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
• IPv4
• Private

FE80:1234::1
• IPv6
• Private
Sample Public Addresses

201.23.5.104 • IPv4 • Public

2001::2:ABC:123 • 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)
- 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
Important IPv6 Prefix Notations

- **/8**: 11111111xxxxxxx.xxxxxxxxxxxxxxxxxxxxx
- **/16**: 1111111111111111.xxxxxxxxxxxxxxxxxxxxx
- **/32**: 1111111111111111.1111111111111111.xxxxxxxxxxxxxxxxxxxxx
- **/48**: 1111111111111111.1111111111111111.1111111111111111.xxxxxxxxxxxxxxxxxxxxx
- **/56**: 1111111111111111.1111111111111111.1111111111111111.1111111111111111.xxxxxxxxxxxxxxxxxxxxx
- **/64**: 1111111111111111.1111111111111111.1111111111111111.1111111111111111.xxxxxxxxxxxxxxxxxxxxx
Zero Compression

- IPv6 addresses are zero compressed.
- Double colon can appear only once.
- Zero compression on special addresses.
# IPv4 / IPv6 Address Structure

<table>
<thead>
<tr>
<th>Network Prefix</th>
<th>8 Bits</th>
<th>8 Bits</th>
<th>8 Bits</th>
<th>8 Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Octet1</td>
<td>Octet2</td>
<td>Octet3</td>
<td>Host</td>
</tr>
</tbody>
</table>

IPv4 Sample Address: 204.12.34.5

<table>
<thead>
<tr>
<th>Network Prefix</th>
<th>48 Bits</th>
<th>16 Bits</th>
<th>64 Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>001…….</td>
<td>Subnet ID</td>
<td>Interface ID</td>
</tr>
</tbody>
</table>

IPv6 Sample Address: 2001:5c0:8fff:ffe::1

<table>
<thead>
<tr>
<th>Network Prefix</th>
<th>128 - n Bits</th>
<th>n Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FE80……...</td>
<td>Interface ID</td>
</tr>
</tbody>
</table>

IPv6 Sample Address: FE80:1234::1
IPv6 Address Types

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

Multicast address:
ff02::1

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

Unicast Host

Anycast Hosts

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
Importance of IPv6 Network Prefix

- First part of network prefix important!

- Example: 2001:5c0:8ff: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

Types of IPv6 unicast addresses:

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

Global Unicast Address
2001:5c0:8fff:0003::3f53
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
C:\WINDOWS\system32>ipconfig

Windows IP Configuration

Ethernet adapter Local Area Connection:
  Connection-specific DNS Suffix : 192.168.1.100
  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 : 169.254.100.29
  Autoconfiguration IP Address . . : 169.254.100.29
  Subnet Mask . . . . . . . . . . : 255.255.0.0
  IP Address . . . . . . . . . . : 2001:5c0:8fff:fffe::3f53
  IP Address . . . . . . . . . . : fe80::2ff:8cfe:fe10:3976%5
  Default Gateway . . . . . . . : 2001:5c0:8fff:fffe::3f52

Tunnel adapter Teredo Tunneling Pseudo-Interface:
  Connection-specific DNS Suffix : fe80::5445:5245:444f%6
  IP Address . . . . . . . . . . : fe80::5445:5245:444f%6
  Default Gateway . . . . . . . :

Tunnel adapter Automatic Tunneling Pseudo-Interface:
  Connection-specific DNS Suffix : fe80::5efe:169.254.100.29%2
  IP Address . . . . . . . . . . : fe80::5efe:169.254.100.29%2
  Default Gateway . . . . . . . :

Tunnel adapter Automatic Tunneling Pseudo-Interface:
  Connection-specific DNS Suffix : fe80::5efe:192.168.1.100%2
  IP Address . . . . . . . . . . : fe80::5efe:192.168.1.100%2
  Default Gateway . . . . . . . :
Global Unicast Network Prefix

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

Global Unicast Address
2001:5c0:8fff:0003::3f53
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

<table>
<thead>
<tr>
<th>Network Prefix</th>
<th>48 Bits</th>
<th>16 Bits</th>
<th>64 Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>001……</td>
<td>Subnet ID</td>
<td>Interface ID</td>
<td></td>
</tr>
</tbody>
</table>

Global Unicast Address

2001:5c0:8ff:ffe::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 IPCconfig

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 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

```
<table>
<thead>
<tr>
<th></th>
<th>10 Bits</th>
<th>54 Bits</th>
<th>64 Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1111111010</td>
<td>zeroes</td>
<td>Interface ID</td>
</tr>
</tbody>
</table>
```

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
IPv6 Address Space Allocations

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

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 : 0013D38D61FB  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 : all options
## IPv6 Stateless Autoconfiguration

**IPv6 Stateless Autoconfiguration**

### Filter: icmpv6

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>19:885381</td>
<td>fe80::213:d3ff:fe8 ff02::1:ff8d:61fb</td>
<td>ICMPv6 Multicast listener report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>19:885395</td>
<td>fe80::213:d3ff:fe8 ff02::2</td>
<td>ICMPv6 Router solicitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>19:885416</td>
<td>::</td>
<td>fff:1::ff8d:61fb</td>
<td>ICMPv6 Neighbor solicitation</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>21:885387</td>
<td>fe80::213:d3ff:fe8 ff02::1:ff8d:61fb</td>
<td>ICMPv6 Multicast listener report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>23:885313</td>
<td>fe80::213:d3ff:fe8 ff02::2</td>
<td>ICMPv6 Router solicitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>27:885227</td>
<td>fe80::213:d3ff:fe8 ff02::2</td>
<td>ICMPv6 Router solicitation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **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:** 0x000000
- **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

<table>
<thead>
<tr>
<th>80 Bits</th>
<th>16 Bits</th>
<th>32 Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>zeroes</td>
<td>FFFF</td>
<td>IPv4 Address</td>
</tr>
</tbody>
</table>

**IPv4 Mapped IPv6 Address**

::ffff:192.168.0.1

**IPv4 Compatible IPv6 Address**

::192.168.0.1
C:\WINDOWS\system32>ipconfig

Windows IP Configuration

Ethernet adapter Local Area Connection:
  Connection-specific DNS Suffix : 192.168.1.100
  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)

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

Multicast address : FF02::1

Multicast Group
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

<table>
<thead>
<tr>
<th>IPv6 multicast address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF02::1</td>
<td>The all-nodes address</td>
</tr>
<tr>
<td>FF02::2</td>
<td>The all-routers address</td>
</tr>
<tr>
<td>FF02::5</td>
<td>The all-Open Shortest Path First (OSPF) routers address</td>
</tr>
<tr>
<td>FF02::6</td>
<td>The all-OSPF designated routers address</td>
</tr>
</tbody>
</table>
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.
Questions

??????

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Session Number 12151