IPv6:: It's Happening!

Nathan Sherrard - Systems Architect

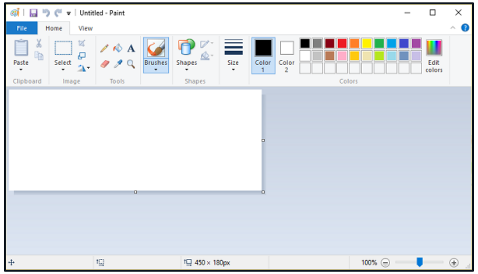
BRKIPV-2191

Agenda

- Introduction
- State of the Industry
- Protocol Primer
- Addressing Plans
- Transition Technologies
- Next Steps

About Nathan

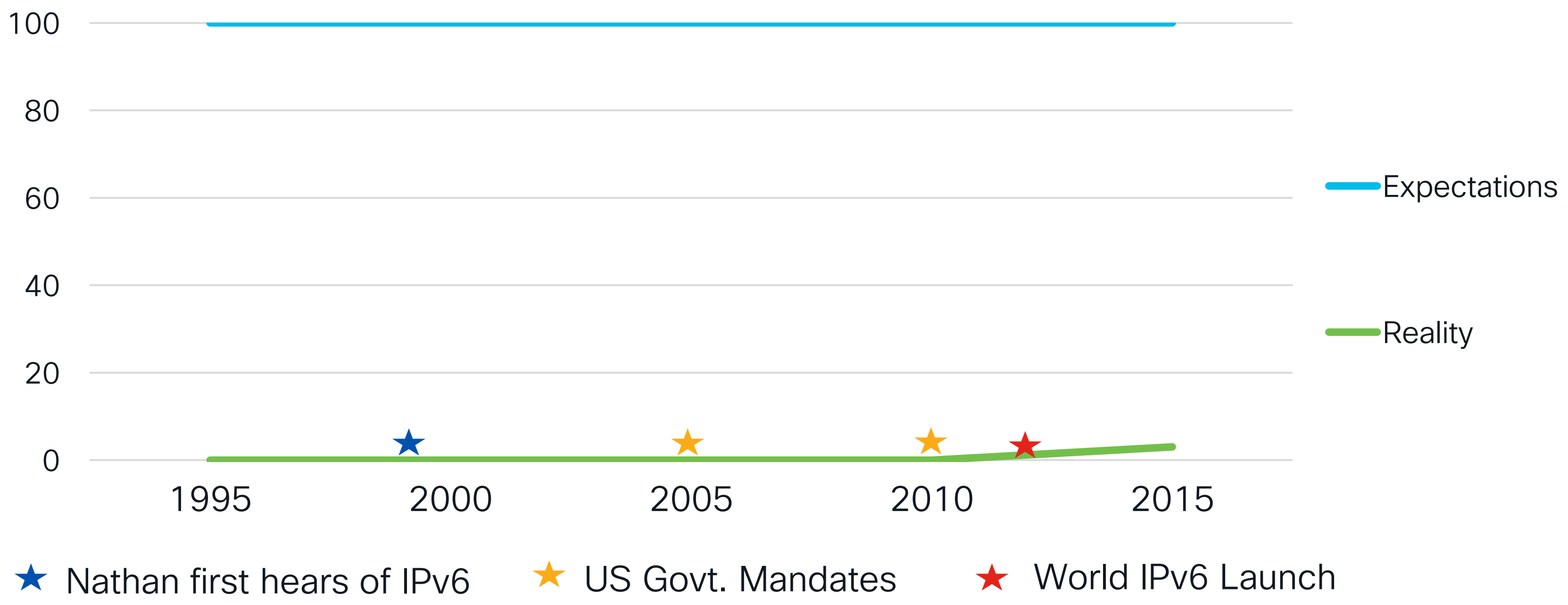
WIRESHARK



Visual Studio Code

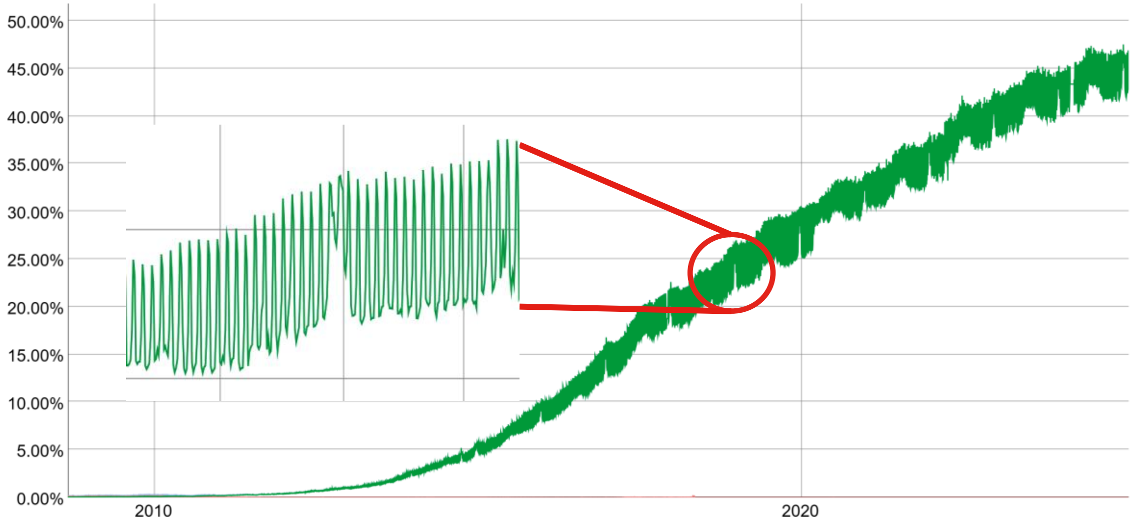
IPv6::
State of the Industry

IPv6 Adoption

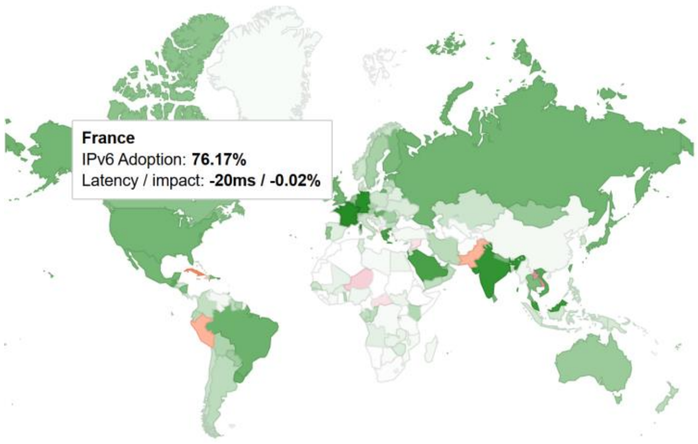


Global IPv6 Stats

Google Global Traffic %



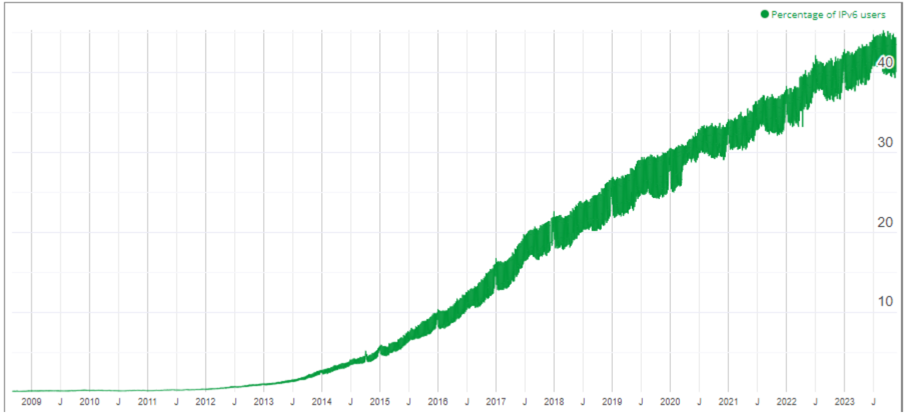
Google Per-country adoption



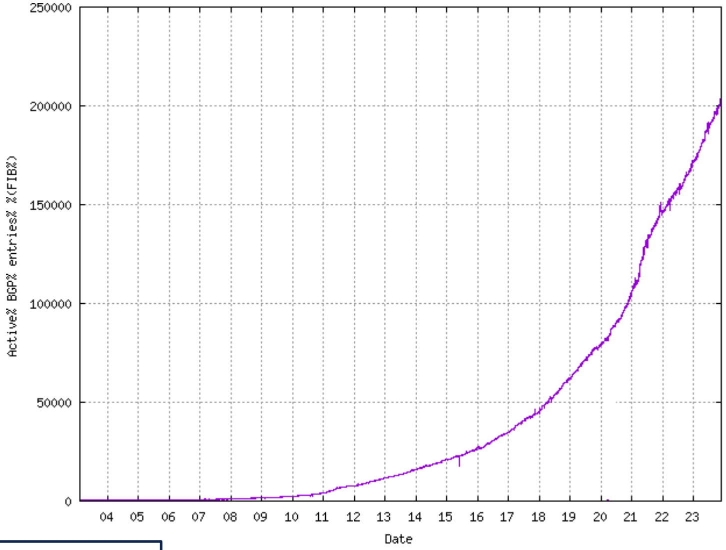
https://www.google.com/intl/en/ipv6/statistics.html

Global IPv6 Stats

Cisco 6Lab Data



IPv6 Prefixes in Global Table



Facebook US: 61%

Akamai US: 52%

Cisco Live US/EMEA: 47%

Cisco Live Melbourne: 54%

https://6lab.cisco.com/stats/cible.php?country=world&option=users
https://www.cidr-report.org/v6/as2.0/#General_Status
https://www.facebook.com/ipv6/?tab=ipv6_country
https://www.akamai.com/internet-station/cyber-attacks/state-of-the-internet-report/ipv6-adoption-visualization

State of Affairs – pre-2012 (World IPv6 Launch)

A Vicious Cycle

https://commons.wikimedia.org/wiki/File:Mexican_Standoff.jpg (Author: Martin SoulStealer)

Driving Factors

- IPv4 address exhaustion
  - Limited availability / costly
  - NAT use … is complicated
- More IPv6 support
  - Clients
  - Networks
  - Web Content
  - Cloud Providers
  - Standards
- Mobile Devices, IOT, Containers
- Organizational mandates
- Alternate Business Models

https://commons.wikimedia.org/wiki/File:US_Navy_110519-N-VA590-457_Sailors_participate_in_the_three-person,_four-legged_race_during_Sports_Day_at_Nong_Prue_Municipality_Sports_Field.jpg
This image was released by the United States Navy with the ID 110519-N-VA590-457

IPv6 2021 OMB Memorandum

- "The strategic intent is for the Federal government to deliver its information services, operate its networks, and access the services of others using only IPv6."
- Regarding dual-stack: "in recent years it has become clear that this approach is overly complex to maintain and unnecessary."

