local unicast addresses are similar to the private addresses such as 10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16 used in IPv4 networks.
- Routers will not forward any packet with site-local source or destination address outside the site.
- **Site local unicast addresses are deprecated within IPv6(RFC 3879)**
- Site scope multi-cast still available



FECn - FEFn = Site Local

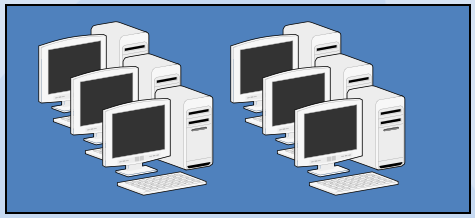
IPv6 Address Space Allocations

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]




DeFacto Site Local Unicast Addresses

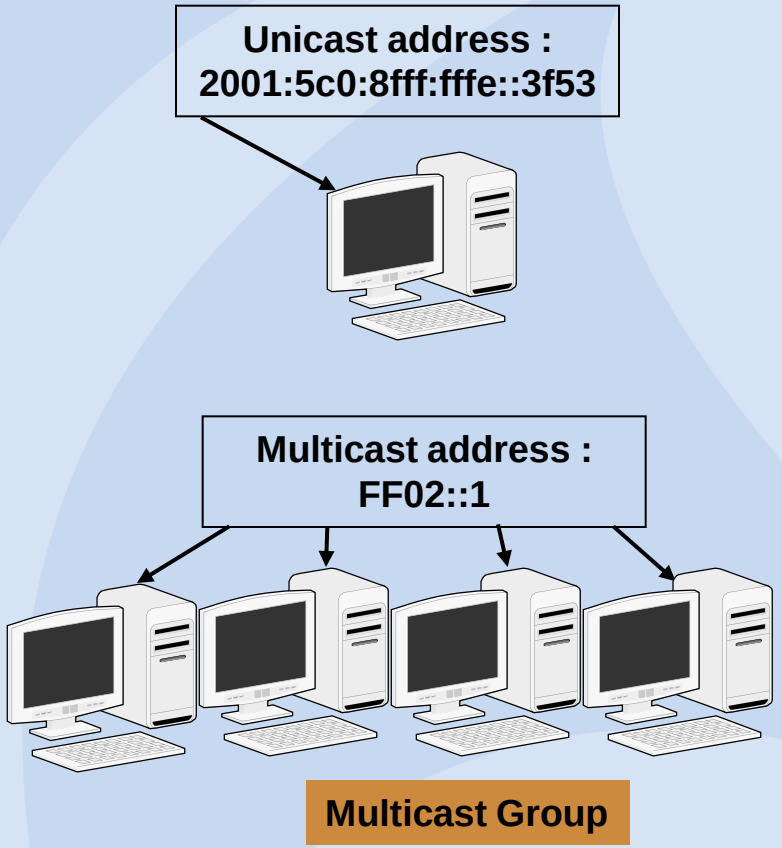
- **Site local unicast addresses are deprecated within IPv6(RFC 3879)**
- ULA (Unique Local Unicast) addresses are being used as site-local.
- Large address space but conflicts?



FC00:: /7 = ULA

IPv6 Multicast

- What is multicasting?
  - Multicast traffic is sent to a single address but is processed by multiple hosts.
  - Multicasting is similar to a newsletter subscription. As only subscribers receive the newsletter when it is published, only host computers that belong to the multicast group receive and process traffic sent to the multicast group's address.
  - The set of hosts using a specific multicast address is called a multicast group.



- In IPv4, Multicast uses:
  - Class D IP address: (224.xx.xx.xx – 239.xx.xx.xx)

IPv6 Multicast Addressing

IPv6 multicast addresses are reserved and assigned from the Format Prefix 1111 1111 (0xFF). The following is a partial list of IPv6 multicast addresses that are reserved for IPv6 multicasting and registered with the Internet Assigned Numbers Authority (IANA). The address shown below are multicast for the same link.

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

Summary

IPv6 is much more than a larger address!

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