



# IPv6

IPv6 Addressing Overview



## In This Section

- + Recommended IPv6 Resources
- + IPv6 Addressing Format
  - + Global, link-local, site-local, unique local, EUI-64
- + IPv6 Neighbor Discovery
- + IPv6 SLAAC
- + IPv6 General Prefix

# Recommended IPv6 Resources

- + Books
  - + [IPv6 Theory Protocol & Practice](#)
  - + [Microsoft Press - Understanding IPv6](#)
- + Online Resources
  - + Microsoft MSDN Knowledgebase
    - + [Internet Protocol \(IP\) for IPv6](#)
  - + [Cisco IPv6 Knowledge Base Portal](#)

# IPv6 Overview

- + [RFC 2460 - Internet Protocol, Version 6 \(IPv6\) Specification](#)
- + Much larger address space than IPv4
  - + IPv4 uses 4 Byte (32 Bit) Addresses
    - +  $2^{32} = 4,294,967,296$  addresses
  - + IPv6 uses 16 Byte (128 Bit) Addresses
    - +  $2^{128} \sim 340$  undecillion ( $3.4 \times 10^{38}$ )

# IPv4 vs. IPv6 Addressing Format

## + IPv4 Dotted Decimal

- + d.d.d.d

- + d = one byte

## + IPv6 Hexadecimal

- + hhhh:hhhh:hhhh:hhhh:hhhh:hhhh:hhhh:hhhh

- + hh = one byte

# IPv6 Address Types

- + [RFC 4291 - IP Version 6 Addressing Architecture](#)
  - + Section 2.4. Address Type Identification
    - + *The type of an IPv6 address is identified by the high-order bits of the address, as follows*

# IPv6 Link Local Addresses

- + Addresses locally significant to a link
  - + FE80::/10 (1111 1110 10)
  - + Equivalent of 169.254.0.0/16 in IPv4
- + Never routable between interfaces
- + Used for...
  - + Stateless Address Auto-configuration (SLAAC)
  - + Neighbor Discovery
  - + Router Discovery

# IPv6 Site Local Addresses

- + Addresses locally significant to a “site”
  - + FEC0::/10 (1111 1110 11)
- + No one could agree on what a “site” is
  - + [RFC 3879 - Deprecating Site Local Addresses](#)

# IPv6 Unique Local Addresses

- + [RFC 4193 - Unique Local IPv6 Unicast Addresses](#)
- + ULA is Private Use IPv6 addressing
  - + FC00::/7 (1111 110)
- + Equivalent to RFC 1918
  - + 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16
- + Likely unique but not routable via global BGP

# IPv6 Global Unicast Addresses

- + Technically everything else
  - + IANA currently allocating 2000::/3
- + Per RFC end hosts must...
  - + Have 64-bit interface ID
    - + nnnn:nnnn:nnnn:nnnn:hhhh:hhhh:hhhh:hhhh/64
  - + Use EUI-64 format for interface ID

# Modified EUI-64 Addressing

- + [RFC 4291 - IP Version 6 Addressing Architecture](#)
  - + Appendix A: Creating Modified EUI-64 Format Interface Identifiers
- + Ethernet MAC to EUI-64 conversion
  - + Invert Universal/Local (U/L) bit
    - + 7th most significant bit
  - + Insert padding 0xFF 0xFE in the middle

# IPv6 Temporary Addresses

- + [RFC 4941 - Privacy Extensions for Stateless Address Autoconfiguration in IPv6](#)
- + MSDN – IPv6 Interface Identifiers
  - + [Randomly generated interface identifiers](#)
- + Prevents tracking users based on MAC address
  - + I.e. EUI-64 result is always the same for a given MAC address

# IPv6 Address Resolution

- + [RFC 4861 - Neighbor Discovery for IP version 6 \(IPv6\)](#)
- + ICMPv6 ND used for layer 3 to layer 2 resolution
  - + Equivalent of IPv4 ARP

# IPv6 Neighbor Discovery Messages

- + Neighbor Solicitation (NS)
  - + Equivalent of ARP request
- + Neighbor Advertisement (NA)
  - + Equivalent of ARP reply
- + Router Solicitation (RS)
- + Router Advertisement (RA)

