Routers Supporting IPv6

- 6Wind
- AddPac Technologies
- ALAXALA Technology
- AlaxaA Networks
- Alcatel/Lucent
- Allied Telesis
- Allied
- Telesyn
- Alpha Networks
- Beijing Jiaxun Feuihong Networks
- Billion Electric
- BITWAY Networking Technology
- BSD (KAME)
- Cisco Systems
- Delta Networks
- Digital China Networks
- D-Link
- DrayTek
- Extreme Networks
- Fiberhome Networks
- Fujitsu
- FugtureSoft
- Harbour Networks
- Hitachi
- Huawei
- IP-infusion
- Juniper Networks
- LG-Nortel
- Linux (USAGI)
- Mercury Corporation
- Microsoft
- NEC
- Netgenetech
- NextHop
- Nokia
- Nortel
- Novell
- Omron
- Panasonic
- Ruijie Networks
- Samsung
- Shanghai Baud Data Communication
- Tsinghua Unisplendor Bitway Networking
- Xoprt
- Yamaha
- Zebra
- ZTE Corporation
- ZyXEL
MTU Path Discovery

- IPv6 routers do not fragment packets
- IPv6 MTU must be at least 1280 bytes
  - Recommended MTU: 1500 bytes
- Nodes should implement MTU PD
  - Otherwise they must not exceed 1280 bytes
- MTU path discovery uses ICMP "packet too big" error messages
  - Be sure to consider them when filtering ICMPv6
Static Routes

- Static route configuration syntax is the same as IPv4
- Except prefix and next hop are IPv6
- Next hop address can be global or link local
  - ICMPv6 Redirect messages need link-local address

prefix       next-hop address
Static Routes on Cisco and Juniper

- **Juniper Networks syntax**
  - IPv4 static route:
    ```
    [edit]
    set routing-options static route [ipv4_prefix/prefix_length] next-hop [ipv4_if_address]
    ```
  - IPv6 static route:
    ```
    [edit]
    set routing-options rib inet6.0 static route [ipv6_prefix/prefix_length] next-hop [ipv6_if_address]
    ```

- **Cisco Systems syntax:**
  - IPv4 static route:
    ```
    ip route [ipv4_prefix] [ipv4_address_mask] [ipv4_if_address]
    ```
  - IPv6 static route:
    ```
    ipv6 route [ipv6_prefix/prefix_length][outgoing interface] [ipv6_if_address]
    ```
RIPng

- RFC 2080 describes RIPngv1, not to be confused with RIPv1
- Based on RIP Version 2 (RIPv2)
- Uses UDP port 521
- Operational procedures, timers and stability functions remain unchanged
- RIPng is not backward compatible to RIPv2
- Message format changed to carry larger IPv6 addresses
Juniper and Cisco RIPng Configurations

Juniper Networks example:

```
[edit protocols ripng]
jeff@Juniper1# show
group Peers {
    export prefixes;
    neighbor fe-0/0/0/0.0;
}
[edit policy-options]
jeff@Juniper1# show
policy-statement prefixes {
    from protocol direct;
    then accept;
}
```

Cisco Systems example:

```
interface Ethernet1/0
  ipv6 address 2001:1100:A:B::1/64
  ipv6 enable
  ipv6 rip Demo enable
  !
  ipv6 router rip Demo
  !
```
Cisco EIGRP

- Supported as of IOS 12.4(6)T
- Same DUAL convergence algorithm
- Simple addition of TLVs to support IPv6
- Differences from EIGRP for IPv4:
  - Configured directly on interface
  - No network statement
  - Requires Router ID
Cisco EIGRP Configuration Example

ipv6 unicast-routing
interface e0
    ipv6 enable
    ipv6 eigrp 1
    no shutdown
!
ipv6 router eigrp 1
    router-id 10.1.1.1
    no shutdown
IS-IS

- RFC 5308, Routing IPv6 with IS-IS (5 pages)
- 2 new TLVs are defined:
  - IPv6 Reachability (TLV type 236)
  - IPv6 Interface Address (TLV type 232)
- IPv6 NLPID = 142