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

THE DIRECTOR

November 19, 2020

M-21-07

MEMORANDUM FOR HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Russell T. Vought
Director

SUBJECT: Completing the Transition to Internet Protocol Version 6 (IPv6)

https://www.whitehouse.gov/wp-content/uploads/2020/11/M-21-07.pdf

IPv6 requirements around the world


WWW.CAC.GOV.CN

请输入检索关键词

front page authoritative Office cyber Informatization Internet international Local Law Policies interaction Education Industry Work

Current location: Home> text security broadcast exchange network enforcement and center and News topics

Notice on Accelerating the Large-Scale Deployment and Application of Internet Protocol Version 6 (IPv6)

July 23, 2021 at 16:00 Source: China Netcom [Print] [Error Correction]

Notice on Accelerating the Large-Scale Deployment and Application of Internet Protocol Version 6 (IPv6)

China Internet Affairs Office issued document [2021] No. 15

All provinces, autonomous regions, municipalities directly under the Central Government, and the Xinjiang Production and Construction Corps Party Committee Network Information Office, Development and Reform Commission, Industry and Information Technology Department (Bureau), and Communications Management Bureau:

The sixth version of the Internet Protocol (IPv6) is an inevitable trend of Internet upgrade and evolution, an important direction of network technology innovation, and the basic support for the construction of a network power. In 2017, the Party Central Committee with Comrade Xi Jinping as the core made a strategic decision to promote the large-scale deployment of IPv6. Over the past three years, all regions and departments have conscientiously implemented the Action Plan for Promoting the Large-Scale Deployment of Internet Protocol Version 6 (IPv6), and made remarkable progress in promoting the large-scale deployment of

China:

- No new private IPv4 as of 2023
- Fully IPv6-only by 2030
- 95% there by 2025

Pay to Stay… on Legacy

AWS News Blog

New – AWS Public IPv4 Address Charge + Public IP Insights

by Jeff Barr | on 28 JUL 2023 | in Amazon EC2, Announcements, Launch, News | Permalink | Comments | Share

0:00 / 0:00

Voiced by Amazon Polly

Public IP Address Type	Current Price/Hour (USD)	New Price/Hour (USD) (Effective February 1, 2024)
In-use Public IPv4 address (including Amazon provided public IPv4 and Elastic IP) assigned to resources in your VPC, Amazon Global Accelerator, and AWS Site-to-site VPN tunnel	No charge	$0.005
Additional (secondary) Elastic IP Address on a running EC2 instance	$0.005	$0.005
Idle Elastic IP Address in account	$0.005	$0.005

IPv6 is an IETF Standard (RFC 8200/STD86)

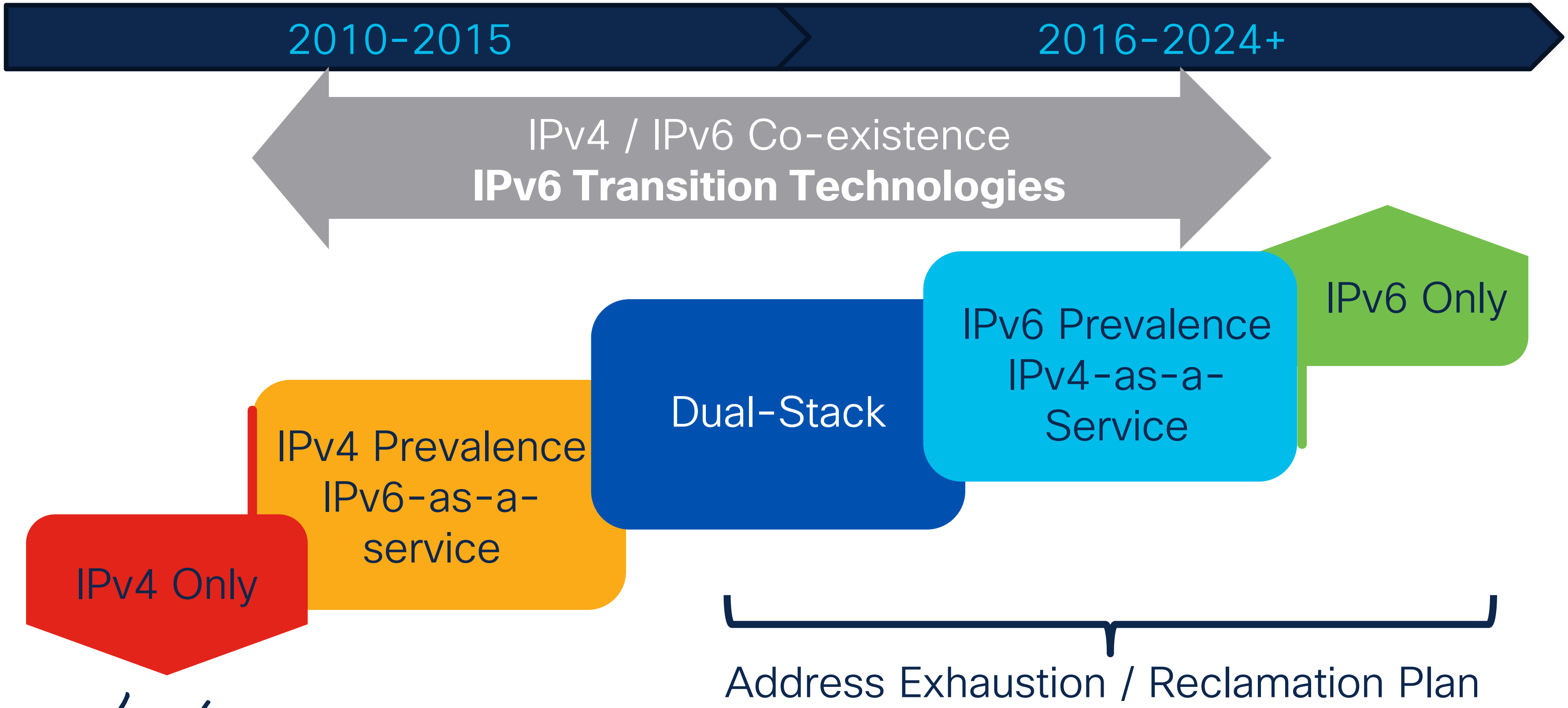
- RFC 8200 rolls up all the previous disparate RFCs about IPv6 into a single RFC
  - Obsoletes 2460 and 1883

- There are more RFCs around **security and best practices** (e.g., RFC 9099)
  - See BRKSEC-2044 - Secure Operations for an IPv6 Network

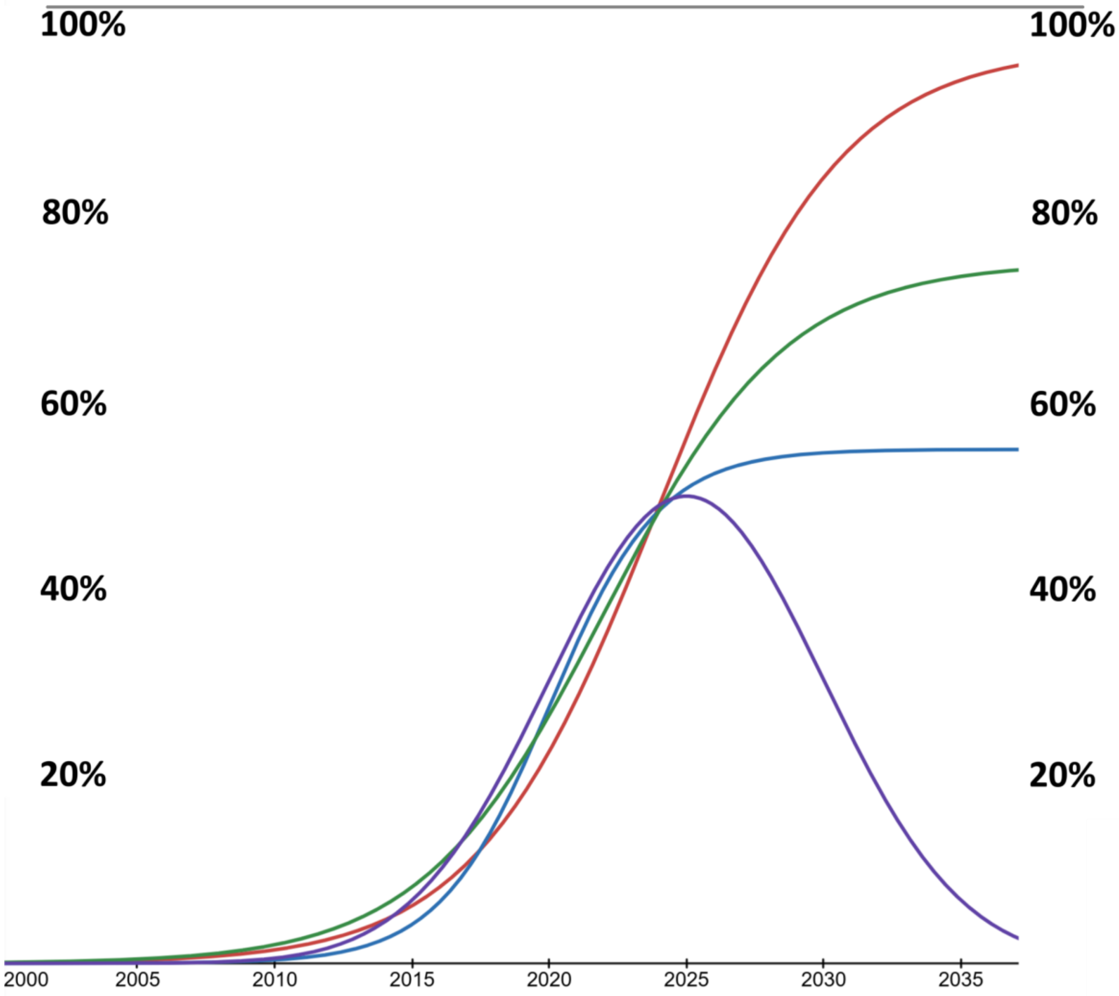
- **IPv6 is ready** to be validated and tested in your environment
  - You can start planning deployment, adoption, and operations

- https://www.system.de/ipv6-rfc/
- https://www.rfc-editor.org/rfc-index.html

IPv6 Multi-Year Evolution



Any guesses?


100%
80%
60%
40%
20%
100%
80%
60%
40%
20%
2000
2005
2010
2015
2020
2025
2030
2035

"How did you go bankrupt?"
Bill asked.
"Two ways,"
Mike said.
"Gradually and then suddenly."