# IPv6 SLAAC

- + [RFC 4862 – IPv6 Stateless Address Autoconfiguration](#)
- + Automatically assigns IPv6 address for every on-link prefix
  - + Works only with /64s on the link
  - + Host uses Duplicate Address Detection (DAD) to verify uniqueness of generated address
- + SLAAC is not DHCPv6
  - + Does not include options, e.g. DNS server

# SLAAC and DHCPv6

- + SLAAC commonly works along with DHCPv6
  - + Options are set in Router Advertisement (RA) messages
  - + Tells the host that there is a DHCPv6 server available for addressing options
- + Other-Config-Flag
  - + Use DHCPv6 to receive just addressing options (DNS, TFTP, etc.)
  - + **ipv6 nd other-config-flag**
- + Managed-Config-Flag
  - + Use DHCPv6 for both addressing and options
  - + **ipv6 nd managed-config-flag**

# ND For Host Default Routing

- + Hosts don't receive default gateway from DHCPv6
- + First Hop IPv6 router deduced from ND RA Messages

# IPV6 General Prefix

- + General prefix can be defined to act as shortcut
  - + E.g. If organization is assigned a /32, then all prefixes should be derived from this /32
  - + Helps in renumbering scenarios
- + Defined globally as
  - + **ipv6 general-prefix [NAME\_OF\_PREFIX] 2001:123::/32**
- + Applied to link as
  - + **ipv6 address [NAME\_OF\_PREFIX] ::1/64**
- + General prefix and subnet are merged to derive full address





# IPv6

IPv6 Routing Overview



## In This Section

- + IPv6 Routing Overview
- + IPv6 Static Routing
- + IPv6 VRF Support

# IPv6 Routing Overview

- + IPv6 routing off by default
  - + Enabled with **ipv6 unicast-routing**
  - + Enables routing and ICMPv6 ND RAs
- + IPv6 routing is supported by all protocols
  - + Static, RIPng, EIGRPv6, OSPFv3, IS-IS, MP-BGP, & Policy Routing
- + Dynamically learned routes recurse to remote link-local
  - + Implies Global Unicast isn't required
  - + Implies static layer 3 to layer 2 resolution for Link Local is needed on multipoint NBMA

# IPv6 Static Routing

- + Same static routing implications as IPv4
  - + Routing to a next-hop
    - + Resolve layer 2 address of next-hop
  - + Routing to a multipoint interface
    - + Resolve layer 2 address of final destination
    - + Proxy ND and Proxy IND design issues
  - + Routing to a point-to-point interface
    - + No layer 2 resolution required

# VRF Support

- + VRFs can include both IPv4 and IPv6 interfaces
  - + Not all dynamic protocols are IPv6 VRF aware in all versions
- + Must use “vrf definition [name]” syntax, and enable the IPv6 address family
  - + **vrf upgrade-cli** also an option
- + Interface Command
  - + **vrf forwarding [VRF Name]**
  - + Places the interface and both IPv4/IPv6 in specified VRF





# IPv6

IPv6 over DMVPN



## In This Section

- + IPv6 over IPv4 DMVPN
- + DMVPN Over IPv6 Transport

# IPv6 over IPv4 DMVPN

- + DMVPN uses IPv4 mGRE for transport
  - + GRE is a multi-protocol encaps
  - + Implies IPv6 can be supported
- + How IPv6 over IPv4 DMVPN works
  - + Build the IPv4 underlay and overlay
    - + E.g. IPsec spoke to hub
  - + Use IPv6 NHRP to resolve IPv6 IGP or IPv6 BGP

# DMVPN Over IPv6 Transport

- + DMVPN can also use IPv6 mGRE for transport
  - + Eventually IPv4 will be the legacy protocol
  - + Transport will be native IPv6
- + Configured as...
  - + **tunnel mode gre multipoint ipv6**
  - + Uses IKEv2 for optional IPsec





# IPv6

EIGRPv6



## In This Section

- + EIGRPv6 Overview
- + EIGRPv6 Configuration

# EIGRPv6 Overview

- + Similar in operation to IPv4 EIGRP
  - + Transport via protocol 88 to unicast and multicast FF02::A
- + “shutdown” by default in EIGRPv6 Classic Mode
  - + “no shutdown” under process
- + Enabled on all IPv6 links in EIGRPv6 Named Mode
  - + **address-family ipv6 unicast <VRF> autonomous-system <ASN>**
  - + Process is NOT shutdown by default
  - + To exclude a link:
    - + “af-interface X”
    - + “shutdown”
- + Like OSPFv3 & BGP, IPv4 formatted Router-ID needed





