

Introduction to IS-IS

ISP Workshops



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Acknowledgements

- ❑ This material originated from the Cisco ISP/IXP Workshop Programme developed by Philip Smith & Barry Greene
- ❑ Use of these materials is encouraged as long as the source is fully acknowledged and this notice remains in place
- ❑ Bug fixes and improvements are welcomed
 - Please email *workshop (at) bgp4all.com*

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BGP Videos

- NSRC has made a video recording of this presentation, as part of a library of BGP videos for the whole community to use:
 - https://learn.nsrc.org/bgp#intro_to_routing

The screenshot displays the NSRC (Network Startup Resource Center) website. The navigation bar includes links for Home, About, BGP for All (highlighted), perfSONAR, ScienceDMZ, FedIdM, and Contact Us, along with a search bar. The main content area is divided into three columns:

- BGP for All:** A text-based introduction to BGP, explaining its role as the primary routing protocol for the Internet and autonomous systems. It also mentions that understanding routing options can lead to efficiencies and collaboration opportunities.
- Introduction to Routing:** A list of video topics including Internet Routing, Routing Protocols, Introduction to IS-IS (UPDATED), IS-IS Levels, IS-IS Adjacencies, Best Configuration Practices for IS-IS on Cisco IOS, IS-IS Authentication, Default Routes and IPv6, Introduction to OSPF, OSPF Areas, OSPF Adjacencies, Best Configuration Practices for OSPF on Cisco IOS, OSPF Authentication, Default Routes and IPv6, Comparing OSPF and IS-IS, Choosing between OSPF and IS-IS, Migrating from OSPF to IS-IS, Migration Plan, and Finalizing Migration.
- Introduction to BGP:** A list of video topics including Introduction to Border Gateway Protocol, Transit and Peering, Autonomous Systems (UPDATED), How BGP works, Supporting Multiple Protocols, IBGP versus EBGP, Setting up EBGP, and Setting up IBGP.

On the right side, there is a video player for "BGP for All" with a play button and a "Watch on YouTube" button. Below the video player, there are sections for "BGP Case Studies" and "Communities".

BGP Case Studies:

- Peering Priorities ^{NEW}
- Transit Provider Peering at an IXP ^{NEW}
- Customer Multihomed between two IXP members ^{NEW}
- Traffic Engineering for an ISP connected to two IXes ^{NEW}
- Traffic Engineering for an ISP with two interfaces on one IX LAN ^{NEW}
- Traffic Engineering and CDNs ^{NEW}

Communities:

- Communities: RFC 1998 Traffic Engineering
- Communities: Simplifying Traffic Engineering
- How to Apply Communities to Originated Routes
- How to Use Communities for Service Identification

IS-IS

- Intermediate System to Intermediate System
- ISO 10589 specifies OSI IS-IS routing protocol for ConnectionLess-mode Network Services (CLNS) traffic
 - A Link State protocol with a 2 level hierarchical architecture
 - Type/Length/Value (TLV) options to enhance the protocol
- RFC 1195 added IP support
 - Integrated IS-IS
 - I/IS-IS runs on top of the Data Link Layer

IS-IS

- Known as a Link State Routing Protocol
 - The other link state routing protocol is OSPF
 - Each node in the network computes the map of connectivity through the network
 - Both use Edsger Dijkstra's algorithm for producing shortest path tree through a graph
 - Dijkstra, E. W. (1959). "A note on two problems in connexion with graphs". *Numerische Mathematik* **1**: 269–271
 - <http://www-m3.ma.tum.de/foswiki/pub/MN0506/WebHome/dijkstra.pdf>
- The other type of Routing Protocol is Distance Vector
 - Like RIP and Cisco's EIGRP
 - Each node shares its view of the routing table with other nodes

