

IPv6 Addressing

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Inside Products, Inc.

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Session Number 12151

Our SHARE Sessions – San Francisco



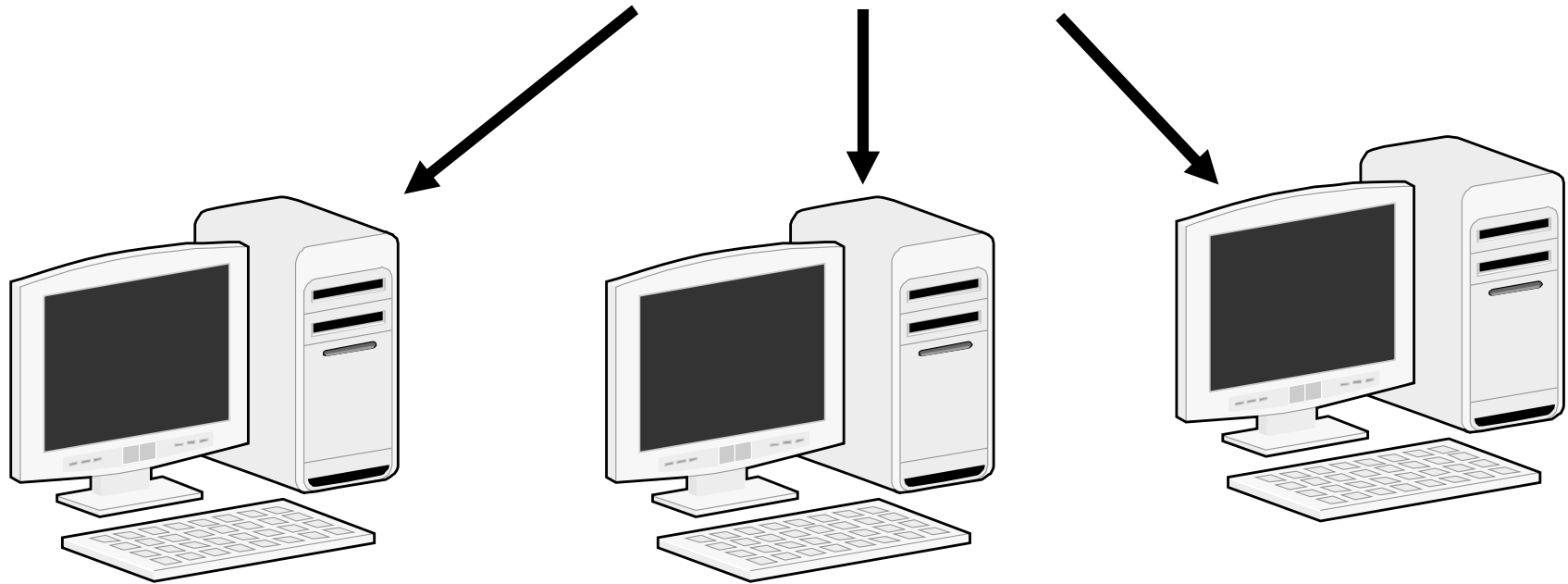
- 12151: IPv6 Addressing
Tuesday, February 5, 2013: 3:00 PM-4:00 PM
- 12947: IPv6 Security Implications for System Z
Thursday, February 7, 2013: 12:15 PM-1:15 PM
- 12886: Getting Started with IPv6 at DTCC
Thursday, February 7, 2013: 3:00 PM-4:00 PM

Agenda

- 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, statefull)
- Address types, unicast, multicast, anycast
- Address categories: global, site local, link local
- Unique Local Unicast addresses
- Zero compression
- Special addresses (loopback, unspecified, IPv4 mapped IPv6)
- Broadcast address elimination

Network Addresses

Each one needs one!



Let's Look at Some Addresses



What is this?

