

لایه سوم در معماری شبکه (لایه اینترنت)

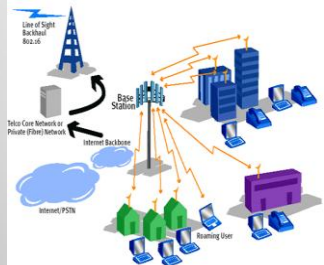
Internet Protocol Version 6 (IPv6)

تهیه و تنظیم:

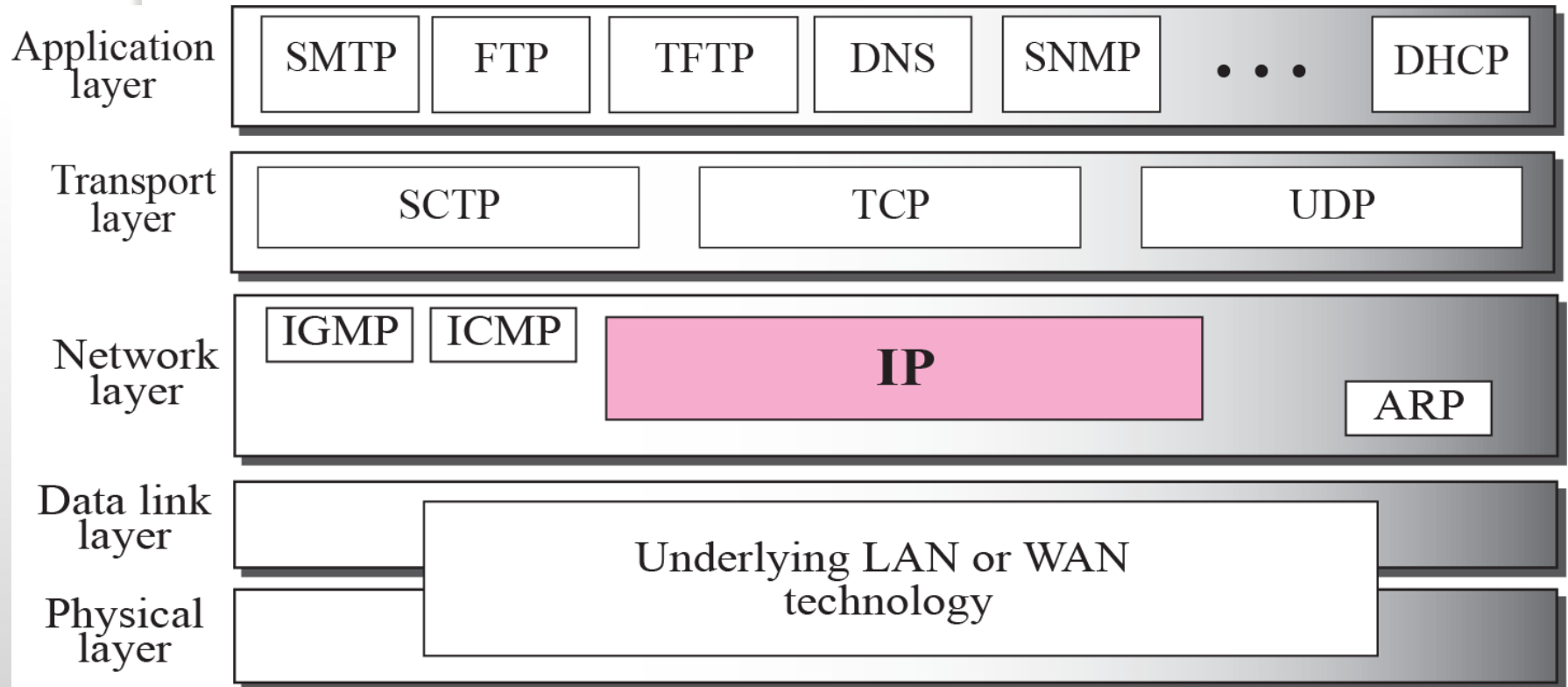
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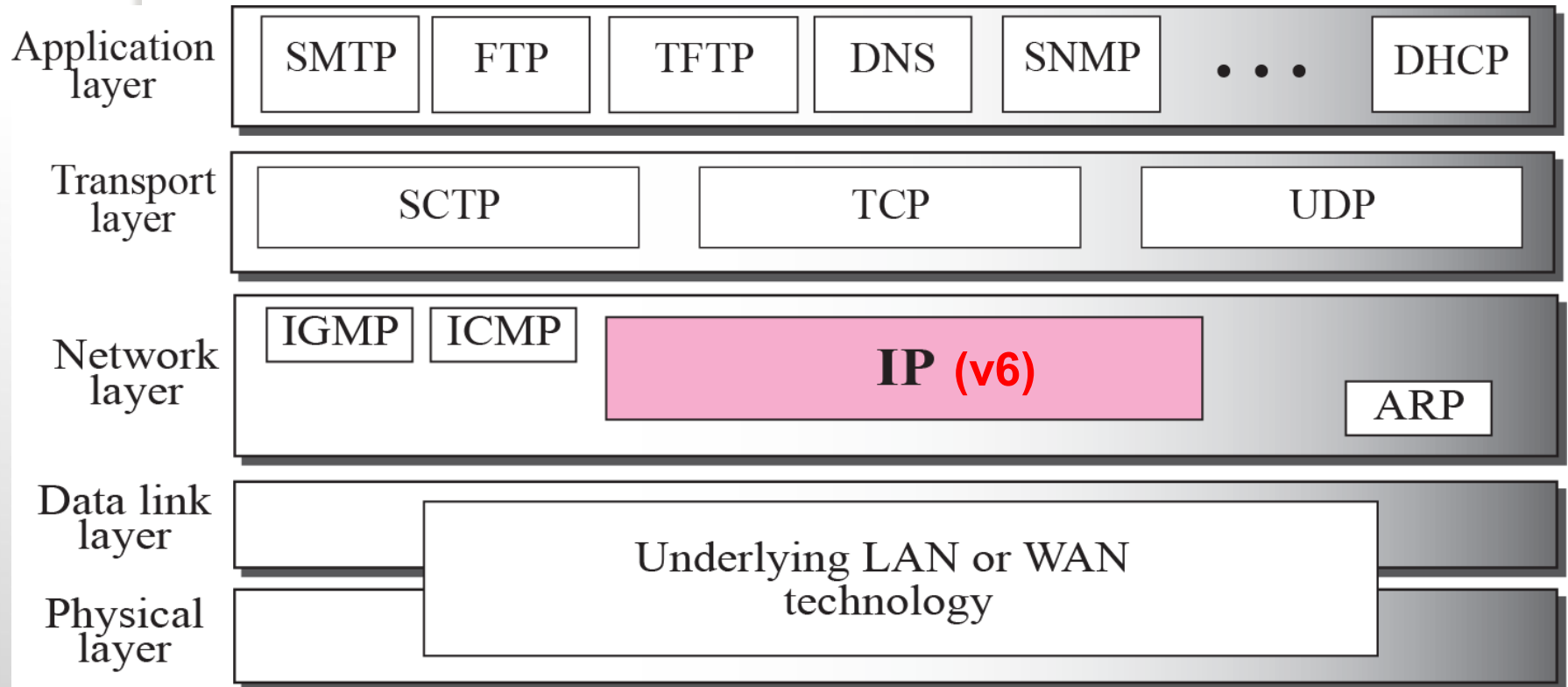
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TCP/IP(v6)



TCP/IP(v6)