IS-IS

- Routers with IS-IS enabled on them look for neighbouring routers also running IS-IS
 - Hello Protocol Data Units (PDUs) are exchanged
 - The “Hello” packet includes the list of known neighbours, and details such as “hello interval” and “router dead interval”
 - Hello interval – how often the router will send Hellos
 - Router dead interval – how long to wait before deciding router has disappeared
 - The values of “hello interval” and “router dead interval” do not need to match on both neighbours (unlike for OSPF)
 - When a neighbouring router responds with matching details, a neighbour relationship is formed



IS-IS Neighbour Relationships

- A relationship is formed between neighbouring routers for the purpose of exchanging routing information
 - This is called an **ADJACENCY**

IS-IS Adjacencies

- ❑ Once an adjacency is formed, neighbours share their link state information
 - Information goes in a **Link State PDU** (LSP)
 - LSPs are flooded to all neighbours
- ❑ New information received from neighbours is used to compute a new view of the network
- ❑ On a link failure
 - New LSPs are flooded
 - The routers recompute the routing table

IS-IS across a network

- ❑ All routers across the network form neighbour relationships with their directly attached neighbours
- ❑ Each router computes the routing table
- ❑ Once each router has the same view of the network, the network has **converged**
- ❑ The IGP design for a network is crucially important to ensure **scalability** and **rapid convergence**
- ❑ Generally: **the fewer the prefixes, the faster the convergence**

IS-IS Levels

- IS-IS has a 2 layer hierarchy
 - Level-2 (the backbone)
 - Level-1 (the edge)
- A router can be
 - Level-1 (L1) router
 - Level-2 (L2) router
 - Level-1-2 (L1L2) router
- Most small to medium networks (up to ~500 routers) are happily using just Level-2

IS-IS

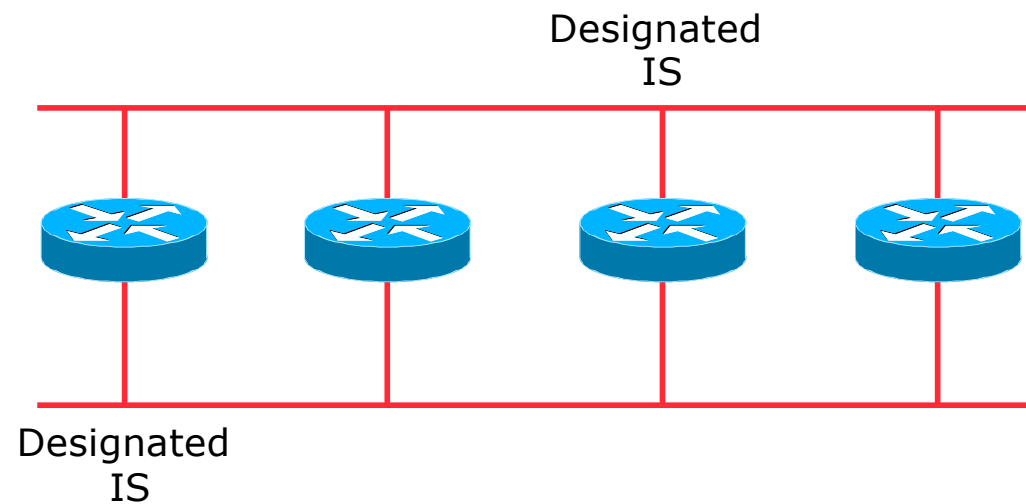
- IS-IS is multiprotocol
 - Integrated IS-IS carries CLNS and IPv4 address families
 - RFC5308 adds IPv6 address family support
 - RFC5120 adds multi-topology support
- IS-IS extended to carry IPv6 prefixes
 - Either sharing topology with IPv4
 - When IPv4 and IPv6 topologies are identical
 - Or using “multi-topology”, independent of IPv4
 - Allows incremental rollout of IPv6

Links in IS-IS

- Two types of links in IS-IS:
 - Point-to-point link
 - Only one other router on the link, forming a point-to-point adjacency
 - Multi-access network (e.g. ethernet)
 - Potential for many other routers on the network, with several other adjacencies
- IS-IS in multi-access networks has optimisations to aid scaling
 - One router is elected to originate the LSPs for the whole multi-access network
 - Called “**Designated Intermediate System**”
 - Other routers on the multi-access network form adjacencies with the DIS

