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IPv6 Addressing

Tech Talk

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Introduction to IPv6 Addressing and the basics

What is IPv6 Addressing

IPv6 is the successor to the first address format of the internet, IPv4.

Now the question arises “Was there an IPv5 address version?” the answer is yes. It was originally designed to be a streaming protocol but never made it out of its second version draft.

So it was never officially / formally adopted as a standard addressing protocol.

Current Percentage of IPv6 Usage

Google IPv6 usage by percentage world wide is roughly 20%-22%.

The U.S. is currently about 32%-35%

Current IP Addressing IPv4 and the new version IPv6

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IPv4
Deployed 1981
Address Size:
32-bit number

Address Format
Dotted Decimal Notation:
192.168.252.0/24

Prefix Notation:
192.168.252.0/24

Number of Address:
2^{32}=
~4,294,967,296

IPv6
Deployed 1999
Address Size:
128-bit number

Address Format
Hexadecimal Notation:
3FFE:F200:0234:AB00:0123:4567:8901:ABCD

Prefix Notation:
3FFE:F200:0234::/48

Number of Address:
2^{128}=
~340 undecillion,282 decillion,366 nonillion,920 octillion,
938 septillion,463 sextillion,463 quintillion,374 quadrillion,
607 trillion,431 billion,768 million,211 thousand,456

IPv6 Address Space

IETF - RFC 2460

IPv6 Provides Expanded IP Address Space

2128 =

340,282,366,920,938,463,463,374,607,431,768,211,456

(three hundred forty UNDECILLION addresses)

3.4 x 1038

This is the equivalent to the number of grains of sand on the planet earth

But IPv6 is More Than Expanded Address Space:

–An Opportunity to Re-Engineer IPv4

- Improved Support for Multicasting, Security, & Mobile Aps
- Multiple Addresses per Interface
- Host Auto-Configuration Capability
- Security Incorporated in the IPv6 Protocol
- MTU Discovery Incorporated in the IPv6 Protocol
- Traffic Engineering Provisions Incorporate

The rules of IPv6 address format

Address Format

Is made up of 8 groups (Quartets)

Each group has 4 hexadecimal Numbers

- Total of 32 hexadecimal numbers

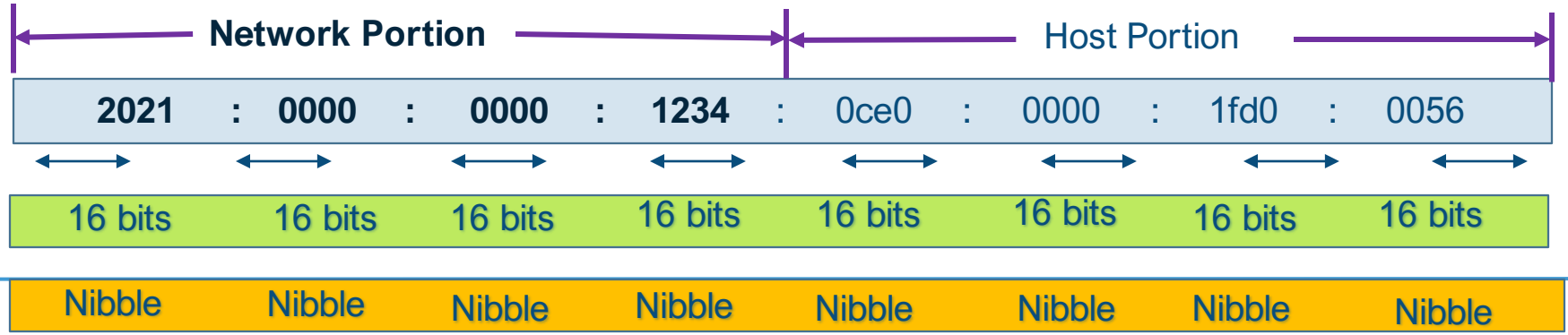
Each Group has a 16 bit value- i.e. 16x8=128

Each IP address is 128 bits in length

Each quartet is separated by colon (:)

Each quartet is also known as a NIBBLE

example 2021:0000:0000:1234:0ce0:0000:1fd0:0056



The IPv6 Address Format

128-Bit Address Binary Format:

00100110000000111101110000000000001111101010100000000000011001000011001010110011000100001111011110001001000000101000111110001

Subdivide Into Eight (8) 16-bit Groups:

0010011000000111 1011100000000000 0000111111010101 0
0000000000000011 0010000110010101 1001100010000111
1011110001001000 0010100011110001

Convert Each 16-bit Group to Hexadecimal:

(separate with a colon)

2607:b800:0faa:0003:2195:9887:bc48:28f1

2607:b800:faa:3:2195:9887:bc48:28f1

Hex	Binary	Hex	Binary
0	0000	8	1000
1	0001	9	1001
2	0010	A	1010
3	0011	B	1011
4	0100	C	1100
5	0101	D	1101
6	0110	E	1110
7	0111	F	1111

Example 2 of IPv6 Addressing Format

Consider the following 128-bit address written in the binary format: 1

00100000000000010000110110111000000000000000000000010111
10011101100000010101010100000000011111111111111110001010
00100111000101101 0

Divide this 128-bit address into 16-bit blocks: 2

0010000000000001 0000110110111000 0000000000000000
0000000000000000 0000001010101010 0000000011111111
1111111000101000 1001110001011010

Convert each block into the hexadecimal format: 3

2001:0DB8:0000:0000:02AA:00FF:FE28:9C5A

Remove the leading zeros to simplify it:

2001:DB8::2AA:FF:FE28:9C5A 4

Two Rules for Compressing IPv6 Addresses
Rule 1: Omitting Leading 0s

Only leading 0s can be excluded, trailing 0s must be included.
Or leads to ambiguity…

?

2001 : 0DB8 : ab : 1234 : 5678: 9abcd: ef12: 3456

2001 : 0DB8 : 00ab : 1234 : 5678: 9abcd: ef12: 3456
2001 : 0DB8 : ab00 : 1234 : 5678: 9abcd: ef12: 3456
2001 : 0DB8 : 0ab0 : 1234 : 5678: 9abcd: ef12: 3456

Rule 2: Double Colon :: Choices

Only a single contiguous string of all-zero segments can be represented with a double colon.

Although the rule states that both of these are correct…

2001 : DB8 : 0000 : 0000 : 1234 : 0000 : 0000 : 5678

RFC 5952

2001 : DB8 :: 1234 : 0 : 0 : 5678

or

2001 : DB8 : 0 : 0 : 1234 :: 5678

… RFC 5952 states that the longest string of zeroes must be replaced with the :: and if they are equal then the first string of 0's should use the :: representation.

Maximum reduction of the address is known as the "compressed" format.