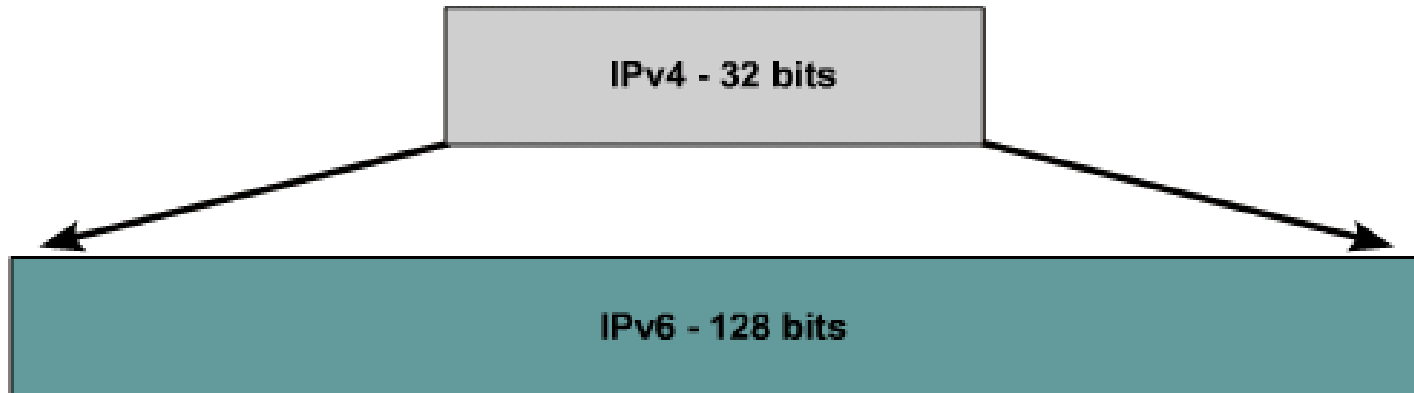




Features of IPv6

- Larger Address Space
- Aggregation-based address hierarchy
 - Efficient backbone routing
- Efficient and Extensible IP datagram
- Stateless Address Autoconfiguration
- Security (IPsec mandatory)
- Mobility

IPv6: Large Address Space



IPv4

- 32 bits or 4 bytes long
 - $\approx 4,200,000,000$ possible addressable nodes

IPv6

- 128 bits or 16 bytes: four times the bits of IPv4
 - $\approx 3.4 * 10^{38}$ possible addressable nodes
 - $\approx 340,282,366,920,938,463,374,607,432,768,211,456$
 - $\approx 5 * 10^{28}$ addresses per person

128-bit IPv6 Address

8 groups of 16-bit hexadecimal numbers separated by “:”

- IPv6 addresses are 128 bits in length and written in hexadecimal.
- IPv6 addresses are not case-sensitive and can be written in either lowercase or uppercase.
- The preferred format for writing an IPv6 address is

X:X:X:X:X:X:X:X

- with each “x” consisting of four hexadecimal values.
- In IPv6, a hextet is the unofficial term used to refer to a segment of 16 bits, or four hexadecimal values.
- Examples of IPv6 addresses in the preferred format:

2001:0db8:0000:1111:0000:0000:0000:0200

2001:0db8:0000:00a3:abcd:0000:0000:1234

128-bit IPv6 Address

3FFE:085B:1F1F:0000:0000:0000:00A9:1234

8 groups of 16-bit hexadecimal numbers separated by “:”

Leading zeros can be removed

3FFE:85B:1F1F::A9:1234



:: = all zeros in one or more group of 16-bit hexadecimal numbers

128-bit IPv6 Address

16bits

3FFE:085B:1F1F:0000:0000:0000:00A9:1234

8 groups of 16-bit hexadecimal numbers separated by “:”

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:: = all zeros in one or more group of 16-bit hexadecimal numbers

128-bit IPv6 Address

16bits

3FFE:085B:1F1F:0000:0000:0000:00A9:1234

8 groups of 16-bit hexadecimal numbers separated by “:”

Leading zeros can be removed

Examples:

- 01ab can be represented as 1ab
- 09f0 can be represented as 9f0
- 0a00 can be represented as a00
- 00ab can be represented as ab

Note: This rule only applies to leading 0s, NOT to trailing 0s, otherwise the address would be ambiguous.

Text Representation of IPv6 Addresses

"Preferred" form: 1080:0:FF:0:8:800:200C:417A

Compressed form: FF01:0:0:0:0:0:0:43

becomes FF01::43

IPv4-mapped:

0:0:0:0:0:FFFF:10.1.68.3

or ::FFFF:10.1.68.3

Type	Format
Preferred	2001 : 0db8 : 0000 : 1111 : 0000 : 0000 : 0200
No leading zeros	2001 : db8 : 0 : 1111 : 0 : 0 : 0 : 200



Types of IPv6 Addresses

Unicast

- One address on a single interface
- Delivery to single interface

Multicast


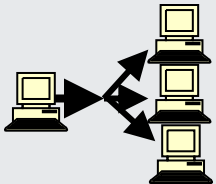
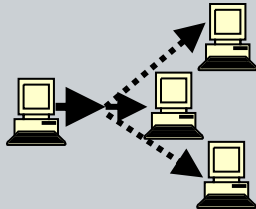
- Address of a set of interfaces
- Delivery to all interfaces in the set

Anycast

- Address of a set of interfaces
- Delivery to a single interface in the set

No broadcast addresses

Types of IPv6 Addresses

Address Type	Description	Topology
Unicast	<p>“One to One”</p> <ul style="list-style-type: none">• An address destined for a single interface.• A packet sent to a unicast address is delivered to the interface identified by that address.	
Multicast	<p>“One to Many”</p> <ul style="list-style-type: none">• 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	<p>“One to Nearest” (Allocated from Unicast)</p> <ul style="list-style-type: none">• An address for a set of interfaces.• In most cases these interfaces belong to different nodes.• A packet sent to an anycast address is delivered to the closest interface as determined by the IGP.	

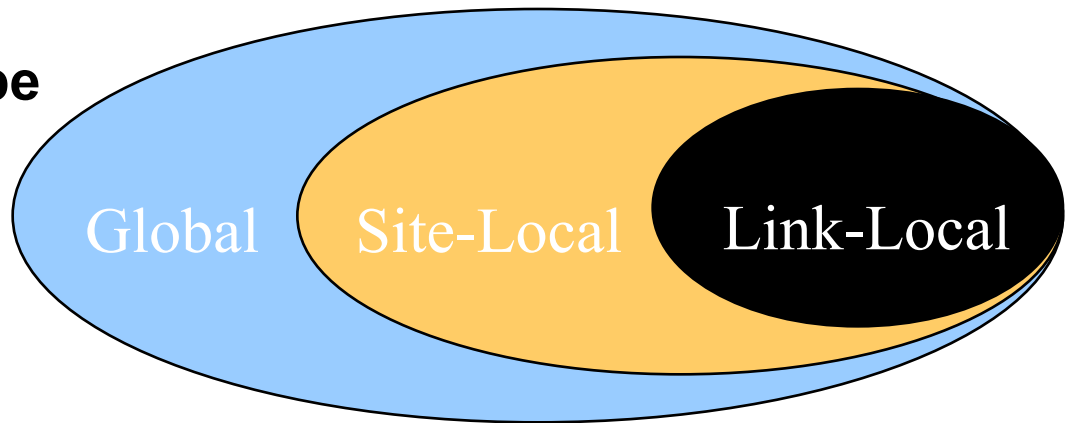
IPv6 - Addressing Model

Addresses are assigned to interfaces
change from IPv4 model :

Interface 'expected' to have multiple addresses

Addresses have scope

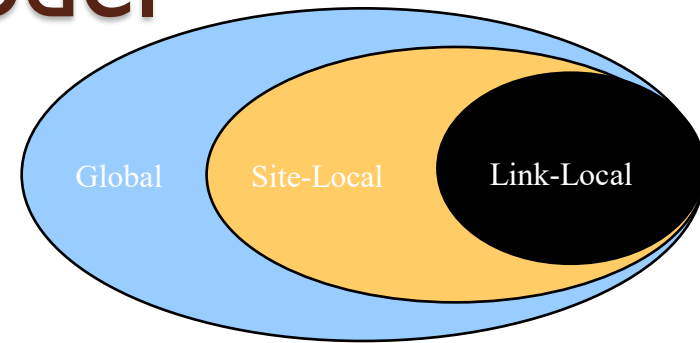
- Link Local
- Site Local
- Global



Addresses have lifetime

Valid and Preferred lifetime

IPv6 - Addressing Model



- **Global Routing Prefix:**

- The global routing prefix is the prefix, or network, portion of the address that is assigned by the provider, such as an ISP, to a customer or site. The global routing prefix will vary depending on ISP policies.