“Make it as simple as possible, but no simpler.”
— Albert Einstein
IS-IS on Juniper Routers

```plaintext
[edit]
jeff@Juniper1# show interfaces
fe-0/0/0/0 {
    unit 0 {
        family iso;
        family inet6 {
            address 2001:2200:a:1::2/64;
        }
    }
}

[edit]
jeff@Juniper1# show protocols isis
interface fe-0/0/0.0;
interface fe-0/0/1.0;
interface fe-0/0/2.0;
```
IS-IS on Cisco Routers

```
interface ethernet-1
  ip address 10.1.1.1 255.255.255.0
  ipv6 address 2001:0001::45c/64
  ip router isis
  ipv6 router isis

interface ethernet-2
  ip address 10.2.1.1 255.255.255.0
  ipv6 address 2001:0002::45a/64
  ip router isis
  ipv6 router isis

router isis
  address-family ipv6
  exit-address-family
  net 42.0001.0000.0000.072c.00
```
OSPFv3

- Unlike IS-IS, entirely new version required
- RFC 2740
- Fundamental OSPF mechanisms and algorithms unchanged
- Packet and LSA formats are different
OSPFv3 Differences from OSPFv2

• Runs per-link rather than per-subnet
  ▪ Multiple instances on a single link
• More flexible handling of unknown LSA types
  ▪ More network changes without adjacency disruptions possible
• Link-local flooding scope added
  ▪ Similar to flooding scope of type 9 Opaque LSAs
  ▪ Area and AS flooding remain unchanged
• Authentication removed
  ▪ Uses IPv6 Authentication (AH) extension header instead
• Neighboring routers always identified by RID
• Removal of addressing semantics
  ▪ IPv6 addresses not present in most OSPF packets
  ▪ RIDs, AIDs, and LSA IDs remain 32 bits
# OSPFv3 LSAs

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x2001</td>
<td>Router-LSA</td>
</tr>
<tr>
<td>0x2002</td>
<td>Network-LSA</td>
</tr>
<tr>
<td>0x2003</td>
<td>Inter-Area-Prefix-LSA</td>
</tr>
<tr>
<td>0x2004</td>
<td>Inter-Area-Router-LSA</td>
</tr>
<tr>
<td>0x4005</td>
<td>AS-External-LSA</td>
</tr>
<tr>
<td>0x2006</td>
<td>Group-Membership-LSA</td>
</tr>
<tr>
<td>0x2007</td>
<td>Type-7-LSA (NSSA)</td>
</tr>
<tr>
<td>0x0008</td>
<td>Link-LSA</td>
</tr>
<tr>
<td>0x2009</td>
<td>Intra-Area-Prefix-LSA</td>
</tr>
</tbody>
</table>
OSPFv3: Intra-Area-Prefix LSA

- **OSPFv2:**
  - Prefixes are advertised in Router (Type 1) LSAs
    - Primary purpose of Type 1 LSAs is to compute SPF tree
  - Any addition/deletion/change of prefix requires flood of new Type 1 LSA
    - Yet prefix change does not affect SPF tree
  - SPF re-calculation is needlessly triggered
  - Partial Route Calculation (PRC) cannot help OSPFv2 to scale

- **OSPFv3:**
  - Prefixes are advertised in Intra-Area-Prefix LSAs
    - Not Router LSAs
  - Intra-Area-Prefix LSAs do not trigger SPF run
  - Scalability much improved in very large areas
    - More comparable to IS-IS
  - PRC becomes useful for OSPFv3
Juniper and Cisco OSPFv3 Configuration

Cisco Systems example

interface Ethernet1/0
  ipv6 address 2001:1100:A:B::1/64
  ipv6 enable
  ipv6 ospf 1 area 0.0.0.0
!

Juniper Networks example

[edit]
jeff@Juniper1# show protocols ospf3
area 0.0.0.0 {
  interface fe-0/0/0.0;
  interface fe-0/0/1.0;
  interface fe-0/0/2.0;
}

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Multiprotocol BGP-4

- MP-BGP defined in RFC 2283
- Two BGP attributes defined:
  - **Multiprotocol Reachable NLRI** advertises arbitrary Network Layer Routing Information
  - **Multiprotocol Unreachable NLRI** withdraws arbitrary Network Layer Routing Information
  - Address Family Identifier (AFI) specifies what NLRI is being carried (IPv6, IP Multicast, L2VPN, L3VPN, IPX...)

