IPv6 concepts and applicability on AIX

<mark>Scope of this document</mark>

This document helps user to understand how to set up and use Ipv6 in AIX. ----- what is IPv6,header format, why is it needed for AIX,representation,various address types, Address & route configuration for AIX in single mode and mixed mode, NDP & it's corresponding daemons,communicating over IPv6 with use cases, scope & zone,EUI-64 format,stateless versus static working together, concept of Global and Local IPv6 IP, important differences with Ipv4,some troubleshoots .

<mark>Contents</mark>

1. What is IPv6?

IPv6 stands for Internet Protocol version 6 created by The [Internet Engineering Task Force](#) (IETF). Similar to IPv4 , it provides the unique, numerical IP addresses necessary for Internet-enabled devices to communicate. IPv6-address is the 128-bit address.

2. Why there is a need to use IPv6 for AIX?

The Internet, in its current form, has used up all its IPv4 addresses. According to the Number Resource Organization, the world officially ran out of IPv4 address in February 2011.

The expanded addressing capacity of IPv6 will support thousands of new LPARS with a Global IP. IPv6 has address auto-configuration facility. Router will send the prefix of the local link in its router advertisements. A host

can generate its own IP address by appending its link-layer (MAC) address, converted into Extended Universal Identifier (EUI) 64-bit format, to the 64 bits of the local link prefix.IPv6 supports multicast rather than broadcast. Multicast allows packets to be sent to multiple destinations simultaneously, . Disinterested hosts no longer must process broadcast packets, hence better security. IPv6's simplified packet header makes packet processing more efficient. With more Virtualization coming way, IPv6 addressing will help better way as we are not left with any more free public IPv4 addresses.

3.   How does a IPv6 header look like?

```
0       4       8       12      16      20      24      28      32

| version |  Traffic Class  |          Flow Label                |
|     Payload Length        |    Next Header    |   Hop Limit    |
|                                                                |
|                  Source Address(128 bit)                       |
|                                                                |
|                                                                |
|                 Destination Address(128 bit)                   |
|                                                                |
```
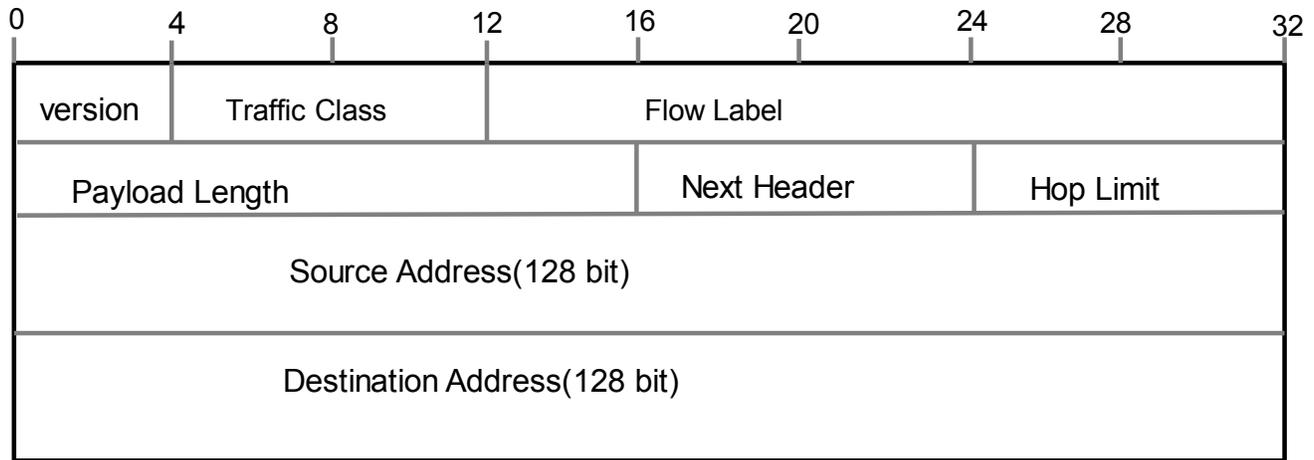
IPv6 Header Format

Version – 4-bit version number of Internet Protocol = 6.

Traffic class – 8-bit traffic class field.

Flow label – 20-bit field.