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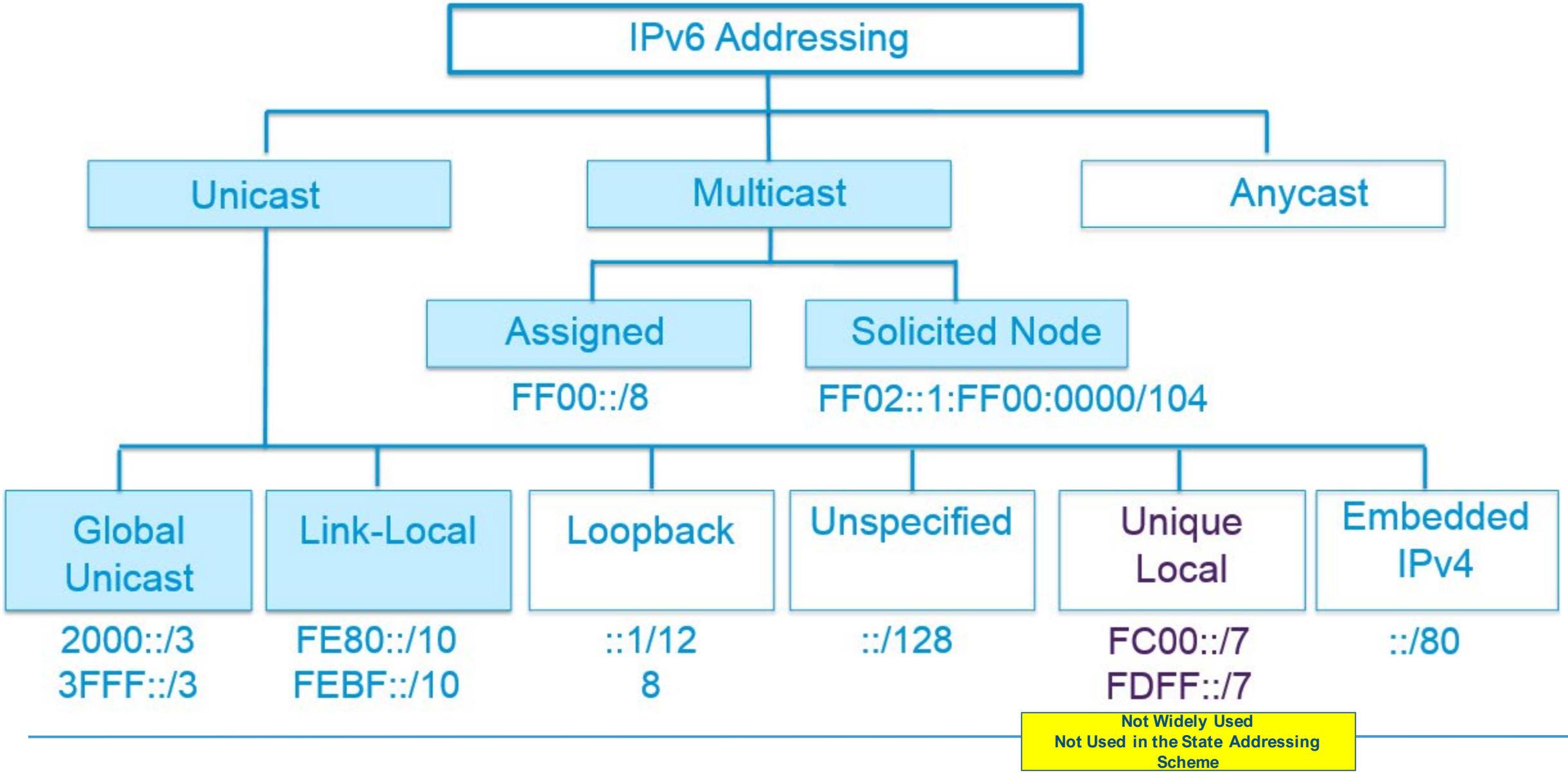
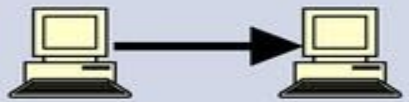
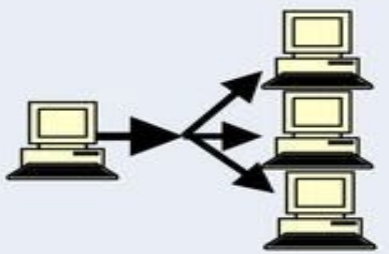
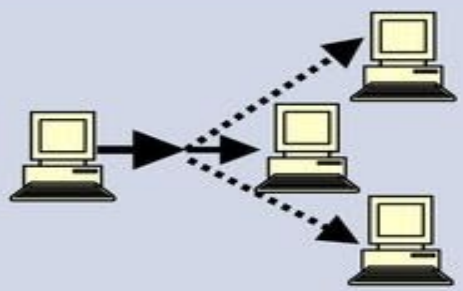
IPv6 Addressing Types


IPv6 Addressing
Unicast
Multicast
Anycast
Assigned
FF00::/8
Solicited Node
FF02::1:FF00:0000/104
Global Unicast
2000::/3
3FFF::/3
Link-Local
FE80::/10
FEBF::/10
Loopback
::1/128
Unspecified
::/128
Unique Local
FC00::/7
FDFF::/7
Embedded IPv4
::/80
Not Widely Used
Not Used in the State Addressing Scheme

Some Types of IPv6 Addresses and Their First Hex Digit(s)

Address Type	**First Hex Digits**
Global Unicast	2 or 3 (originally); all not otherwise reserved (today)
Unique Local	FD- Most closely related to Private Addressing in IPv4
Multicast	FF
Link Local	FE80- Most closely related to APIPA in IPv4

IPv6 Address Types

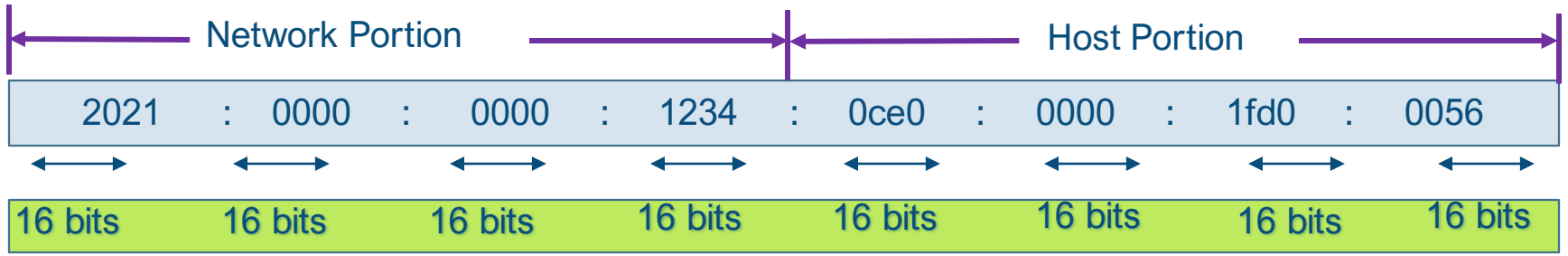
Address Type	Description	Topology
Unicast	*"One to One"* • An address destined for a single interface. • A packet sent to a unicast address is delivered to the interface identified by that address.	
Multicast	*"One to Many"* • An address for a set of interfaces (typically belonging to different nodes). • A packet sent to a multicast address will be delivered to all interfaces identified by that address.	
Anycast	*"One to Nearest"* (Allocated from Unicast) • An address for a set of interfaces. • In most cases these interfaces belong to different nodes. • created "automatically" when a single unicast address is assigned to more than one interface. • A packet sent to an anycast address is delivered to the closest interface as determined by the IGP.	