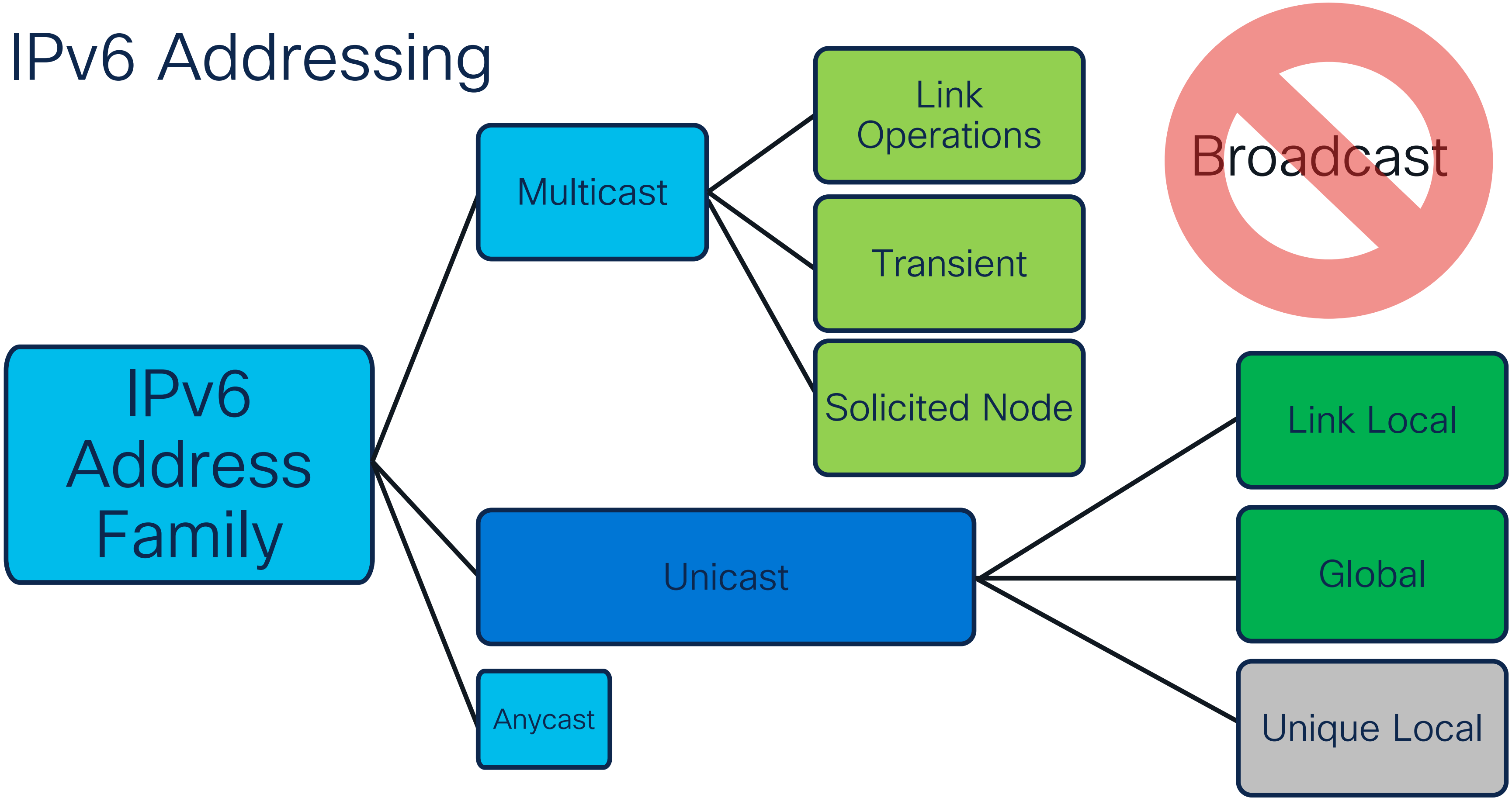
The Sun Also Rises

Ernest Hemingway

IPv6::
The Protocol

cisco Live!

IPv6 Addressing



Hexadecimal Is Really Not That Difficult

- Widely used in computing and programming
  - Hex is a base 16 numerical system
  - Typically expressed by 0x, i.e. 0x34
- Every nibble is a Hex character
  - 4 bits have 16 combinations
  - Easier than high school algebra

100s	10's	1's
0	5	2
1	7	2
5	8	9

256's	16's	1's
	3	4
	a	c
2	4	d

Binary	Hex	Decimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

IPv6 Address Format

- IPv6 addresses are 128 bits long (32 hex characters)
  - 8 groups (words, quads, hextets) of 16 bits separated by (:)
  - RFC5952 - lower case, leading zeros, zero compression

2001:0db8:0046:a1d1:0000:0000:0000:0001

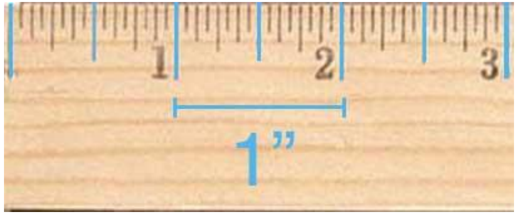
2001:db8:46:a1d1:0:0:0:1

2001:db8:46:a1d1::1

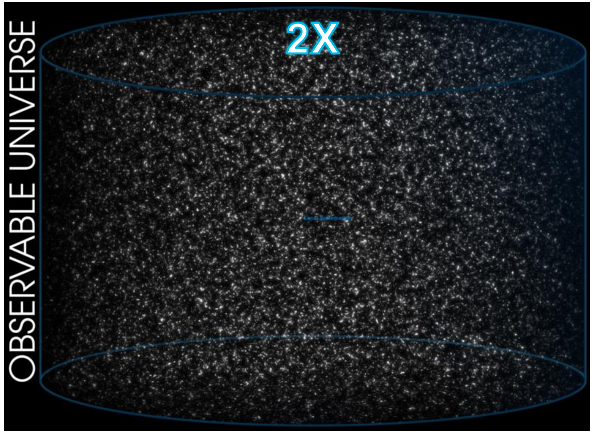
Prefix | **Interface Id**

2001	:	0db8	:	0046	:	a1d1	:	0000	:	0000	:	0000	:	0001
16 bits		16 bits		16 bits		16 bits		16 bits		16 bits		16 bits		16 bits

Perspective



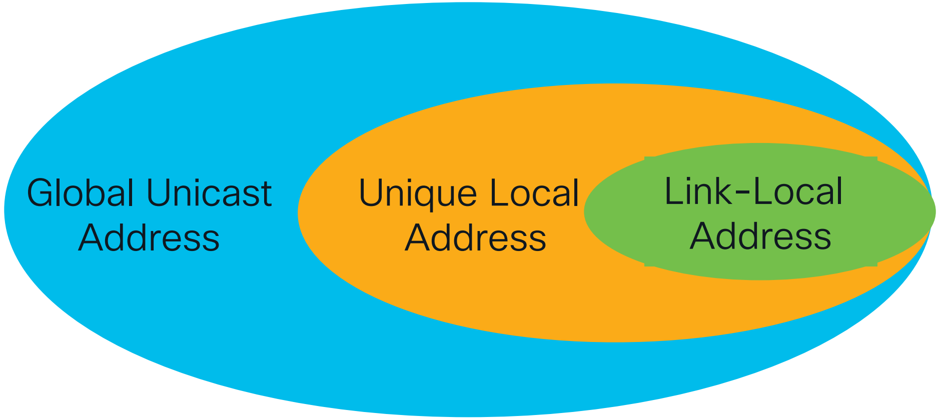
- Total # of IPv4 addresses:
  4,294,967,296
- Total # of IPv6 addresses:
  340,000,000,000,000,000,000,000,000,000,000,000,000



- Don’t bring IPv4 thinking into a IPv6 world!
- We now have the space to do things better

IPv6 Unicast Address Types

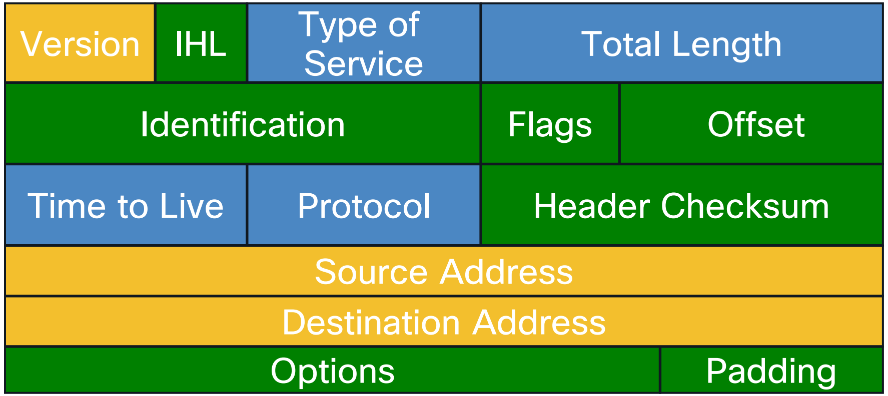
- Link-Local Address (LLA)
  - fe80::/10 range
  - Locally significant to LAN segment
  - Used in many aspects of IPv6 operation
- Unique Local Address (ULA)
  - Routable within administrative domain
  - Poor comparison to RFC1918 IPv4 Addressing
  - fc00::/7
  - Avoid if possible!
- Global Unicast Address (GUA)
  - Routable on the Internet
  - 2000::/3



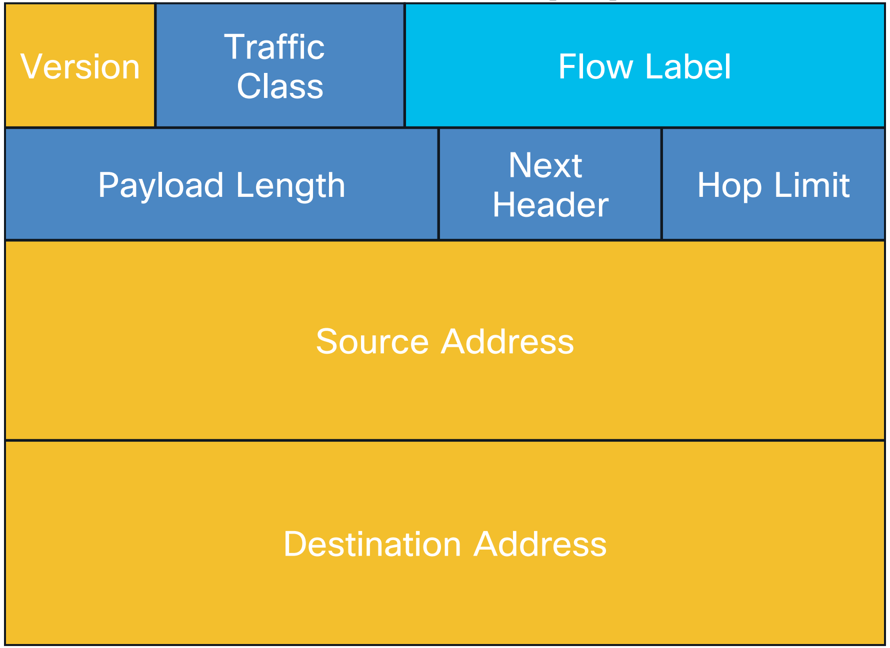
Scope

IPv4 and IPv6 Header Comparison

IPv4 Header (20-60)



IPv6 Header (40)