Payload length – 16-bit unsigned integer, which is the rest of the packet that follows the IPv6 header, in octets.

Next header – 8-bit selector. Identifies the type of header that immediately follows the IPv6 header. Uses the same values as the IPv4 protocol field.

Hop limit – 8-bit unsigned integer. Decremented by one by each node that forwards the packet. The packet is discarded if the hop limit is decremented to zero.

Source address – 128 bits. The address of the initial sender of the packet.

Destination address – 128 bits. The address of the intended recipient of the packet. The intended recipient is not necessarily the recipient if an optional routing header is present.

4.   How to represent an Ipv6 Address in AIX?

A. To represent IPv6 Global IP

```
┌──────────────────────────────────────┐
│                                      │
│        IPv6-Address/Prefix-Length    │
│                                      │
└──────────────────────────────────────┘
```

IPv6 Global Address contains two parts:
       -------prefix
       -------interface ID

An example of IPv6:
`2001:1234:5723:ABCD:5678:D14E:DBCA:0764/64`

There are:
+ 8 groups of 4 hexadecimal digits.
+ Each group represents 16 bits (4 hexa digits * 4 bit)
+ Separator is ":"

If there are consecutive 0s in the fields, they can be aggregated using double colon.
`Example: 2001:1000:1001:0000:0000:0000: 6e80:e102 can be represented as`
`2001:1000:1001::6e8:e102.`

B. To represent IPv6 Link-Local address,

```
┌──────────────────────────────────────┐
│      IPv6-Address%zoneid/Prefix-Length │
└──────────────────────────────────────┘
```

For Link-Local Addresses there is an extra parameter called zone-id which is the interface identifier.

5.   What are the different address types in IPv6?

Address Type	Description
Unicast	An address destined for a single interface.
Multicast	Delivered to a group of interfaces identified by that address.
Anycast	Delivered to the closest interface as determined by the IGP

Table 1: IPv6 Address Types

Unicast IPv6 Addresses ::: IPv6 unicast addresses can be aggregated with prefixes of arbitrary bit-length similar to IPv4 addresses under Classless Interdomain Routing (CIDR).

Address Type	Description
Link-Local	A link-local address is required on each physical interface. Used for automatic address configuration, neighbor discovery, to communicate with other nodes on the same link. A link-local address is automatically assigned. This type of address is not routable. Starts with fe80::
Site-Local	Site-local addresses are designed to be used for addressing inside of a site without the need for a global prefix. A site-local address cannot be reached from another site. A site-local address is not automatically assigned to a node. Not routable outside of the site. Starts with fec0::
Global	The global routing prefix is a (typically hierarchically-structured) value assigned to a site (a cluster of subnets/links). The subnet ID is an identifier of a link within the site. The interface ID

	is used to identify an interface on a link; interface IDs are required to be unique within a subnet prefix.

Table 2: IPv6 Unicast Address Types

IPv6 Global unicast IP can also be categorized

Address Type	Description
Statefull	Statefull Autoconfiguration(DHCPv6)
Stateless	Stateless auto-configuration. Router will send the prefix of the local link in its router advertisements. A host can generate its own IP address by appending its link-layer (MAC) address, converted into Extended Universal Identifier (EUI) 64-bit format, to the 64 bits of the local link prefix
Static	Addresses are not auto-generated, instead statically assigned.

6.   How to configure Ipv6 for AIX?

6.1 Static Global IP configuration:
Static Ip can be configured using ifconfig ,chdev, smit. IP configured using ifconfig will not update ODM data and will not sustain over reboot. IP configured using smit or chdev will update Odm and sustain over reboot.
Example:
6.1.1.using ifconfig
```
ifconfig en2 inet6 2001:1000:3000::30/64 up
```
6.1.2 using smit
```
smit tcpip-> IPV6 Configuration->IPV6 Network Interfaces-> Change / Show
Characteristics of an IPV6 Network Interface
```
6.1.3 using chdev
```
chdev -l en1 -a netaddr6=2001::1 -a prefixlen=64 -a state='up'
```

6.2 Stateless local Ip configuration: Link-Local:
autoconf6 can be used to configure Link-Local IP
Example: `autoconf6 -A`
`        autoconf6 -i <interface_name>`
to exclude sit0 ineterface
`        autoconf6 -6i <interface_name>`

