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IPv6 Intro to Intermediate

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Agenda

- Why IPv6, Why Now?
- IPv6 Addressing & Headers
- IPv6 Host Configuration
- IPv6 Link Operations
- Other IPv6 Address's
- IPv6 in Cisco CLI
- Summary

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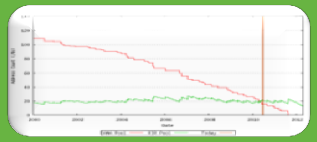
Why IPv6, Why Now?

The Internet of Everything

TOMORROW starts here.
Today, more than 99% of our world is still not connected to the Internet.
But we're working on it.

Market Factors Driving IPv6 Adoption

IPv4 Address Depletion



2011

National IPv6 Strategies

Mandate

IPv6

IPv6 OS, Content & Applications

Microsoft Google

Pref. by App's in W7, S2008, OSX

CISCO

Infrastructure Evolution

comcast at&t verizon

4G, DOCSIS 3.0, CGN

RFC 6540 - IPv6 support is no longer considered optional.

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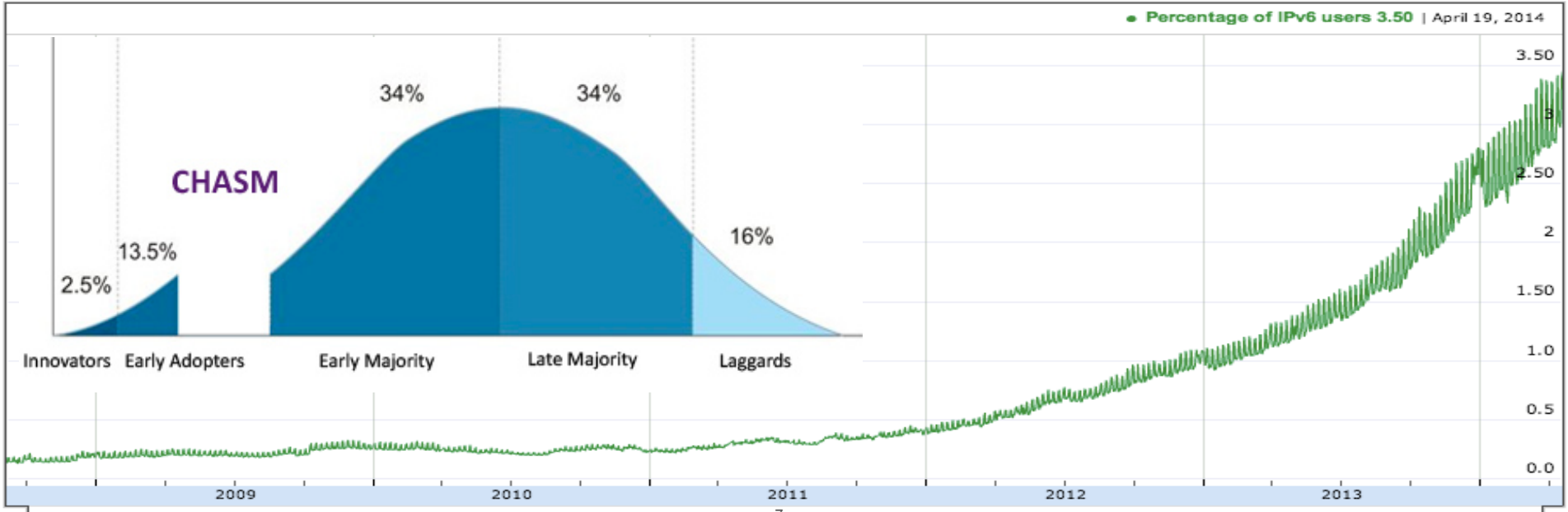
Why IPv6, Why Now?

- Early Adopters, from ~2001-2005 (6bone)
- Chasm, Refinement from 2005-2009 (Tunneling)
- Early Majority, Launch June 2012 (Transitioning)



IPv6 Addressing & Headers

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So How Big Is The IPv6 Address Space?

340,282,366,920,938,463,374,607,432,768,211,456

(IPv6 Address Space - 340 undecillion, 282 decillion, 366 nonillion, 920 octillion, 938 septillion, 463 sextillion, 463 quintillion, 374 quadrillion, 607 trillion, 431 billion, 768 million, 211 thousand and 456

vs

Antares
15th Brightest
star in the sky

4,294,967,296

(IPv4 Address Space - 4 Billion)

Our Sun

- **Lot's of talk about how big, it's BIG, do NOT worry about waste**
- **Each /64 prefix contains 18 Quintillion host address's (18,446,744,073,709,551,616)**
- **Theoretical vs. Practical deployment, still not an issue**

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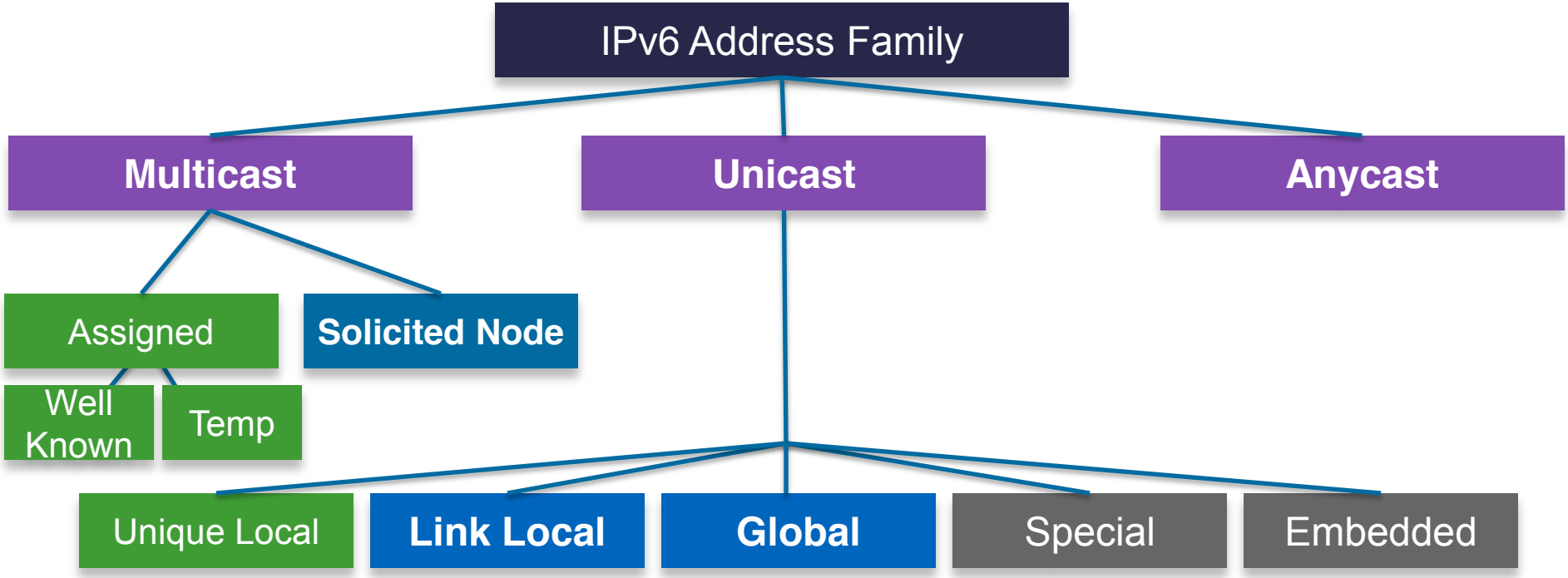
IPv6 Address Family