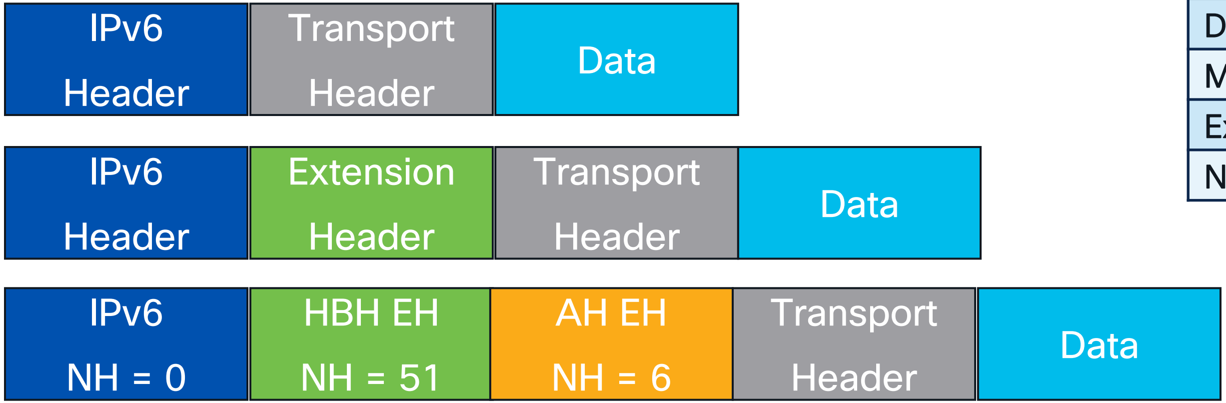


- Length was variable
- Fields in green are removed
- Options appear in extension headers

Extension Headers (EH) ~ Layer 3.5

- EH are daisy chained, processed in order
- EHs have a Next Header field
- Length is variable, ends on 64-bit boundary
- All EHs and Upper-Layer Headers must be in the initial fragment

Extension Header	Type
Hop-by-Hop Options	0
Destination Options	60
Routing Header	43
Fragment Header	44
Authentication Header	51
ESP Header	50
Destination Options	60
Mobility Header	135
Experimental	253,254
No Next Header	59



IPv6 over Ethernet

IPv6 has a specific Ethertype ID

Destination Ethernet Address	Source Ethernet Address	0x0800	IPv4 Header and Payload

Destination Ethernet Address	Source Ethernet Address	0x86DD	IPv6 Header and Payload

IPv6 relies heavily on Multicast

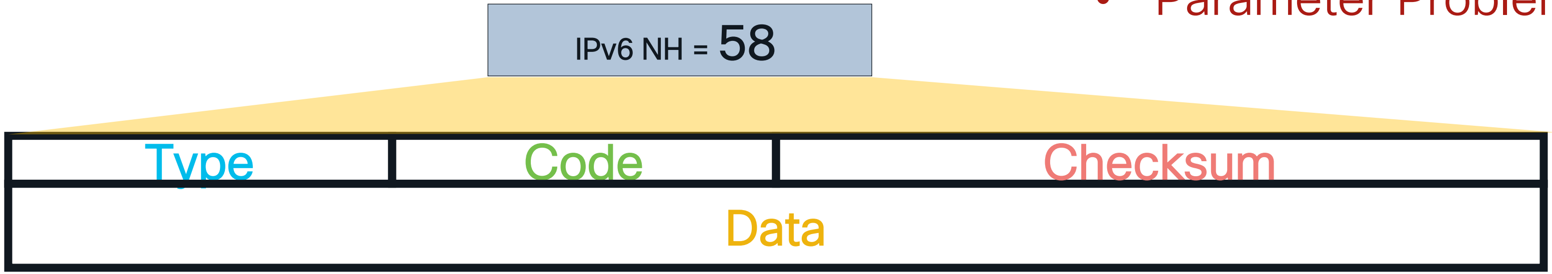
33	33	xx	xx	xx	xx

ICMPv6 Messages

See: RFC 4890

- Neighbor or router discovery (133-137)
- Multicast Listener Discovery (130-132, 143)
- Diagnostics using Ping, *Traceroute* (128, 129)

- Destination Unreachable (1)
- Packet Too Big (2)
- Time Exceeded (3)
- Parameter Problem (4)

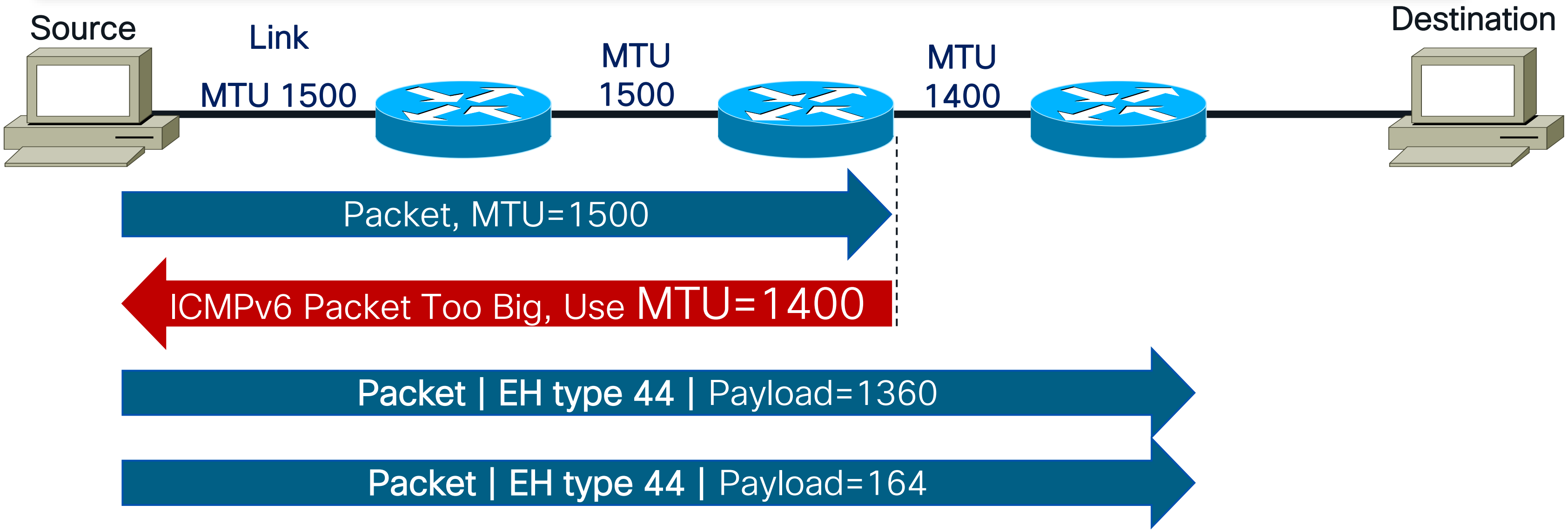


- Type – (0-127) = Error messages, (128-255) = Informational messages
- Code – More granularity within the type
- Checksum – Computed over the entire ICMPv6 & pseudo header
- Data – Contents of “offending”, filled to 1280 bytes (error) or specific message format (info)

Path MTU Discovery

Fragmentation Header:

Next Header	Reserved	Fragment Offset	Res	M
Identification				



IPv6 Multicast Address (RFC 4291)

- Prefix ff00::/8
- Changes based on flag settings

8-bits	4-bits	4-bits	112-bits
1111 1111	0 R P T	Scope	Variable format

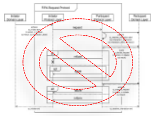
Flags	
O	Reserved
R = 0 R = 1	No embedded RP Embedded RP
P = 0 P = 1	Without Prefix Address based on Prefix
T = 0 T = 1	Well Known Address Temporary address

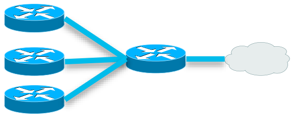
Scope	
1	Node
2	Link
3	Realm
4	Admin
5	Site
8	Organization
e	Global

LL Groups	
::1	All Nodes
::2	All Routers
::5	OSPF
::6	OSPF DR
::a	EIGRP
::fb	mDNSv6
::1:2	DHCPv6

Special Use Addresses

- Localhost
  - 0:0:0:0:0:0:0:1=> ::1
- Unspecified address
  - 0:0:0:0:0:0:0:0=> 0::0 => :: => ::/128
- Documentation Prefix
  - 2001:db8::/32
  - 3fff::/20 (NEW!)
- Discard Prefix
  - 100::/64
- Default Route
  - ::/0



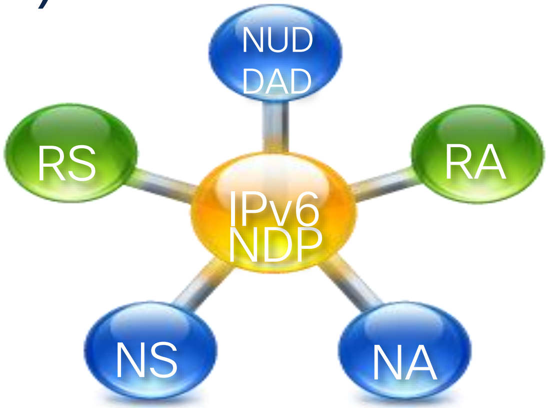


IPv6::
The Protocol

Link Operations

Informational

Neighbor Discovery Protocol – (NDP)



Using

Solves the following problems:

- Router discovery
- Prefix discovery
- Parameter discovery
- Address autoconfiguration
- Address resolution
- Next-hop determination
- Neighbor unreachability detection
- Duplicated address detection
- Redirects

Using 5 ICMPv6 packet type

Router solicitation (133)
Router advertisement (134)
Neighbor solicitation (135)
Neighbor advertisement (136)
Redirect (137)

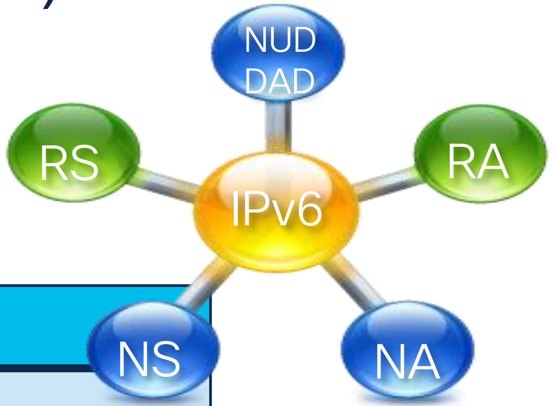
Containing

Option Name	Type
Source Link Layers Address	1
Target Link-Layer Address	2
Prefix Information	3
Redirected Header	4
MTU	5
RDNSS	25
DNS Search List	31

BRKIPV-1616
BRKENT-3002

Informational

Neighbor Discovery Protocol – (NDP)



- Should use Link Local (fe80::/64) as its source
- Hop Limit must be set to 255
  - Generalized TTL Security Mechanism

