CHAPTER 7

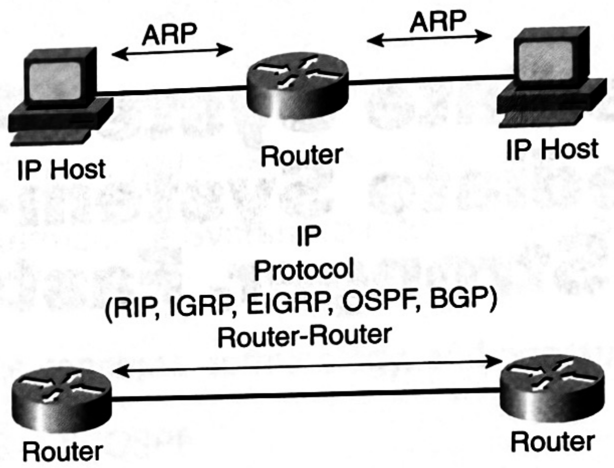
Intermediate System-to-Intermediate System—Better, Stronger, Faster, and Scarier

IS-IS is a hierarchical link-state interior routing protocol similar to OSPF. The International Organization for Standardization (ISO) originally developed IS-IS to route packets using Network Service Access Point (NSAP) addresses, and not IP addresses.

Comparing IS-IS and IP Networks

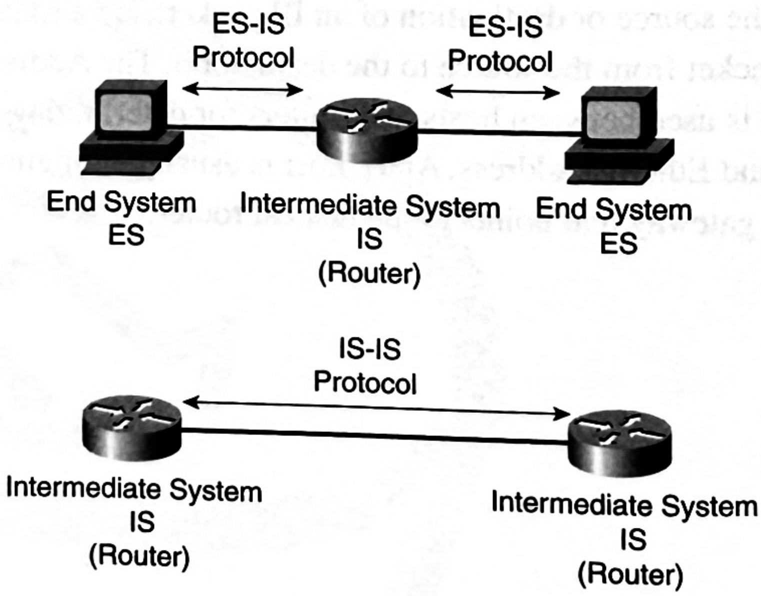
In the IP world, the two main entities are hosts and routers. (See Figure 7-1.) An IP protocol is used between routers for the exchange of routing information. A host is usually the source or destination of an IP packet, and a router's job is to deliver the IP packet from the source to the destination. The Address Resolution Protocol (ARP) is used between hosts and routers for determining the mapping between an IP and Ethernet address. An IP host is usually configured with a static route or default gateway that points to the nearest router.

Figure 7-1 In the IP World, Routers Route Packets Between IP Hosts



In the ISO world, routers are referred to as ***intermediate systems (IS)*** and hosts as ***end systems (ES)***. In Figure 7-2, a router is the IS between ESs. Thus, the routing protocol that exchanges routing information between ISs is called Intermediate System-to-Intermediate System, or IS-IS. (If you used this same approach in the IP world, you could call all IP routing protocols Router-to-Router [R-R] protocols.) Instead of a static or default route, ISO uses the ES-IS protocol for end stations to discover the nearest router or IS.

Figure 7-2 In the ISO World, ISs Route Packets Between ESs



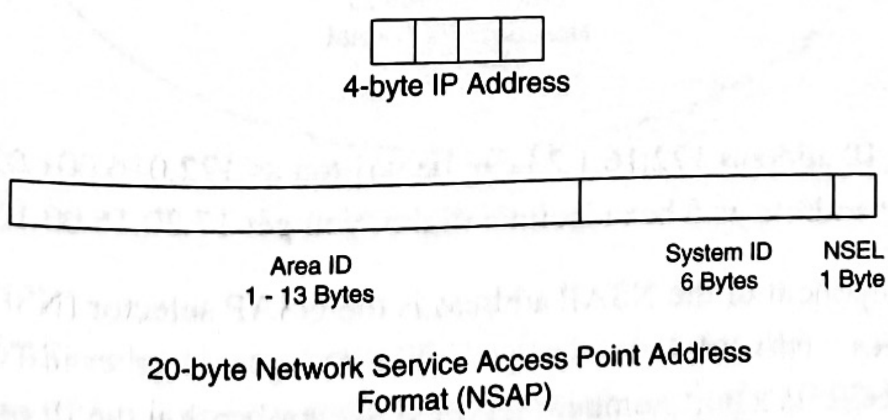
In the early days of networking, the ISO and IP protocols battled to be the adopted standard for the Internet. We know that IP won; there is not an ISO Internet, but an IP Internet. IS-IS was adapted to route IP packets in addition to ISO packets. IS-IS can be configured to route NSAP packets only, IP packets only, or both. Typically, you find IS-IS routing both and this form of the protocol is called ***Integrated IS-IS***. Why do you need to route both if there is not an ISO Internet? Although Integrated IS-IS routes IP, it still uses NSAP addresses for neighbor discovery. Therefore, it is important to understand the structure of NSAP addresses and how they create a hierarchical multi-area network.

Having to work with two addressing formats, NSAP and IP, is what tends to make IS-IS a scary protocol. You may be comfortable with IP addresses, but not with NSAP addresses. What you need to understand about NSAP addresses in relationship to IS-IS, however, is relatively straightforward. After a discussion of the structure and use of NSAP addresses, and a few examples, you should have no problems using them with IS-IS.