Multiple Addresses on a Single Interface

Unicast and Anycast addresses are routinely comprised of two logical parts:

- 1. 64-bit network prefix address this is used for routing purposes
- 2. 64-bit interface identifier this is used to identify a host device's network interface

bits	48 (or more)	16 (or fewer)	64
field	*routing prefix*	*subnet id*	*interface identifier*

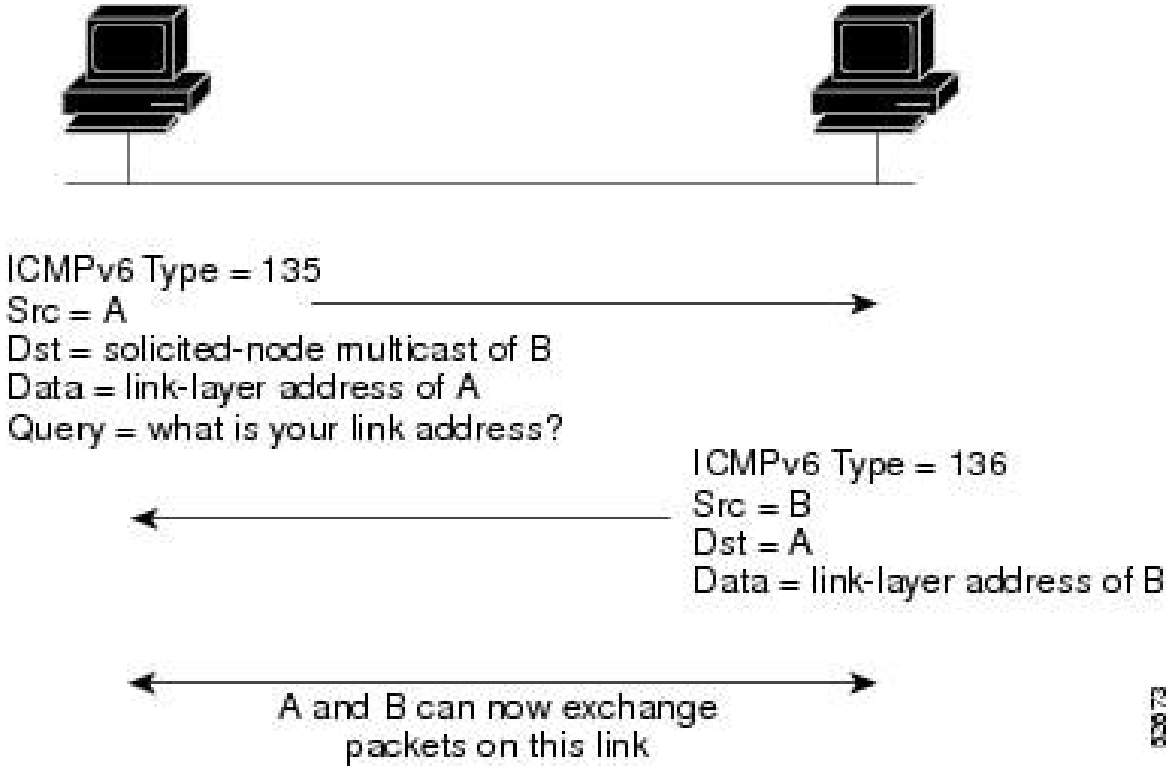


Key IPv6 Local-Scope Multicast Addresses

Short Name	Multicast Address	Meaning	IPv4 Equivalent
All-nodes	FF02::1	All-nodes (all interfaces that use IPv6 that are on the link)	A subnet broadcast address
All-routers	FF02::2	All-routers (all IPv6 router interfaces on the link)	None
All-OSPF, All-OSPF-DR	FF02::5, FF02::6	All OSPF Routers and all OSPF designated routers, respectively	224.0.0.5, 224.0.0.6
EIGRPv6 Routers	FF02::A	All routers using EIGRP for IPv6 (EIGRPv6)	224.0.0.10

IPv6 Neighbor Solicitation Message

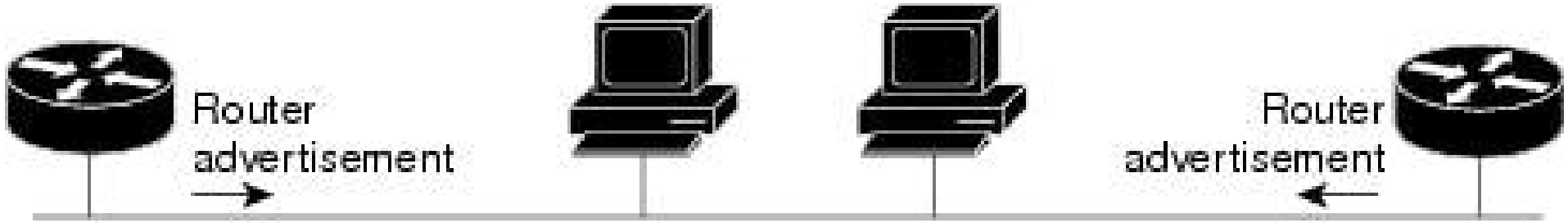
The value of 135 in the Type field of the ICMP packet header identifies a neighbor solicitation message. These messages are sent on the local link when a node wants to determine the link-layer address of another node on the same local link.



IPv6 Router Advertisement Message

Router advertisement (RA) messages have a value of 134 in the Type field of the ICMP packet header. They are periodically sent out each configured interface of an IPv6 router.

For stateless autoconfiguration to work properly, the advertised prefix length in RA messages must always be 64 bits.