6.3 Stateless Global Ip configuration: SLAAC(Stateless Address Autoconfiguration)
6.3.1 Configuring ndpd-router
  6.3.1.i. Run autoconf6 for those interfaces which will be used to send router prefix
```
autoconf6 -i <interface_name>
```
  6.3.1.ii. Create the file gateway6 file as below. Mentioned about interfaces which will be used to send router advertisement.
```
#vi /etc/gateway6
option rtadv=y
prefix if=en2 prefix=2020:1234:5678:9122::/64
prefix if=en7 prefix=2020:1234:5678:9127::/64
```

  6.3.1.iii. Make the ipv6 forwarding on
```
no -o ip6forwarding=1
```

6.3.1.iv. Start ndpd-router
```
startsrc -s ndpd-router
```

6.3.2 configuring ndpd-host
6.3.2.i. Run autoconf6 for those interfaces which has L2 connectivity with the interfaces of router,
```
autoconf6 -i <interface_name>
```
6.3.2.ii. Start ndpd-host
```
startsrc -s ndpd-host
```

User needs to be careful while entering into mixed mode configuration.

7. How to configure IPv6 route in AIX?

1. Route Configuration for STATELESS IPv6 address.
When configuring STATELESS IPv6 address I.e LL and SLAAC , route is also autoconfigured. The command used to create LL I.e "autoconf6 -i <interface>" will also create corresponding route for the interface configured. When SLAAC is created , this route will be overwritten by ndpd-host.

2. Route Configuration for STATIC IPv6 address
Route needs to be configured manually in case of STATIC GLOBAL IPv6 addresses.
Example: Adding a host route
```
route add -inet6 -host 2002::/64 fe80::3ca6:70ff:fe00:3005%3  -policy 1 -i en2
```
Example : Adding a default route
```
route add -inet6 default fe80::2
```
to check the routing table
```
netstat -rn -f inet6
```


3. Route Configuration for mixed mode
while both SLAAC and STATIC are to be present, there certain steps need to be followed

a. Use Case1 :User wants to set a default STATIC route when LL is already configured
autoconf6 already add default route while configuring LL. Post this if STATIC IP is configured and user want to use that as a default route , it will not work. If user wants STATIC IP to be used as default route , it should block autoconf6 to add a default route . Step to do that is
```
autoconf6 -iR <interface>
```
```
route add -inet6 default <STATIC_GLOBAL_IP>
```
Alternative way can be delete default route set by autoconf6, and then configure STATIC route

b. Use Case 2:User wants to preserve STATIC route, which by default is overwritten upon configuring SLAAC
As stated in step a , say user add a default STATIC route. But when ndpd-host daemon is run, STATIC IP is overwritten. To avoid this while configuring STATIC route do as follows
```
route add -inet6 default <STATIC_GLOBAL_IP> -static
```


8. What is NDP and corresponding daemons supported in AIX?

A. Defining NDP
NDP stands for "Neighbor Discovery protocol" for IP Version 6. IPv6 nodes on the same link use Neighbor

Discovery to discover each other's presence, to determine each other's link-layer addresses, to find routers, and to maintain reachability information about the paths to active neighbors.
The IPv6 Neighbor Discovery protocol corresponds to a combination of the IPv4 protocols Address Resolution Protocol , ICMP Router Discovery and ICMP Redirect.
It defines mechanisms for solving each of the following problems----Router Discovery,Prefix Discovery, Parameter Discovery,Address Autoconfiguration,Address resolution,Next-hop determination,Neighbor Unreachability Detection,Duplicate Address Detection,Redirect.
NDP defines five different ICMP packet types: A pair of Router Solicitation and Router Advertisement messages, a pair of Neighbor Solicitation and Neighbor Advertisements messages, and a Redirect message.

B. Daemons
The daemon controlling host side is ndpd-host; at router side it's ndpd-router.
a. ndpd-router
   It receives Router Solicitations and sends Router advertisements. The /etc/gateway6 file provides options for ndpd-router. The ndpd-router daemon exchanges packets on all the known interfaces UP with a Link-Local Address.
b. ndpd-host
   Performs Router Discovery, Prefix Discovery, Parameter Discovery and Redirects. The ndpd-host command deals with the default route, including default router, default interface and default interface address.The ndpd-host command exchanges packets on all the known interfaces UP with a Link-Local Address

9.   How to communicate over IPv6 among nodes?

There can be multiple Ipv6 addresses of different types for a single interface. Hence the communication over Ipv6 has to work for all of them.