Figure 7-3 shows the formats of IP and NSAP addresses. An NSAP address can be 8 to 20 bytes in length and has three components:

- Area ID
- System ID
- NSAP selector (NSEL)

Figure 7-3 IP and NSAP Address Formats



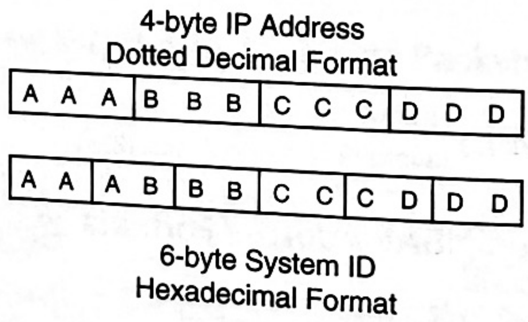
The area ID can be 1 to 13 bytes in length. The area ID determines a router's IS-IS area. This is similar to the area IDs used by OSPF. An OSPF area ID is a 32-bit number while an IS-IS area ID is 1 to 13 bytes, or 8 to 104 bits in length.

The system ID identifies a router. The system ID can be any hexadecimal value that fits into six bytes. When configuring a router for IS-IS, you are free to choose the system ID. For example, if you have three IS-IS routers, you can use the following system IDs:

- 111111111111 for router 1
- 222222222222 for router 2
- 333333333333 for router 3

Another approach is to use the IP address of a router's loopback interface for the system ID. An IP address is 4 bytes and when written in the dotted decimal format, each byte can have a value between 0 and 255. If you write the dotted decimal format for an IP address and use 3 decimal digits for each byte, the dotted decimal representation will have 12 digits as shown in Figure 7-4.

Figure 7-4 Converting an IP Address to an IS-IS System ID



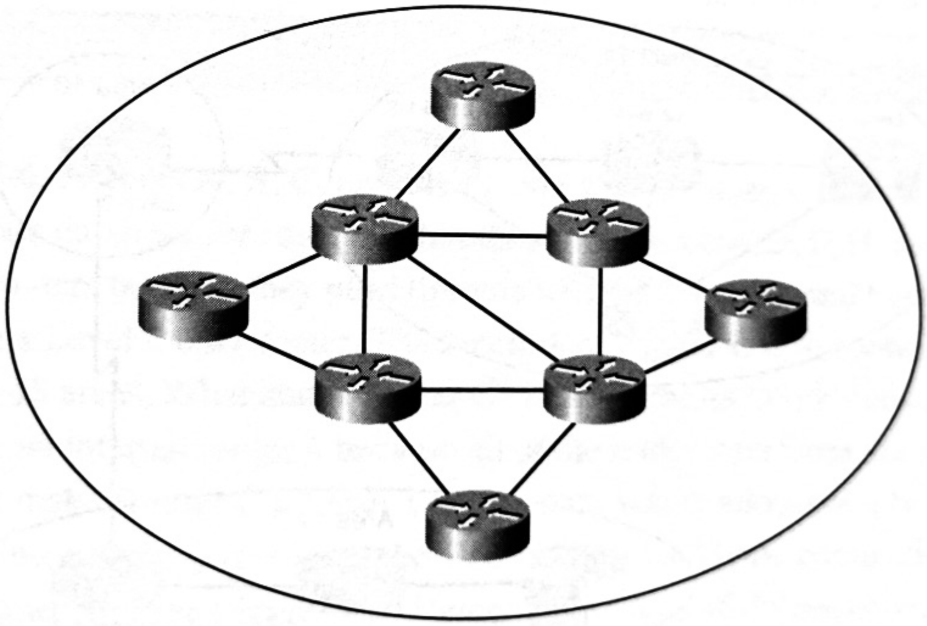
For example, IP address 172.16.1.23 can be written as 172.016.001.023. If you rewrite the IP address as 6 hexadecimal digits, you get 17.20.16.00.10.23.

The third component of the NSAP address is the NSAP selector (NSEL). The NSEL specifies a network layer service similar to a port number in TCP/IP. For example, in TCP/IP, a port number identified the application the IP packet should be sent to on the receiving host. Because NSAP addresses are not used for routing, the NSEL is not used to select the destination application (IP is used for this function), so the NSEL value is set to 0. Therefore, a selector value of 0 identifies a router. A router that is configured for IS-IS area 1 with a loopback address of 10.1.2.3 has an NSAP address of 01.01.00.01.00.20.03.00, assuming you are using the loopback IP address to determine the IS-IS system ID.

IS-IS Areas

An IS-IS network can be configured as a single or multiple area network. When using a single area, the area number can be any number that fits into 13 bytes. (See Figure 7-5).