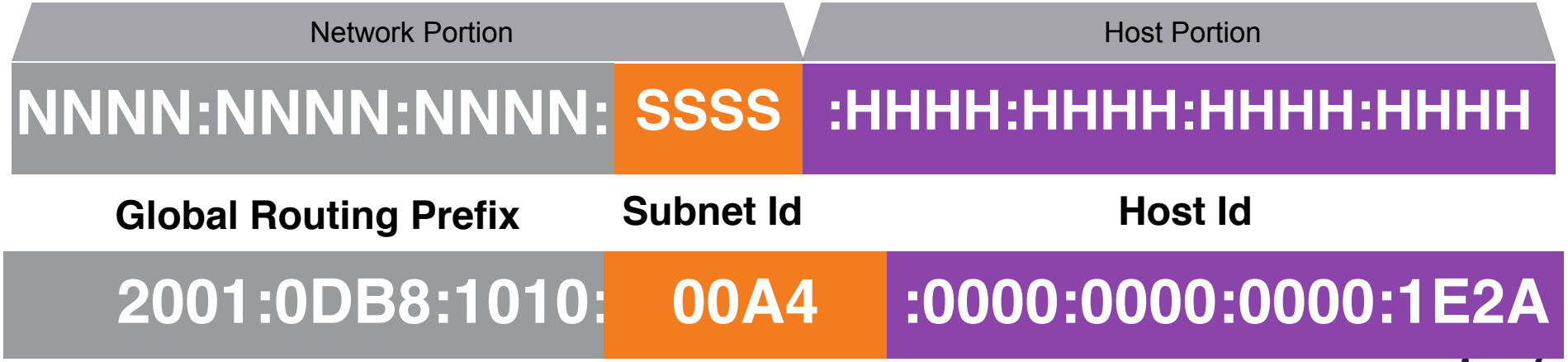


***IPv6 does not use broadcast addressing**

IPv6 Address Format

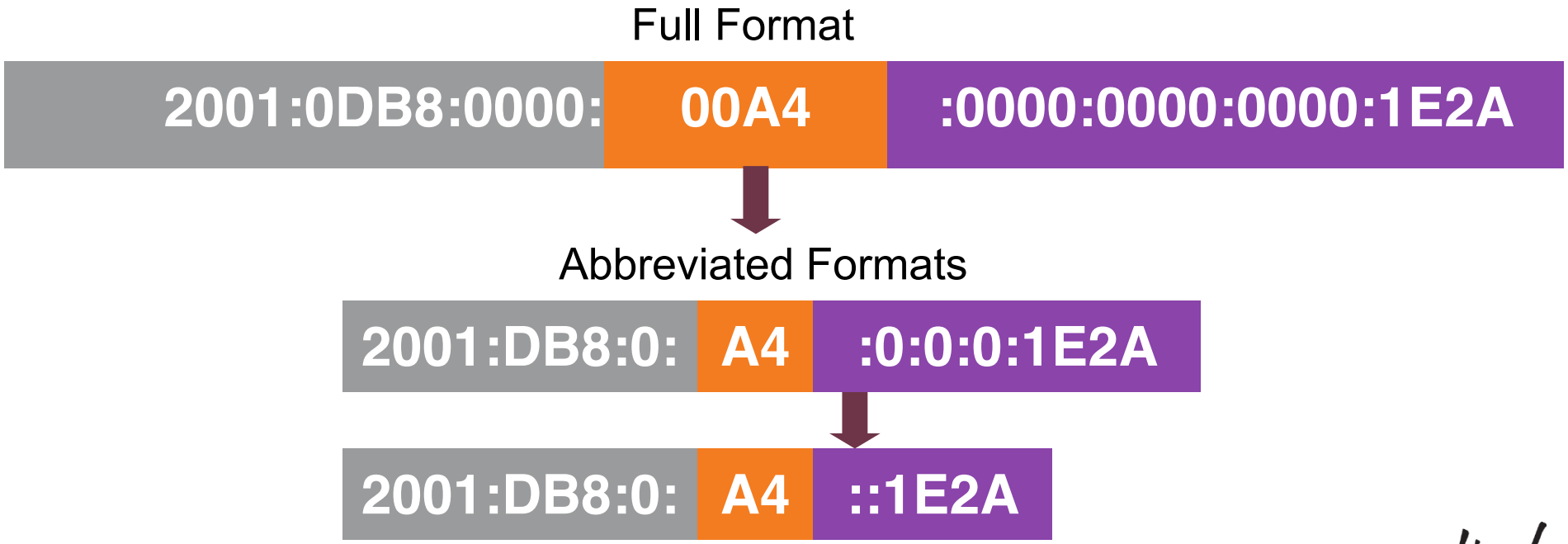
- IPv6 addresses are 128 bits long
  - Segmented into 8 groups of 16 bits separated by (:)
  - 32 HEX characters – CAsE DoEs not mAttEr
    - It's a Prefix, not a mask,
    - Word, Group or Quad..

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

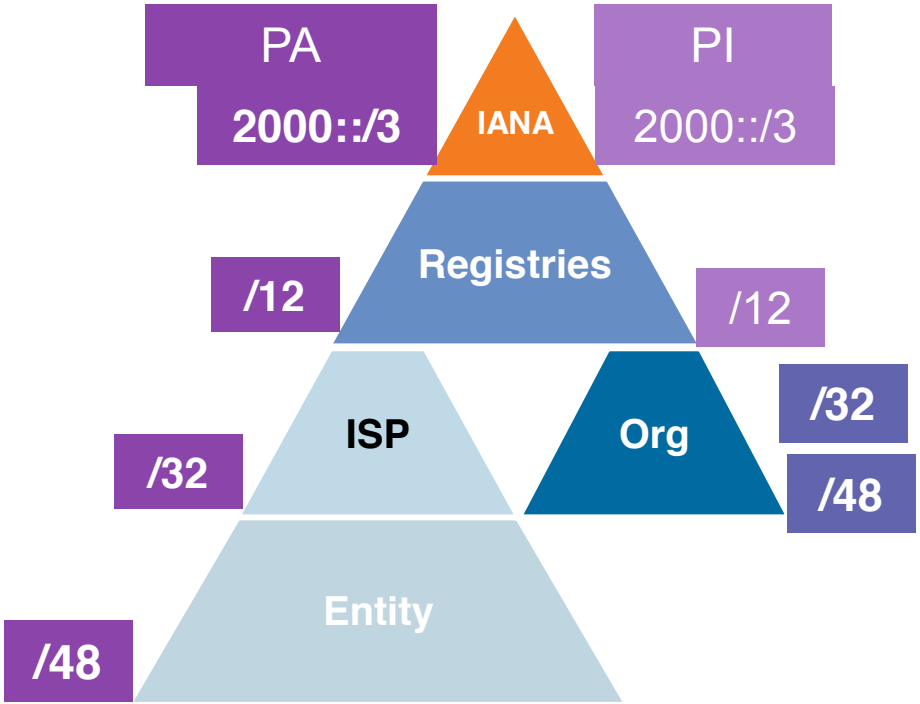


Abbreviating IPv6 Addresses (RFC5952)

- Leading 0's can be omitted
- The double colon (::) can appear only once



IANA & Regional Internet Registries



- Recommended Allocations
- Consumer, SMB /56 /60 /64
- Municipal Government, Enterprise, Single AS /48
- State Governments, Universities (LIR) /32 /36 /40 /44 /48