IPv4	IPv6
ARP Request	Neighbor Solicitation
ARP Reply	Neighbor Advertisement
Broadcast	All-Nodes Multicast or Solicited Node Multicast
Default Gateway via DHCP	Default Gateway via Router Advertisement
Address Assignment via DHCP	Address assignment via Router Advertisement + SLAAC OR DHCPv6

Informational

Solicited Node Multicast

- Required & special form of multicast used for neighbor resolution
- Every interface with an IPv6 Unicast address must:
  - Create corresponding solicited node multicast (ff02::1:ff00:0/104)
- All Layer 3 IPv6 multicast packets must:
  - Map to corresponding Layer 2 multicast (33-33-xx-xx-xx-xx)

IPv6 Source	fe80::04cb:57ff:fe**3c:deca**
IPv6 Destination	ff02::1:ff**3c:deca**
Ethernet Destination	33-33-FF-**3C-DE-CA**
Ethernet Source	02-CB-57-**3C-DE-CA**

Solicited Node Multicast Example

Informational

```
R1#sh ipv6 int e0
Ethernet0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::200:CFF:FE3A:8B18
  Global unicast address(es):
    2001:DB8:46:1234::1 subnet is 2001:DB8:46:1234::/64
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:1
    FF02::1:FF3A:8B18
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND router advertisements are sent every 200 seconds
```

← **Solicited-Node Multicast Addresses**

*If EUI format is used then the 1st solicited node mcast addr is used for both the LL & GU

Neighbor Solicitation & Advertisement

Informational

- Node A needs to resolve node B's link address, Map's L3 to L2
- Multicast for resolution (new), Unicast for reachability (cache)
- Node B will add node A to its neighbor cache during this process w/o sending NS

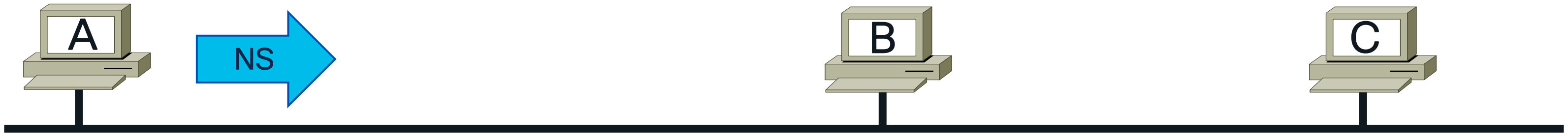
ICMPv6 Type	135 NS
IPv6 Source	fe80::a
IPv6 Destination	**ff02::1:ff00:b**
Hop Limit	255
Target Address	2001:db8:46:46::b
Query	**What is B link layer address?**
Opt. 1 SLLA	A's Link Layer Address

ICMPv6 Type	136 NA
IPv6 Source	fe80::b
IPv6 Destination	fe80::a
Target Address	2001:db8:46:46::b
Option 2 TLLA	**B's Link Layer Address**
***Flags**	R = Router S = Response to Solicitation O = Override cache information

Duplicate Address Detection (DAD)

Informational

- Unspecified Source (::), No Option 1 SLLA
- Probing the local link to verify address uniqueness
- Most vendors now use Optimistic DAD



ICMPv6 Type	135 NS
IPv6 Source	UNSPEC = ::
IPv6 Dest.	A’s Solicited Node Multicast ff02::1:ffab:cdef
Query	Anyone Using “fe80::1234:5678:90ab:cdef”

Node A can start using queried address

Router Solicitation and Advertisement

- Router Solicitations (RS) are sent by nodes at boot up
- Router Advertisements (RA) go out in response to RS *and* at regular intervals
- Routers forward packets as well as provide provisioning services

RS	
ICMP Type	133
IPv6 Source	fe80::a
IPv6 Destination	ff02::2
Opt. 1 SLLA	SRC Link Layer Address

RA	
ICMP Type	134
IPv6 Source	fe80::1
IPv6 Destination	fe80::a
Data	Options, subnet prefix, lifetime, autoconfig flag

Router Advertisement

- M-Flag – Stateful DHCPv6 to acquire IPv6 address
- O-Flag – Stateless DHCPv6 in addition to SLAAC
- Preference Bits – Low, Med, High
- Router Lifetime – Must be >0 for Default Router
- Options - Prefix Information, Length, Flags
- L bit – Only way a host get a On Link Prefix
- A bit – SLAAC (Stateless Autoconfiguration)
  - Typically opposite of 'M' flag

Type: 134 (RA)
Code: 0
Checksum: 0xff78 [correct]
Cur hop limit: 64
∞ Flags: 0x84
1... .... = Managed **(M flag)**
.0.. .... = Not other **(O flag)**
..0. .... = Not Home (H flag)
...0 1... = Router pref: High
Router lifetime: (s)**1800**
Reachable time: (ms) 3600000
Retrans timer: (ms) 1000
ICMPv6 Option 3 (Prefix Info)
Prefix length: 64
∞ Flags: 0x84
1... .... = On link (L Bit)
.... 0... = No Auto (A Bit)
Prefix: 2001:0db8:4646:1234::/64

IPv6::
The Protocol

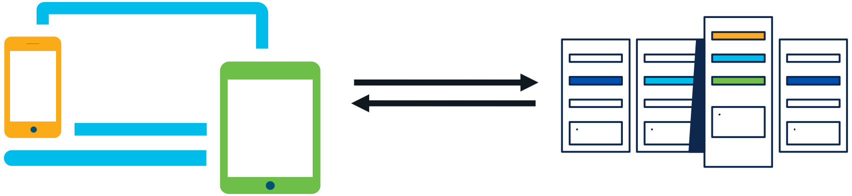
Interface ID’s

IPv6 interface ID Assignment

Similar to IPv4

Statically configured

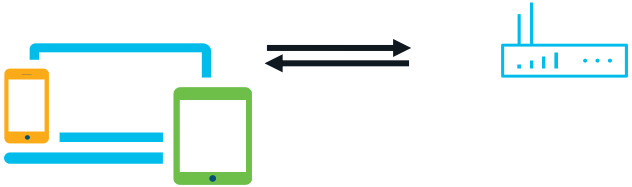
Assigned via DHCPv6



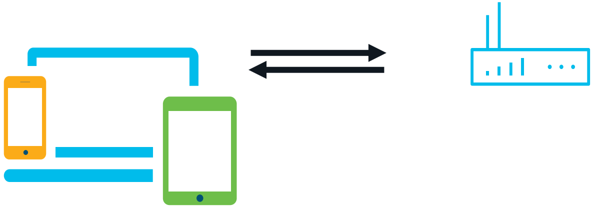
IPv6 interface ID Assignment

New to IPv6

StateLess Address Auto Configuration
SLAAC EUI64

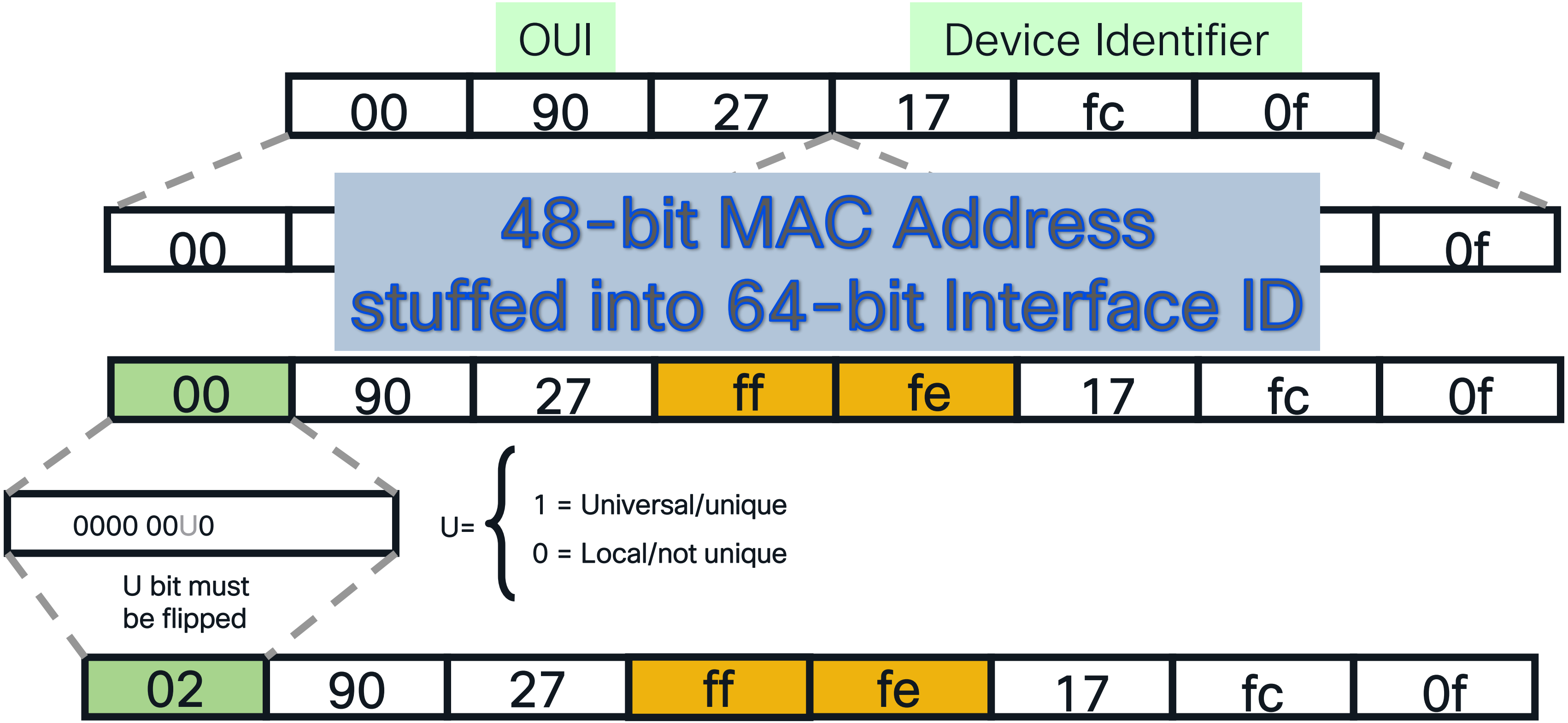


SLAAC RFC 8981
Temporary Address Extensions for Stateless Address Autoconfiguration in IPv6 formerly Privacy Extensions



Extended Unique Identifier (EUI64)

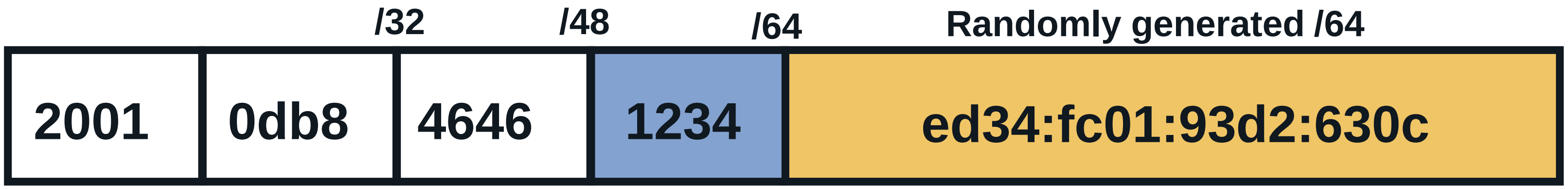
No longer used by most Host OS's



IPv6 Privacy Extensions (RFC 8981)