1600 Pennsylvania Ave
NW Washington, DC 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

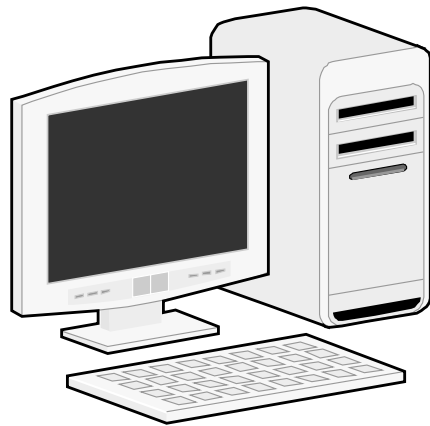
FE80 : 1234 : : 1

FF01 : : 2

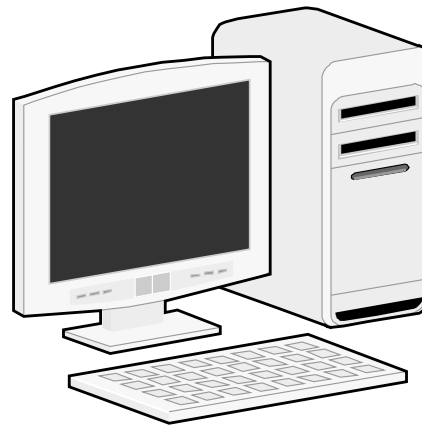
::

TCP/IP Network

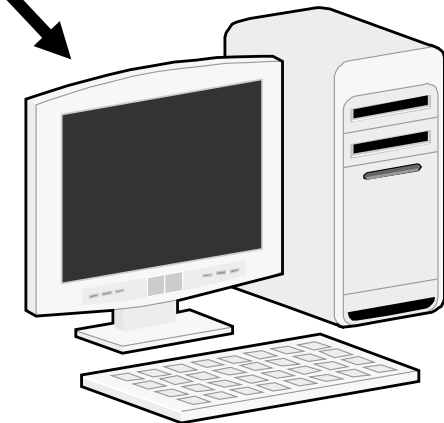
Addresses



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

Private vs. Public Addresses



Public: 1600 Pennsylvania
Ave NW, Washington, DC
20500

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

Sample Private Addresses



192.168.1.1

FE80:1234::1

- IPv4
- Private

- IPv6
- Private

Sample Public Addresses



201.23.5.104

2001::2:ABC:123

- IPv4
- Public

- IPv6
- Public

Addressing Notations

- Decimal notation (IPv4)
 - 1.2.3.4
- Hexadecimal notation (IPv6)
 - 00 - FF
- Binary
 - 1 byte = 8 bits

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

/8

```
11111111xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

00xx::
FFxx::



/16

```
11111111111111111111xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

0000::
FFFF::

Important IPv6
Prefix Notations

/32

```
11111111111111111111.1111111111111111.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

0000:0000::
FFFF:FFFF::

/48

```
11111111111111111111.1111111111111111.
11111111111111111111.1111111111111111.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

0000:0000:0000::
FFFF:FFFF:FFFF::

/56

```
11111111111111111111.1111111111111111.
11111111111111111111.1111111111111111.
11111111111111111111.1111111111111111.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

0000:0000:0000:00xx::
FFFF:FFFF:FFFF:FFxx::

/64