Designated IS

- There is ONE designated router per multi-access network
 - Generates network link advertisements
 - Assists in database synchronization
 - Scales IS-IS for multi-access (ethernet) networks

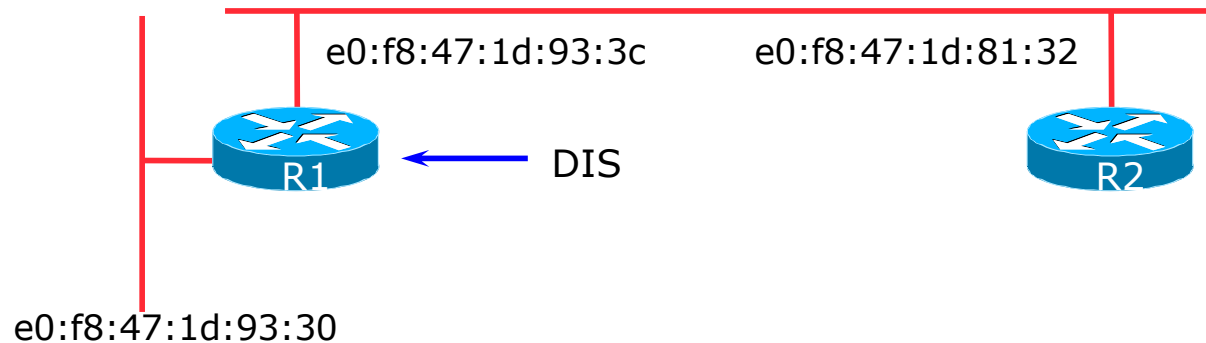


Selecting the Designated Router

- ❑ Configured priority (per interface)
 - Configure high priority on the router to be the DIS

```
interface gigabitethernet0/1
isis priority 127 level-2
```

- ❑ Else priority determined by highest MAC address
 - Best practice is to set two routers to be highest priority – then in case of failure of the DIS there is deterministic fall back to the other



Adjacencies: Cisco IOS Examples

- To find CLNS adjacency state, use:

```
show clns neighbor
```

System Id	Interface	SNPA	State	Holdtime	Type	Protocol
Router2	Fa0/0	ca01.9798.0008	Up	23	L2	M-ISIS
Router3	Se1/0	*HDLC*	Up	26	L2	M-ISIS

- To find IS-IS adjacency state, use:

```
show isis neighbor
```

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
Router2	L2	Fa0/0	10.10.15.2	UP	24	Router2.01
Router3	L2	Se1/0	10.10.15.6	UP	27	00

Adjacencies: JunOS Examples

- To find IS-IS adjacency state, use:

```
philip@R1> show isis adjacency
```

Interface	System	L State	Hold (secs)	SNPA
xe-1/0/0.0	R2	2 Up	8	3c:61:4:26:40:a5
xe-1/1/0.0	R3	2 Up	9	3c:8a:b0:cf:72:95

IS-IS NSAP Address

- ❑ IP based routing protocols have a router-id to uniquely identify a router
- ❑ In IS-IS, the IS (router) is identified by a Network Entity Title (NET)
 - Can be from 64 to 160 bits long
 - The NET is the address of a Network Service Access Point (NSAP), identifying an instance of IS-IS running on the IS
- ❑ ISPs typically choose NSAP addresses thus:
 - First 8 bits – pick a number (usually 49)
 - Next 16 bits – area
 - Next 48 bits – router loopback address
 - Final 8 bits – zero
- ❑ Example:
 - NSAP: 49.0001.1921.6800.1001.00
 - Router: 192.168.1.1 (loopback) in Area 1

IS-IS NSAP Address (Alternative)

