Cisco IOS Interior Routing Protocols

Unicast Routing Protocols Comparison

	RIP	EIGRP	OSPF	IS-IS	BGP
Type	Distance Vector	Distance Vector	Link State	Link State	Path Vector
Algorithm	Bellman-Ford	DUAL	Dijkstra	Dijkstra	Path Selection
Admin Distance	120	90/170 (external)/5 (summary)	110	115	20/200 (IBGP)
Standard	RFCs 2080, 2453	Cisco proprietary	RFCs 2328, 5340	ISO 10589, RFC 1142	RFC 4271
Supported Protocols	IPv4, IPv6	IPv4, IPv6, IPX, Appletalk	IPv4, IPv6	IPv4, IPv6, CLNP	IPv4, IPv6
Transport	UDP/520	IP/88	IP/89	Layer 2	TCP/179
Authentication	Plain, MD5	MD5	Plain, MD5, AH (v3)	Plain, MD5	MD5
Multicast Address	224.0.0.9	224.0.0.10	224.0.0.5-6	N/A	N/A

RIP

RIP Implementations

RIPv1
Original RIP implementation, limited to classful routing (obsolete)

RIPv2
Introduced support for classless routing, triggered updates, and multicast announcements (RFC 2453)

RIPng (RIP Next Generation)
Extends RIPv2 to support IPv6 routing (RFC 2080); functions very similarly to RIPv2 and is subsequently as limited

Terminology

Split-Horizon
Mitigates routing loops by ensuring a route is never advertised back to the neighbor from which it was learned

Poison Reverse
Learned routes are advertised back to their originator as explicitly invalid

Troubleshooting

```
show ip[v6] protocols
show ip[v6] rip database
debug ip rip { database | events }
debug ipv6 rip [interface]
```

RIP Configuration

Interface Configuration

```
interface type number

 ! Enable RIPng on the interface
ipv6 rip name enable

 ! Configure manual route summarization
ip summary-address rip IPv4-address subnet-mask
ipv6 rip name summary-address IPv6-prefix

 ! Enable MD5 authentication (RIPv2 only)
ip rip authentication mode md5
ip rip authentication key-chain key-chain
```

RIP Configuration

Global Configuration

```
 ! Enable RIPv2 IPv4 routing
router rip
 version 2

 ! Disable RIPv2 automatic summarization
 no auto-summary

 ! Designate RIPv2 interfaces by network
 network IPv4-network

 ! Identify unicast-only neighbors
 neighbor IP-address

 ! Originate a default route
 default-information originate

 ! Designate passive interfaces
 passive-interface {interface | default}

 ! Modify equal-cost load balancing
 maximum-paths 1-16

 ! Modify timers
 timers basic update invalid hold flush

! Enable RIPng IPv6 routing
ipv6 router rip name

 ! Toggle split-horizon and poison-reverse
 [no] split-horizon
 [no] poison-reverse
```

EIGRP

Metric Formula

$$256 * (K_1 * \textbf{bw} + \frac{K_2 * \textbf{bw}}{256 - \textbf{load}} + K_3 * \textbf{delay}) * \frac{K_5}{\textbf{rel} + K_4}$$

- **bw** = 10^7 / minimum path bandwidth in kbps
- **delay** = interface delay in µsecs / 10

Packet Types

1	Update
3	Query
4	Reply
5	Hello
8	Acknowledge

Default K Values

K_1	1
K_2	0
K_3	1
K_4	0
K_5	0

Terminology

Reported Distance
The metric for a route advertised by a neighbor

Feasible Distance
The distance advertised by a neighbor plus the cost to get to that neighbor

Stuck In Active (SIA)
The condition when a route becomes unreachable and not all queries for it are answered; adjacencies with unresponsive neighbors are reset

Passive Interface
An interface which does not participate in EIGRP but whose network is advertised

Stub Router
A router which advertises only a subset of routes, and is omitted from the route query process

Default Timers

	LAN (>T1)	WAN (<=T1)
Hello	5 sec	60 sec
Hold	15 sec	180 sec

Troubleshooting

```
show ip[v6] eigrp {interfaces | neighbors }
show ip[v6] eigrp topology
clear ip[v6] eigrp [AS-number] neighbors
debug ip[v6] eigrp [neighbor]
```

EIGRP Configuration

Interface Configuration

```
interface type number

 ! Enable EIGRP for IPv6 on the interface
ipv6 eigrp AS-number

 ! Set the maximum bandwidth EIGRP can consume (can be >100%)
ip[v6] bandwidth-percent eigrp AS-number 1-999999

 ! Configure manual summarization of outbound routes
ip summary-address eigrp AS-number IPv4-address subnet-mask [AD]
ipv6 summary-address eigrp AS-number IPv6-prefix [AD]

 ! Enable MD5 authentication
ip[v6] authentication mode eigrp AS-number md5
ip[v6] authentication key-chain eigrp AS-number key-chain

 ! Modify interface hello and hold timers
ip[v6] hello-interval eigrp AS-number seconds
ip[v6] hold-time eigrp AS-number seconds

 ! Toggle split horizon
[no] ip[v6] split-horizon eigrp AS-number
```