- Use of MP-BGP extensions for IPv6 defined in RFC 2545
  - IPv6 AFI = 2
  - BGP TCP session can be over IPv4 or IPv6
  - Advertised Next-Hop address must be global IPv6 address
    - And can be followed by a link-local IPv6 address
    - Resolves conflicts between IPv6 rules and BGP rules
router bgp 1
  no synchronization
  no bgp default ipv4-unicast
  bgp log-neighbor-changes
  neighbor 2001:2200:A:1::2 remote-as 200
  no auto-summary
!
address-family ipv6
  neighbor 2001:2200:A:1::2 activate
  exit-address-family
!
M-BGP for IPv6 on Juniper

[edit]
jeff@Juniper1# show protocols bgp
group v6-peers {
    type external;
    family inet6 {
        unicast;
    }
    export v6-export;
    peer-as 200;
    neighbor 2001:2200:a:2::2;
}
IPv6 Multicast Routing

- PIM-SM
  - “Basic” PIM-SM
  - PIM-Bidir
  - PIM-SSM
- MP-BGP
- Legacy protocols not supporting IPv6:
  - DVMRP
  - PIM-DM
PIM-SSM
Multicast Operational Models

- **Any-Source Multicast (ASM)**
  - Basic PIM-SM
    - Smaller-scale many-to-many applications
    - “Few-to-many” applications
    - Examples: Conferencing, small chat rooms, data distribution
  - Bidirectional PIM (PIM-Bidir)
    - Larger-scale many-to-many applications
    - Examples: Full-participation voice/video/multimedia conferencing, massively multiplayer gaming, large chat rooms
- **Single-Source Multicast (SSM)**
  - PIM-SSM
    - Single-to-many applications
    - Examples: Audio, video content distribution
    - Requires MLDv2 (equivalent to IGMPv3 for IPv4)
Rendezvous Point (RP) Discovery

- PIM-SM, PIM-Bidir require RP for shared trees
  - PIM-SSM does not require RP
- Static RP Configuration
  - Currently most widely used method for IPv4 multicast
  - But will it scale operationally?
- Bootstrap Router (BSR) protocol
- Embedded RP addresses
  - Promising for automated RP discovery without added mechanism
- No Auto-RP for IPv6
  - Never widely deployed anyway
Embedded RP Addresses: RFC 3306

- Leverages Unicast-Prefix-Based Multicast Addresses
  - RFC 3306
  - Format is intended for dynamic IPv6 multicast address allocation
  - Can support both ASM and SSM models

**Standard IPv6 Multicast Address Format**

```
0xFF | Flags (4 bits) | Scope (4 bits) | Group ID (112 bits)
```

**Unicast-Prefix-Based Multicast Address Format**

```
0xFF | Flags (4 bits) | Scope (4 bits) | Reserved (8 bits) | PLEN (8 bits) | Network Prefix (64 bits) | Group ID (32 bits)
```

- **R** = Embedded RP Address
- **P** = Multicast address based on network prefix
- **T** = Transient address

PLEN (Prefix Length) = 0 for SSM
Embedded RP Addresses

**Group Address:**

- **Prefix:** FF70::/12
- **RIID:** RP Interface ID
- **Prefix Length:** > 0, ≤ 64

<table>
<thead>
<tr>
<th>0xFF</th>
<th>0111</th>
<th>Scope (4 bits)</th>
<th>Resv. (4 bits)</th>
<th>RIID (4 bits)</th>
<th>PLEN (8 bits)</th>
<th>RP Network Prefix (64 bits)</th>
<th>Group ID (32 bits)</th>
</tr>
</thead>
</table>

**Derived RP Address:**

- **Prefix:** FF70::/12
- **RIID:** RP Interface ID
- **Prefix Length:** > 0, ≤ 64

**Example:**
- **RP Prefix:** = 2001:DB8:ABCD:1234::/64
- **RP Interface ID:** = 7
- **RP Address:** = 2001:DB8:ABCD:1234::7
- **Scope:** = Organization Local (8)
- **Group ID:** = 0x14
- **Group Address with Embedded RP Address:** = FF78:740:2001:DB8:ABCD:1234::14
Inter-Domain IPv6 Multicast

- MP-BGP
- SSM models with PIM-SSM
- ASM models problematic
  - No IPv6 version of MSDP
  - Embedded RP might help here
  - For now, “big SSM communities” will work
    - But need a more scalable solution for the long run
Conclusions

- Unicast IPv6 routing essentially the same as unicast IPv4
  - If you understand IPv4 routing, you “have it made”
- OSPFv3 is a big improvement over OSPFv2
  - Changes based on 10 years’ experience
  - Discussions underway to extend OSPFv3 for IPv4
- Simple IPv6 multicast very similar to IPv4 multicast
  - “Simple” is mostly what is in use now
- Complex (large scale and/or interdomain) IPv6 multicast still needs work
  - But, then, so does large-scale IPv4 multicast
  - IPv6 solutions should prove to be simpler in the long run
Thank You

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