- A simpler alternative, assuming a well documented ISP design
 - First 8 bits – pick a number (usually 49)
 - Next 16 bits – area
 - Next 16 bits – PoP identifier
 - Next 16 bits – Router identifier
 - Final 8 bits – zero
- Example:
 - NSAP: 49.0001.0009.0003.00
 - Router: #3 in PoP 9 in Area 1

IS-IS on Cisco IOS

- Starting IS-IS in Cisco's IOS

```
router isis as42
```

- Where "as42" is the process ID

- IS-IS process ID is local to the router

- Allows the possibility of running multiple instances of IS-IS on one router
- The process ID is not passed between routers
- Some ISPs configure the process ID to be the same as their BGP Autonomous System Number

IS-IS on Cisco IOS

- ❑ Cisco IOS default is for all routers to be L1L2
 - This is suboptimal – all routers need to be L2 only
- ❑ Once IS-IS is started, other required configuration under the IS-IS process includes:

```
log-adjacency-changes
```

- Capture adjacency changes in the system log

```
metric-style wide
```

- Set metric-style to wide

```
is-type level-2-only
```

- Set IS type to level 2 only (router-wide configuration)

```
net 49.0001.<loopback>.00
```

- Set NET address

Adding interfaces to IS-IS

- ❑ To activate IS-IS on an interface:

```
interface Gigabit 4/0  
ip router isis as42
```

- Puts interface subnet address into the LSDB
- Enables CLNS on that interface

- ❑ To disable IS-IS on an interface:

```
router isis as42  
passive-interface Gigabit 2/0
```

- Disables CLNS on that interface
- Puts the interface subnet address into the LSDB

- ❑ No IS-IS configuration for an interface

- No CLNS run on interface, no interface subnet in the LSDB

IS-IS interface costs

- ❑ All interfaces have a default metric of 10
 - Fine for a uniform network, but most backbones have different link capacities between routers & PoPs
 - Many operators set default metric to 100000
- ❑ Many operators develop their own interface metric strategy
 - ```
isis metric 100 level-2
```
  - Sets interface metric to 100
  - Care needed as the sum of metrics determines the best path through the network
- ❑ IS-IS chooses lowest cost path through a network
- ❑ IS-IS will load balance over paths with equal total cost to the same destination

# IS-IS on JunOS (1)

---

- The NET is set on the Loopback interface:

```
set interfaces lo0 unit 0 family iso address 49.0001.<loopback>.00
```

- IS-IS is all configured within “protocols”

- Set wide metrics only:

```
set protocols isis level 2 wide-metrics-only
```

- Set level-2 only:

```
set protocols isis level 1 disable
```

- Set multi-topology:

```
set protocols isis topologies ipv6-unicast
```

## IS-IS on JunOS (2)

---

- ❑ All interfaces participating in IS-IS need to have address family ISO added:

```
set interfaces xe-0/1/0 unit 0 family iso
set interfaces xe-0/1/3 unit 0 family iso
```

- ❑ Remaining IS-IS configuration

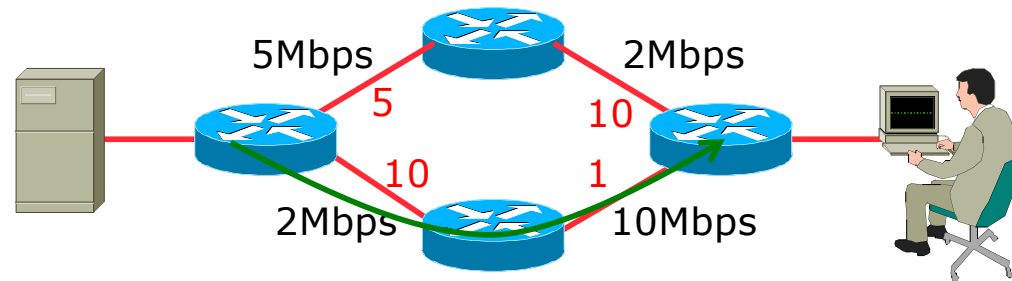
- Use “passive” for interfaces where no adjacencies are expected but link address will be distributed by IS-IS:

```
set protocols isis interface lo0.0 passive
set protocols isis interface xe-0/1/0.0 point-to-point
set protocols isis interface xe-0/1/0.0 level 1 disable
set protocols isis interface xe-0/1/0.0 level 2 metric 20
set protocols isis interface xe-0/1/0.0 level 2 ipv6-unicast-metric 20
set protocols isis interface xe-0/1/3.0 passive
```