Unicast IPv6 Address Types

Link-Local – Non routable within layer 2 domain (**FE80**::/10)

FE80:0000:0000:0000::HHHH:HHHH:HHHH:HHHH

Unique-Local – Routable within administrative domain (**FC00**::/7)

FC0G:GGGG:GGGG:**SSSS**::HHHH:HHHH:HHHH:HHHH

FD0G:GGGG:GGGG:**SSSS**::HHHH:HHHH:HHHH:HHHH

Global – Routable across the Internet (**2000**::/3)

2000:NNNN:NNNN:**SSSS**::HHHH:HHHH:HHHH:HHHH

3FFF:NNNN:NNNN:**SSSS**::HHHH:HHHH:HHHH:HHHH

IPv6 over Ethernet

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

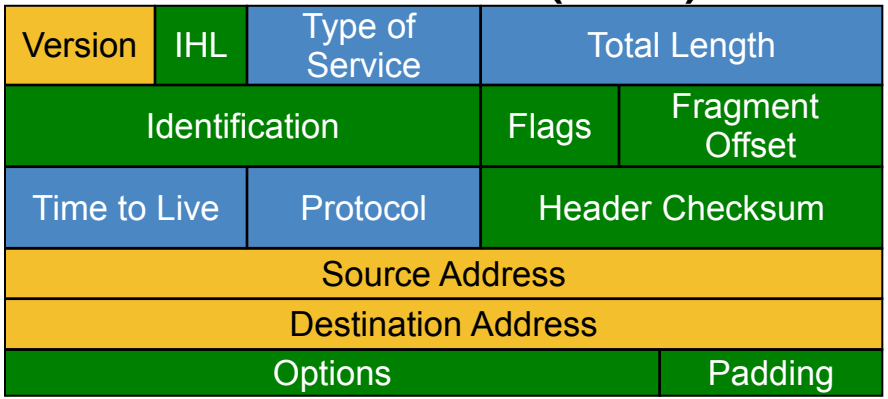
Destination Ethernet Address	Source Ethernet Address	0x86DD	IPv6 Header and Payload

- IPv6 has a specific Ethernet Protocol ID
- IPv6 relies heavily on Multicast

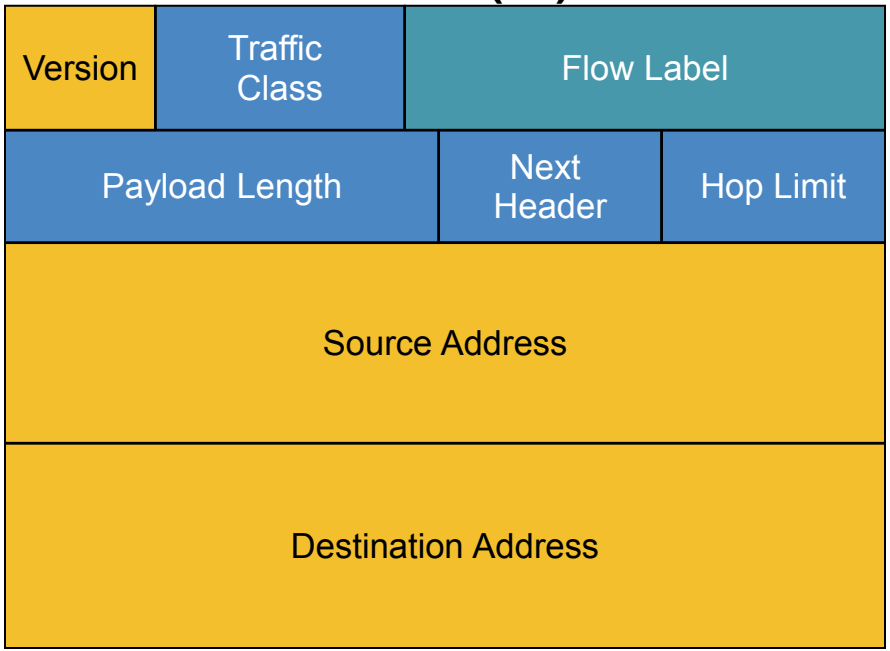
I bit = Local Admin, L bit = Multicast/Broadcast

IPv4 and IPv6 Header Comparison

IPv4 Header (20-60)

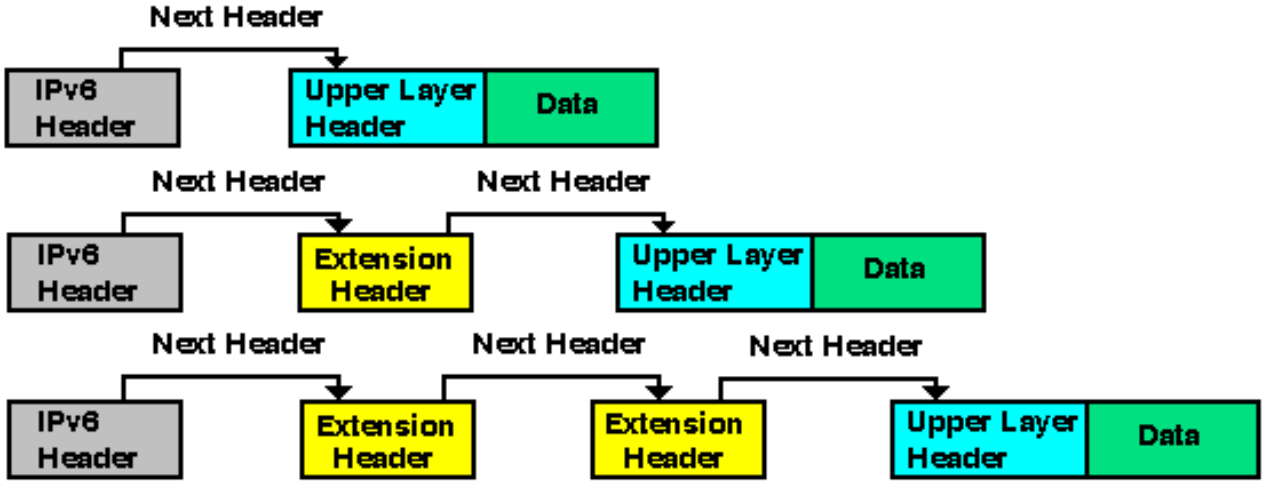


IPv6 Header (40)



- **Length is constant in IPv6**
- **Fragmentation occurs in (EH)**
- **Option's occur in (EH)**
- **UDP must have valid Checksum, unlike v4.**
- **Upper layer checksums use the Pseudo Header format: SRC/DST Addr + Next Header**

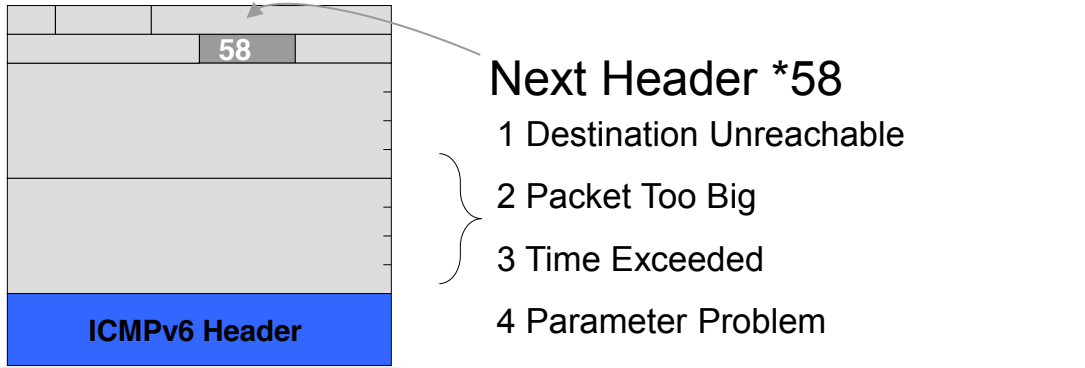
Extension Headers (~ Layer 3.5)