Figure 7-5 Single Area IS-IS Network

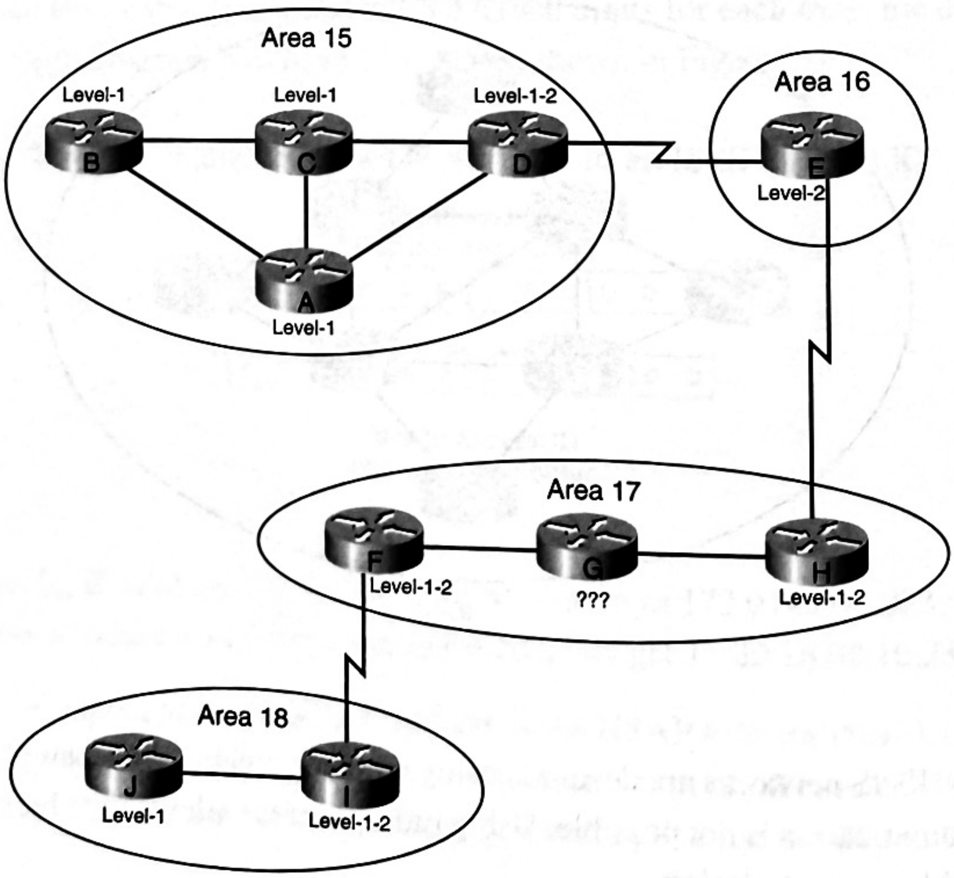


Normally, IS-IS networks are designed using multiple areas. When a single area is used, summarization is not possible. Using multiple areas allows for a hierarchical and scalable network design.

There are two types of routing in an IS-IS network. Routing within an area is called ***Level 1 routing***. Routing between IS-IS areas is called ***Level 2 routing***. Level 1 IS-IS routers only maintain a database of intra-area routes. Level 2 IS-IS routers maintain a database of inter-area routes. In OSPF, Level 1 routing is referred to as *intra-area routing* and Level 2 routing as *interarea routing*.

When multiple areas are used in a network design, OSPF requires a backbone area, or area 0. All nonzero OSPF areas must be connected to the backbone, or area 0, through an Area Border Router (ABR). IS-IS also has a backbone, but not a backbone area. An IS-IS backbone is a contiguous chain of Level 2 capable routers. If you can trace a continuous line through level-2 capable IS-IS routers to or through every IS-IS area, you have a valid IS-IS network design. Figure 7-6 is a multiple area IS-IS network and each router, except for Router G, is designated as either a Level 1, Level 2, or Level 1-2 router.

Figure 7-6 Multiple Area IS-IS Network



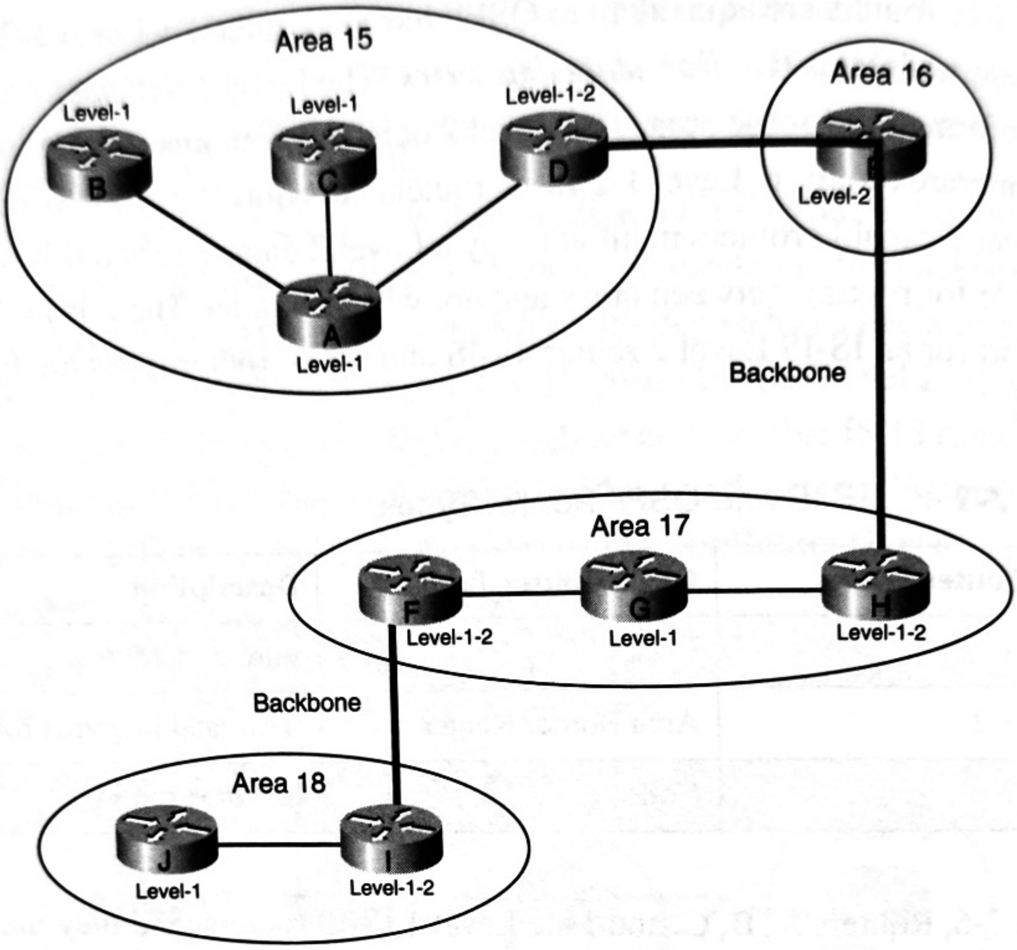
A Level 1 router is a router that maintains one IS-IS link-state database. A Level 1 IS-IS link-state database contains routing information for routing within an area. Level 1 IS-IS routers are equivalent to OSPF internal routers. A Level 1-2 capable IS-IS router maintains two ***link-state databases***. The Level 1 database contains routing information for the area. The Level 2 database contains routing information for interarea routing. Level 1-2 IS-IS routers are equivalent to OSPF ABRs. IS-IS Level 2 capable routers maintain only a Level 2 database, and they are responsible for routing between areas and not within an area. There is no OSPF counterpart for an IS-IS Level 2 router. IS-IS and OSPF router types are listed in Table 7-1.