Router advertisement packet definitions:

- ICMPv6 Type = 134
- Src = router link-local address
- Dst = all-nodes multicast address
- Data = options, prefix, lifetime, autoconfig flag

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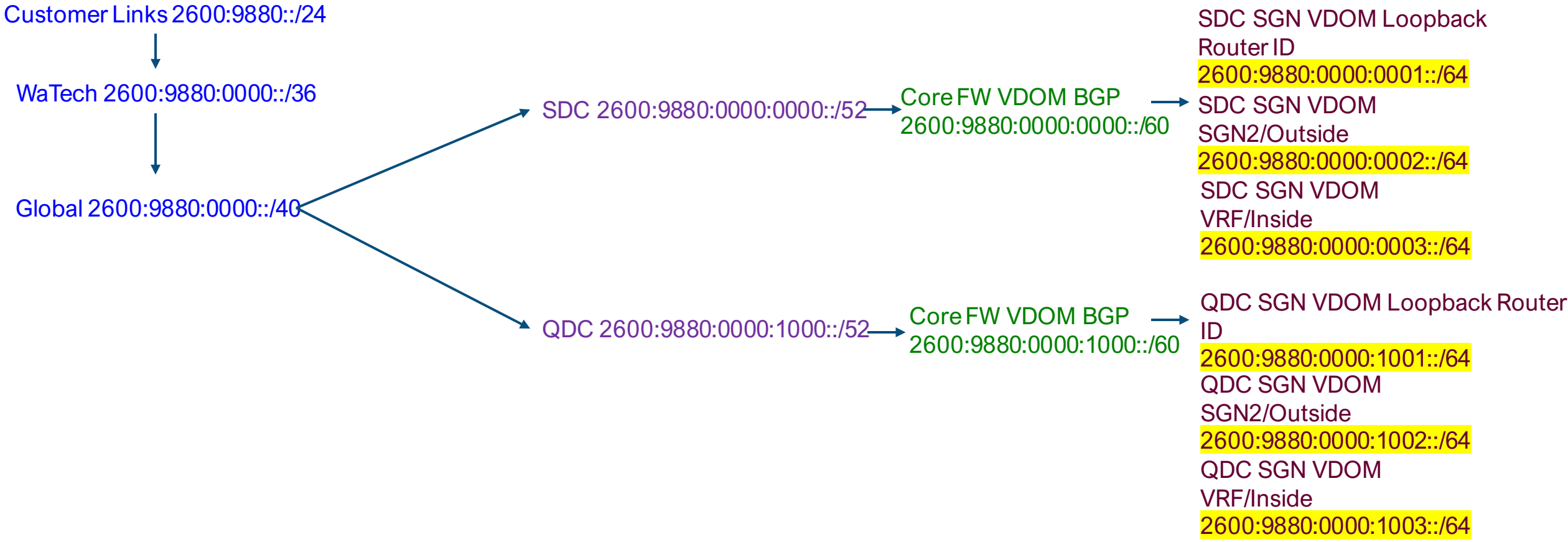
Ipv6 Washington State Allocation Strategy

IPv6 Breakdown and Allocation Example
Nibble Boundary's are important



IPv6 Breakdown and WaTech State Allocation

36 (268,435,456 networks /64) Allocated to each agency. Nibble Boundary
37 (134,217,728 networks /64)
38 (67,108,864 networks /64)
39 (33,554,432 networks /64)
40 (16,777,216 networks /64) Nibble Boundary
41 (8,388,608 networks /64)
42 (4,194,304 networks /64)
43 (2,097,152 networks /64)
44 (1,048,576 networks /64) Nibble Boundary
45 (524,288 networks /64)
46 (262,144 networks /64)
47 (131,072 networks /64)
48 (65,536 networks /64) This is the smallest network Watech will accept from any state agency. Nibble Boundary
49 (32,768 networks /64)
50 (16,384 networks /64)
51 (8,192 networks /64)
52 (4,096 networks /64) Nibble Boundary
53 (2,048 networks /64)
54 (1,024 networks /64)
55 (512 networks /64)
56 (256 networks /64) Nibble Boundary
57 (128 networks /64)
58 (64 networks /64)
59 (32 networks /64)
60 (16 networks /64) Nibble Boundary
61 (8 networks /64)
62 (4 networks /64)
63 (2 networks /64)
64 (host addresses 18,446,744,073,709,551,616) This is the address space issued to agencies from WaTech. Nibble Boundary

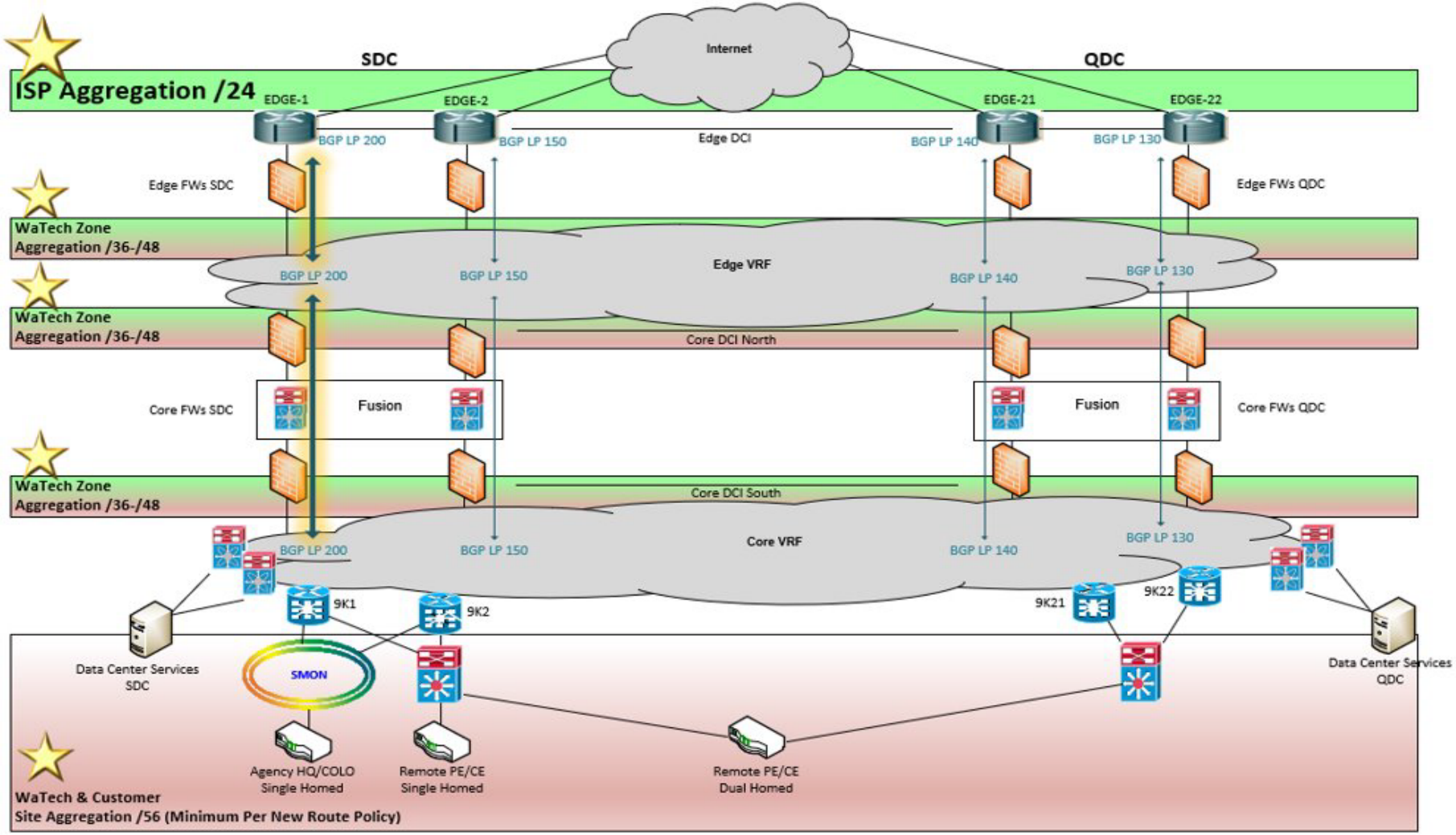
***48 is the industry standard and is the smallest address size accepted on the internet (WWW).