Extension Header *	Type
Hop-by-Hop Options	0
Routing Header	43
Destination Options	60
Fragment Header	44
ESP Header	50
Authentication Header	51
Mobility Header	135
Shim6	140
Experimental	253,254
No Next Header	59

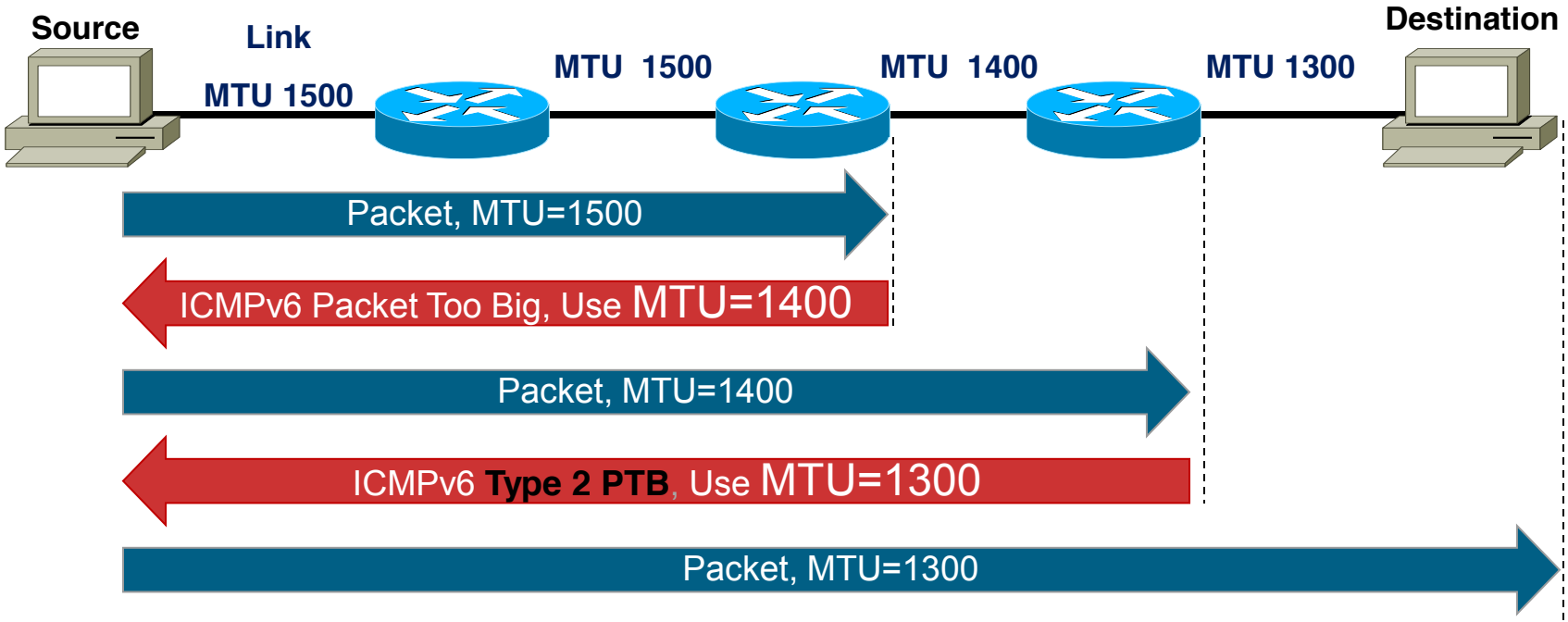
- EH are daisy chained, processed in order
- Length is variable, must be on 8 byte boundary, typically 24 bytes
- If HbH is present, must be first, must be processed, likely in SW

ICMPv6

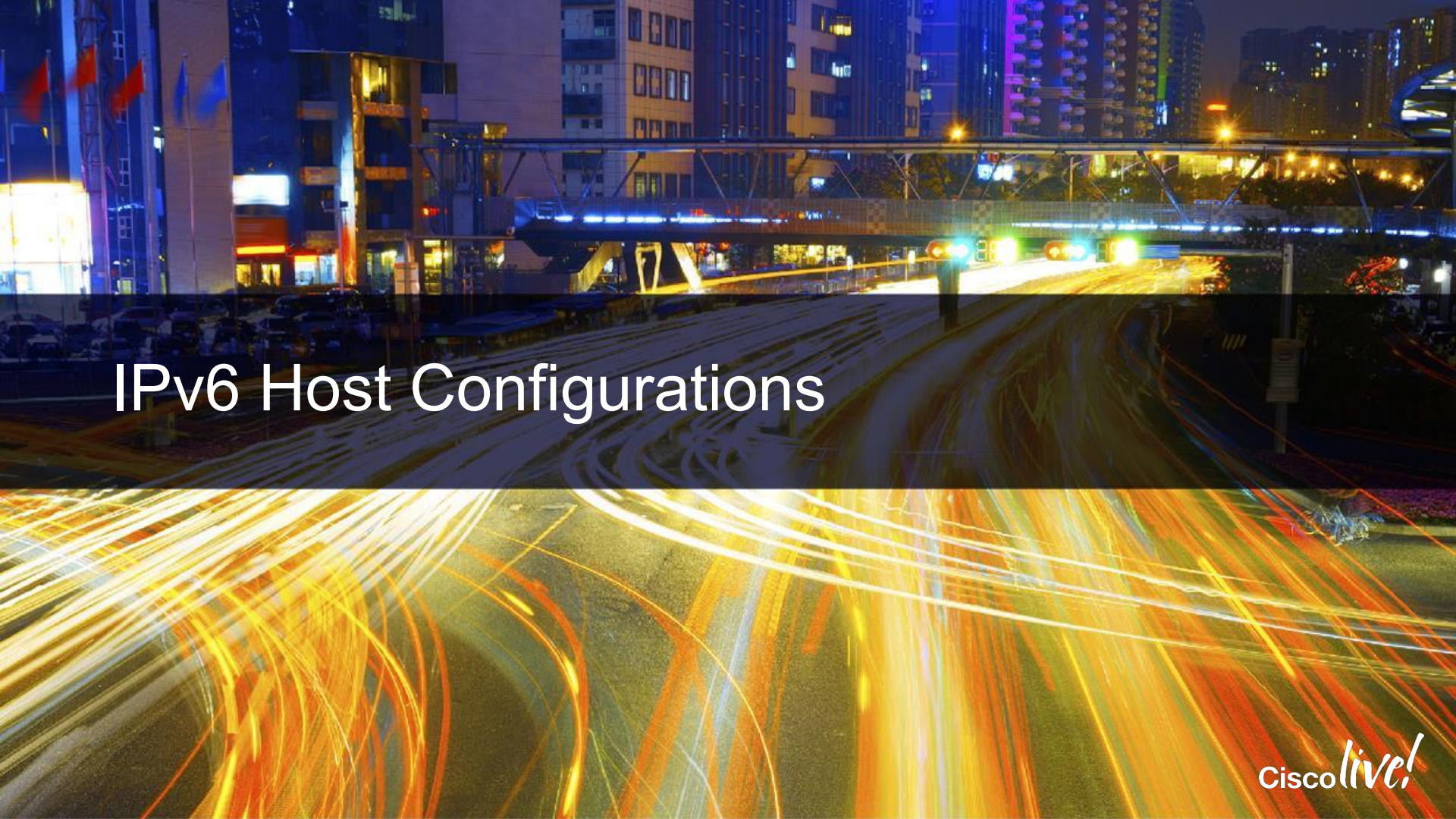


- Neighbor Discovery, Router Discovery, Path MTU Discovery and (MLD)
  - **Type – (1-127) = Error Messages, (128-255) = Informational Messages**
  - **Code – More Granularity within the Type**
  - **Checksum – computed over the entire ICMPv6**
  - **Data - Original Header Return (8 bytes), then fill to Min MTU (1280)**