Table 7-1 IS-IS and OSPF Router Types

IS-IS Router Type	OSPF Router Type	Description
Level 1	Internal	Intra-area routing
Level 1-2	Area Border Router	Intra- and interarea routing
Level 2	None	Interarea routing

In Figure 7-6, Routers A, B, C, and J are Level 1 IS-IS routers, and they maintain one link-state database for routes within their area. Routers D, F, H, and I are Level 1-2 routers because they need to route within their areas and between areas. Router E is a Level 2 only router. The function of Router E is to route only between IS-IS areas. What about Router G? If this were an OSPF network, Router G would be an internal router—because all of the router interfaces are in the same area. If you make Router G a Level 1 only router, you would have a broken IS-IS network—because there would not be a contiguous backbone connecting areas 15, 16, 17, and 18. (See Figure 7-7.) Remember that an IS-IS backbone is a contiguous chain of Level 2 capable routers used to connect all IS-IS areas.

Figure 7-7 IS-IS Backbone Must Be a Contiguous Chain of Level 2 Capable Routers



Router G must be configured as a Level 1-2 router to have a contiguous backbone connecting all IS-IS areas. (See Figure 7-8).

An IS-IS backbone is more flexible and scalable than an OSPF backbone, or area 0. For example, if you want to merge two OSPF networks, you have to ensure that every nonzero area is connected to area 0. In Figure 7-9, all nonzero areas must be connected to the backbone or area 0. With OSPF, ensuring that all nonzero areas are physically connected to the backbone can be difficult.

Figure 7-8 For a Contiguous IS-IS Backbone, Router G Must Be Configured as a Level 1-2 Capable Router

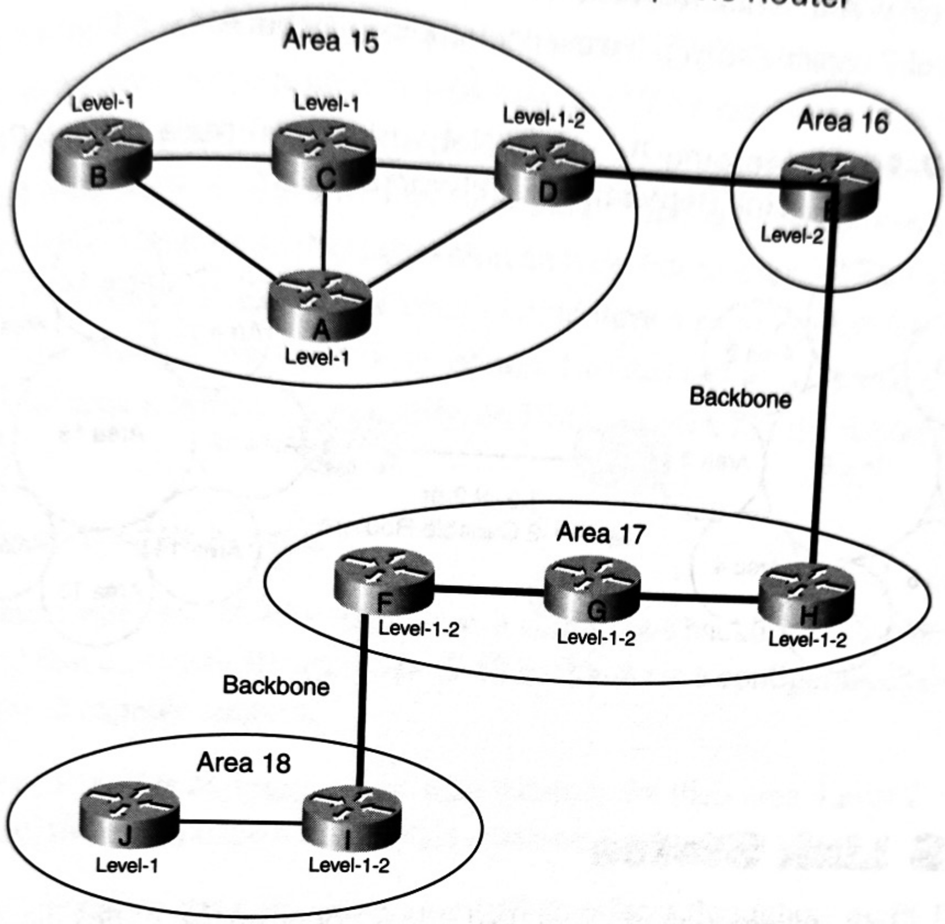
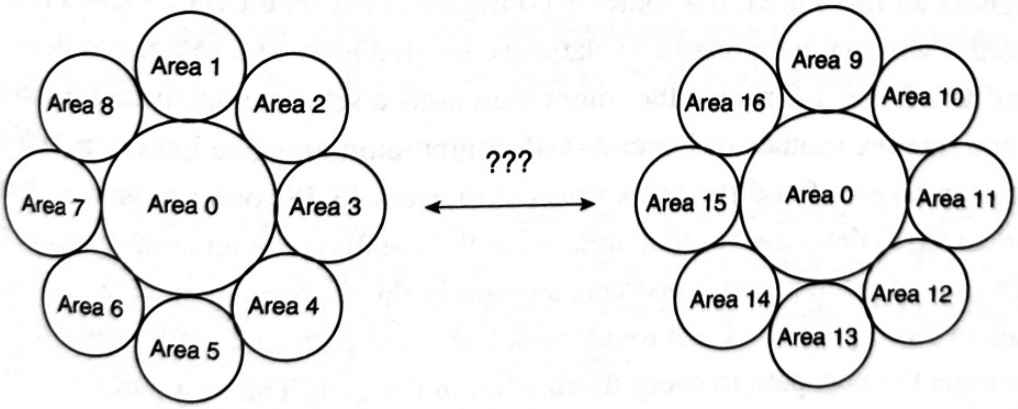
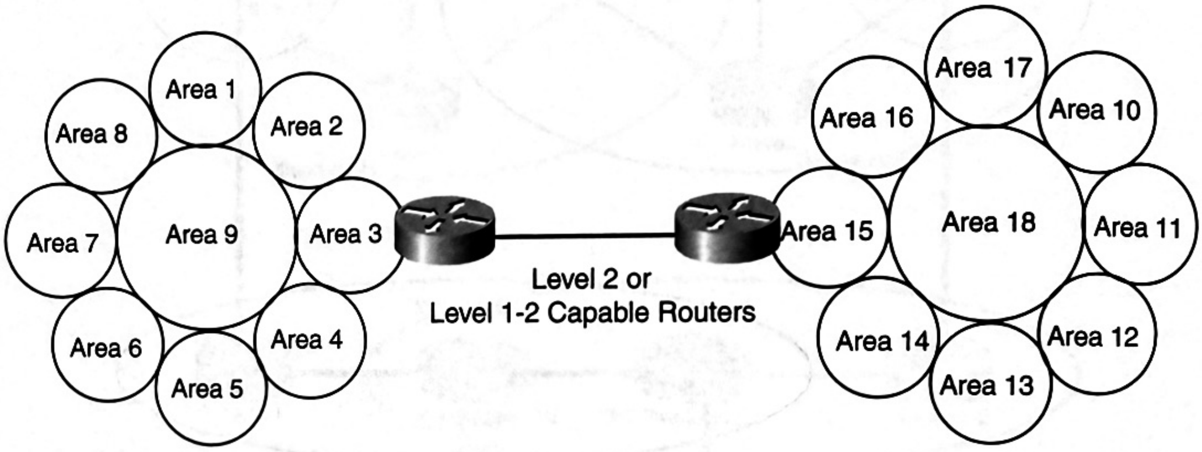