- Randomly generated for each interface
- Enabled by default in Windows, Android, iOS, Mac OS/X, Linux
- Temporary address rotation in addition

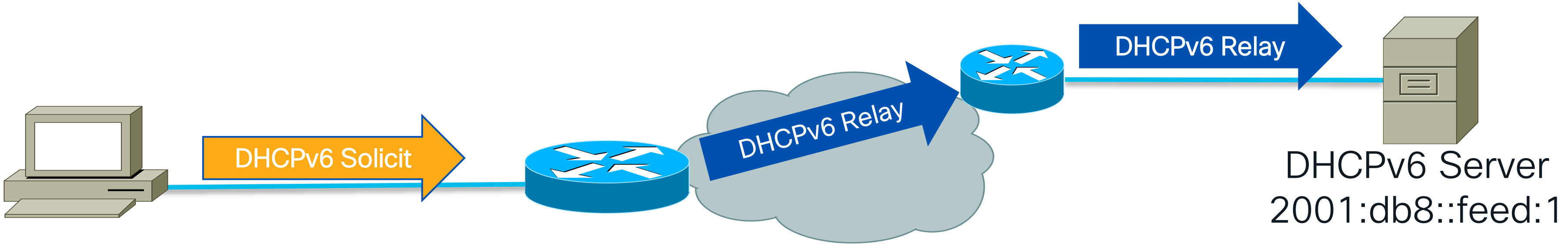
- RFC 7217
- Generate IID’s that are Stable/Constant for each subnet
- IID’s Change As Hosts Move From One Network to Another



DHCPv6
Stateful

- SOLICIT (any servers) →
- ← ADVERTISE (want this address)
- REQUEST (I want that address) →
- ← REPLY (It's yours)

- Source – fe80::1234, Destination - ff02::1:2
- Client UDP 546, Server UDP 547
- DUID – Different from v4 (not MAC!), used to identify clients
- Original Multicast encapsulated in unicast (**relay**)



DHCPv6

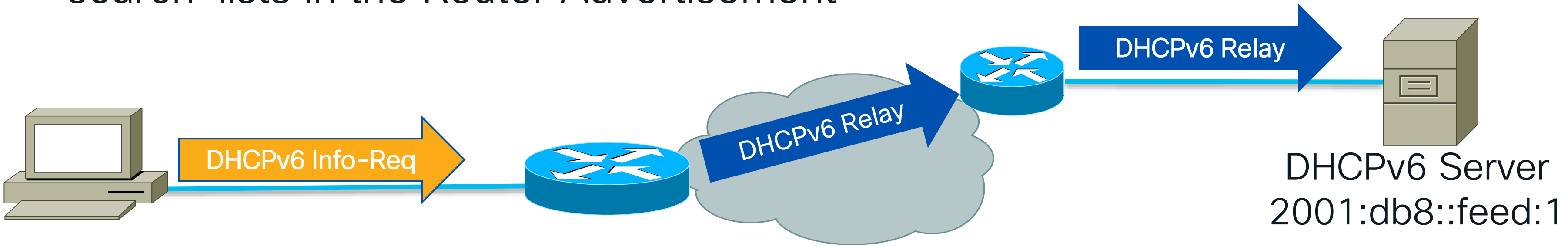
Stateless

BRKENT-2008

- Use SLAAC for address, but still desire extra information
- Same source/dest addresses and ports as Stateful
- Managed flag = 0
- O flag = 1
- RDNSS allow DNS recursive servers and DNS search-lists in the Router Advertisement

INFORMATION-REQUEST (any servers) →
Option Requests

← REPLY (Here is your config parameters)



Router Advertisement Sent

```
> Ethernet II, Src: Arcadyan_a2:2c:05 (b8:f8:53:a2:2c:05), Dst: IPv6mcast_01 (33:33:00:00:00:01)
> Internet Protocol Version 6, Src: fe80::baf8:53ff:fea2:2c05, Dst: ff02::1
v Internet Control Message Protocol v6
    Type: Router Advertisement (134)
    Code: 0
    Checksum: 0xa04a [correct]
    [Checksum Status: Good]
    Cur hop limit: 64
  > Flags: 0x40, Other configuration, Prf (Default Router Preference): Medium
    Router lifetime (s): 900                  0... .... = Managed address configuration: Not set
    Reachable time (ms): 0
    Retrans timer (ms): 0
  v ICMPv6 Option (Prefix information : 2600:4040:46c7:500::/64)
      Type: Prefix information (3)
      Length: 4 (32 bytes)
      Prefix Length: 64
    > Flag: 0xc0, On-link flag(L), Autonomous address-configuration flag(A)
      Valid Lifetime: 7200
      Preferred Lifetime: 7200
      Reserved
      Prefix: 2600:4040:46c7:500::
  > ICMPv6 Option (Route Information : High 2600:4040:46c7:500::/56)
  > ICMPv6 Option (Recursive DNS Server 2600:4040:46c7:500::1)
  > ICMPv6 Option (MTU : 1500)
  > ICMPv6 Option (Source link-layer address : b8:f8:53:a2:2c:05)
```

BRKENT-3002

Endpoint Validation

```
natha  ~  0ms  ipconfig /all                         pwsh  100%  09:37:02

Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . : myfiosgateway.com
   Description . . . . . . . . . . . : Killer(R) Wi-Fi 6 AX1650s
   Physical Address. . . . . . . . . : 04-6C-59-0D-95-8A
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv6 Address. . . . . . . . . . . : 2600:4040:46c7:500:f813:a911:3d11:334b(Preferred)
   Temporary IPv6 Address. . . . . . : 2600:4040:46c7:500:c35:d878:d18b:78ee(Preferred)
   Link-local IPv6 Address . . . . . : fe80::ff1c:1776:bf67:54ba%14(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.1.177(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Wednesday, May 10, 2023 12:02:00 PM
   Lease Expires . . . . . . . . . . : Saturday, May 20, 2023 8:46:36 AM
   Default Gateway . . . . . . . . . : fe80::baf8:53ff:fea2:2c05%14
                                       192.168.1.1
   DHCP Server . . . . . . . . . . . : 192.168.1.1
   DHCPv6 IAID . . . . . . . . . . . : 151284825
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-2B-76-54-14-04-6C-59-0D-95-8A
   DNS Servers . . . . . . . . . . . : 2600:4040:46c7:500::1
                                       192.168.1.1
   NetBIOS over Tcpip. . . . . . . . : Enabled

natha  ~  271ms  netsh int ipv6 show int 14

Interface Wi-Fi Parameters
----------------------------------------------
Link MTU                          : 1500 bytes
```

IPv Foo

learn.microsoft.com	23.78.127.96
js.monitor.azure.com	13.107.226.40
wcpstatic.microsoft.com	13.107.253.40

learn.microsoft.com	2600:1408:7400:1a6::3544
js.monitor.azure.com	2620:1ec:48:1::40
wcpstatic.microsoft.com	2620:1ec:48:1::40

ipv4.jamieweb.net	157.230.83.95
accounts.google.com	2607:f8b0:4004:c1b::54

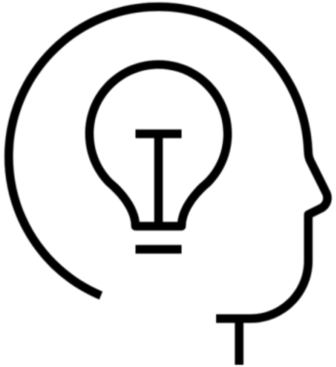
packetpushers.net	2606:4700:3033::6815:5087
fonts.googleapis.com	2607:f8b0:4004:c09::5f
fonts.gstatic.com	2607:f8b0:4004:c09::5e
promo.packetpushers.net	66.165.234.114
www.googletagmanager.com	2607:f8b0:4004:c17::61

Numerous ‘netsh’, ‘ip’ and ‘ifconfig’ commands for Windows, Linux and Mac

IPv6::
Addressing Plans

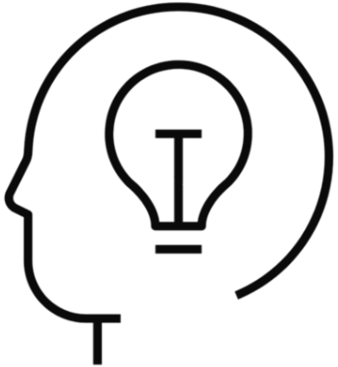
A shift in thinking...

IPv4



Addresses

IPv6



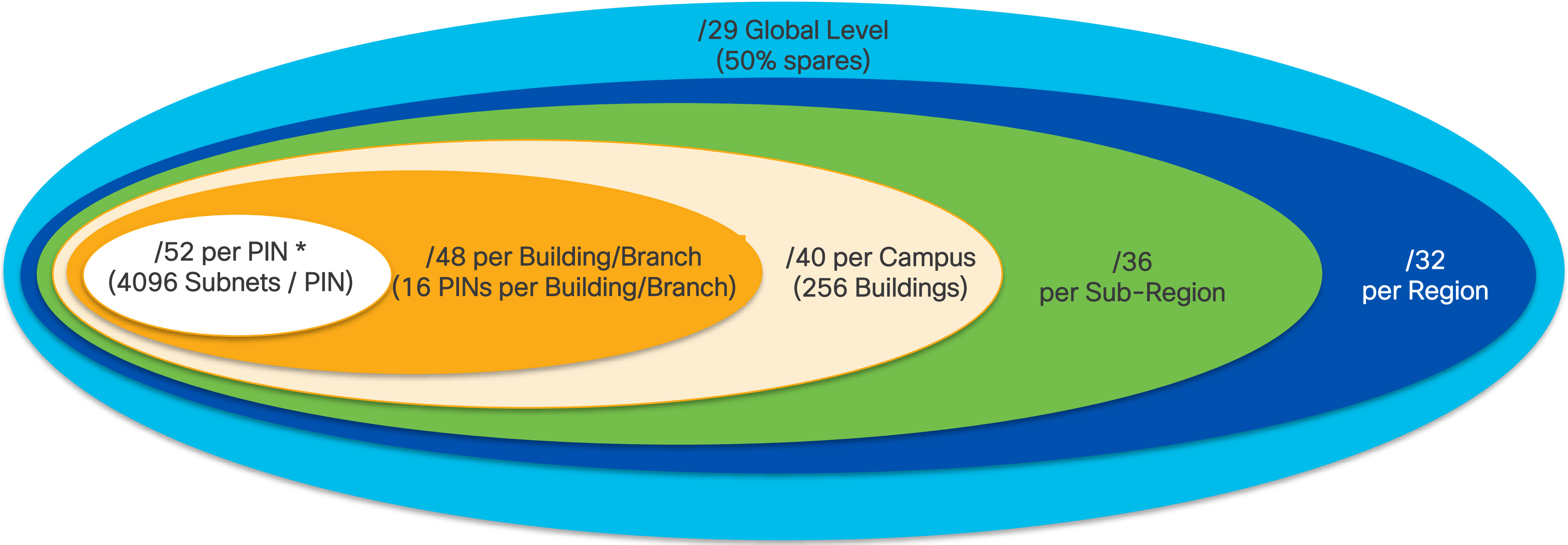
Subnets

IPv6 Address Space - PA vs. PI

- Provider Aggregatable (“Assigned”) (PA)
  - Original intention for all
  - Residential and small business
  - Prefixes may change (DHCPv6-PD)
- Provider Independent (PI)
  - Now more common in Enterprises
  - Control and stability
  - Requires AS and extra cost
  - Often used with BGP (though not always)
- Considerations
  - Local breakout (DIA) at sites?
  - Will my ISP run BGP with me at each of my sites?
  - Should I get 1 PI block or per-RIR?
  - Will I be multihoming?