```
11111111111111111111.1111111111111111.
11111111111111111111.1111111111111111.
11111111111111111111.1111111111111111.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.
```

0000:0000:0000:0000::
FFFF:FFFF:FFFF:FFFF::



Zero Compression

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

205B:2D9D:DC28:0:0:FC57:0:0



205B:2D9D:DC28::FC57:0:0

or

205B:2D9D:DC28:0:0:FC57::

FF00:4501:0:0:0:0:0:32

FF00:4501::32

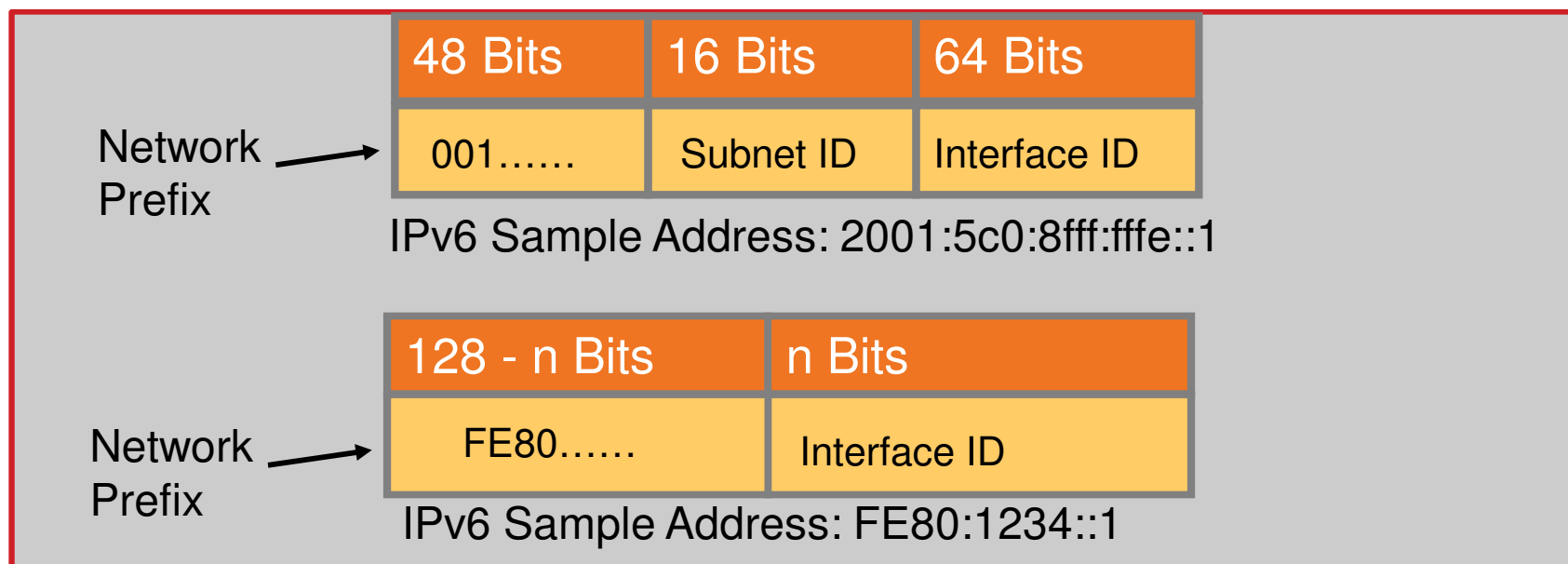
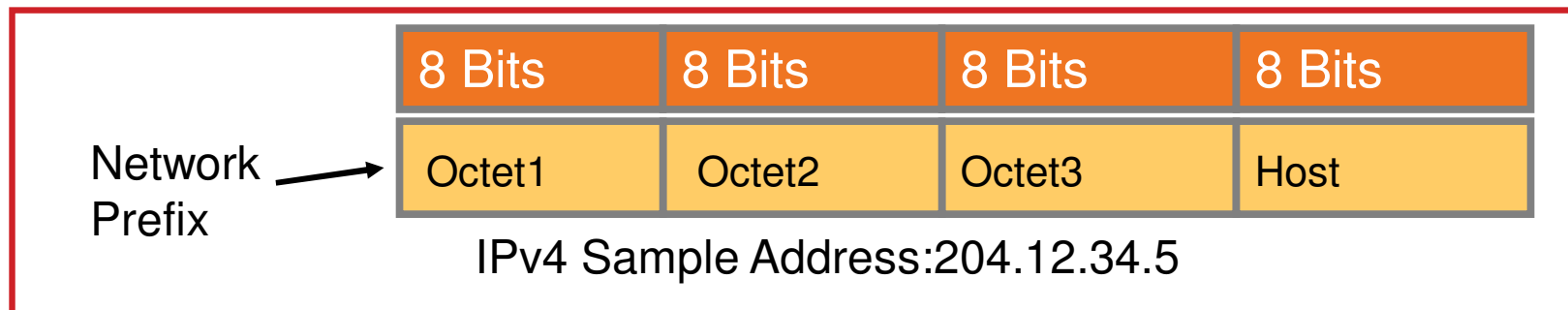
0:0:0:0:0:0:0:1

::1

0:0:0:0:0:0:0:0

::

IPv4 / IPv6 Address Structure



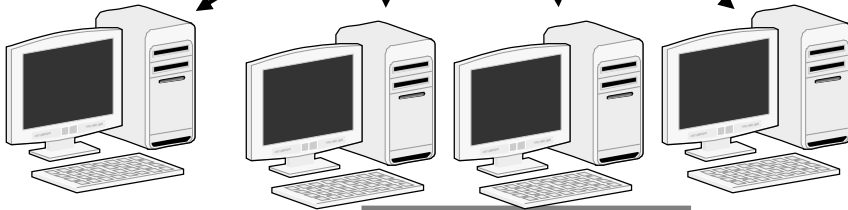
IPv6 Address Types

Unicast address:
2001:5c0:8fff:ffe::3f53



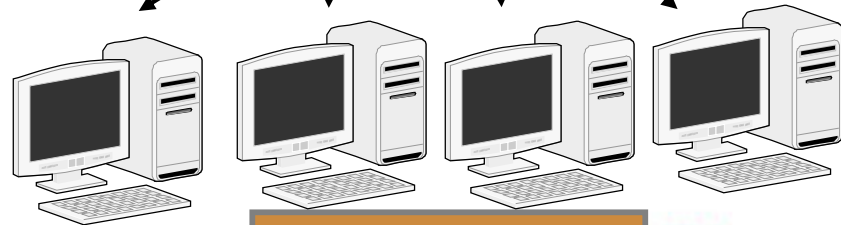