Figure 7-9 All Nonzero OSPF Areas Must Connect to Area 0



If these were IS-IS networks, what would you have to do to merge them? The solution is easy. Add a link between the two IS-IS networks and make the border routers Level 2 capable so you have a contiguous backbone. (See Figure 7-10.)

Figure 7-10 Merging Two IS-IS Networks Requires a Level 2 Capable Link Between the Networks



IS-IS Link States

IS-IS is a link-state routing protocol. IS-IS does not advertise routes like the distance vector protocols. IS-IS advertises link states using ***link-state packets (LSPs)***. IS-IS routers flood, or advertise, their link states to their IS-IS neighbors throughout an IS-IS area. If a router is configured only as a Level 1 IS-IS router, that router will maintain one IS-IS database for that area. If a router has been configured as a Level 1-2 router, the router maintains a separate database for intra-area and interarea routes. A Level 2 IS-IS router maintains one interarea database. Routers in an area flood their link states until every IS-IS router in an area has an identical IS-IS database for that area. After the databases in an area agree, or are synchronized, each router constructs a graph of the prefixes in an area and the routes to those prefixes. Each router runs a shortest path first (SPF) algorithm to determine the best path to every destination in the area. The best paths to every destination are then installed in the local IP routing table.

As with OSPF, route summarization cannot be used if one area is only used in an IS-IS network design. Before routes can be transferred from the IS-IS database to the IP routing table, the databases in an area must agree. If routes could be summarized in an area, some routers would have specific routes and some routers would have summaries. If this were possible, the databases in an area would never agree and routes would never be placed in the IP routing table. Routes can be summarized between areas, but not within an area. For example, area 1 could have a summary of routes in area 2 and area 2 could have a summary of routes in area 1. But area 1 cannot have a summary of area 1 routes and area 2 cannot have a summary of area 2 routes. In summary, an IS-IS network has the following properties:

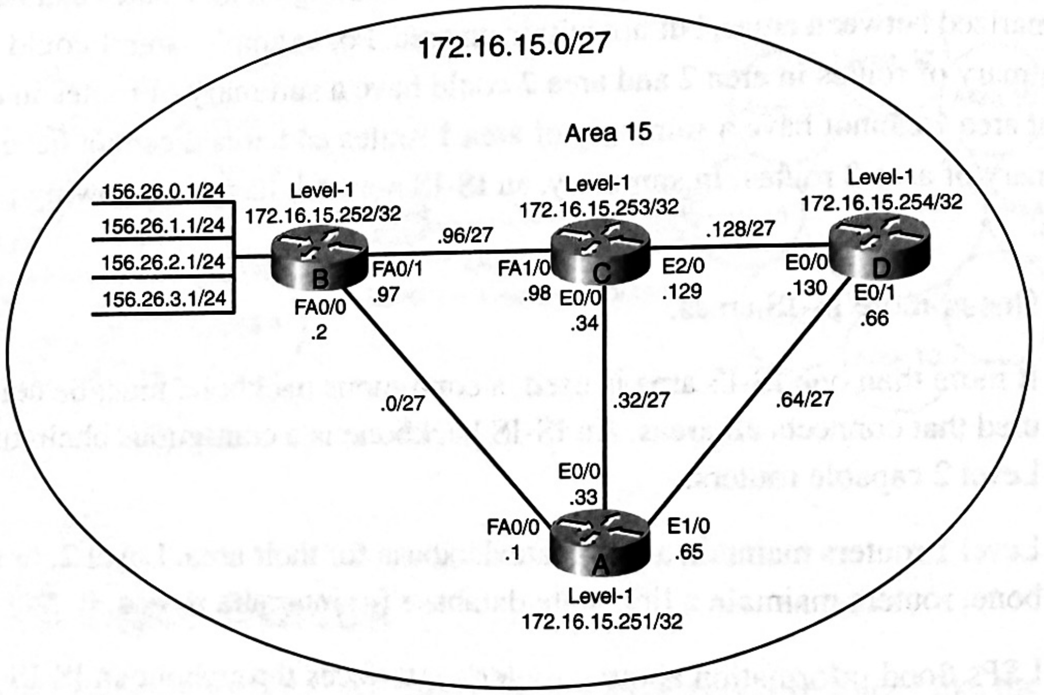
- One or more IS-IS areas.
- If more than one IS-IS area is used, a contiguous backbone must be configured that connects all areas. An IS-IS backbone is a contiguous chain of Level 2 capable routers.
- Level 1 routers maintain a link-state database for their area. Level 2, or backbone, routers maintain a link-state database for interarea routes.
- LSPs flood information about a router's interfaces throughout an IS-IS area.
- IS-IS databases within an area must be identical before a router can calculate the routes that are installed in the IP routing table.
- The SPF algorithm is run on each area database maintained by a router. SPF determines the routes that are installed in the IP routing table.
- Routes can only be summarized between areas, not within an area.