Path MTU Discovery



- Will break ICMP error message rule (by responding for Multicast)
- Must set ALL interfaces to 1280 MTU if you disallow PTB at your FW



IPv6 Host Configurations

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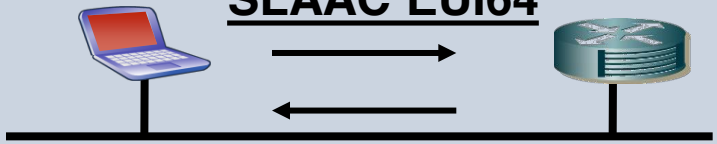
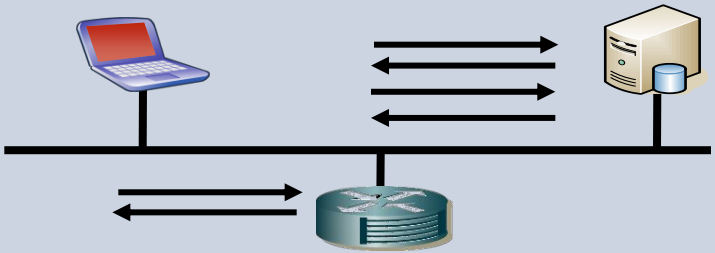
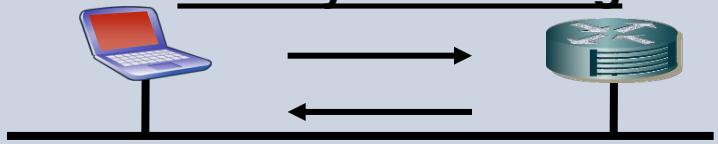
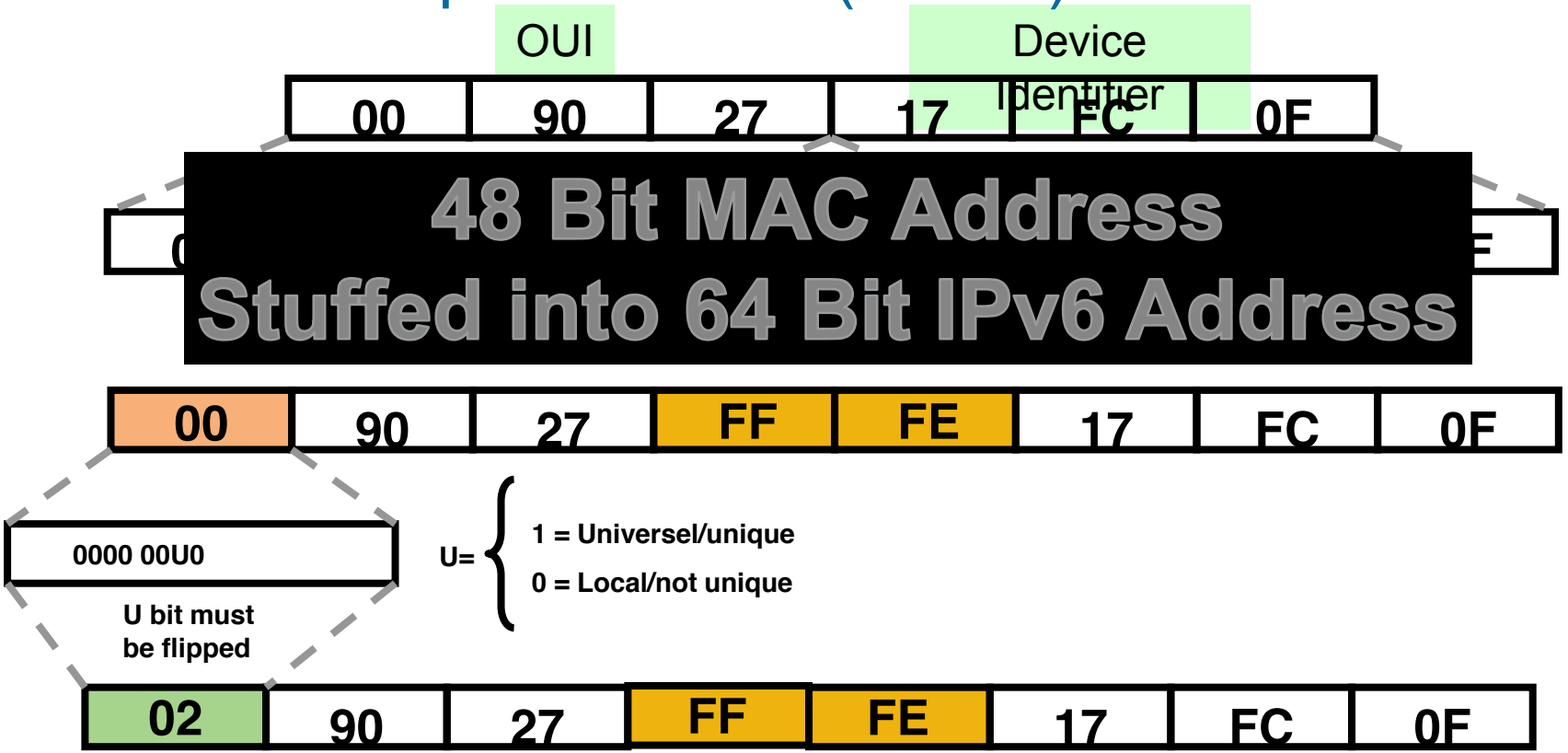
IPv6 Host Portion Address Assignment

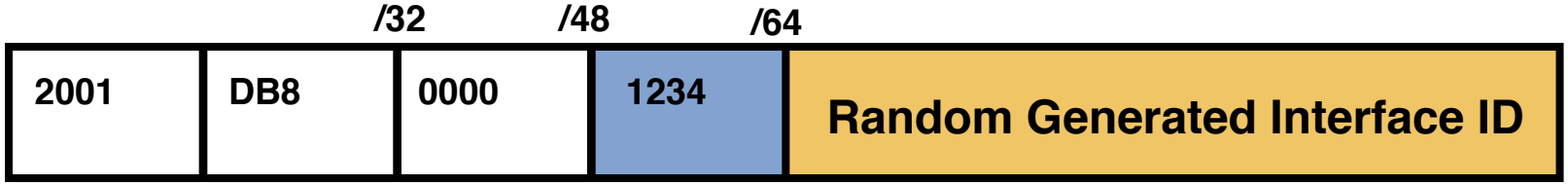
Similar to IPv4	New in IPv6
Manually configured 	**State Less Address Auto Configuration** **SLAAC EUI64** 
Assigned via DHCPv6 	**SLAAC Privacy Addressing** 