Unicast Host

Anycast address:
2001:5c0:8fff:ffe::3f53



Anycast Hosts

Multicast address:
ff02::1



Multicast Host Group

Anycast addresses appear the same as unicast addresses

Addressing Changes



- No broadcast addressing
- Uses IPv6 multicast addressing
- IPv6 address planning is different from IPv4
- IPv4 and IPv6 subnet structure is different

IPv4
Broadcast
Addresses

~~192.168.1.255~~
~~255.255.255.255~~

Importance of IPv6 Network Prefix

- First part of network prefix important!
- Example: **2001:5c0:8fff:0003::3f53**
- Learn:
 - Can you go out on the internet with it,
 - What devices can you talk to,
 - Is it for special function.

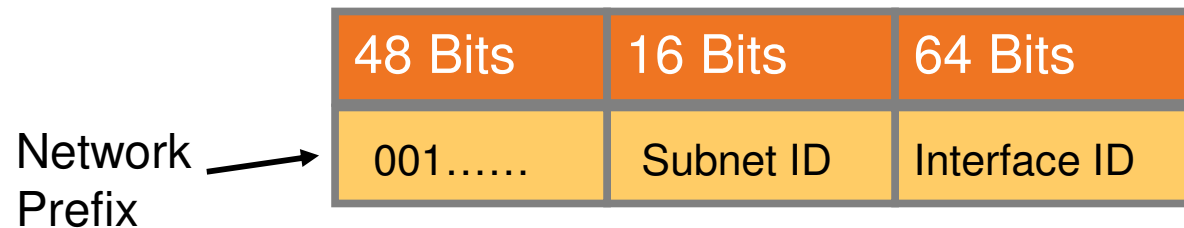
FE80 = Link Local

FFxx = Multicast