http://testmyipv6.com/ipv6_subnet_calc.html

Subnetting Options

/28 0 Nibble	/32 1 Nibble	/36 2 Nibbles	/40 3 Nibbles	/44 4 Nibbles	/48 5 Nibbles	/52 6 Nibbles	/56 7 Nibbles	/60 8 Nibbles	/64 9 Nibbles
/28 - 1 Subnet									
/32 - 16 Subnets	/32 - 1 Subnet								
/36 - 256 Subnets	/36 - 16 Subnets	/36 - 1 Subnet							
/40 - 4096 Subnets	/40 - 256 Subnets	/40 - 16 Subnets	/40 - 1 Subnet						
/44 - 65,536 Subnets	/44 - 4096 Subnets	/44 - 256 Subnets	/44 - 16 Subnets	/44 - 1 Subnet					
/48 - 1,048,576 Subnets	/48 - 65,536 Subnets	/48 - 4096 Subnets	/48 - 256 Subnets	/48 - 16 Subnets	/48 - 1 Subnet				
/52 - 16,777,216 Subnets	/52 - 1,048,576 Subnets	/52 - 65,536 Subnets	/52 - 4,096 Subnets	/52 - 256 Subnets	/52 - 16 Subnets	/52 - 1 Subnet			
/56 - 268,435,456 Subnets	/56 - 16,777,216 Subnets	/56 - 1,048,576 Subnets	/56 - 65,536 Subnets	/56 - 4,096 Subnets	/56 - 256 Subnets	/56 - 16 Subnets	/56 - 1 Subnet		
/60 - 4,294,967,296 Subnets	/60 - 268,435,456 Subnets	/60 - 16,777,216 Subnets	/60 - 1,048,576 Subnets	/60 - 65,536 Subnets	/60 - 4,096 Subnets	/60 - 256 Subnets	/60 - 16 Subnets	/60 - 1 Subnet	
/64 - 68,719,476,736 Subnets	/64 - 4,294,967,296 Subnets	/64 - 268,435,456 Subnets	/64 - 16,777,216 Subnets	/64 - 1,048,576 Subnets	/64 - 65,536 Subnets	/64 - 4,096 Subnets	/64 - 256 Subnets	/64 - 16 Subnets	/64 - 1 Subnet

IPv6 Aggregation Strategy



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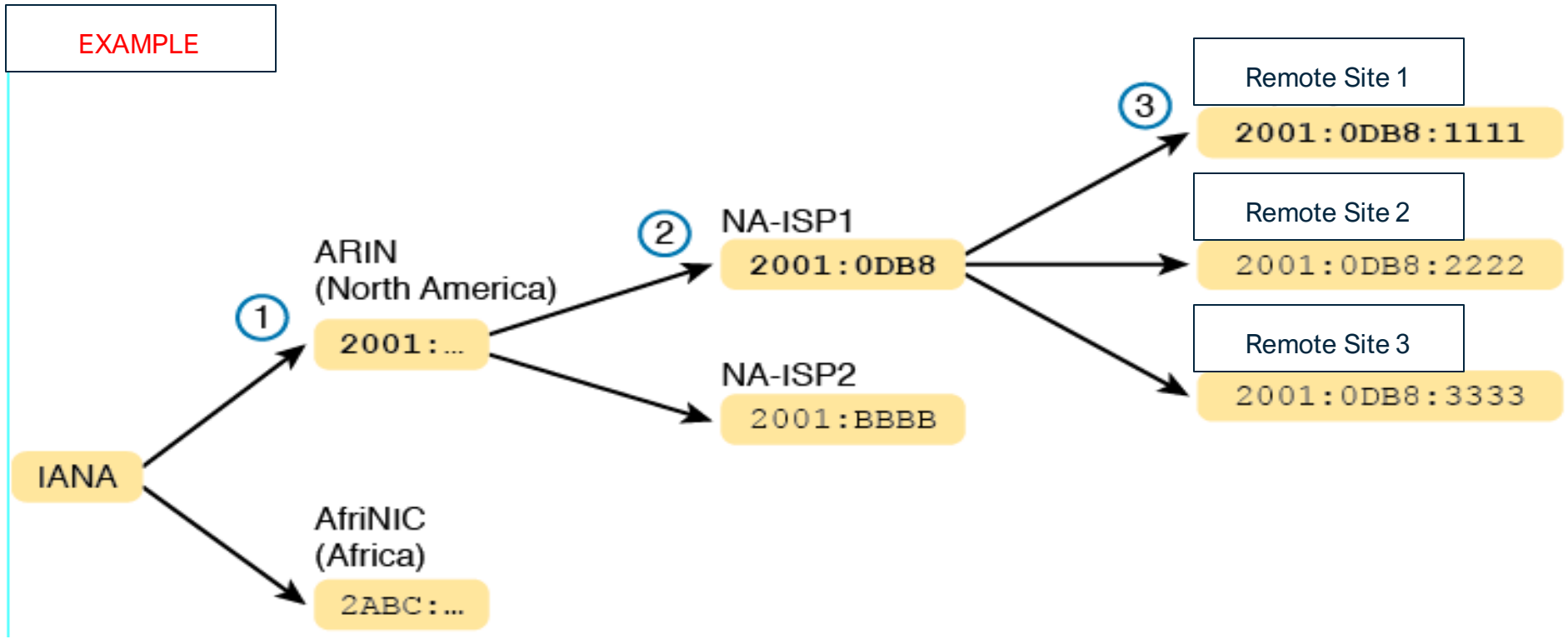
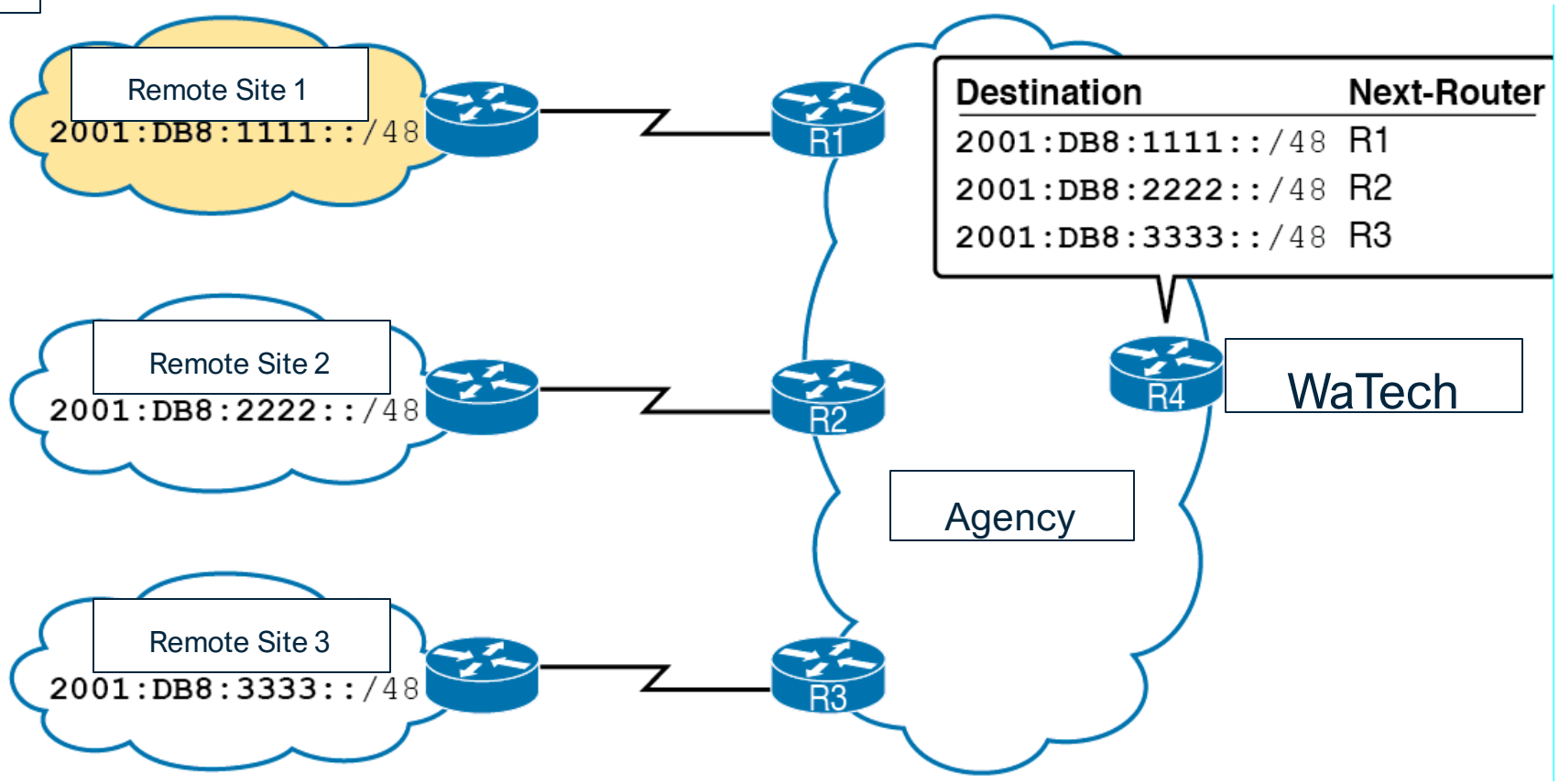
IPv6 Address Application Example