* Secure Neighbor Discovery (SeND)

Extended Unique Identifier (EUI64)



IPv6 Privacy Extensions (RFC 4941)



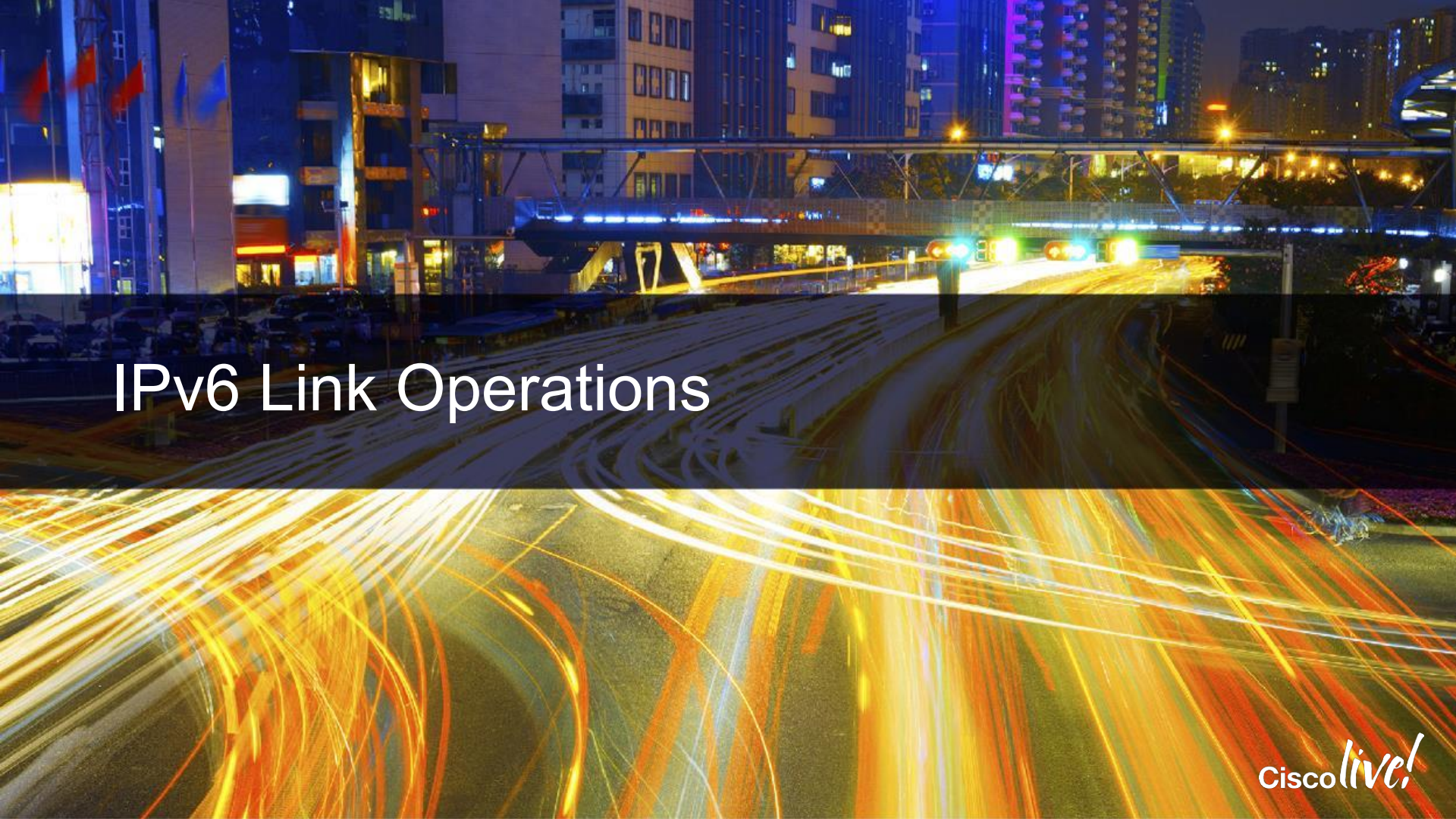
- **Generated on unique 802 using MD5, then stored for next iteration**
- **Enabled by default** in Windows, Android, iOS, Mac OS/X, Linux
- **Temporary or Ephemeral addresses** for client application (web browser)

Recommendation: Good for the mobile user, but not for your organization/corporate networks (Troubleshooting and accountability)

DHCPv6 Protocol Details

DHCP Messages	IPv4	IPv6
Initial Message Exchange	4-way handshake	4-way handshake
Message Types	Broadcast, Unicast	Multicast, Unicast
Client → Server (1)	DISCOVER	SOLICIT (any servers)
Server → Client (2)	OFFER	ADVERTISE (want this address)
Client → Server (3)	REQUEST	REQUEST (I want that address)
Server → Client (4)	ACK	REPLY (It's yours)

- Digital Millennium Copyright Act (DMCA), HIPAA (health), PCI (credit card)
- **FF02::1:2** = All DHCP Agents (servers or relays, Link-local scope)
- **FF05::1:3** = All DHCP Servers (Site-local scope)
- Clients listen on **UDP port 546**; Servers/relays on **UDP port 547**
- Rapid Commit, 2 packet exchange. Solicit/Reply, client sets for options
- ***ipv6 dhcp relay destination*** replaces *ip helper address*



IPv6 Link Operations

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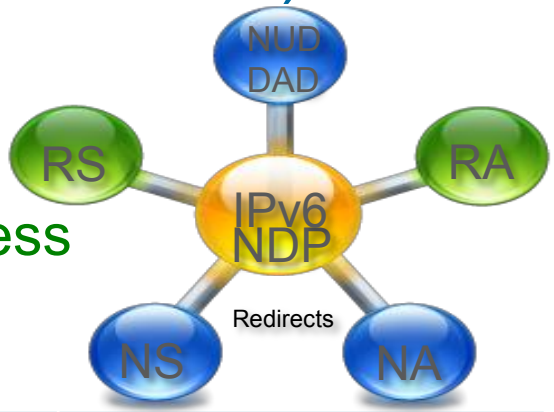
Neighbor Discovery Protocol – NDP (RFC 4861)

- Always uses Link Local (FE80::/64) as its source
- Maps Layer 3 IPv6 address to Layer 2 MAC address
- LINK OPERATIONS (control plane)
- Neighbor discovery messages
  - Router solicitation (ICMPv6 type 133)
  - Router advertisement (ICMPv6 type 134)
  - Neighbor solicitation (ICMPv6 type 135)
  - Neighbor advertisement (ICMPv6 type 136)
  - Redirect (ICMPV6 type 137)



IPv4	IPv6
ARP Request	Neighbor Solicitation
Broadcast	Solicited Node Multicast
ARP Reply	Neighbor Advertisement
Unicast	Unicast

Router Solicitation and Advertisement

RS	
ICMP Type	133
IPv6 Source	FE80::A
IPv6 Destination	FF02::2
Option 1	SRC Link Layer Address

RA	
ICMP Type	134
IPv6 Source	FE80::2
IPv6 Destination	FE80::A
Data	Options, subnet prefix, lifetime, autoconfig flag