- **Subnet ID:**

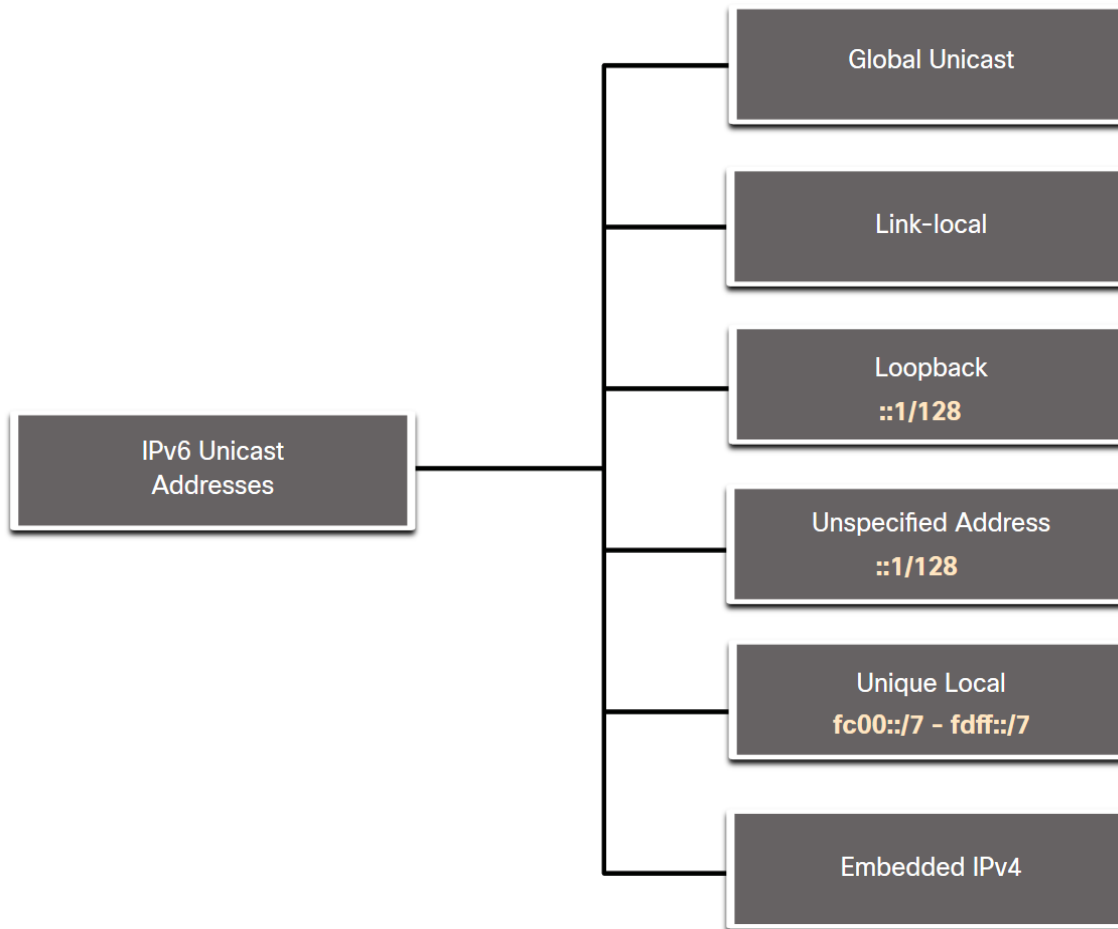
- The Subnet ID field is the area between the Global Routing Prefix and the Interface ID. The Subnet ID is used by an organization to identify subnets within its site.

- **Interface ID:**

- The IPv6 interface ID is equivalent to the host portion of an IPv4 address. It is strongly recommended that in most cases /64 subnets should be used, which creates a 64-bit interface ID.

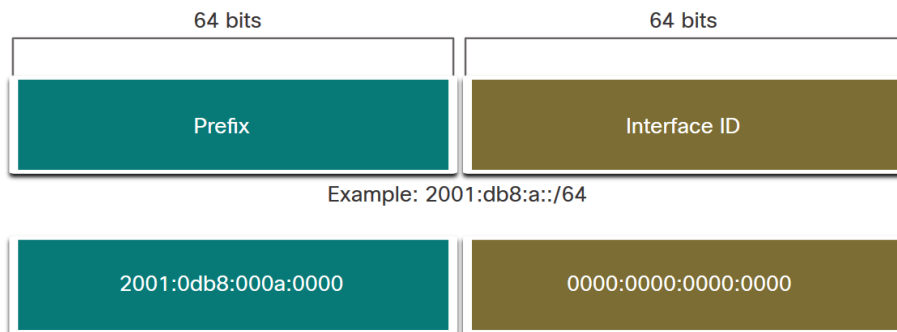
Note: IPv6 allows the all-0s and all-1s host addresses can be assigned to a device. The all-0s address is reserved as a Subnet-Router anycast address, and should be assigned only to routers.

IPv6 - Addressing Model



IPv6 Prefix Length

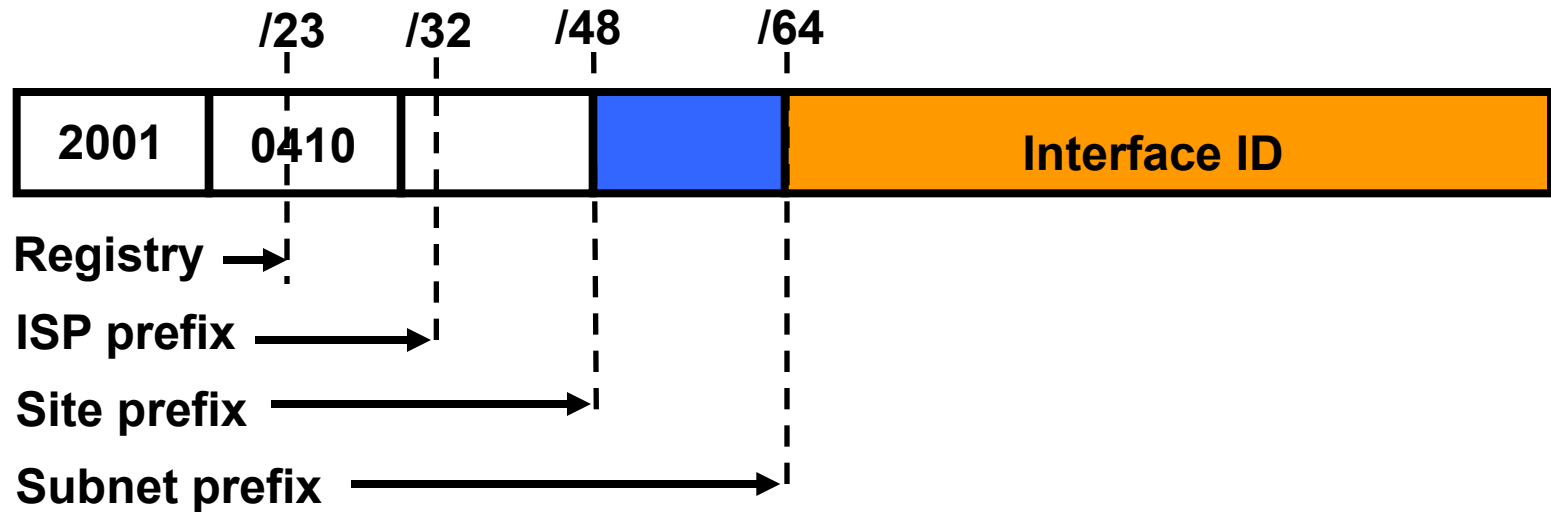
- Prefix length is represented in slash notation and is used to indicate the network portion of an IPv6 address.
- The IPv6 prefix length can range from 0 to 128. The recommended IPv6 prefix length for LANs and most other types of networks is /64.



Note:

It is strongly recommended to use a 64-bit Interface ID for most networks. This is because stateless address autoconfiguration (SLAAC) uses 64 bits for the Interface ID. It also makes subnetting easier to create and manage.