Prefix Assignment with IANA, RIRs, and ISPs



Three Global Routing Prefixes, with One Route per Prefix

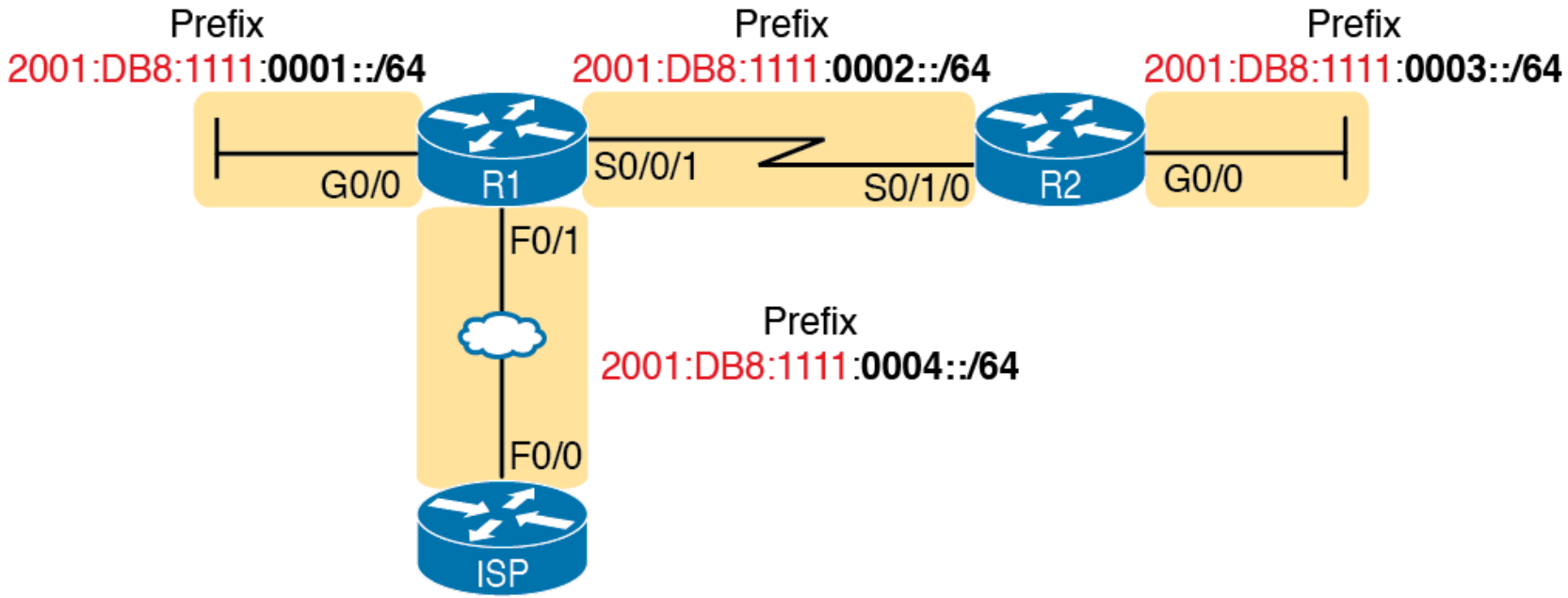
EXAMPLE



Subnets in Remote Site 1, with Global Routing Prefix of 2001:0DB8:1111::/48

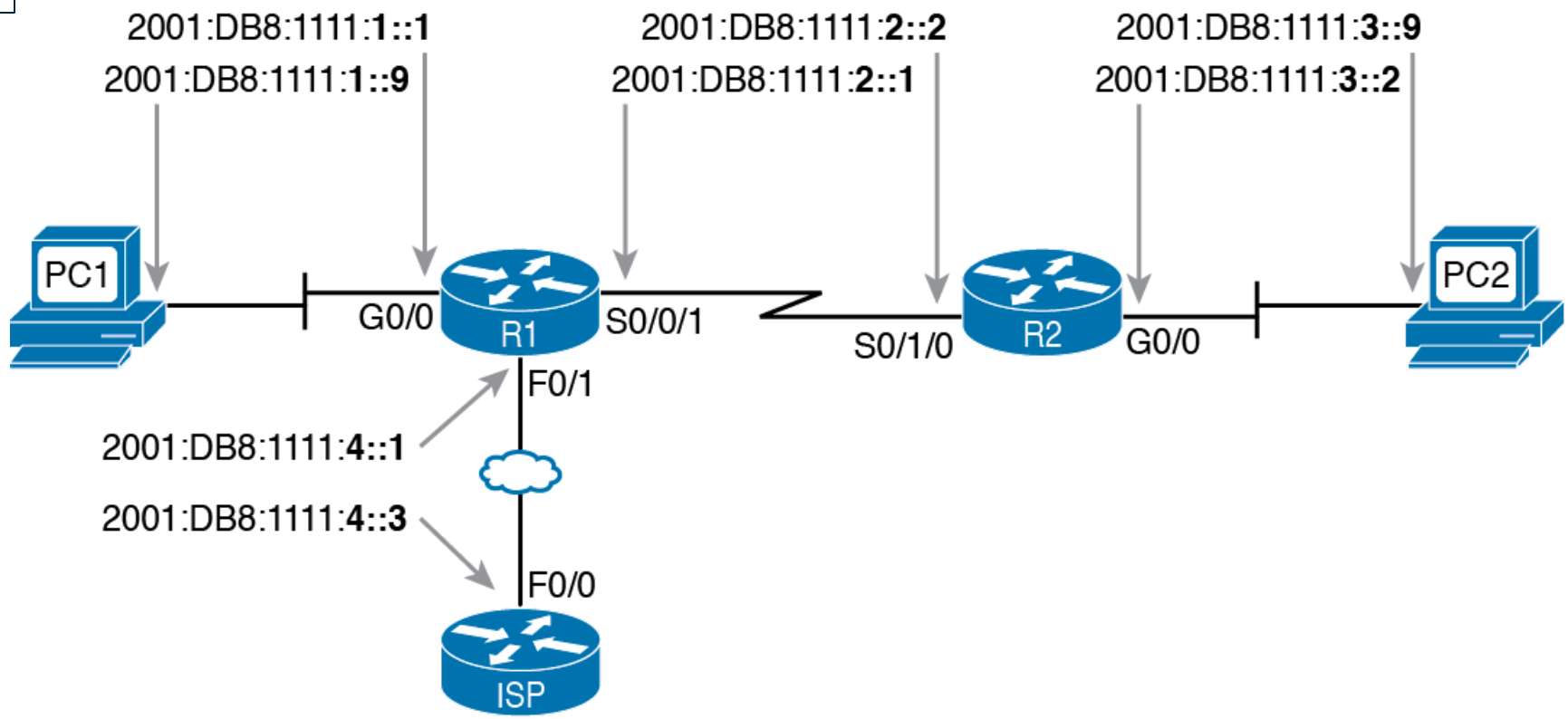
EXAMPLE

Remote Site 1



Example Static IPv6 Addresses Based on the Subnet Design

EXAMPLE



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IPv6 SLAAC (State-Less IP Address Auto-Configuration)

IPv6 SLAAC Defined

- **IPv6 was intentionally designed to allow **S**tate**L**ess IP **A**ddress **A**uto-**C**onfiguration (SLAAC).
  - When stateless auto-configuration is deployed, the host essentially grabs its own IP address with no need for an additional protocol like DHCP.

- With SLAAC, the IPv6 network listens for a Router Advertisement (RA) from the host and then assigns a 64-bit prefix.

- The last 64 bits of the address are derived in a process in which the host device essentially self-determines its address. (This is EUI-64 being implemented).

** **Note: SLAAC will not be used at this time on the State Core Networks as they are mixed addressing environments and SLAAC requires an IPv6 exclusive Domain Forest.**