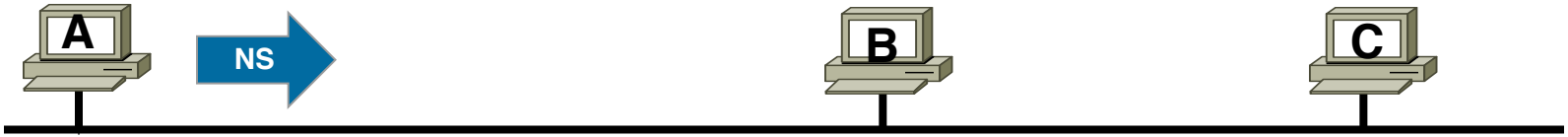
- Router solicitations (RS) are sent by nodes at bootup
- Host needs an RA to finish building it's Address's

RA Message

- M-Flag – Stateful DHCPv6 to acquire IPv6 address
- O-Flag – Stateless DHCPv6 in addition to SLAAC
- H-Flag – Mobile IP home agent
- Preference Bits – Low, Med, High
- Router Lifetime – Must be >0 for Default
- Options - Prefix Information, Length, Flags
- L bit – Only way a host get a On Link Prefix
- A bit – Set to 0 for DHCP to work properly

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: 1000
ICMPv6 Option 3 (Prefix Info)
Prefix length: 64
∞ Flags: 0x80
1… …. = On link (L Bit)
.1.. …. = No Auto (A Bit)
Prefix: 2001:0db8:4646:1234::/64

Duplicate Address Detection (DAD)



ICMP Type	135 NS
IPv6 Source	UNSPEC = ::
IPv6 Dest.	A Solicited Node Multicast FF02::1:FF00:A
Data	FE80::A
Query	Anyone using A?

Node A can start using address A

- ICMPv6 runs on top of IPv6, etype = 86DD, Layer 3.14 :')
- Probe neighbors to verify address uniqueness

Solicited-Node Multicast Address

- For each Unicast and Anycast address configured there is a corresponding solicited-node multicast
- Solicited-node multicast consists of
  - **FF02::1:FF**/104 {lower 24 bits from IPv6 Unicast interface ID}

FE80	0000	0000	0000	1234	5678	9ABC	FC0F
FF02	0000	0000	0000	0000	0001	FFBC	FC0F

Ethernet Multicast
Uses last 32 bits

33	33	FF	BC	FC	0F

Neighbor Solicitation & Advertisement

ICMP Type	135 NS
IPv6 Source	FE80::A
IPv6 Destination	B Solicited Node Multicast FF02::1:FF00:B
Target Address	2001:db8:1:46::B
Code	**0** (need link layer)
Query	What is B link layer address?

ICMP Type	136 NA
IPv6 Source	FE80::B
IPv6 Destination	FE80::A
Target	Type 2
Data	**Link Layer address of B**
***Flags**	R = Router S = Response to Solicitation O = Override cache information

- ARP replacement, Map's L3 to L2.
- Node B will add node A to it's neighbor cache during this process w/o sending NS
- Multicast for resolution (new), Unicast for reachability (cache)

IPv6 on SLAAC

```
C:\Documents and Settings\>netsh
netsh>interface ipv6
netsh interface ipv6>show address
Querying active state...
Interface 5: Local Area Connection
Addr Type  DAD State  Valid Life   Pref. Life   Address
---------  ---------- ------------ ------------ ----------------------------
Public     Preferred  29d23h58m25s  6d23h58m25s 2001:0db8:2301:1:202:8a49:41ad:a136
Temporary  Preferred   6d21h48m47s       21h46m 2001:0db8:2301:1:bd86:eac2:f5f1:39c1
Link       Preferred      infinite     infinite fe80::202:8a49:41ad:a136

netsh interface ipv6>show route
Querying active state...
Publish  Type       Met  Prefix                    Idx  Gateway/Interface Name
-------  --------  ----  ------------------------  ---  --------------------
no       Autoconf     8  2001:0db8:2301:1::/64       5  Local Area Connection
no       Autoconf   256  ::/0                        5  fe80::20d:bdff:f387:f6f9
```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Other IPv6 Addresses

Well Known Multicast Addresses

Address	Scope	Meaning
FF01::1	Node-Local	This Node
FF05::2	Site-Local	All Routers
FF02::1	**Link-Local**	**All Nodes**
FF02::2	**Link-Local**	**All Routers**
FF02::5	**Link-Local**	**OSPFv3 Routers**
FF02::6	**Link-Local**	**OSPFv3 DR Routers**
FF02::9	**Link-Local**	**RIPng**

- FF02, is a permanent address and has link scope
- Link Operations, Routing Protocols, Streaming Services

Special Use Addresses (RFC 5156)

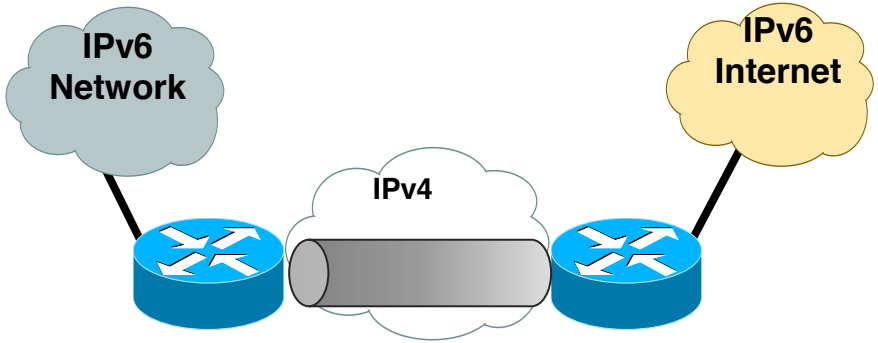
- Loopback
  - 0:0:0:0:0:0:0:1=> ::1
- Unspecified address
  - 0:0:0:0:0:0:0:0=> 0::0 => :: => ::/128
- Documentation Prefix
  - 2001:0DB8::/32
- Discard Prefix
  - 0100::/64
- 6to4 Automatic Tunneling
  - 2002::/16
- Default Route
  - ::/0