Address Allocation

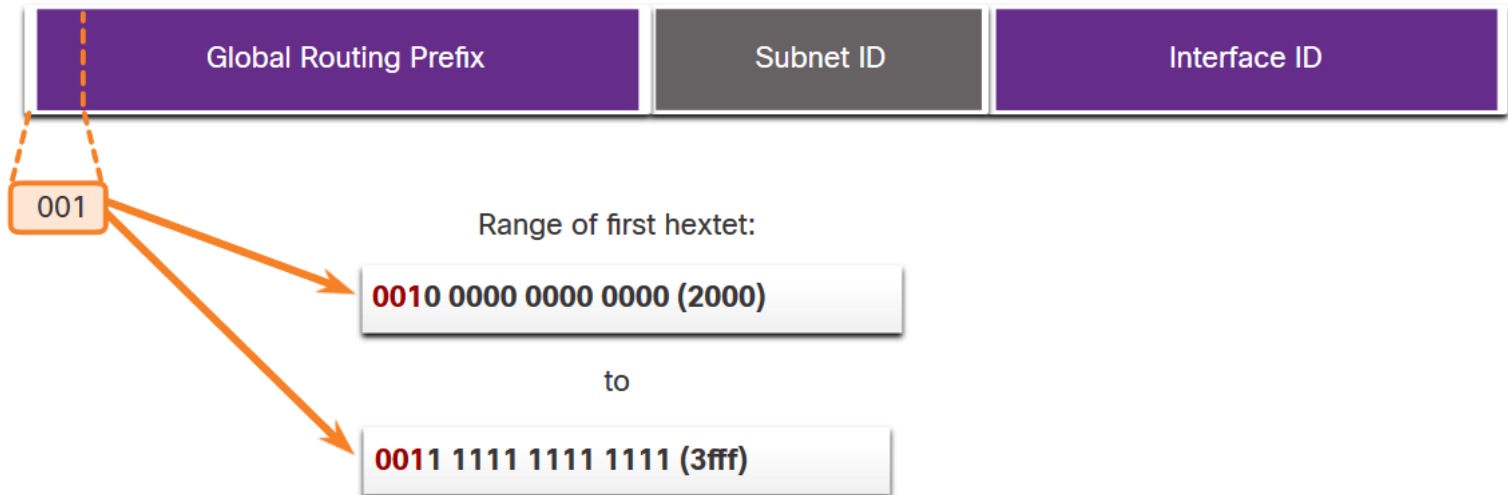


- The allocation process was recently updated by the registries:
 - IANA allocates from 2001::/16 to regional registries
 - Each regional registry allocation is a ::/23
 - ISP allocations from the regional registry is a ::/36 (immediate allocation) or ::/32 (initial allocation) or shorter with justification
 - Policy expectation that an ISP allocates a ::/48 prefix to each customer

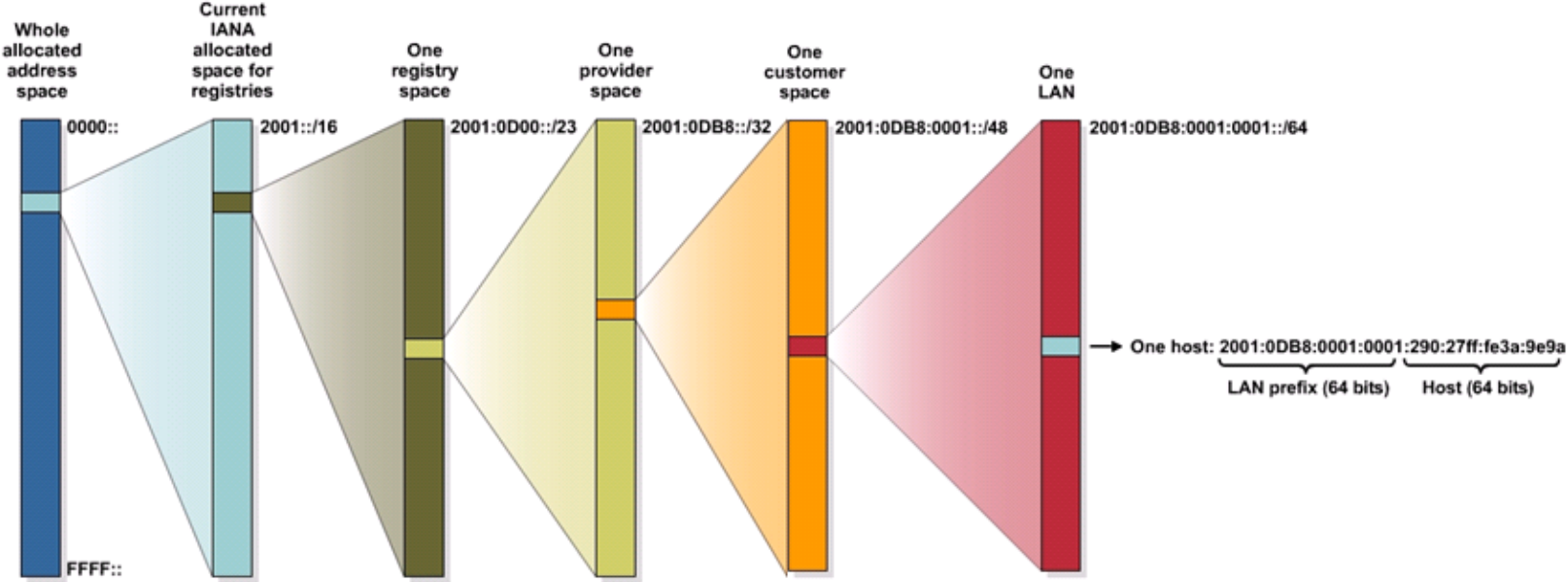
IPv6 Global Unique Addresses

IPv6 global unicast addresses (GUAs) are globally unique and routable on the IPv6 internet:

- Currently, only GUAs with the first three bits of 001 or 2000::/3 are being assigned
- Currently available GUAs begins with a decimal 2 or a 3 (This is only 1/8th of the total available IPv6 address space)



IPv6 Address Allocation Process



IPv4 Addressing Concepts and Their IPv6 Equivalents

IPv4 Address	IPv6 Address
Text representation: Dotted decimal notation	Text representation: Colon hexadecimal format with suppression of leading zeros and zero compression. IPv4-compatible addresses are expressed in dotted decimal notation.
Network bits representation: Subnet mask in dotted decimal notation or prefix length	Network bits representation: Prefix length notation only
DNS name resolution: IPv4 host address (A) resource record	DNS name resolution: IPv6 host address (AAAA) resource record
DNS reverse resolution: IN-ADDR.ARPA domain	DNS reverse resolution: IP6.ARPA domain

IPv4 Addressing Concepts and Their IPv6 Equivalents

IPv4 Address	IPv6 Address
Address Length – 32 bits	128 bits
Address Representation - decimal	hexadecimal
Internet address classes	Not applicable in IPv6
Multicast addresses (224.0.0.0/4)	IPv6 multicast addresses (FF00::/8)
Broadcast addresses	Not applicable in IPv6
Unspecified address is 0.0.0.0	Unspecified address is ::
Loopback address is 127.0.0.1	Loopback address is ::1
Public IP addresses	Global unicast addresses
Private IP addresses (10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16)	Site-local addresses (FEC0::/10)
Autoconfigured addresses (169.254.0.0/16)	Link-local addresses (FE80::/64)

Special IPv6 Addresses

IPv6 Address	Description
::/0	<ul style="list-style-type: none">• All routes and used when specifying a default static route.• It is equivalent to the IPv4 quad-zero (0.0.0.0).
::/128	<ul style="list-style-type: none">• Unspecified address and is initially assigned to a host when it first resolves its local link address.
::1/128	<ul style="list-style-type: none">• Loopback address of local host.• Equivalent to 127.0.0.1 in IPv4.
FE80::/10	<ul style="list-style-type: none">• Link-local unicast address.• Similar to the Windows autoconfiguration IP address of 169.254.x.x.
FF00::/8	<ul style="list-style-type: none">• Multicast addresses.
All other addresses	<ul style="list-style-type: none">• Global unicast address.

IPv6 Multicast Addresses

Reserved Multicast Address	Description
FF02::1	<ul style="list-style-type: none">• All nodes on a link (link-local scope).
FF02::2	<ul style="list-style-type: none">• All routers on a link.
FF02::9	<ul style="list-style-type: none">• All routing information protocol (RIP) routers on a link.
FF02::1:FFxx:xxxx	<ul style="list-style-type: none">• All solicited-node multicast addresses used for host autoconfiguration and neighbor discovery (similar to ARP in IPv4).• The xx:xxxx is the far right 24 bits of the corresponding unicast or anycast address of the node.
FF05::101	<ul style="list-style-type: none">• All Network Time Protocol (NTP) servers.