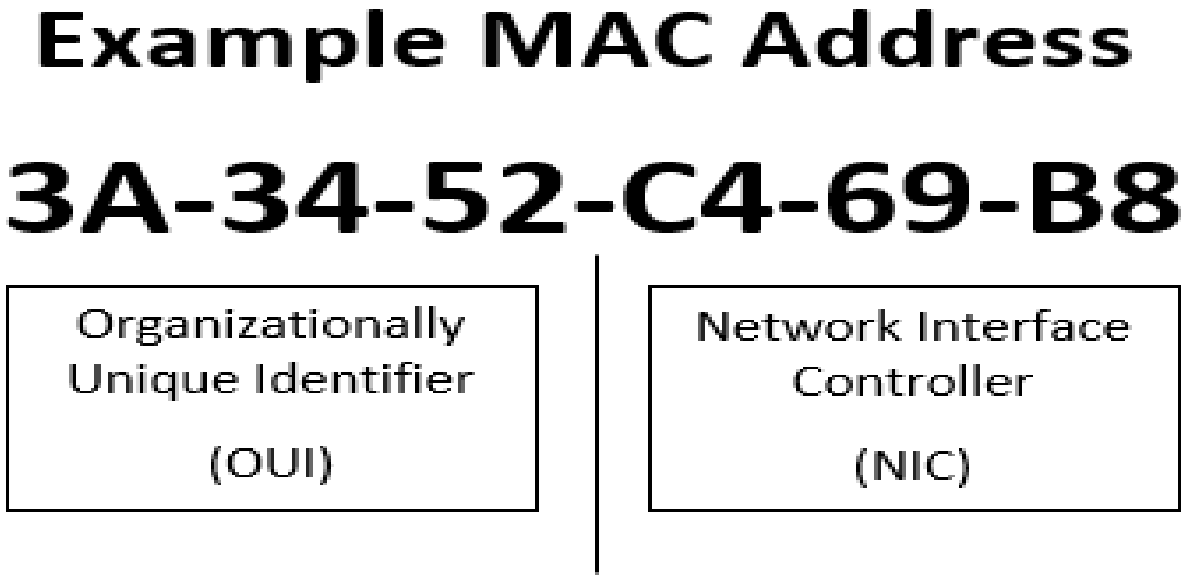
EUI 64 Requirements

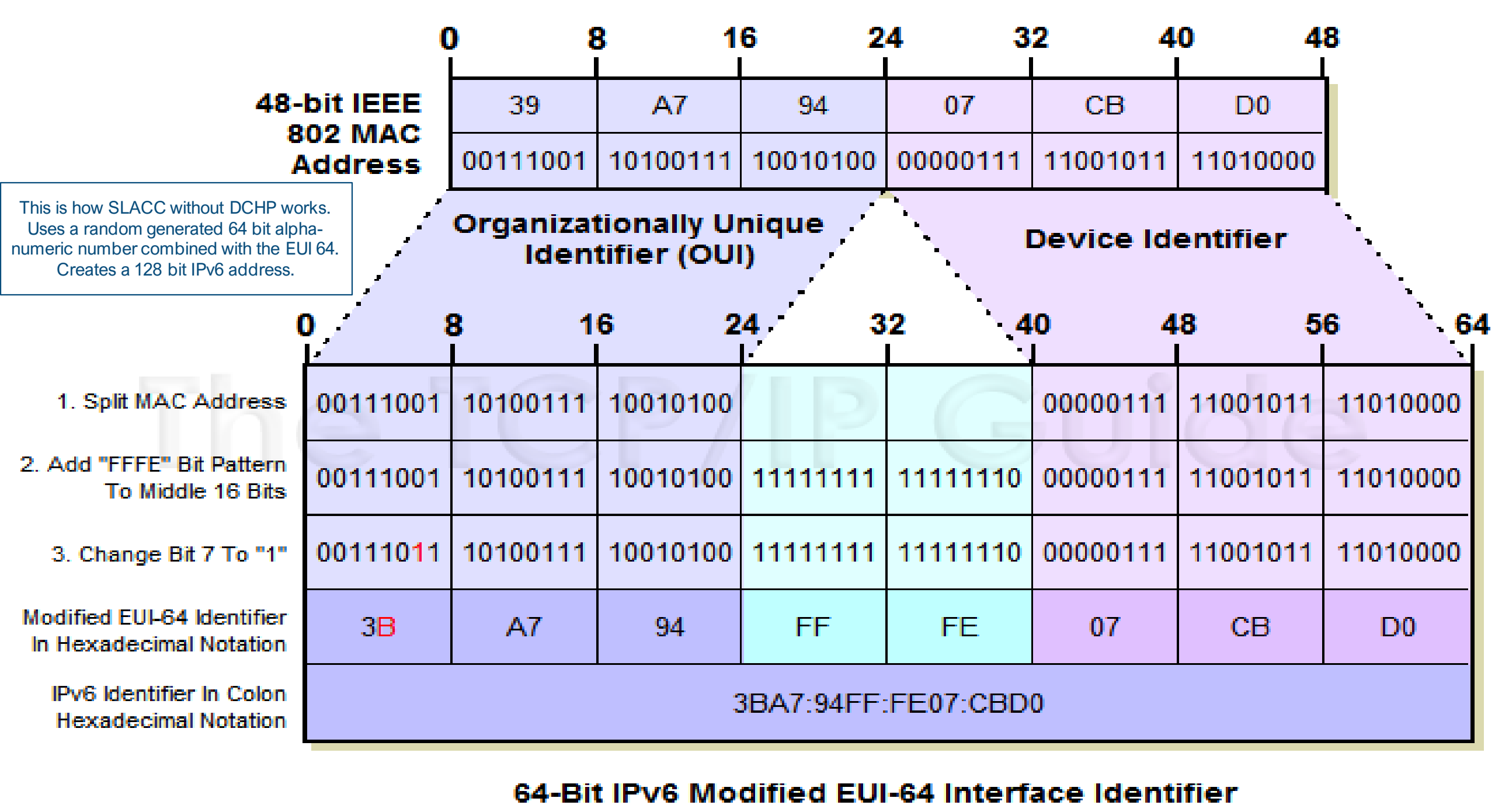
How does EUI 64 work and what are the IPv6 address allocation requirements?

/64 is the allocation requirement as this provides half of the address needed.

Inserting FF:FE in the 48 bit MAC address of the object completes the 64 bit requirement.

Combine the two 64 bit segments and there is now a 128 bit IPv6 address unique to the device the MAC came from.




0
8
16
24
32
40
48
48-bit IEEE 802 MAC Address
39
A7
94
07
CB
D0
00111001
10100111
10010100
00000111
11001011
11010000
This is how SLACC without DCHP works. Uses a random generated 64 bit alpha-numeric number combined with the EUI 64. Creates a 128 bit IPv6 address.
Organizationally Unique Identifier (OUI)
Device Identifier
0
8
16
24
32
40
48
56
64
1. Split MAC Address
00111001 10100111 10010100 00000111 11001011 11010000
2. Add "FFFE" Bit Pattern To Middle 16 Bits
00111001 10100111 10010100 11111111 11111110 00000111 11001011 11010000
3. Change Bit 7 To "1"
00111011 10100111 10010100 11111111 11111110 00000111 11001011 11010000
Modified EUI-64 Identifier In Hexadecimal Notation
3B A7 94 FF FE 07 CB D0
IPv6 Identifier In Colon Hexadecimal Notation
3BA7:94FF:FE07:CBD0
64-Bit IPv6 Modified EUI-64 Interface Identifier

DHCPv6 vs. SLAAC

- If you're running a dual-stack environment, with both IPv4 and IPv6, then it probably makes sense to use DHCP and DHCPv6. This gives you the most consistency and control over your environment.

- If you have moved to an all-IPv6 network and you have no restrictions on who can join the network, then SLAAC is the best option.

- Another way of looking at it is that SLAAC is a more lightweight protocol. It allows hosts to join the network on their own, but it doesn't provide the management layer and auditing capabilities that DHCPv6 offers.

- **** Dual Stack IPv4 and IPv6 is the WaTech standard for

WaTech Policy on Routing IPv6 Addresses Policy 185

Policy 185- DEFINITIONS

Enterprise Service: An enterprise service is a service that all state government agencies with a certain business need or process are required to use, unless