At this point, you should have a basic understanding of the concepts of the IS-IS routing protocol and the operation and structure of an IS-IS network. The next section looks at the basic configuration of IS-IS on Cisco routers, and compares the IS-IS configuration to an OSPF configuration.

Basic Single Area IS-IS Configuration

This section examines the process of configuring a single IS-IS area using the network in Figure 7-11.

Figure 7-11 Single Area IS-IS Network



The steps for a basic single area IS-IS configuration are as follows:

Step 1 Configure a loopback interface on each OSPF router.

Step 2 Configure IP addresses on the physical interfaces.

Step 3 Configure the IS-IS process on each router.

Step 4 Enable IS-IS on the router interfaces.

The loopback addresses, IS-IS system IDs, and router NSAP addresses are listed in Table 7-2. The system IDs and NSAP addresses are derived from the loopback addresses.

Table 7-2 Loopback and System IDs for Figure 7-11

Router	Loopback	System ID	NSAP
A	172.16.15.251/32	17.20.16.01.52.51	15.17.20.16.01.52.51.00
B	172.16.15.252/32	17.20.16.01.52.52	15.17.20.16.01.52.52.00
C	172.16.15.253/32	17.20.16.01.52.53	15.17.20.16.01.52.53.00
D	172.16.15.254/32	17.20.16.01.52.54	15.17.20.16.01.52.54.00

The loopback interfaces on Routers A, B, C, and D are configured first because they are being used for the router's NSAP address. (See Example 7-1.)

Example 7-1 Loopback Interface Configurations

```
Router A
interface Loopback0
 ip address 172.16.15.251 255.255.255.255

Router B
interface Loopback0
 ip address 172.16.15.252 255.255.255.255

Router C
interface Loopback0
 ip address 172.16.15.253 255.255.255.255

Router D
interface Loopback0
 ip address 172.16.15.254 255.255.255.255
```

Four additional loopback interfaces are configured on Router B, so you have some networks to advertise. Loopback interfaces can be used to create virtual networks, so you can experiment with some of the properties of IS-IS. (See Example 7-2.)

Example 7-2 Using Loopback Interfaces to Simulate Physical Networks

```
Router B
interface Loopback1
 ip address 156.26.0.1 255.255.255.0

interface Loopback2
 ip address 156.26.1.1 255.255.255.0

interface Loopback3
 ip address 156.26.2.1 255.255.255.0

interface Loopback4
 ip address 156.26.3.1 255.255.255.0
```

After the loopback and physical interfaces have been configured, the next step is to enable the IS-IS routing process on each router. (See Example 7-3). When an OSPF process is configured, the router ID is taken from one of the IP addresses configured on an interface with loopback addresses having precedence. For IS-IS, the ID of the router is configured under the IS-IS router process, and is referred to as the network entity title (NET).

Example 7-3 IS-IS Process Configuration

```
Router A
router isis
 net 15.1720.1601.5251.00
 is-type level-1

Router B
router isis
 net 15.1720.1601.5252.00
 is-type level-1

Router C
router isis
 net 15.1720.1601.5253.00
 is-type level-1

Router D
router isis
 net 15.1720.1601.5254.00
 is-type level-1
```

By default, an IS-IS router is a Level 1-2 router. The command **is-type level-1** forces the routers to be Level 1 capable only.

With the loopback interfaces configured and the IS-IS process enabled, the next step is to enable interfaces for IS-IS. Similar to the other interior routing protocols you have learned about, once an interface is enabled for a protocol, the prefix and mask configured on the interface will be advertised. In addition, EIGRP, OSPF, and IS-IS try to discover neighbor routers on these interfaces using hello packets. With RIP, IGRP, EIGRP, and OSPF, interfaces are enabled under the routing process. With IS-IS, interfaces are enabled using the interface command **ip router isis** as shown for Router A in Example 7-4. The configurations for Routers B, C, and D are the same as for Router A.

Example 7-4 Enabling Router A Interfaces for IS-IS

```
Router A
interface Loopback0
 ip address 172.16.15.251 255.255.255.255
 ip router isis

interface FastEthernet0/0
 ip address 172.16.15.1 255.255.255.224
 ip router isis

interface Ethernet1/0
 ip address 172.16.15.65 255.255.255.224
 ip router isis

interface Ethernet0/0

 ip address 172.16.15.33 255.255.255.224
 ip router isis
```

Examples 7-1 through 7-4 are the minimum configurations you need to enable IS-IS for the network in Figure 7-11. All IS-IS routes should now be in the routing tables on all IS-IS routers. The IS-IS routes are verified using the **show ip route** command as shown in Example 7-5.

Example 7-5 Verifying Advertising of IS-IS Routes

```
D#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     156.26.0.0/24 is subnetted, 4 subnets
i L1    156.26.2.0 [115/30] via 172.16.15.129, Ethernet0/0
i L1    156.26.3.0 [115/30] via 172.16.15.129, Ethernet0/0
i L1    156.26.0.0 [115/30] via 172.16.15.129, Ethernet0/0
i L1    156.26.1.0 [115/30] via 172.16.15.129, Ethernet0/0
     172.16.0.0/16 is variably subnetted, 9 subnets, 2 masks
C       172.16.15.128/27 is directly connected, Ethernet0/0
i L1    172.16.15.251/32 [115/20] via 172.16.15.65, Ethernet0/1
C       172.16.15.254/32 is directly connected, Loopback0
i L1    172.16.15.253/32 [115/20] via 172.16.15.129, Ethernet0/0
i L1    172.16.15.252/32 [115/30] via 172.16.15.129, Ethernet0/0
i L1    172.16.15.32/27 [115/20] via 172.16.15.65, Ethernet0/1
i L1    172.16.15.0/27 [115/20] via 172.16.15.65, Ethernet0/1
i L1    172.16.15.96/27 [115/20] via 172.16.15.129, Ethernet0/0
C       172.16.15.64/27 is directly connected, Ethernet0/1
```

To determine if all IS-IS neighbors have been discovered, use the command **show isis topology.**(See Example 7-6.)