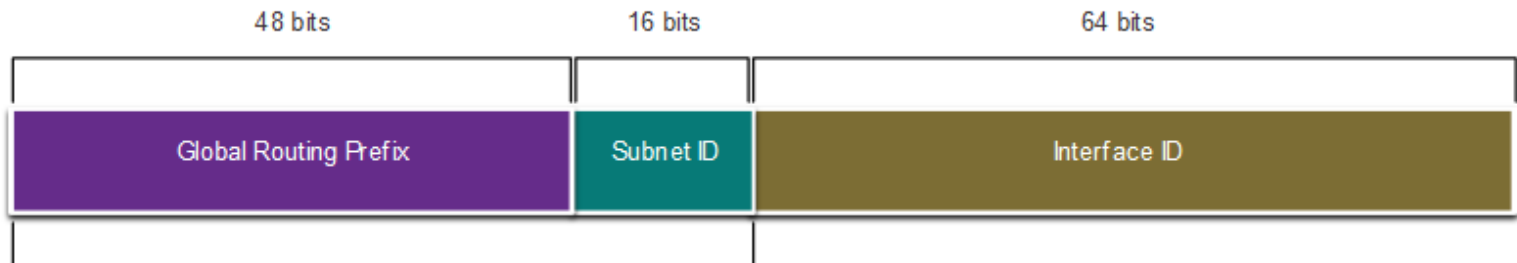
Neighbor Discovery ICMPv6 Packet Types

ICMPv6 Message	Type	Description
Neighbor Solicitation (NS)	135	<ul style="list-style-type: none">• Sent by a host to determine the link-layer address of a neighbor.• Used to verify that a neighbor is still reachable.• An NS is also used for Duplicate Address Detection (DAD).
Neighbor Advertisement (NA)	136	<ul style="list-style-type: none">• A response to a NS message.• A node may also send unsolicited NA to announce a link-layer address change.
Router Advertisement (RA)	134	<ul style="list-style-type: none">• RAs contain prefixes that are used for on-link determination or address configuration, a suggested hop limit value, MTU value, etc.• RAs are sent either periodically, or in response to a RS message.
Router Solicitation (RS)	133	<ul style="list-style-type: none">• When a host is booting it sends out an RS requesting routers to immediately generate an RA rather than wait for their next scheduled time.

Subnet using the Subnet ID

IPv6 was designed with subnetting in mind.

- A separate subnet ID field in the IPv6 GUA is used to create subnets.
- The subnet ID field is the area between the Global Routing Prefix and the interface ID.



A /48 routing prefix + 16 bit Subnet ID = /64 prefix

IPv6 Subnetting Example

Given the 2001:db8:acad::/48 global routing prefix with a 16 bit subnet ID

- Allows 65,536 /64 subnets
- The global routing prefix is the same for all subnets.
- Only the subnet ID hextet is incremented in hexadecimal for each subnet.

Increment subnet ID to create 65,536 subnets

```
2001:db8:acad:0000::/64
2001:db8:acad:0001::/64
2001:db8:acad:0002::/64
2001:db8:acad:0003::/64
2001:db8:acad:0004::/64
2001:db8:acad:0005::/64
2001:db8:acad:0006::/64
2001:db8:acad:0007::/64
2001:db8:acad:0008::/64
2001:db8:acad:0009::/64
2001:db8:acad:000a::/64
2001:db8:acad:000b::/64
2001:db8:acad:000c::/64
Subnets 13 – 65,534 not shown
2001:db8:acad:ffff::/64
```

IPv6 Configuration

Internet Protocol Version 6 (TCP/IPv6) Properties

General

You can get IPv6 settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IPv6 settings.

Obtain an IPv6 address automatically

Use the following IPv6 address:

IPv6 address:	2001:db8:acad:1::10
Subnet prefix length:	64
Default gateway:	2001:db8:acad:1::1

Obtain DNS server address automatically

Use the following DNS server addresses:

Preferred DNS server:	
Alternate DNS server:	

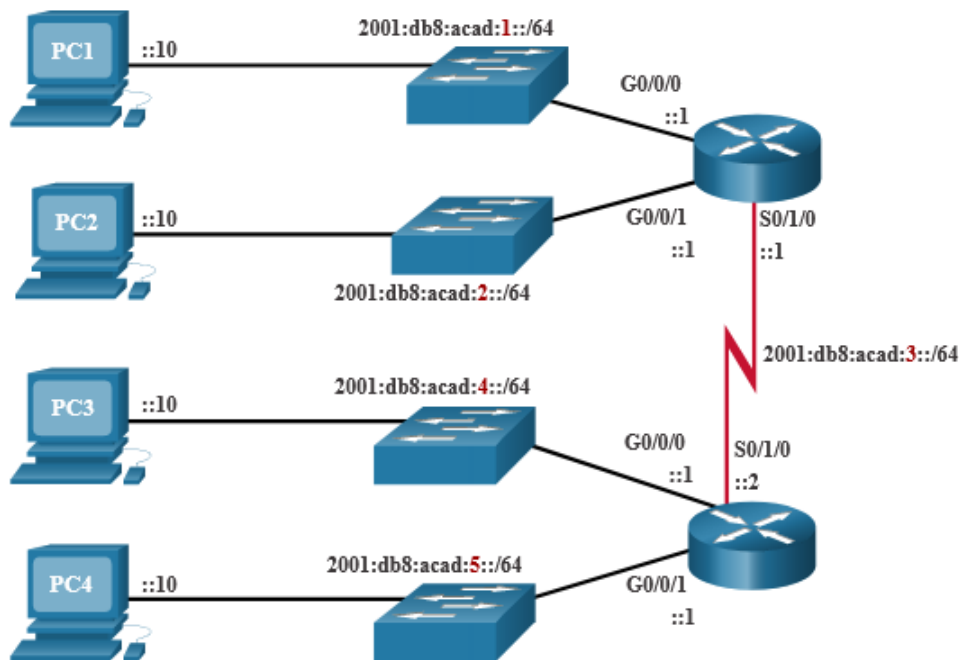
Validate settings upon exit

Advanced...

OK Cancel

IPv6 Subnetting Example

- The example topology requires five subnets, one for each LAN as well as for the serial link between R1 and R2.
- The five IPv6 subnets were allocated, with the subnet ID field 0001 through 0005. Each /64 subnet will provide more addresses than will ever be needed

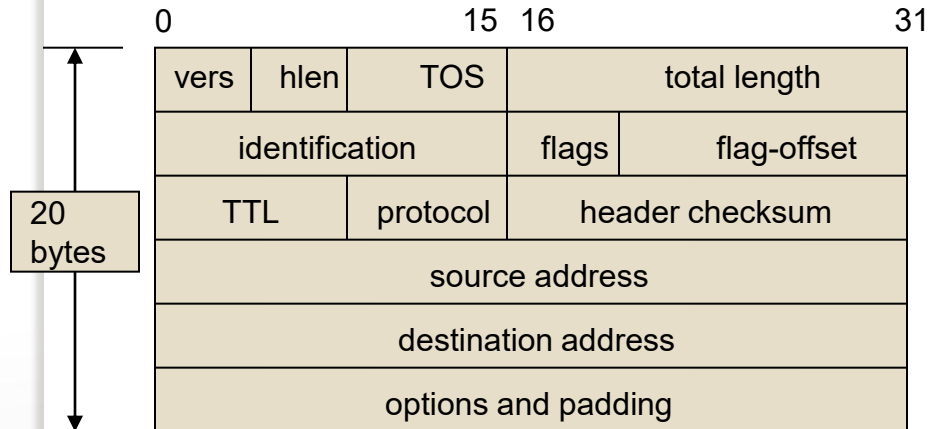


5 subnets allocated from 65,536 available subnets

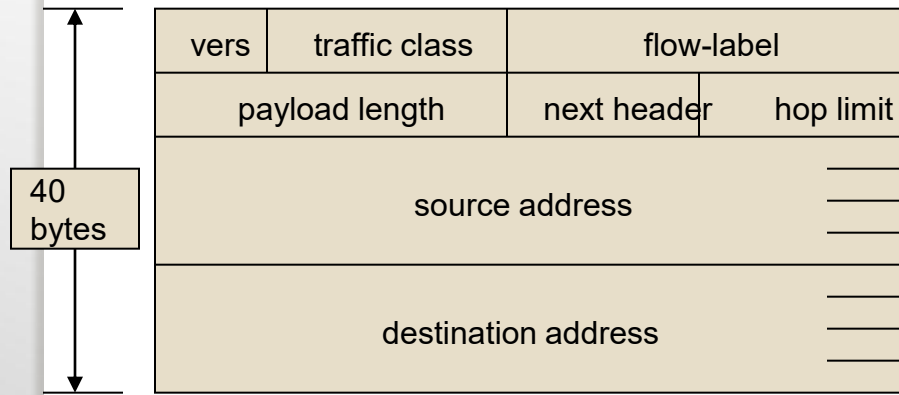
Address Block 2001:0db8:acad::/48

```
2001:db8:acad:0000::/64
2001:db8:acad:0001::/64
2001:db8:acad:0002::/64
2001:db8:acad:0003::/64
2001:db8:acad:0004::/64
2001:db8:acad:0005::/64
2001:db8:acad:0006::/64
2001:db8:acad:0007::/64
2001:db8:acad:0008::/64
2001:db8:acad:ffff::/64
```