A. communication over Link-Local Address
 For this nodes should have layer 2 connectivity. It can be either physical connection or can communicate over vlan(In case of same cec).LL addresses are not routable. Neighbor discovery and Neighbor Solicitation occurs over LL. For configuration of Stateless global IP ;ndpd-router and ndpd-host must have LL on their corresponding interfaces. Using this LL only host performs router discovery and router sends global prefix to host.
Use Case : Ping from Node1 to Node 2. en1 for both nodes on same vlan.

Node 1   en1   LL1/Zoneid1 .... LL2/Zoneid2   en1   Node 2
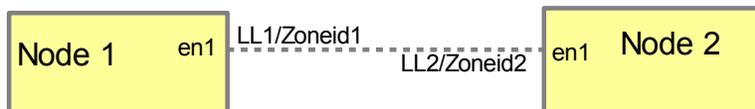
ping LL2%Zoneid1

B. Communication between STATIC GLOBAL IP

Use case: source (Node 1) and destination (Node 2) interfaces are not directly connected either via physical switch or same vlan. Src snd dest interfaces both have static IP of different subnet. Route has been set between src and destination via static ip of a interface in Node 2 node which is directly connected from src.

Node1 (Source) en0 .... en0   Gateway   Node 2
Subnet 1   Subnet 1

en1   Destination
Subnet 2
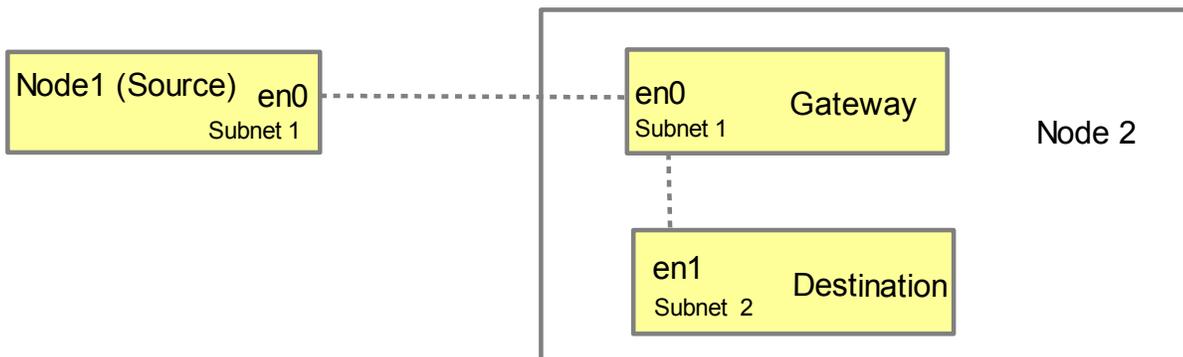
```
# route add -inet6 -host <node2_en1_ip> <node2_en0_ip>
Example:
Step1: Configure STATIC IP at Node1 en0
       #autoconf6 -i en0
       # ifconfig en0 inet6 2001::10/64 up

Step2: Configure STATIC IP at Node2 en1
       # autoconf6 -i en1
       # ifconfig en1 inet6 2002::10/64 up

Step3: ping from Node 1 to Node 2
       # ping -c 4 2002::10
       PING 2002::10: (2002::10): 56 data bytes

       --- 2002::10 ping statistics ---
       4 packets transmitted, 0 packets received, 100% packet loss

Step4: Configure en0 at Node 2 which is connected via switch from en0 of Node 1
       # autoconf6 -i en0
       # ifconfig en0 inet6 2001::11/64 up

Step5: set route from Source to Destination
       # route add -inet6 -host 2002::10 2001::11
       2001::11 host 2002::10: gateway 2001::11

Step6: ping test
       # ping -c 4 2002::10
       PING 2002::10: (2002::10): 56 data bytes
       64 bytes from 2002::10: icmp_seq=0 ttl=255 time=0.559 ms
       64 bytes from 2002::10: icmp_seq=1 ttl=255 time=0.359 ms
       64 bytes from 2002::10: icmp_seq=2 ttl=255 time=0.265 ms
       64 bytes from 2002::10: icmp_seq=3 ttl=255 time=0.266 ms

       --- 2002::10 ping statistics ---
       4 packets transmitted, 4 packets received, 0% packet loss
       round-trip min/avg/max = 0/0/0 ms
```

C. Communication between SLAAC and STATIC GLOBAL
After configuring SLAAC and STATIC , again communication can be established between them depending on Node Configuration. If needed to set route, it can be done as mentioned above.