Example 7-6 Verifying IS-IS Neighbors

```
D#show isis topology

IS-IS paths to level-1 routers
System Id        Metric  Next-Hop         Interface   SNPA
A                10      A                Et0/1       0003.6cb3.ac1c
B                20      C                Et0/0       0004.c109.1dc0
                         A                Et0/1       0003.6cb3.ac1c
C                10      C                Et0/0       0004.c109.1dc0
D                --
```

The output of the **show isis topology** command lists the system ID of the neighbor in the first column. The system ID is symbolic, and does not show the neighbor's

NSAP address. To verify a neighbor's NSAP address, use the command **show isis hostname**, as shown in Example 7-7.

Example 7-7 Displaying IS-IS Router System IDs

```
D#show isis hostname
Level  System ID       Dynamic Hostname  (notag)
 1     1720.1601.5252 B
 1     1720.1601.5253 C
 1     1720.1601.5251 A
     * 1720.1601.5254 D
```

In the second and third columns, the output of the **show isis topology**command lists the metric—or distance—to the neighbor, the next hop router to reach the neighbor, and the interface used to reach the neighbor. The last column lists the Ethernet address of the neighbor router's interface.

At this point you have an understanding of how to configure and verify a basic single area IS-IS network. Before moving on to a multiple area IS-IS network, you will learn about IS-IS metrics.

IS-IS Metrics

All IP routing protocols use interface costs or metrics to determine the best path to a destination. RIP uses a hop count that does not take into account the speed or bandwidth of the interface. IGRP and EIGRP use a four-component metric that consists of delay, bandwidth, reliability, and load. By default, only the delay and bandwidth parameters calculate an IGRP or EIGRP metric. An OSPF metric is calculated from the bandwidth of the network interface. The default IS-IS metric is probably the least useful. With IS-IS, by default, all interfaces have a cost or metric of 10. This can be seen from the IP routing table, or from the output of the **show isis topology**command from Example 7-6.

If you look in the routing table on Router D and inspect the route to the loopback interface on Router C, the cost to reach this network is 20. (See Example 7-8.)

Example 7-8 IS-IS Route Metric from Router D to Router C

```
D#show ip route | include 172.16.15.253
i L1    172.16.15.253/32 [115/20] via 172.16.15.129, Ethernet0/0
```

The cost from Router D to Router C across the Ethernet interface is 10, and the cost from Router C to its loopback address is also 10. This gives a total cost of 20.

The cost from Router C to reach the first loopback interface on Router B is also 20, as shown in Example 7-9.

Example 7-9 IS-IS Route Metric from Router C to Router B

```
C#show ip route | include 172.16.15.252
i L1    172.16.15.252/32 [115/20] via 172.16.15.97, FastEthernet1/0
```

From an IS-IS point of view, the cost from Router D to Router C is the same as the cost from Router C to Router B. IS-IS does account for the fact that the fast Ethernet network is 10 times faster than the Ethernet network. This is because of using a default metric, or cost, of 10 for every interface. The default IS-IS metric is referred to as an ***IS-IS narrow metric***.

You can help IS-IS by modifying the metric of each interface. If you use the same calculation as OSPF, an Ethernet interface has a cost of 10—and a fast Ethernet interface has a cost of 1. IS-IS interface metrics are modified using the **isis metric** interface command. On Routers A, B, and C, the IS-IS cost of the fast Ethernet interfaces is changed to be 1 instead of 10—as shown in Example 7-10 for the fast Ethernet interface on Router A. Routers B and C have similar configurations.

Example 7-10 Modifying the IS-IS Interface Metric

```
Router A
interface FastEthernet0/0
 ip address 172.16.15.1 255.255.255.224
 ip router isis
 isis metric 1
```

You should now see a difference in the cost from Router D to C as compared to the cost to go from Router C to B. (See Example 7-11.)

Example 7-11 Verifying the New IS-IS Route Metrics

```
D#show ip route | include 172.16.15.253
i L1     172.16.15.253/32 [115/20] via 172.16.15.129, Ethernet0/0

C#show ip route | include 172.16.15.252
i L1     172.16.15.252/32 [115/11] via 172.16.15.97, FastEthernet1/0
```

For IS-IS to calculate a true shortest path, the metrics of all the interfaces need to be changed to reflect the difference in interface bandwidths. This can be done easily, but if you have a large network, this process is prone to error. Metrics in IGRP, EIGRP, and OSPF are more convenient because the metrics are automatically calculated based on the interface parameters.

Another limitation of using default IS-IS metrics is that only 6 bits are used for Level 1 routes and 10 bits for Level 2 routes. For Level 1 routes, there are 2^6-1, or 63, different metric values. This may not be sufficient depending on the mix of interfaces in the network. For example, if you have a gigabit Ethernet interface as the fastest interface in the network, you can set the IS-IS metric to 1. Fast Ethernet has one-tenth the bandwidth, so you can set the IS-IS metric to 10. Ethernet would then have a metric of 100 but the largest IS-IS metric is 63. Therefore, you cannot adequately represent a mix of high- and low-speed interfaces in an IS-IS network using the default metric size.

To overcome the problems with the default metric size, IS-IS can be configured to use a larger or wider metric that uses 24 bits for intra-area routes and 32 bits for interarea routes. IS-IS can be enabled to use ***IS-IS wide metrics*** using the **metric-style wide**command under the IS-IS router configuration as shown for Router A in Example 7-12.

Example 7-12 Configuring IS-IS for Wide Metrics

```
Router A
router isis
 net 15.1720.1601.5251.00
 is-type level-1
 metric-style wide
```

Interface metrics can now be configured with a value in the range of 1 to 16,777,214. This new range is sufficient to handle any mix of interface speeds, but you still need to manually configure a metric on every IS-IS interface. When using wide metrics, the default interface metric is still 10.