Header comparison



IPv4



IPv6

Removed (6)

- ID, flags, flag offset
- TOS, hlen
- header checksum

Changed (3)

- total length => payload
- protocol => next header
- TTL => hop limit

Added (2)

- traffic class
- flow label

Expanded

- address 32 to 128 bits

IPv4 vs IPv6 Header

IPv4 Header

Version	IHL	Type of Service	Total Length	
Identification		Flags	Fragment Offset	
Time to Live	Protocol	Header Checksum		
Source Address				
Destination Address				
Options			Padding	

IPv6 Header

Version	Traffic Class	Flow Label		
Payload Length		Next Header	Hop Limit	
Source Address				
Destination Address				

- Legend**
- Field names kept from IPv4 to IPv6
 - Fields not kept in IPv6
 - Name & position changed in IPv6
 - New field in IPv6

Major Improvements of IPv6 Header

- **No option field:** Replaced by extension header. Result in a fixed length, 40-byte IP header.
- **No header checksum:** Result in fast processing.
- **No fragmentation at intermediate nodes:** Result in fast IP forwarding.



Fixed Length for the basic header

- IPv4 header of variable length = min^m **20 bytes**

- IPv6 = main header length fixed at **40 bytes**

- Leads to fast header processing
- No need of Header Length (Hd Len) field in IPv4 – obsolete

- **Fragmentation only by traffic source**

- Source does Path MTU (PMTU) discovery.

- Freeing routers from having to fragment them

- No need of IPv4 Identification, Flag, Fragment Offset

Note: The PMTU Discovery can be processing intensive. It is important to remember, however, that in IPv6 the MTU on any link > 1280 bytes, as specified in RFC 2460.



Header checksums are eliminated

- IP header checksum recalculated by every node switching the packet due to changing TTL values, thus taxing router resources.

- Improvements on **L2 technologies and their 32-bit CRC support** since the introduction of IPv4 combined with **layer 4 checksums** provides sufficient protection to make the layer 3 header checksum unnecessary.

- Packet Header Checksum was eliminated in IPv6 and is in turn enforced at upper layers.

IPv6 Header Fields

Based on these rules, RFC 2460 defines the following IPv6 header fields:

1. Version (4 bits)

- 4 bits are used to indicate the version of IP and is set to 6

2. Traffic Class (8 bits)

- same function as the Type of Service field in the IPv4 header.

3. Flow Label (20 bits)

- identifies a flow and it is intended to enable the router to identify packets that should be treated in a similar way without the need for deep lookups within those packets.
- set by the source and should not be changed by routers along the path to destination.
- unique & powerful tool to IPv6
- Can be used with differentiated services (DiffServ) as well as integrated services (IntServ) and Resource ReSerVation Protocol (RSVP2).

IPv6 Header Fields

4. Payload Length (16 bits)

- With the header length fixed at 40 bytes, it is enough to indicate the length of the payload to determine the length of the entire packet.

5. Next Header (8 bits)

- Indicates either the first extension header (if present) or the protocol in the upper layer (such as TCP, UDP, or ICMPv6).
- When indicating an upper layer protocol above the Internet layer, the same values used in the IPv4 Protocol field are used here.

6. Hop Limit (8 bits)

- In IPv6, the IPv4 TTL was appropriately renamed Hop Limit because it is a variable that is decremented at each hop, and it does not have a temporal dimension.

IPv6 Header Fields

7. **Source IPv6 Address (128 bits)**

- Stores the IPv6 address of the originating host.

8. **Destination IPv6 Address (128 bits)**

- Stores the IPv6 address of the current destination host.



Address Configuration ...

Address Configuration ...

- 3 ways to configure network interfaces:
 - Manually, Stateful, Stateless
- IPv6 Addresses: Separated into 2 parts: **network id** and **interface id**.
- Includes:
 - Link-local addresses: prefix FE80::0 +
 - interface id (EUI-64 format) (Network Interface Layer)
- How to get the first one !?!

Address Configuration ...

Devices can obtain Global Unified Addresses (GUA) dynamically through Internet Control Message Protocol version 6 (ICMPv6) messages.

- **Router Solicitation (RS)** messages are sent by host devices to discover IPv6 routers
- **Router Advertisement (RA)** messages are sent by routers to inform hosts on how to obtain an IPv6 GUA and provide useful network information such as:
 - Network prefix and prefix length
 - Default gateway address
 - DNS addresses and domain name

Address Configuration ...

The RA can provide three methods for configuring an IPv6 GUA :

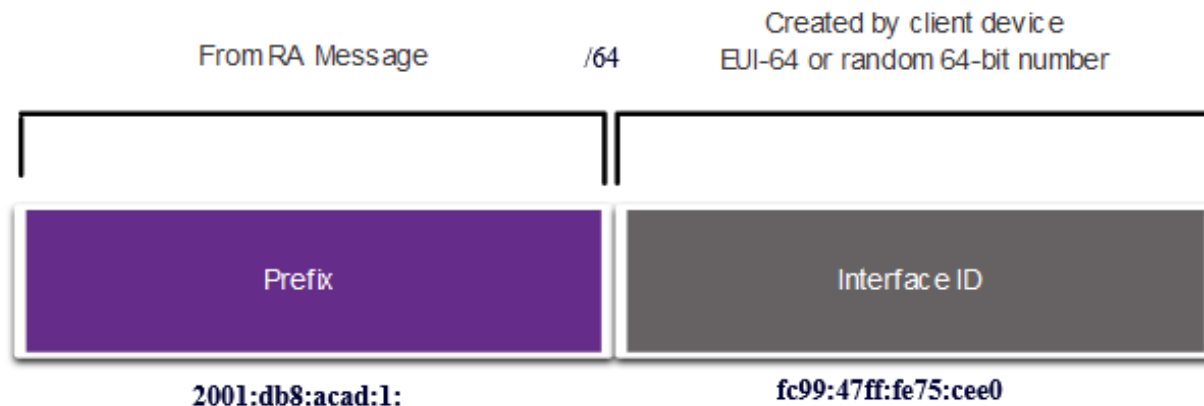
- SLAAC (StateLess Address Auto Configuration)
- SLAAC with stateless DHCPv6 server

- Stateful DHCPv6 (no SLAAC)

Reminder ... And always can be Manually

Method I: SLAAC

- SLAAC allows a device to configure a GUA without the services of DHCPv6.
- Devices obtain the necessary information to configure a GUA from the ICMPv6 RA messages of the local router.
- The prefix is provided by the RA and the device uses either the EUI-64 or random generation method to create an interface ID.