Address Overview Example

Breaking down the /28



Nibble Boundaries!

* PIN = Place In the Network – A framework to classify functional areas of the network
e.g., Lab, Desktop, DC, DMZ, etc.

Address Planning Continued

More Examples

2001:0db8::/32 – allocated from RIR

`PPPP:PPPP:CGGG:LLSS ::/64`

P = Global Prefix from RIR (2001:0db8)
C = Campus vs. Cloud vs. Colo
G = Geographic breakdown
L = Logical/Functional breakdown (PIN)
S = Subnet

`PPPP:PPPP:CGGG:LSSS ::/64`

`PPPP:PPPP:CGGL:LSSS ::/64`

`PPPP:PPPC:GGGL:LSSS ::/64`

`PPPP:PPPC:GGGG:LLSS ::/64`

~~`PPPP:PPPP:CGGG:GLSS ::/64`~~

/48 is longest prefix allowed in global routing tables

Address Planning Continued

Template Addressing Example

(13th Nibble) Functional Identifier

'Site' Identifier

PIN (16)

Subnets / PIN (4096)

/48	/52	/64

2001:0db8:729c::/48

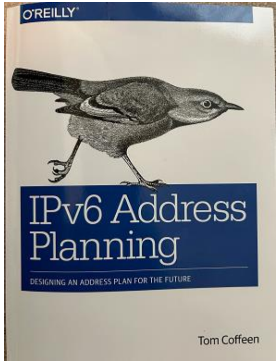
- 0 = *Reserved*
- 2 = Infrastructure
- 4 = Desktop (wired)
- 6 = Wireless (corp)
- 8 = Guest Wi-fi
- A = Lab
- C = Building DC
- E = DMZ
- F = *Reserved*
- *'Even' = Future Use*

2001:0db8:729c:4000::/52 - Desktop PIN

- 2001:0db8:729c:4200::/64 – Desktop VLAN 200
- 2001:0db8:729c:4201::/64 – Desktop VLAN 201

2001:0db8:029c:a000::/52 - Lab PIN

- 2001:0db8:029c:a004::/64 – Lab Subnet 4
- 2001:0db8:029c:a005::/64 – Lab Subnet 5



Address Planning: The 4 Rules

1. SIMPLE ← Remember Rule #1
   - You don't want to spend weeks explaining it!
2. Embed Information
   - To help troubleshooting and operation of the network
   - Examples: location, country, PIN, VLAN, IPv4 addresses in Link Local and/or Global Addresses
3. Build-in Reserve
   - Cater for future growth, mergers & acquisitions, new locations
   - Reserved vs. assigned
4. Aggregatable
   - Good aggregation is essential, just one address block (per location), we can take advantage of this (unlike in IPv4!)
   - Ensures scalability and stability

IPv6:: Transition Technologies

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Dual-Stack (former recommendation)

- Transition from IPv4 to Dual-stack
  - Then IPv6-only can be introduced
- Node has both IPv4 and IPv6 addresses
  - Clients, servers, network, services
- IPv6 is preferred over IPv4
  - RFC 6724 – Host Address Selection
  - RFC 8305 - Happy Eyeballs

https://commons.wikimedia.org/wiki/File:Ships_that_pass_in_the_night,_Atlantic_City,_New_Jersey.png (Author: Unknown) (public domain)

Dual-Stack – Pros and Cons

Pros

- Classic standard solution model
- Supports legacy (IPv4) applications
- Widely available
- Once services are on IPv6, IPv4 can simply be discontinued

Cons

- Doesn’t solve IPv4 exhaustion
- Increased CapEx+OpEx
- Scalability concerns
- Policy synchronization
- Security: larger attack surface
- Hidden brokenness

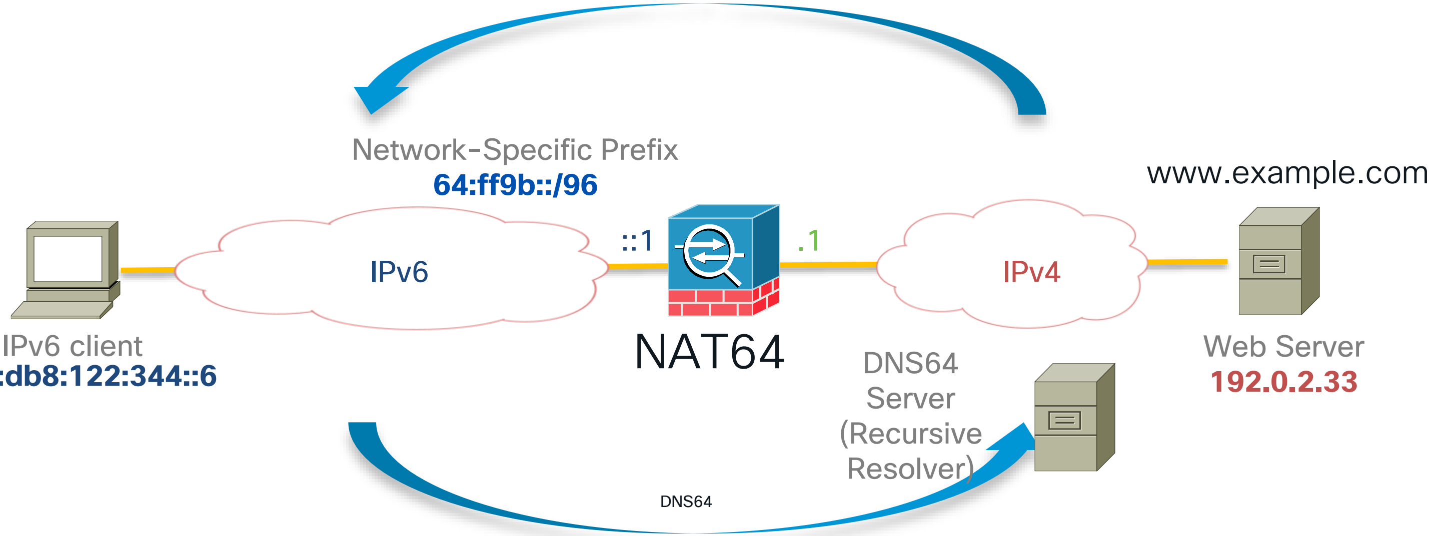
IPv6-only Transition Technologies

- **Dual-Stack** (former go-to, now only when necessary)
- **NAT64 + DNS64** - common in enterprise
  - Allows access to IPv4 resources from IPv6 clients
- **SLB64** – easy; common for data center / servers
  - Presents IPv6 address to outside
- 464XLAT - mobile service provider … for now?
- MAP-T / MAP-E / DS-Lite / lw4o6 – access provider
- 6rd – legacy access provider
- Teredo/ISATAP/6to4 – legacy tunnels

DNS64 Operation

←Step 5 Translates it to a **AAAA** record (embed IPv4 address on end of network-specific prefix)

←Step 4 DNS64 server receives **A** record for IPv4 server



Step 1→ **IPv6** client queries **AAAA** record for IPv4 server

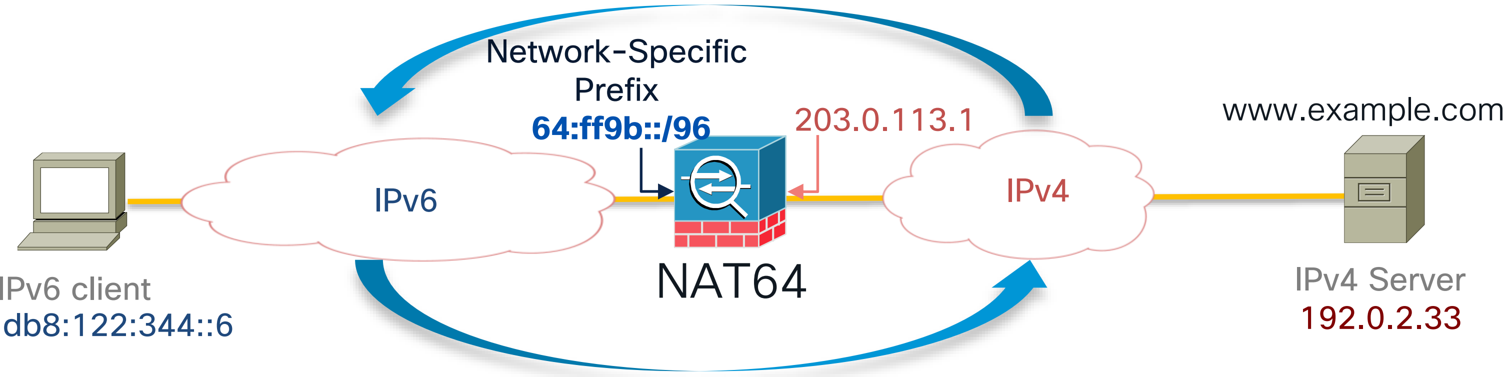
←Step 2 DNS64 receives “empty” **AAAA** record