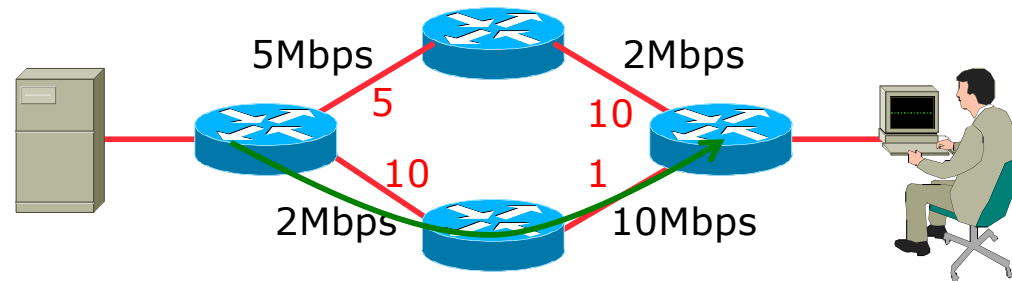
# IS-IS Metric Calculation

- Best path/lowest cost = 11

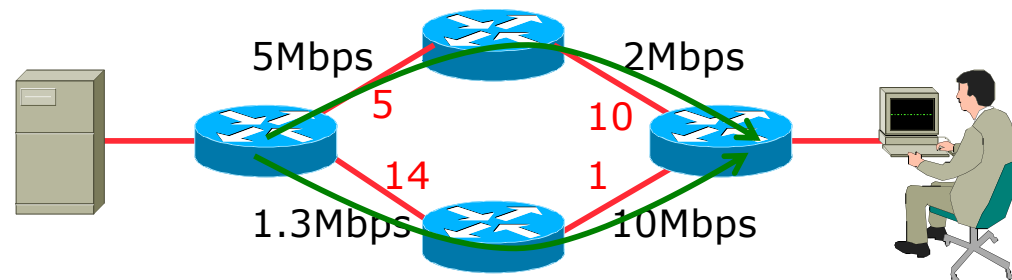


# IS-IS Metric Calculation

- Best path/lowest cost = 11



- Equal cost paths = 15



# IS-IS Neighbour Authentication on Cisco IOS

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- ❑ Neighbour authentication is highly recommended
  - Prevents unauthorised routers from forming neighbour relationships and potentially compromising the network
- ❑ Create a suitable key-chain

```
key chain isis-as42
 key 1
 key-string <password>
!
```

- There can be up to 255 different keys in each key chain

# IS-IS Neighbour Authentication on Cisco IOS

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- Apply key-chain per interface:

```
interface Gigabit 4/0
 isis authentication mode md5 level-2
 isis authentication key-chain isis-as42 level-2
!
```

- Apply key-chain to IS-IS process (all interfaces):

```
router isis as42
 authentication mode md5 level-2
 authentication key-chain isis-as42 level-2
!
```

# IS-IS Neighbour Authentication on JunOS

---

- ❑ Neighbour authentication is highly recommended
  - Prevents unauthorised routers from forming neighbour relationships and potentially compromising the network

- ❑ Create and apply key to all processes:

```
set protocols isis level 2 authentication-key "9RLzhfW4iG.mTwZ5Fd9OC7-V"
set protocols isis level 2 authentication-type md5
```

- ❑ Cisco IOS interoperability:

```
set protocols isis loose-authentication-check
```

# Originating a Default Route (Cisco IOS IPv4)

---

- How to always originate a default route into IS-IS:

```
router isis as42
 default-information originate
```