2001 = Global Unicast

0000 = Special

Types of Unicast Addresses



Global Unicast Address

2001:5c0:8fff:0003::3f53

Types of IPv6 unicast addresses:

- global unicast,
- link-local unicast, and
- site-local unicast.

IPv6 Global Unicast Address



- Global unicast address: 48-bit network prefix, 16-bit subnet ID, 64 bit interface ID
- Router interface: 64 bits
- Current global unicast address allocation: 2000::/3 (binary 001)

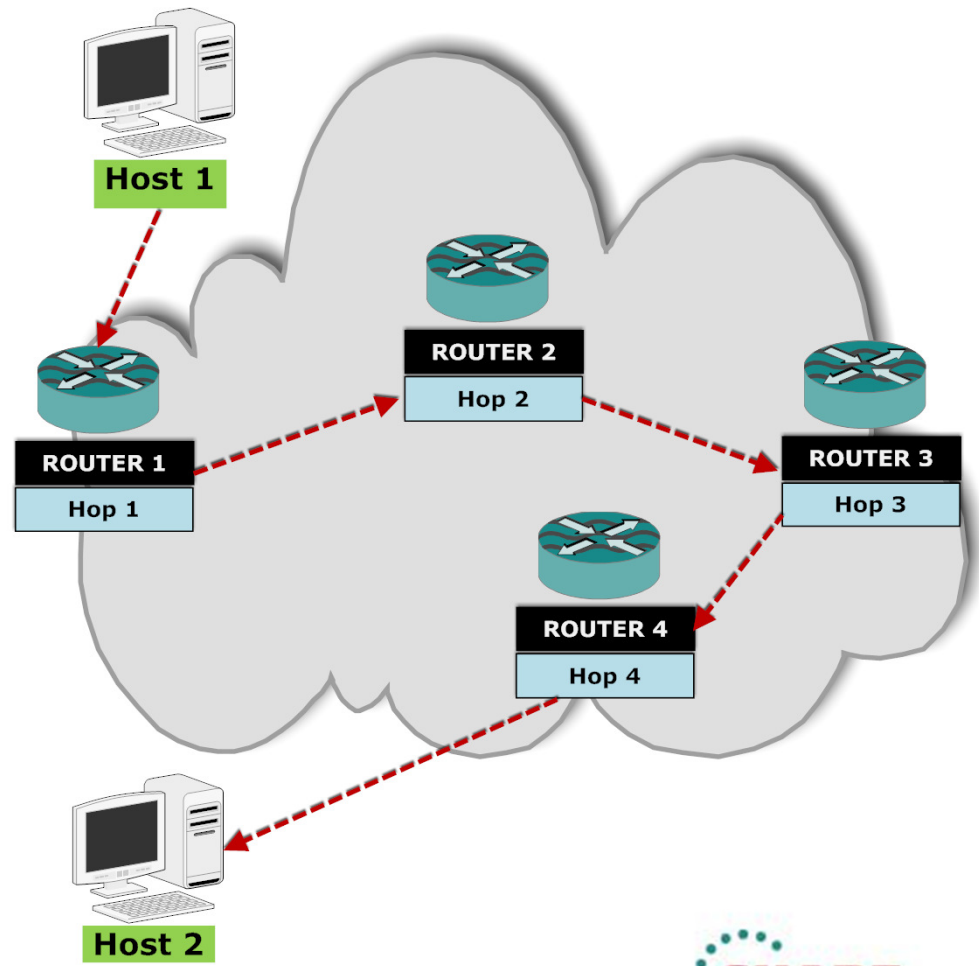


Global Unicast Address

2001:5c0:8fff:0003::1

IPv6 Global Unicast Address

- IPv6 global unicast address= IPv4 global unicast address
- Plan network in hierarchy
- Limit routing table entries



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 . . . . . :
```