EIGRP Configuration

Global Configuration

```
 ! Enable EIGRP for an autonomous system
[ipv6] router eigrp AS-number

 ! Specify a router ID formatted in IPv4 dotted-decimal
[eigrp] router-id router-ID

 ! Disable automatic classful summarization (IPv4 only)
no auto-summary

 ! Enable EIGRP on interfaces by network (IPv4 only)
network IPv4-address wildcard-mask

 ! Modify maximum paths for equal-cost load balancing
maximum-paths 1-16

 ! Configure multiplier for unequal-cost load balancing
variance 1-128

 ! Configure K values to manipulate the metric formula
metric weights 0 k1 k2 k3 k4 k5

 ! Explicitly identify neighbors on NBMA links
neighbor IP-address interface

 ! Designate passive interfaces
passive-interface {interface | default}

 ! Enable stub routing
[eigrp] stub [receive-only | connected | static | summary | redist]
```

OSPF

OSPFv2 Link State Advertisements

Router Link (Type 1)
Lists neighboring routers and the cost to each; flooded within an area

Network Link (Type 2)
Generated by a DR; lists all routers on an adjacent segment; flooded within an area

Network Summary (Type 3)
Generated by an ABR; advertises routes between areas

ASBR Summary (Type 4)
Injected by an ABR into the backbone to advertise the presence of an ASBR in a non-backbone area

External Link (Type 5)
Generated by an ASBR and flooded throughout the AS to advertise a route external to OSPF

Group Membership (Type 6)
Used by Multicast OSPF; unsupported by IOS

NSSA External Link (Type 7)
Generated by an ASBR in a not-so-stubby area; converted into a type 5 LSA by the ABR when leaving the area

OSPFv3 Link State Advertisements

	Name	v2 Equiv.
0x2001	Router LSA	Type 1
0x2002	Network LSA	Type 2
0x2003	Inter-area prefix LSA	Type 3
0x2004	Inter-area router LSA	Type 4
0x4005	AS-external LSA	Type 5
0x2006	Group membership LSA	Type 6
0x2007	Type-7 LSA	Type 7
0x0008	Link LSA	N/A
0x2009	Intra-area prefix LSA	N/A

Router Roles

Internal Router
All interfaces reside within the same area

Backbone Router
A router with at least one interface in area 0

Area Border Router (ABR)
Connects two or more areas

AS Boundary Router (ASBR)
Connects to additional routing domains (redistribution to or from other protocols)

Area Types

Standard Area
Default OSPF area type

Stub Area
External link (type 5) LSAs are replaced with a single default route

Totally Stubby Area
Type 3, 4, and 5 LSAs are replaced with a default route

Not-So-Stubby Area (NSSA)
A stub area containing an ASBR; type 5 LSAs are converted to type 7 within the area

External Route Types

E1
Considers the cost to the advertising ASBR plus the external cost of the route

E2 (Default)
The external cost of a route as seen by the ASBR; internal OSPF cost is not considered

Troubleshooting

```
show ip[v6] ospf [process] interface
show ip[v6] ospf [process] neighbor
show ip[v6] ospf border-routers
show ip[v6] ospf database [LSA-type]
show ip[v6] ospf virtual-links
debug ip[v6] ospf […]
```

Metric Formula

$$\text{cost} = \frac{\textit{reference-bandwidth}}{\textbf{link speed}}$$

Adjacency States

1	Down	**5**	ExStart
2	Attempt	**6**	Exchange
3	Init	**7**	Loading
4	2-Way	**8**	Full

Message Types

1	Hello	**4**	LS Update
2	DB Descr.	**5**	LS Ack
3	LS Request		

DR/BDR Election

- The DR serves as a common point for all adjacencies on a multiaccess segment
- The BDR also maintains adjacencies with all routers in case the DR fails
- Does not occur on point-to-point or multipoint links
- Default priority (0-255) is 1; highest priority wins; 0 cannot be elected
- DR preemption will not occur unless the current DR is reset

Virtual Links

- Tunnel formed to join two areas across an intermediate
- Both end routers must share a common non-stub area
- At least one end must reside in area 0
- Transition tool; not ideal for permanent designs

Network Types

	Nonbroadcast (NBMA)	Multipoint Broadcast	Multipoint Nonbroadcast	Broadcast	Point-to-Point
DR/BDR Elected	Yes	No	No	Yes	No
Neighbor Discovery	No	Yes	No	Yes	Yes
Hello/Dead Timers	30/120	30/120	30/120	10/40	10/40
Defined By	RFC 2328	RFC 2328	Cisco	Cisco	Cisco
Supported Topology	Full Mesh	Any	Any	Full Mesh	Point-to-Point