they have received a waiver as described in the Waivers and Appeals section below. Agencies must not adopt a similar service unless they have this waiver.

Types: Enterprise Services can support common administrative business processes such as accounting, payroll, etc., or they can include Information

Technology applications or services commonly used by agencies.

Criteria to Establish an Enterprise Service: The following criteria must be satisfied to establish an Enterprise

Service: There is a need to collect standard data across agencies, and/or

It is feasible to define and develop a standard business process across state government agencies

WaTech Policy on Routing IPv6 Addresses

Policy 185.20

Technology Standard: 185.20

Name of Enterprise Service: Internet Protocol (IP) Address Management

The business processes associated with Internet Protocol (IP) Address Management have been designated as an enterprise service:

- Develop and maintain statewide IP addressing schema and supporting plan
- Acquire address ranges from ARIN in support of that statewide plan (appropriate numbers and classes of addresses)
- Create standards and protocols for use of addresses or ranges of addresses
- Identify blocks of address ranges to be assigned to specific agencies.

IP Address Management enterprise service designation would not include any assignment of addresses allotted to an agency.

This enterprise service designation DOES NOT apply to the K-20 Network.

For questions about this enterprise service or to request a waiver, please contact the OCIO Policy & Waiver Mailbox.

APPROVAL DATE: June 20, 2017

APPROVED BY: CIO Michael Cockrill

WaTech Policy on Routing IPv6 Addresses

*****WaTech will only route the IPv6 addresses that have been allocated to the agency from WaTech Enterprise Services.**

WaTech EDN provisioning will assist agencies that have not received their allocation.

Peering process requires a ticket sent to NCE initially to begin the onboarding process for agencies.

Configuring your internal LAN for IPv6 infrastructure:

Here are the recommended approved Vendors to assist you- WWT, Presidio, NASPO

Questions

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