- Originate a default route into IS-IS only if a default route exists in the RIB from BGP:

```
ip access-list standard BGP-NH
 permit <ebgp neighbor address>
!
ip prefix-list DEFAULT-ROUTE permit 0.0.0.0/0
!
route-map DEFAULT-ORIG permit 10
 match ip address prefix-list DEFAULT-ROUTE
 match ip next-hop BGP-NH
!
router isis as42
 default-information originate route-map DEFAULT-ORIG
```

# Originating a Default Route (Cisco IOS IPv6)

---

- How to always originate a default route into IS-IS:

```
router isis as42
 address-family ipv6
 default-information originate
```

- Originate a default route into IS-IS only if a default route exists in the RIB from BGP:

```
ipv6 access-list BGP-NHv6
 permit ipv6 host <ebgp neighbor link-local address> any
!
ipv6 prefix-list DEFAULT-v6ROUTE permit ::/0
!
route-map DEFAULT-ORIGv6 permit 10
 match ipv6 address prefix-list DEFAULT-v6ROUTE
 match ipv6 next-hop BGP-NHv6
!
router isis as42
 address-family ipv6
 default-information originate route-map DEFAULT-ORIGv6
```

# Originating a Default Route (JunOS)

---

## □ How to originate a default route into IS-IS:

- Set up Static default routes to Discard (or wherever needed):

```
set routing-options rib inet6.0 static route ::/0 discard
set routing-options static route 0.0.0.0/0 discard
```

- Create the (multi-protocol) policy:

```
set policy-options policy-statement ISIS-DEF-ORIG term IPv4 from family inet
set policy-options policy-statement ISIS-DEF-ORIG term IPv4 from protocol static
set policy-options policy-statement ISIS-DEF-ORIG term IPv4 from route-filter 0.0.0.0/0 exact
set policy-options policy-statement ISIS-DEF-ORIG term IPv4 then accept
set policy-options policy-statement ISIS-DEF-ORIG term IPv6 from family inet6
set policy-options policy-statement ISIS-DEF-ORIG term IPv6 from protocol static
set policy-options policy-statement ISIS-DEF-ORIG term IPv6 from route-filter ::/0 exact
set policy-options policy-statement ISIS-DEF-ORIG term IPv6 then accept
set policy-options policy-statement ISIS-DEF-ORIG term ALL from protocol isis
set policy-options policy-statement ISIS-DEF-ORIG term ALL then accept
```

- And then apply to IS-IS:

```
set protocols isis export ISIS-DEF-ORIG
```



# IS-IS on Point-to-Point Ethernet

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## □ IS-IS on point-to-point ethernet:

- DIS election is not needed on a point-to-point link – so it is disabled, which is more efficient

### ■ Cisco IOS:

```
interface Gigabit 4/0
 isis network point-to-point
```

### ■ JunOS:

```
set protocols isis interface xe-0/1/0.0 point-to-point
```

- As DIS election is independent of IP, the above command is generic – there is no need for an IPv6 equivalent

# Handling IPv6 in IS-IS for Cisco IOS

---

- To add IPv6 support in IS-IS:

```
interface Gigabit 4/0
 ipv6 router isis as42
```

- Topologies:

- For single topology, nothing else is required
- For multi-topology, include:

```
router isis as42
 address-family ipv6
 multi-topology
```

# Handling IPv6 in IS-IS for JunOS

---

- To add IPv6 support in IS-IS:
  - Nothing needed if IPv6 configured on interface
  - Remember to set metric appropriately:

```
set protocols isis interface xe-0/1/0.0 level 2 ipv6-unicast-metric 20
```

- Topologies:
  - For single topology, nothing else is required
  - For multi-topology, include:

```
set protocols isis topologies ipv6-unicast
```

# Conclusion

---

- IS-IS is a Link State Routing Protocol
- Quick and simple to get started
  - But has a myriad of options and features to cover almost all types of network topology
  - ISPs keep their IS-IS design **SIMPLE**
  - >500 routers running in L2 is entirely feasible

# Introduction to IS-IS



ISP Workshops