OSPF Configuration

Interface Configuration

```
interface type number

 ! Enable OSPF on the interface
ip[v6] ospf process-ID area area

 ! Identify neighbors for NBMA links (OSPFv3)
ipv6 ospf neighbor IPv6-address

 ! Set interface cost manually
ip[v6] ospf cost 1-65535

 ! Configure DR election priority
ip[v6] ospf priority 0-255

 ! Specify network type (broadcast, point-to-point, etc.)
ip[v6] ospf network type

 ! Modify interface hello and dead intervals
ip[v6] ospf hello-interval seconds
ip[v6] ospf dead-interval seconds

 ! Enable MD5 authentication (OSPFv2)
ip ospf authentication message-digest
ip ospf message-digest-key key-id md5 key-string

 ! Enable IPsec authentication (OSPFv3)
ipv6 ospf auth ipsec spi spi-number { md5 | sha1 } string
```

OSPF Configuration

Global Configuration

```
 ! Create an OSPF process
[ipv6] router ospf process-ID

 ! Specify a router ID formatted as IPv4 dotted-decimal
 router-id router-ID

 ! Modify the default reference bandwidth
auto-cost reference-bandwidth speed-in-mbps

 ! Assign interfaces to areas by network (OSPFv2)
network IPv4-address wildcard-mask area area

 ! Identify neighbors for NBMA links (OSPFv2)
neighbor IPv4-address [cost 1-65535]

 ! Configure summaries on area border routers
area area range { IPv4-address subnet-mask | IPv6-prefix }

 ! Summarize external routes (ASBRs only)
summary-address IPv4-address subnet-mask [not-advertise]
summary-prefix IPv6-prefix [not-advertise]

 ! Originate a default route
default-information originate [always]

 ! Designate stub, totally stubby, or not-so-stubby areas
area area { stub | nssa } [no-summary]

 ! Create a virtual link
area area virtual-link router-ID
```

Integrated IS-IS

NSAP Addressing

	Interdomain Part			Domain-Specific Part	
NSAP	AFI	IDI	HODSP	System ID	SEL
Condensed	Area				
Example	49	0005.80ff.f800.0000	0001	0000.0c00.1234	00

Interdomain Part (IDP)
Portion of the address used in routing between autonomous systems; assigned by ISO

Domain-Specific Part (DSP)
Portion of the address relevant only within the local AS

Authority and Format Identifier (AFI)
Identifies the authority which dictates the format of the address

Initial Domain Identifier (IDI)
An organization belonging to the AFI

High Order DSP (HODSP)
The area within the AS

System ID
Unique router identifier; 48 bits for Cisco devices (often taken from an Ethernet MAC address)

NSAP Selector (SEL)
Identifies a network layer service; always 0x00 in a NET

Network Types

	Broadcast	Point-to-Point
DIS Elected	Yes	No
Neighbor Discovery	Yes	Yes
Hello/Dead Timers	10/30	10/30

Troubleshooting

```
show [clns | isis] neighbors
show clns interface
show isis [ipv6] topology
show isis [database | spf-log]
debug [clns | isis] […]
```

ISO Routing Levels

Level 0	Used to locate end systems
Level 1	Routing within an area (IS-IS)
Level 2	Routing between areas (IS-IS)
Level 3	Inter-AS routing

Terminology

Type-Length-Value (TLV)
Variable-length modular datasets carried by PDUs

IS-IS Hello (IIH)
Establish and maintain neighbor adjacencies

Link State PDU (LSP)
Carry TLVs encompassing link state information

Sequence Number Packet (SNP)
Used to request and advertise LSPs; can be complete (CSNP) or partial (PSNP)

Network Entity Title (NET)
Unique router ID; includes area ID

Designated Intermediate System (DIS)
A pseudonode responsible for emulating point-to-point links across a multi-access segment

Adjacency Requirements

- Interface MTUs must match
- Levels must match
- Areas must match (if level 1)
- System IDs must be unique
- Authentication must succeed

DIS Election

- Highest-priority interface elected
- Highest SNPA (e.g. MAC or DLCI) breaks tie
- Highest system ID breaks SNPA tie
- Default interface priority is 64
- Current DIS may be preempted, unlike OSPF

IS-IS Configuration

Interface Configuration

```
interface type number

 ! Enable IS-IS on an interface
ip[v6] router isis

 ! Specify interface routing level
isis circuit-type { level-1 | level-1-2 | level-2-only }

 ! Set interface metric
isis [ipv6] metric { 1-16777214 | maximum }

 ! Designate the network as point-to-point
isis network point-to-point

 ! Configure DIS election priority
isis priority 0-127 [ level-1 | level-2 ]

 ! Modify interface hello and dead intervals
isis hello-interval seconds [ level-1 | level-2 ]
isis hello-multiplier 3-1000 [ level-1 | level-2 ]

 ! Enable MD5 authentication
isis authentication mode md5
isis authentication key-chain key-chain
```

IS-IS Configuration

Global Configuration

```
 ! Enable IS-IS routing
router isis

 ! Specify one or more NET addresses
 net NET

 ! Set global routing level (default level-1-2)
is-type { level-1 | level-1-2 | level-2-only }

 ! Configure IPv4 route summaries
summary-address IP-address subnet-mask [level]

 ! Configure IPv6 route summaries
address-family ipv6
 summary-prefix IPv6-prefix [level]

 ! Originate a default route
default-information originate
```