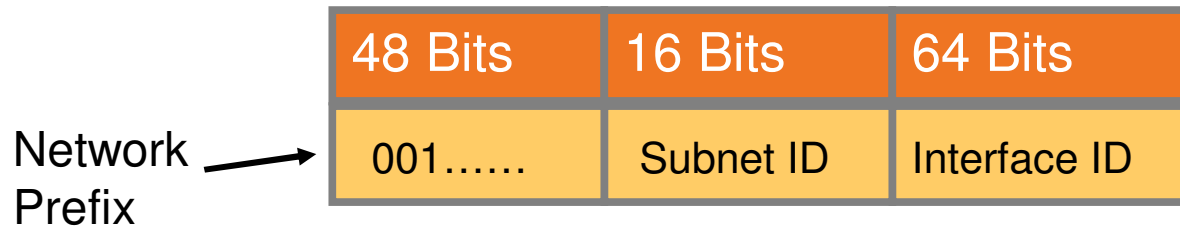
Tunnel adapter Automatic Tunneling Pseudo-Interface:

```
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  
Default Gateway . . . . . :
```

Global Unicast Network Prefix



Global Unicast Address

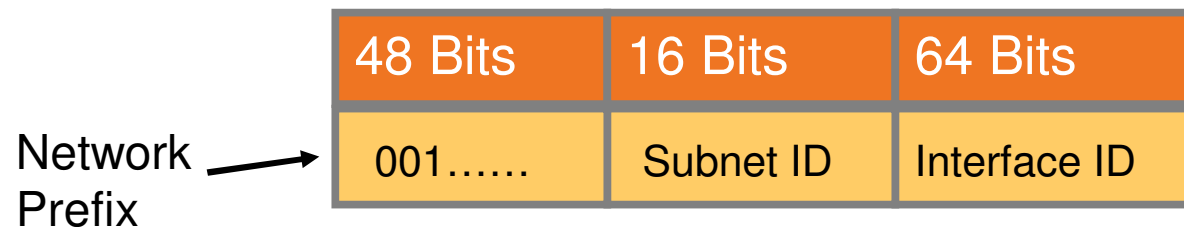
2001:5c0:8ff:0003::3f53

- 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



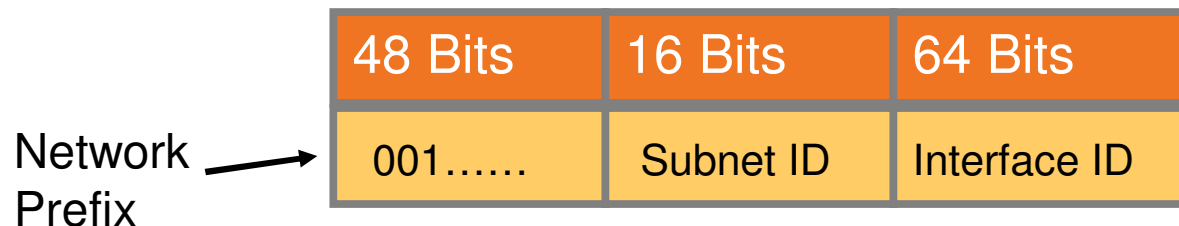
Global Unicast Address

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

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:fffe::1

EUI-64 Format

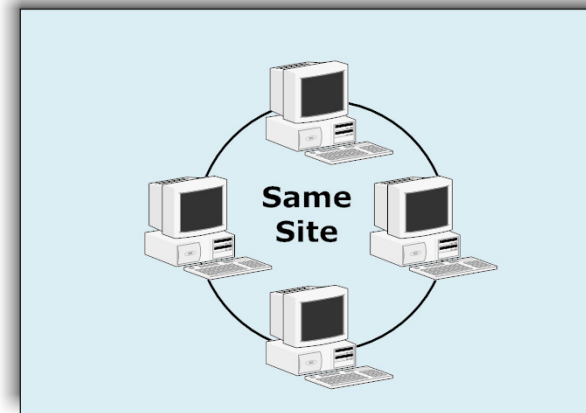
- IID: based on the link-layer (MAC) address
- EUI-64 format : OUI field + FFFE + Serial Number

Example on Windows PC: result of IPConfig

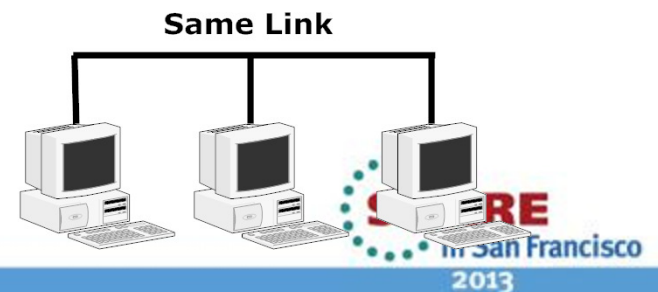
Ethernet adapter Local Area Connection:
Description : Realtek Family Fast Ethernet NIC
Physical Address : 00-**11-D8**-39-29-2B
Autoconfiguration Enabled . : Yes
IP Address : fe80::2**11:d8**ff:fe**39:292b**%4

IPv6 Private Addresses

- Link-local or site-local
- Never routed outside a company or link
- Start with hex FE then 8 to F (1111 1110 1)
- Most common: FE80 (link-local)



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

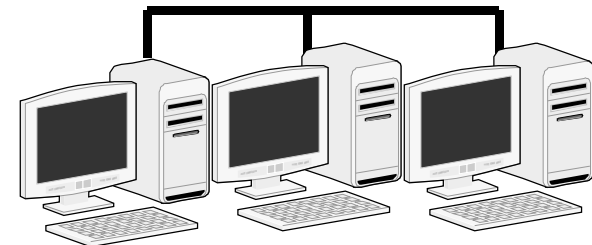
Fe80:211:d8ff:fe39:292b

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 = 10.0.0.0/8 or 192.168.0.0/16
- Site-local address + NAT used for topology hiding
- **IPv6 site-local unicast deprecated**
- Impacts network architecture, security, Internet access
- 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



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



FC00:: /7 = ULA

IPv6 Reserved Addresses



- Defined by the IETF
- Includes:
 - Unspecified,
 - Loopback and
 - IPv4 Embedded addresses
- See:
<http://www.iana.org/assignments/ipv6-address-space/ipv6-address-space.xml>