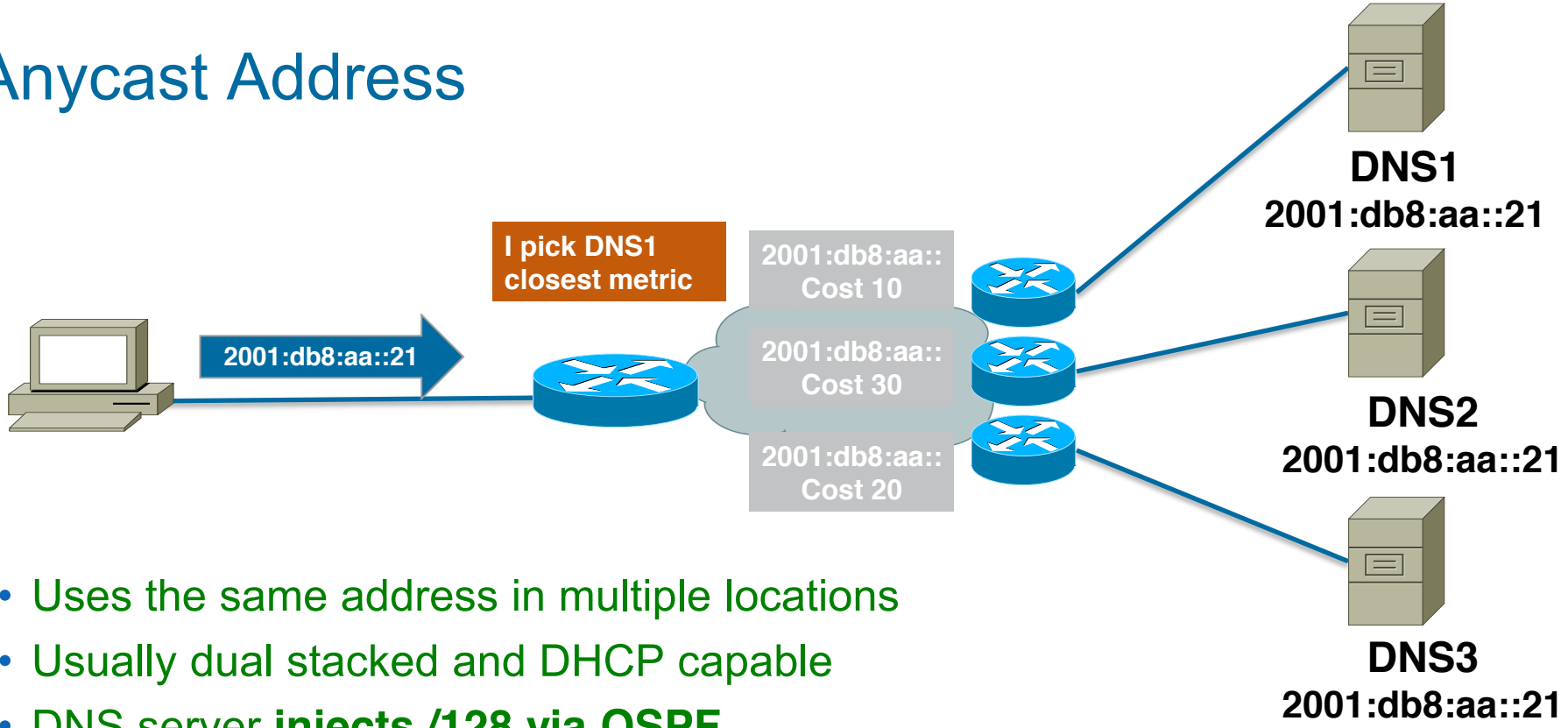



Embedded Address's

- IPv4 Compatible
  - 0:0:0:0:0:0.A.B.C.D/96
  - 0:0:0:0:0:0.192.168.30.1
  - ::C0A8:1E01
  - Used by IPv6 aware devices, now deprecated
- IPv4 Mapped
  - 0:0:0:0:0:FFFF.A.B.C.D/96
  - 0:0:0:0:0:FFFF.192.168.30.1
  - ::FFFF:C0A8:1E01
  - Used in automatic tunneling by device with no IPv6 knowledge



Anycast Address



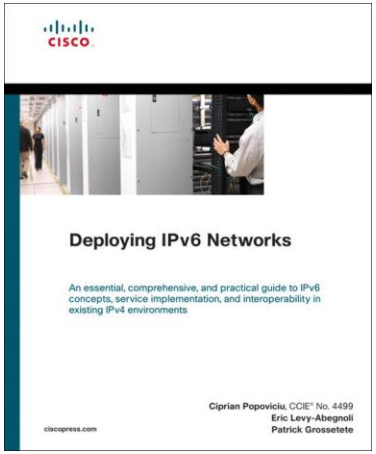
- Uses the same address in multiple locations
- Usually dual stacked and DHCP capable
- DNS server **injects /128 via OSPF**
- Servers also have a management IP address for other L3 functions

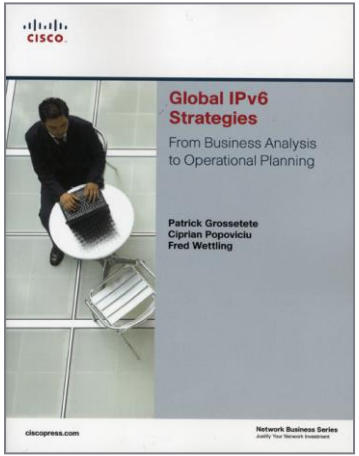
Summary

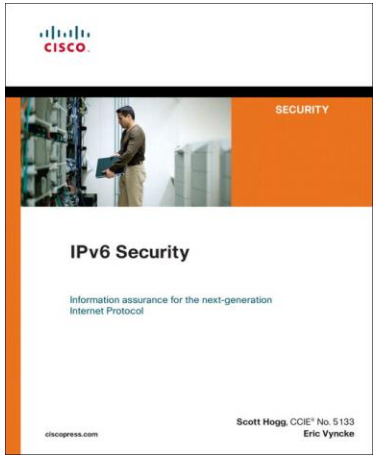
Reference Materials

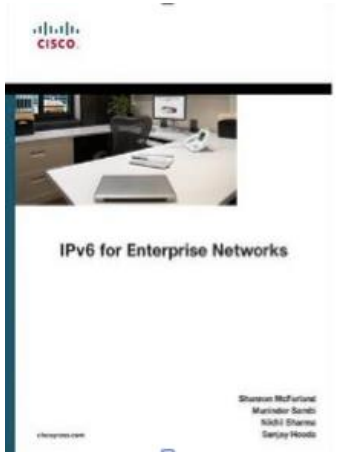
- IPv6 Knowledge Base Portal: http://www.cisco.com/web/solutions/netsys/ipv6/knowledgebase/index.html
- Deploying IPv6 in the Internet Edge: http://www.cisco.com/en/US/docs/solutions/Enterprise/Borderless_Networks/Internet_Edge/InternetEdgeIPv6.html
- Deploying IPv6 in Campus Networks: http://www.cisco.com/en/US/docs/solutions/Enterprise/Campus/CampIPv6.html
- Deploying IPv6 in Branch Networks: http://www.cisco.com/en/US/docs/solutions/Enterprise/Branch/BrchIPv6.html
- Smart Business Architecture – IPv6 Guides:http://www.cisco.com/en/US/netsol/ns982/networking_solutions_program_home.html

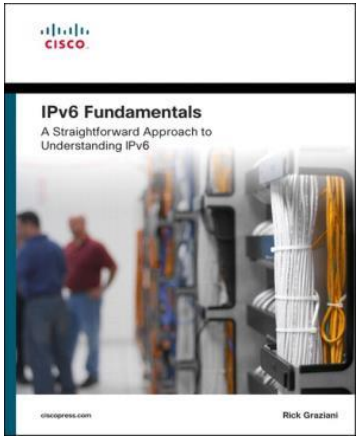
Recommended Reading

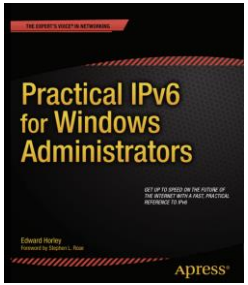


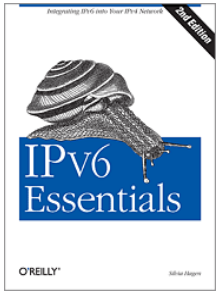


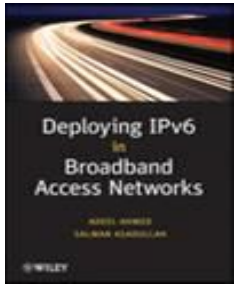












Key Take Away

- Gain **Operational Experience** now
- Security enforcement is possible
- Control IPv6 traffic as you would IPv4
- “Poke” your Provider’s
- IPv6 is here now are you?


Thank you.


CISCO