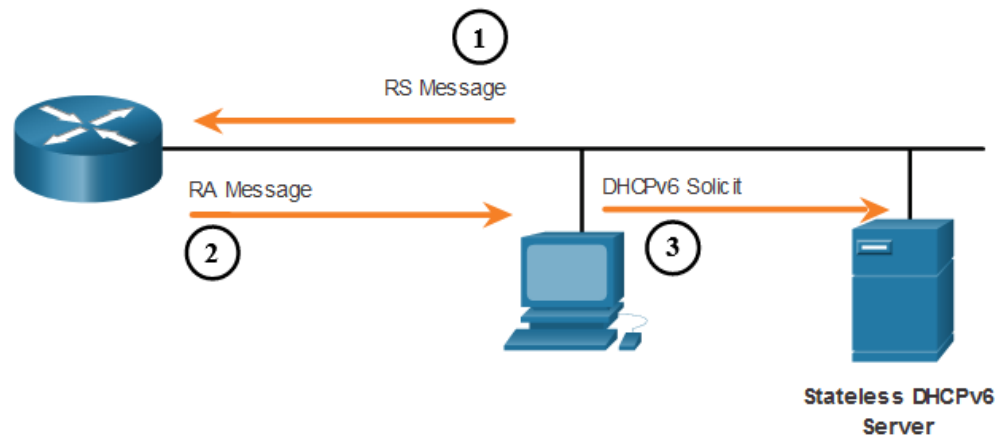


Method 2: SLAAC and Stateless DHCP

An RA can instruct a device to use both SLAAC and stateless DHCPv6

The RA message suggests devices use the following:

- SLAAC to create its own IPv6 GUA
- The router LLA, which is the RA source IPv6 address, as the default gateway address
- A stateless DHCPv6 server to obtain other information such as a DNS server address and a domain name



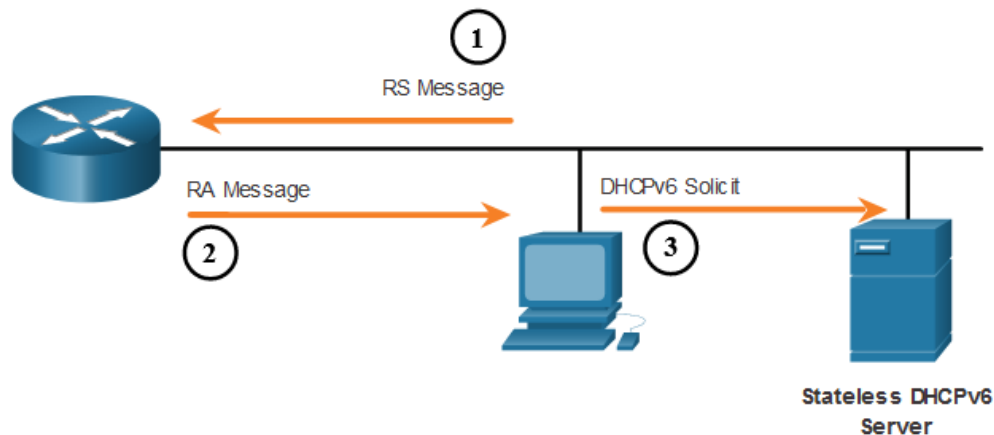
Method 3: Stateful DHCPv6

An RA can instruct a device to use stateful DHCPv6 only.

Stateful DHCPv6 is similar to DHCP for IPv4. A device can automatically receive a GUA, prefix length, and the addresses of DNS servers from a stateful DHCPv6 server.

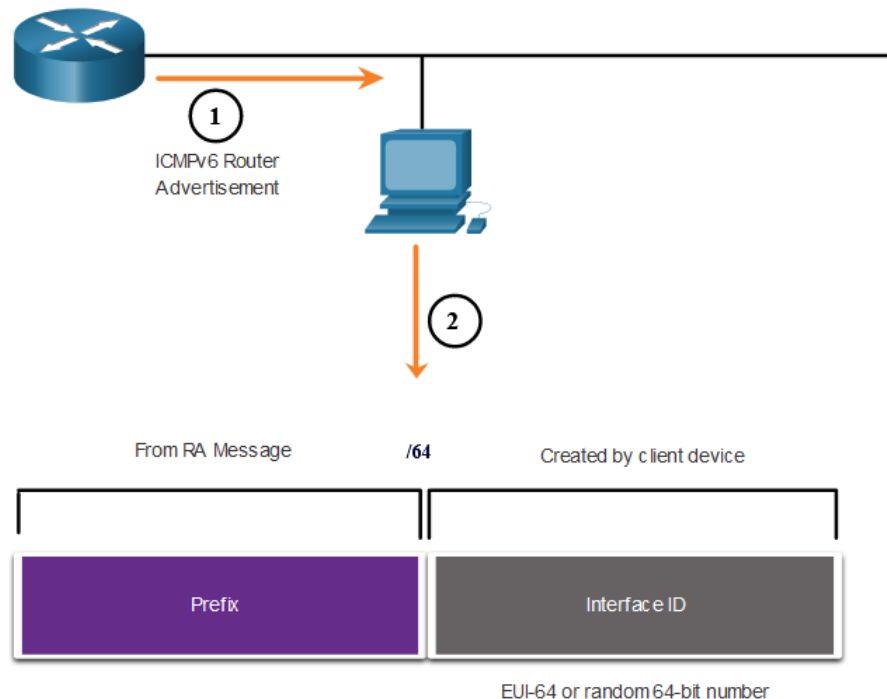
The RA message suggests devices use the following:

- The router LLA, which is the RA source IPv6 address, for the default gateway address.
- A stateful DHCPv6 server to obtain a GUA, DNS server address, domain name and other necessary information.



EUI-64 Process vs. Randomly Generated

- When the RA message is either SLAAC or SLAAC with stateless DHCPv6, the client must generate its own interface ID.
- The interface ID can be created using the EUI-64 process or a randomly generated 64-bit number.





Extension Headers

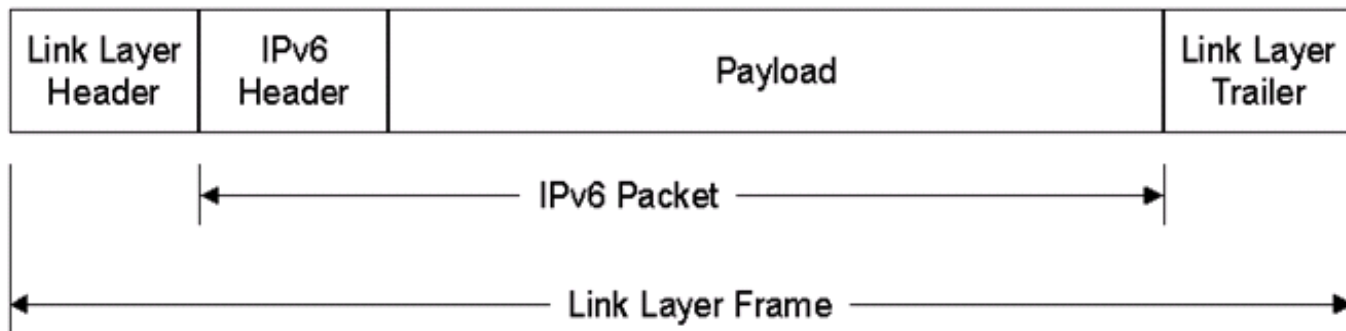
- Routing – Extended routing, like IPv4 loose list of routers to visit
- Fragmentation – Fragmentation and reassembly
- Authentication – Integrity and authentication, security
- Encapsulation – Confidentiality
- Hop-by-Hop Option – Special options that require hop-by-hop processing
- Destination Options – Optional information to be examined by the destination node

Values of the Next Header Field

Value (in decimal)	Header
0	Hop-by-Hop Options Header
6	TCP
17	UDP
41	Encapsulated IPv6 Header
43	Routing Header
44	Fragment Header
46	Resource ReSerVation Protocol
50	Encapsulating Security Payload
51	Authentication Header
58	ICMPv6
59	No next header
60	Destination Options Header

IPv6 Packets over LAN Media

- A link layer frame containing an IPv6 packet consists of the following structure:
 - Link Layer Header and Trailer
 - IPv6 Header
 - Payload



IPv6 Packets over LAN Media

For typical LAN technologies such as IEEE 802.3 (Ethernet), IEEE 802.5 (Token Ring), and Fiber Distributed Data Interface (FDDI), IPv6 packets are encapsulated in one of two ways

1. Ethernet II header
2. Sub-Network Access Protocol (SNAP) header
 - EtherType field is set to **0x86DD** to indicate IPv6.