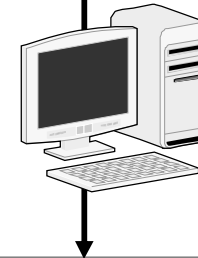
0000:: /8 = Reserved

IPv6 Unspecified Address

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

0000 = Unspecified

Who am I? (IPv4)
DHCP



Who am I? (IPv6)
Stateless Autoconfiguration

```
164 ADCD      PACKET      00000004 08:14:04.416323 Packet Trace
```



```
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    : 0013D38D61FB0000000000000000000000 Flags: 0
Server Host Name:
Boot FileName     :
Vendor Info       : 638253633501033D07010013D38D61FB3204C0A801650C0C42617272792D636
Vendor Info       : 6D706171511000000042617272792D636F6D7061712E3C084D53465420352E3
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



Filter: **icmpv6** Expression... Clear Apply

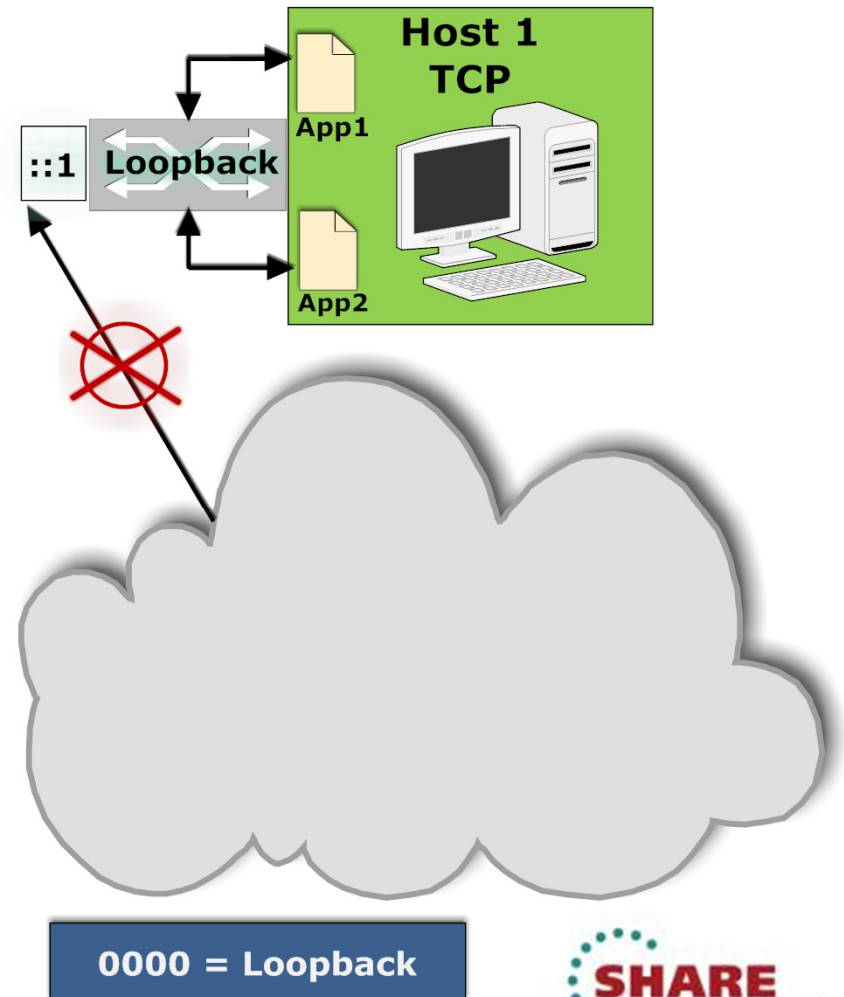
No.	Time	Source	Destination	Protocol	Info
38	19.885381	fe80::213:d3ff:fe8	ff02::1:ff8d:61fb	ICMPv6	Multicast listener report
39	19.885395	fe80::213:d3ff:fe8	ff02::2	ICMPv6	Router solicitation
40	19.885416	::	ff02::1:ff8d:61fb	ICMPv6	Neighbor solicitation
43	21.885387	fe80::213:d3ff:fe8	ff02::1:ff8d:61fb	ICMPv6	Multicast listener report
46	23.885313	fe80::213:d3ff:fe8	ff02::2	ICMPv6	Router solicitation
52	27.885227	fe80::213:d3ff:fe8	ff02::2	ICMPv6	Router solicitation

Frame 40 (78 bytes on wire, 78 bytes captured)

- Ethernet II, Src: 192.168.1.102 (00:13:d3:8d:61:fb), Dst: IPv6-Neighbor-Discovery_ff:8d:61:fb (33:33:ff:8d:61:fb)
Destination: IPv6-Neighbor-Discovery_ff:8d:61:fb (33:33:ff:8d:61:fb)
Source: 192.168.1.102 (00:13:d3:8d:61:fb)
Type: IPv6 (0x86dd)
- Internet Protocol Version 6
Version: 6
Traffic class: 0x00
Flowlabel: 0x00000