# IPv6

OSPFv3



## In This Section

- + OSPFv3 Overview
- + OSPFv3 Configuration

# OSPFv3 Overview

- + [RFC 5340 - OSPF for IPv6](#)
- + Similar in many operations to OSPFv2
  - + Transport via protocol 89 to unicast and multicasts FF02::5 & FF02::6
- + Normal OSPF rules still apply
  - + Adjacency parameters
  - + OSPFv3 network types

# OSPFv3 LSAs 8 & 9

- + New LSAs introduced in OSPFv3
  - + Type 8 (Link) - Used for Link Local addresses
  - + Type 9 (Intra Area Prefix) - Used for prefixes on the links
- + New LSAs separate topology graph from NLRI
  - + OSPFv2 has subnet info in LSAs 1 & 2 for Intra-Area
    - + If prefix add or remove, run full SPF
  - + OSPFv3 uses LSAs 8 & 9 to reference LSA 1
    - + If a stub network is add or remove, full SPF not required

# OSPFv3 Configuration

- + Enabled at link level
  - + **ipv6 ospf [process-id] area [area-id]**
  - + Automatically enables global process
- + Like EIGRPv6 & BGP, IPv4 formatted Router-ID needed

# OSPFv3 IPsec Authentication

- + OSPFv3 uses IPsec for...
  - + Authentication
    - + IPsec AH or ESP
  - + Encryption
    - + IPsec ESP
- + No ISAKMP support, so keys must be manually configured
  - + Copy and paste is your friend

# Multiprotocol OSPFv3

- + OSPFv3 can advertise both IPv4 & IPv6 NLRI
  - + Two separate trees, v4 and v6 run independently but use same data structures
  - + Similar to ISIS Multi-Topology
- + To advertise IPv4 NLRI, must have both v4 and v6 on the link
  - + “ipv6 enable” on transit links is the minimum required for v6
  - + For IPv4 – can have all links unnumbered to Loopback 0 (arbitrary)

# Multiprotocol OSPFv3 Configuration

- + Enabled on Link-Level
  - + `ospfv3 [process-id] [ipv4 | ipv6] area [area num]`
- + Options under OSPFv3 routing process
  - + `router ospfv3 [process-id]`
- + Show commands
  - + `show ospfv3...`





# IPv6

IPv6 BGP



## In This Section

- + IPv6 BGP Overview
- + IPv6 BGP Configuration

# IPv6 BGP Overview

- + [RFC 2545 - Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing](#)
  - + Uses MP\_REACH\_NLRI and MP\_UNREACH\_NLRI for IPv6
  - + AFI = 2 (IPv6) SAFI = 1 (unicast)
- + Normal BGP rules apply
  - + Requires underlying IGP for TCP transport
  - + EBGp loop prevention via AS-Path
  - + iBGP loop prevention via full mesh, RRs, Confederation
  - + Same attributes and best-path selection process

# IPv6 BGP Transport

- + Transport and NLRI are independent
  - + Transport can be IPv4 or IPv6
  - + NLRI advertised via AFI 2 SAFI 1
    - + address-family ipv6 unicast
- + Advertising IPv6 NLRI via IPv4 BGP session results in next-hop issues
  - + Can be manually fixed with a route-map
  - + Also **no bgp default ipv6-nexthop**
    - + If peer is directly connected, use IPv6 address of the peer (not the encoded ::FFFF: address)





# IPv6

IPv6 over MPLS



## In This Section

- + IPv6 over MPLS
  - + 6PE
  - + 6VPE

# 6PE

- + Provider Edge Router (6PE) over MPLS
  - + Allows tunneling of traffic in global IPv6 table over IPv4 MPLS core
- + How 6PE Works
  - + Form IPv6 BGP peering from PE to CE in global
  - + Form IPv6 BGP + Label peering from PE to PE in global
  - + Traffic in core follows IPv4 label path between PEs

# 6VPE

- + IPv6 VPN Provider Edge Router (6VPE) over MPLS
  - + Tunneling of traffic in IPv6 VRF table over IPv4 MPLS core
  - + Similar to regular MPLS L3VPN
- + How 6VPE Works
  - + Form IPv6 peering from PE to CE in VRF
  - + Form VPNv6 BGP peering from PE to PE in global
  - + Traffic in core follows IPv4 label path between PEs