Data-Link Technology	IPv4 Protocol ID	IPv6 Protocol ID
Ethernet	0x0800 (EtherType)	0x86DD (EtherType)
ATM	0x0800	0x86DD
PPP (IPCP)	0x8021	0x8057
Cisco HDLC	0x0800	0x86DD

IPv4 and IPv6 Coexistence

IPv4 VS IPv6



IPv4 and IPv6 Coexistence

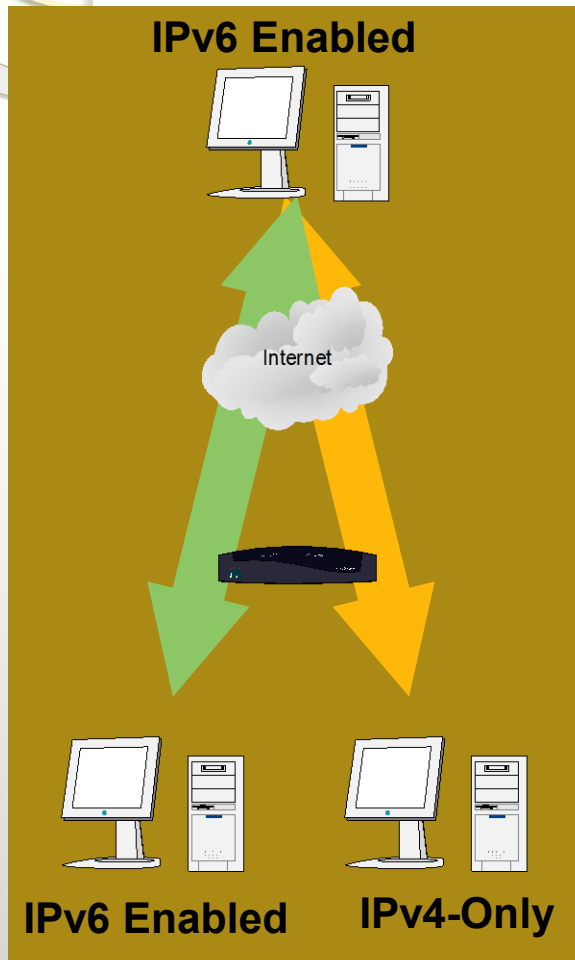
Both IPv4 and IPv6 will coexist in the near future and the transition will take several years.

The IETF has created various protocols and tools to help network administrators migrate their networks to IPv6.

These migration techniques can be divided into three categories:

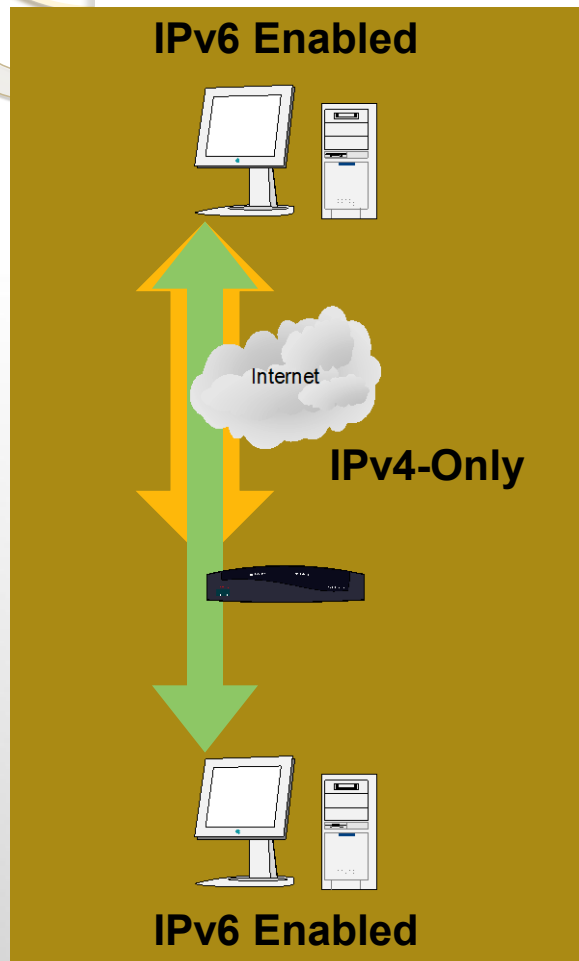
- **Dual stack** -The devices run both IPv4 and IPv6 protocol stacks simultaneously.
- **Tunneling** – A method of transporting an IPv6 packet over an IPv4 network. The IPv6 packet is encapsulated inside an IPv4 packet.
- **Translation** - Network Address Translation 64 (NAT64) allows IPv6-enabled devices to communicate with IPv4-enabled devices using a translation technique similar to NAT for IPv4.

Tools – Dual Stack



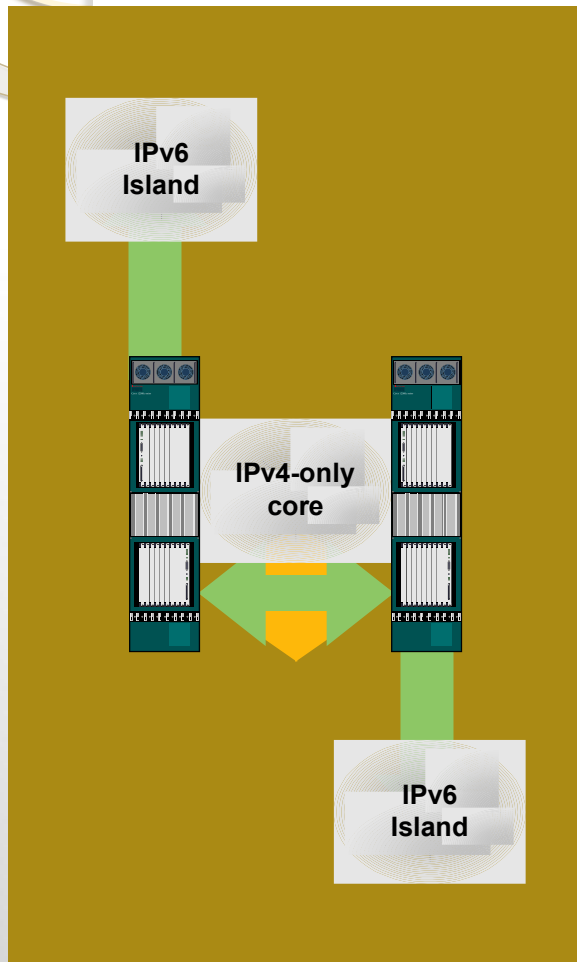
- Primary tool
- Allows continued 'normal' operation with IPv4-only nodes
- Address selection rules generally prefer IPv6
- DSTM variant allows temporary use of IPv4 pool

Tools – Tunneling



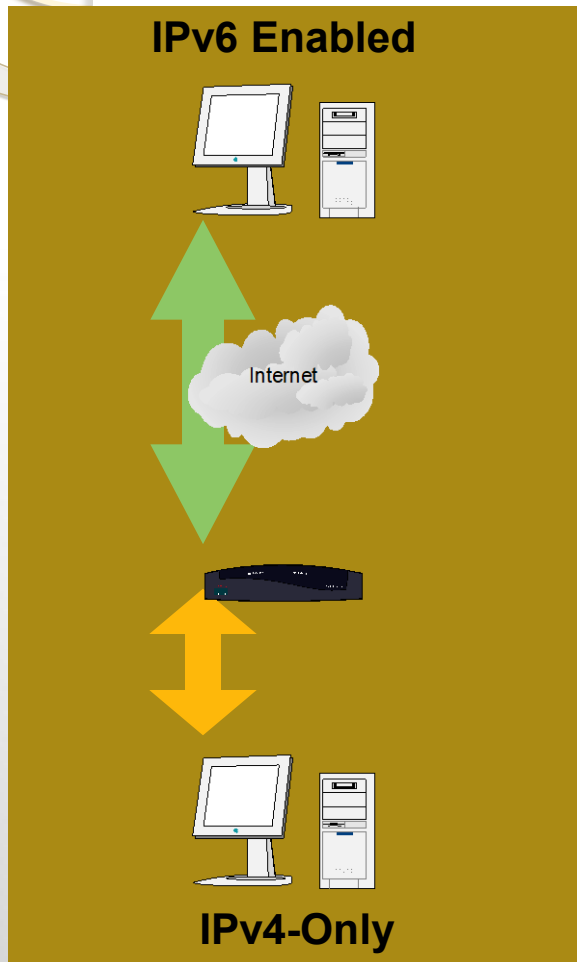
- Nodes view IPv4 network as a logical NBMA link-layer
- May be used in conjunction with dual-stack

Tools – BGP tunnel



- Service provider can incrementally upgrade PE routers with active customers
- Sites are connected to Dual Stack MP-BGP-speaking edge router
- Transport across the IPv4 core can be any tunneling mechanism

Tools – Translation



- Allows for the case where some components are IPv6-only while others are IPv4-only
- Tool of last resort
- Pay attention to scaling properties
- Same application issues as IPv4/IPv4 translation



Features of IPv6

- Larger Address Space
- Aggregation-based address hierarchy
 - Efficient backbone routing
- Efficient and Extensible IP datagram
- Stateless Address Autoconfiguration
- Security (IPsec mandatory)
- Mobility