Step 3→ DNS64 asks for **A** record of IPv4 server

NAT64 Operation

←Source IPv6 **64:ff9b**::c000:221 Dest. IPv6 2001:db8:122:344::6

←Source IPv4 192.0.2.33 Dest. IPv4 203.0.113.1



→ Source IPv6 2001:db8:122:344::6 Dest. IPv6 **64:ff9b**::c000:221

→Source IPv4 203.0.113.1 Dest. IPv4 192.0.2.33

IPv6-only Transition Technologies

- **Dual-Stack** (former go-to, now only when necessary)
- **NAT64 + DNS64** - common in enterprise
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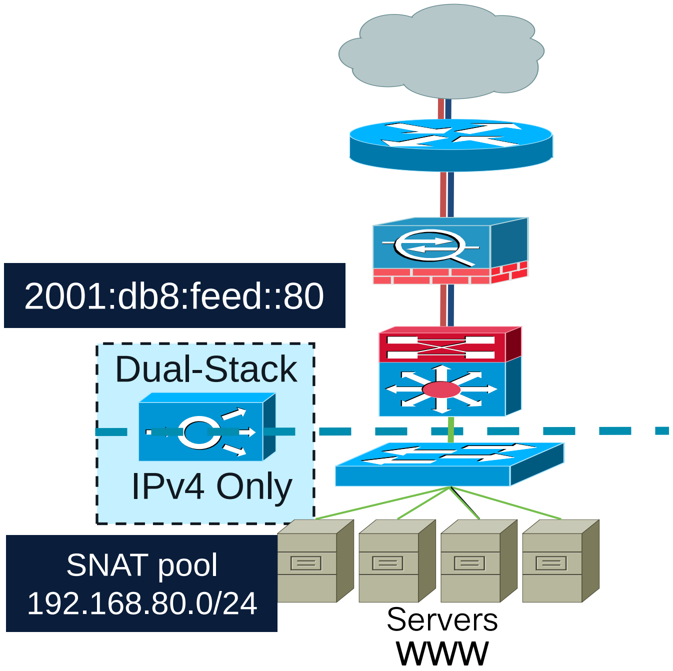
SLB64 Translation Technique

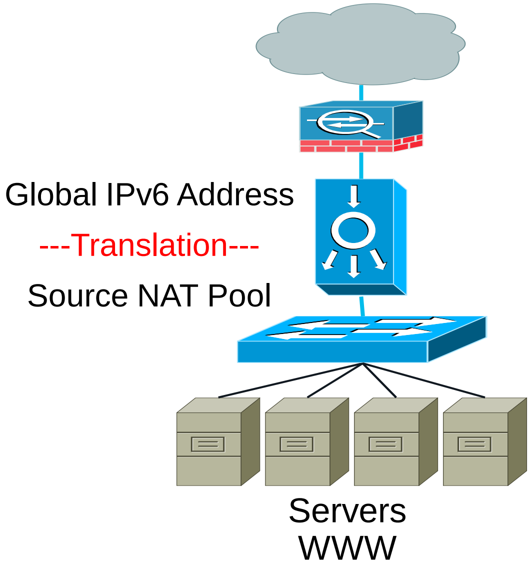
- Almost every network has some load balancing
- Router; ADC; Reverse Proxy
- Create Virtual IP (VIP)
  - Tie the VIP to servers (WWW)
  - Publish VIP AAAA record in DNS
- Establish a source NAT pool
  - Use as IPv4 source after translation
- Wide vendor support (on-prem and cloud)
- Very quick to deploy



X-Forwarded-For (XFF) / Forwarded Headers

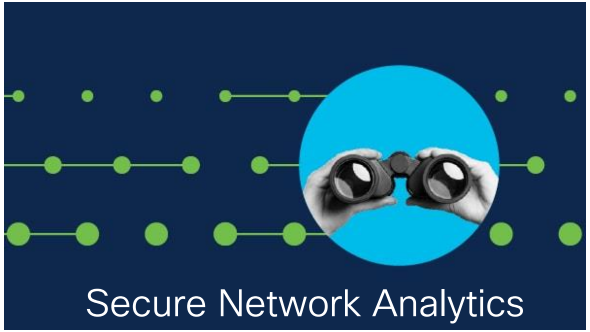
- Web Server Logging for Geo Location, Analytics, Security
- Source IP of client requests will be logged as SNAT address
- Use X-Forwarded-For (or Forwarded) field of the HTTP header

```
GET / HTTP/1.1
Host: www.foo.org
User-Agent: Mozilla Firefox/3.0.3
Accept: text/html,application/xhtml+xml,application/xml
Accept-Language: en-us,en
Keep-Alive: 300
X-Forwarded-For: 2001:db8:ea5e:1:49fa:b11a:aaf8:91a5
Connection: keep-alive
```



IPv6::
More Next Steps

Network Validation



- NetFlow / IPFIX
  - What percentage of traffic is IPv4 vs IPv6?
  - Which network segments/subnets/VLANs are 100% IPv6, 100% IPv4?
  - Which servers are primarily IPv6, primarily IPv4?
  - Which clients are primarily IPv6, primarily IPv4?

  - Secure Network Analytics (formerly StealthWatch)
  - Catalyst (DNA) Center Assurance

Be Aware of What’s Changed

- **Deprecated**/rarely used: 6to4, Teredo, ISATAP, NAT-PT, SeND, Mobile IPv6
- Abandoning of **IPSec** as required for end-to-end connections
- Move from **EUI-64** to Privacy/Temporary addresses
- Rarity of **extension headers** (especially multiple!)
- Proliferation of **PI space** and the corresponding **larger allocations** readily available from the RIR’s (i.e., no longer just /48’s you get from your SP)

Cisco Live Amsterdam 2025 IPv6 Learning Map

Sunday–9th

TECIPV-2000 13:45
IPv6 in the Host and in the Local Network

Monday–10th

TECENT-2150 8:30
6+3=100! Use IPv6 and Python 3 to Transform how you do Networking

TECIPV-2001 8:45
IPv6 Beyond the Local Network

Tuesday–11th

BRKIPV-1007 8:00
Deploying Catalyst Center for IPv6 Networks

BRKSEC-2044 10:30
Secure Operations for an IPv6 Network

IBOIPV-2000 13:30
Sharing Experience on IPv6 Deployments

BRKSPG-2203 14:30
Introduction to SRv6 uSID Technology

BRKIPV-2191 16:30
IPv6:: It's Happening!

Wednesday–12th

BRKEWN-2834 8:00
IPv6-Enabled Wireless (Wi-Fi) Access: Design and Deployment Strategies

CTF-1001 10:15
IPv6: The Internet's best kept secret!

BRKIPV-2186 13:15
IPv6 Networking in a Cloud Native World

CISCOU-1038 14:45
IPv6 Groove: Get By with a Little Help from My Friends!

BRKENT-2008 13:00
Goodbye Legacy, the Move to an IPv6-Only Enterprise

BRKIPV-1616 16:00
IPv6 – What Do You Mean There Isn't a Broadcast?

Thursday–13th

IBOENT-2811 11:30
Everything You Wanted to Know about IPv6 but Were Afraid to Ask

IBOIPV-2000 13:30
Sharing Experience on IPv6 Deployments

BRKSPG-3198 14:15
Advanced Innovations in SRv6 uSID and IP Measurements

BRKOPS-2223 15:00
The Network of the Future is Here - Let's Automate your IPv6 deployment with Python!

BRKIPV-2228 17:00
The Automation Travel Guide for Your IPv6 Journey!

Friday –14th

BRKIPV-2418 9:00
Deploying IPv6 Routing Protocols: Specifics and Considerations

BRKENT-3340 11:00
The Hitchhiker's Guide to Troubleshooting IPv6

BRKENT-3002 11:15
IPv6 Security in the Local Area with First Hop Security

Walk in Labs

LABIPV-1639	IPv6 Foundations: A Dive into Basic Networking Concepts
LABIPV-2640	IPv6 Deep Dive: Beyond Basics to Brilliance
LABMPL-1201	SRv6 Basics
LABSP-2129	SRv6 Micro-Segment Basics
LABSP-3393	Implementing Segment Routing v6 (SRv6) Transport on NCS 55xx/5xx and Cisco 8000: Advanced

Instructor-led Labs

LTRIPV-2222	Implementing Future-Ready Networks - Deploy IOS XE IPv6 Configuration with Python!
LTRSPG-2212	SRv6 and Cloud-Native: A Platform for Network Service Innovation

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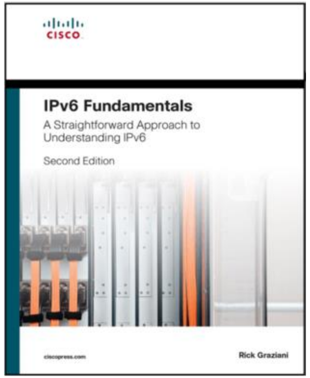
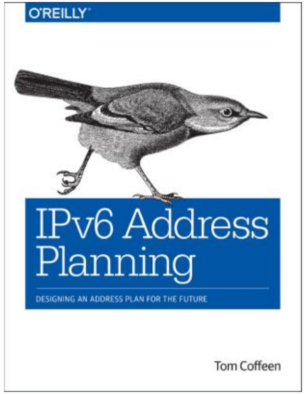
Resources



IPv6 Buzz Podcast - packetpushers.net/series/ipv6-buzz/

Infoblox IPv6 Center of Excellence - blogs.infoblox.com/category/ipv6-coe/

RIPE IPv6 Info Centre - www.ripe.net/publications/ipv6-info-centre



ARIN IPv6 Information - www.arin.net/resources/guide/ipv6/

APNIC IPv6 Information - www.apnic.net/community/ipv6/

RFC 9099: Operational Security Considerations for IPv6 Networks - www.rfc-editor.org/rfc/rfc7381

Webex App

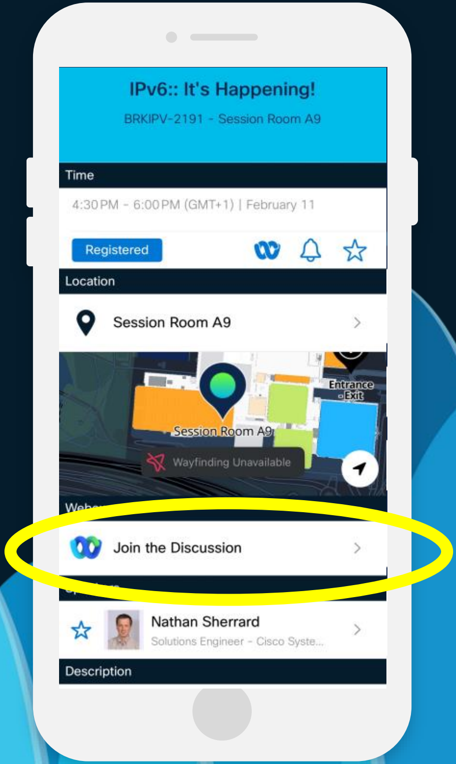
Questions?

Use the Webex app to chat with the speaker after the session

How

1. Find this session in the Cisco Events mobile app
2. Click “Join the Discussion”
3. Install the Webex app or go directly to the Webex space
4. Enter messages/questions in the Webex space

Webex spaces will be moderated by the speaker until February 28, 2025.



Fill Out Your Session Surveys

Participants who fill out a minimum of 4 session surveys and the overall event survey will get a unique Cisco Live t-shirt.

(from 11:30 on Thursday, while supplies last)

All surveys can be taken in the Cisco Events mobile app or by logging in to the Session Catalog and clicking the ‘Participant Dashboard’

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- Visit the Cisco Showcase for related demos
- Book your one-on-one Meet the Engineer meeting
- Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs
- Visit the On-Demand Library for more sessions at ciscolive.com/on-demand. Sessions from this event will be available from March 3.

Contact me on Webex Teams or nsherrar@cisco.com

Thank you

GO **BEYOND**