10. What is Ipv6 scope and zone?

zone is the property of an interface . Each interface of interface local scope(scope 2) , belongs to specific zone. Using zone id, node decides the outgoing interface. In case of multihomed host, each interface is recognized by a LL address. On-Link interfaces(having layer 2 connectivity) are reachable using LL and corresponding zone id.

Format is :

```
    ┌ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┐
    │       ping  LL%zoneid.        │
    └ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┘
```

Example: Say Node A and Node B have layer 2 connectivity over interface en2 and en3 respectively.(Can be connected over physical switch or might share same vlan).

```
Node A:            autoconf6 -i en2
                       creates LL1%3
Node B:            autoconf6 -i en3
                       creates LL2%4
```

while communicating to en3 of Node B from Node A use:

```
ping LL2%3
```

Like this it's specifying use en2 as outgoing interface while you try to reach en3 of Node B.

11.   How to form LL from hardware address?

Example: Say the hardware address for a ethernet adapter is : 8a:01:60:4f:ca:02
```
        EUI-64 format would be- 8a01:60ff:fe4f:ca02
        LL address would be fe80::8801:60ff:fe4f:ca02
Steps:
1.Form EUI 64 format from hardware Address by inserting ff:fe
2.Compliment 7th Bit from MSB.
3.insert fe80:: as prefix.
```

12.   Important differences between Ipv4 and IPv6

Besides their differences in address format and header format , There are few concept differences between both version which needs to be considered.

IPv4	IPv6
1.There is broadcast messages present in IPv4	1. There is no broadcast message in IPv6.Instead a link-local scope all-nodes multicast address is used for broadcast.
2.IPv4 can be categorized as public and Private IP.	2. There is no such Private and Public IPv6 address; instead IPv6 is categorized depending on the scope like----- Link-Local, Site-Local,Global etc.
3. The way Ipv4 address is assigned is either Static or Dynamic(DHCP).	3.Dynamic IPv6 address can be auto-generated as well. Auto-generation is either Stateless(SLAAC) or Statefull(DHCPv6)
4. ARP performs IP to MAC conversion.	4. Similar job is performed by NDP

13.   Troubleshoots

a. ping is not working to a remote LL IP

LL IP is not routable. Both interfaces should have L2 connectivity. Even after this if ping is not working, check if zone id is correctly mentioned along with the remote IP while pinging.
Correct format is mentioned in point 11 above.

b.ndpd-host is overwriting existing static global IP of the node

"*startsrc -s ndpd-host*" will overwrite any global Ip present in the system; to preserve use

startsrc -s ndpd-host -a '-g'

c.How to configure ndpd-hosts in same subnet as ndpd-router.

Till so far we observed, ndpd-router forwards prefix and Ipv6 Unicast Global IP is auto-generated at all hosts.
Now say we want to have the router also into same subnet as of all hosts.

Basically we can statically assign IP to router interfaces with the prefix we want the IP to exist. LL should be configured on all required router and hosts interfaces. We need not fill /etc/gateway6 file of router. Let it be empty. Start router and hosts daemons.

What happens is, if not explicitly mentioned in file gateway6, router will forward the prefixes to hosts that it is assigned on it's own interfaces. When these prefixes reach hosts; SLAAC is generated for them. Thus we achieve hosts and router same subnet configuration.

One thing to remember, there should definitely be L2 connectivity between hosts and router interfaces.

d. What is the difference between Global unicast IP and Link-Local IP.

In Ipv6 The local IP which we refer here as Link-Local and the GLOBAL IP(can be SLAAC/STATIC/DHCPv6); question might arise as what's the basic difference in between them and what we actually mean by like local and Global in Ipv6.

The major difference in between them is Link-Local IP is not routable. So the reachability is limited only within a link. But Global IP does not have this limitation. They are routable. We definitely require them to be configured on interfaces which do not reside on same link.