Payload length: 24
Next header: ICMPv6 (0x3a)
Hop limit: 255
Source address: ::
Destination address: ff02::1:ff8d:61fb
- Internet Control Message Protocol v6
Type: 135 (Neighbor solicitation)
Code: 0
Checksum: 0xe302 [correct]
Target: fe80::213:d3ff:fe8d:61fb

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
- May see on IBM mainframe applications

80 Bits	16 Bits	32 Bits
zeroes	FFFF	IPv4 Address

IPv4 Mapped IPv6 Address

::ffff:192.168.0.1

IPv4 Compatible IPv6 Address

~~::192.168.0.1~~

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:

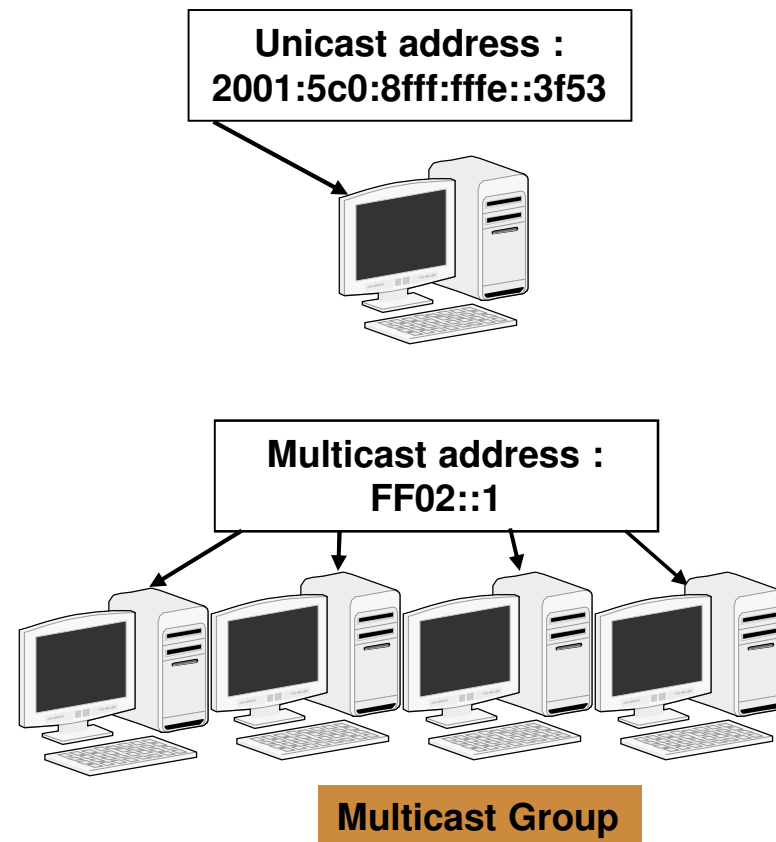
```
Connection-specific DNS Suffix . :  
IP Address. . . . . : fe80::5efe:169.254.100.29%2  
Default Gateway . . . . . :
```

Tunnel adapter Automatic Tunneling Pseudo-Interface:

```
Connection-specific DNS Suffix . :  
IP Address. . . . . : fe80::5efe:192.168.1.100%2  
Default Gateway . . . . . :
```


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)



Common IPv6 Multicast Groups



- IPv6 multicast addresses start with FF.
- See some common groups below.
- Multicast addresses are registered with the Internet Assigned Numbers Authority (IANA).
- For more, 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 Multicast Scope

- 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)

Address Summary

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

2001:00:11:22:33:44

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

ff02::1



fe80:211:d8ff:fe39:292b

fe80:53fe:192:168:1:100

fe80:53fe:169.254.1.100

Questions

?????

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Session Number 12151