IS-IS Multiple Area Configuration

This section uses the network in Figure 7-12 to investigate the properties of a multiple area IS-IS network. The loopback addresses, system IDs, and NSAP addresses for the routers in area 17 are listed in Table 7-3.

Figure 7-12 Multiple Area IS-IS Network

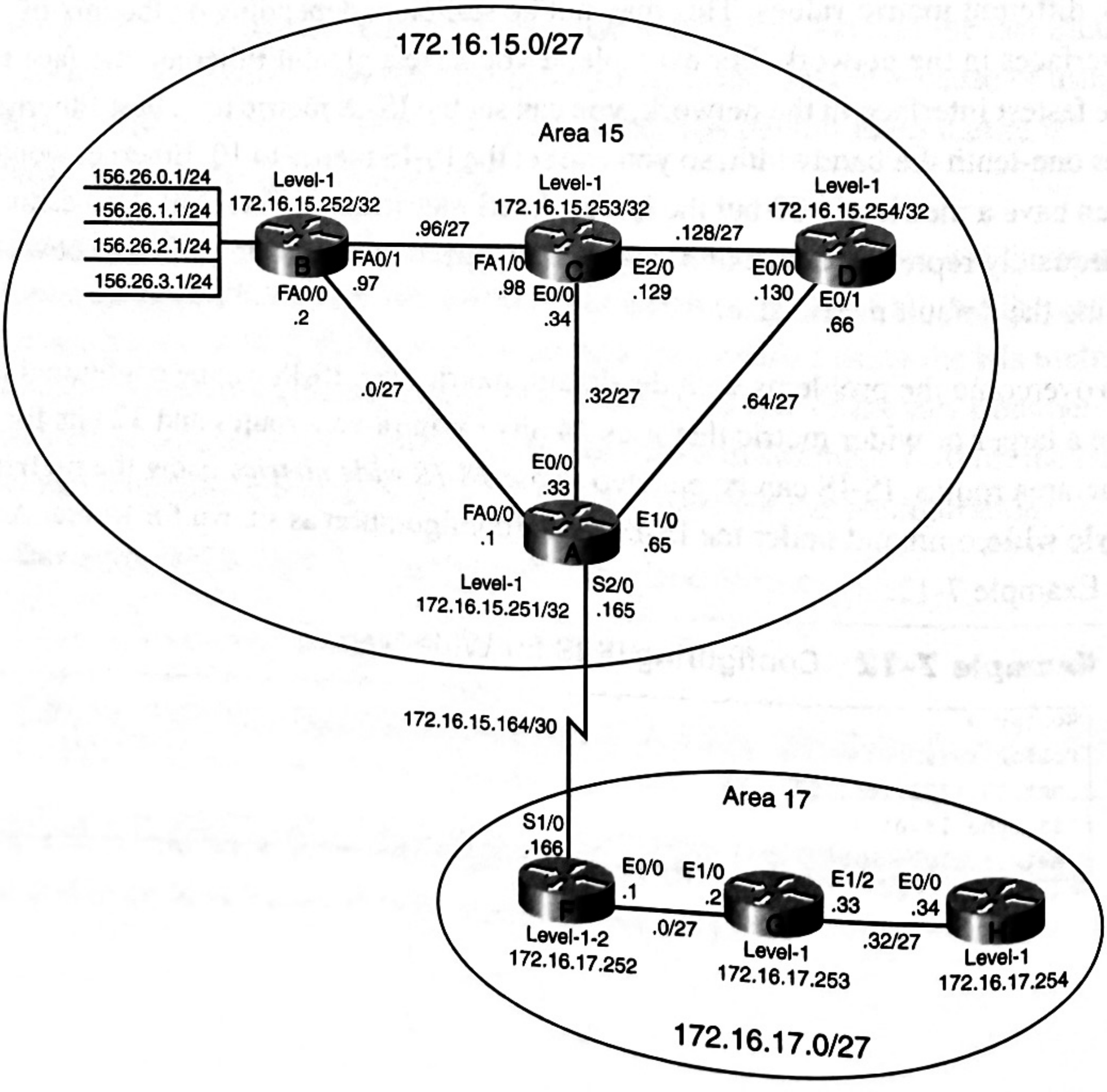


Table 7-3 Additional Loopback and System IDs for Figure 7-12

Router	Loopback	System ID	NSAP
F	172.16.17.252/32	17.20.16.01.72.52	17.17.20.16.01.72.52.00
G	172.16.17.253/32	17.20.16.01.72.53	17.17.20.16.01.72.53.00
H	172.16.17.254/32	17.20.16.01.72.54	17.17.20.16.01.72.54.00

Router A now has a connection to area 17 through Router F. Both Routers A and F need to be configured as Level 1-2 capable routers. Routers G and H do not have any connections to another area, so they can be configured as Level 1 only capable routers. (See Example 7-13.) The link between Routers A and F also needs to be enabled for IS-IS.

Example 7-13 Configuring IS-IS Link Types

```
Router A
router isis
 net 15.1720.1601.5251.00
 is-type level-1-2
 metric-style wide

Router F
interface Loopback0
 ip address 172.16.17.252 255.255.255.255
 ip router isis
router isis
 net 17.1720.1601.7252.00
 is-type level-1-2
 metric-style wide

Router G
interface Loopback0
 ip address 172.16.17.253 255.255.255.255
 ip router isis

router isis
 net 17.1720.1601.7253.00
 is-type level-1
 metric-style wide

Router H
interface Loopback0
```

Example 7-13 Configuring IS-IS Link Types (continued)

```
 ip address 172.16.17.254 255.255.255.255
 ip router isis

router isis
 net 17.1720.1601.7254.00
 is-type level-1
 metric-style wide
```

If you list the configurations, there is no **is-type**command shown in the configurations for Routers A and F. Level 1-2 is the default, so this command does not appear in the configurations.

Routers A and F have a Level 2 neighbor relationship because they are configured for different areas, as shown in Example 7-14.

Example 7-14 Verifying IS-IS Level 2 Capability

```
A#show isis topology level-2
IS-IS paths to level-2 routers
System Id            Metric  Next-Hop                  Interface   SNPA
A                    --
F                    10      F                         Se2/0       *HDLC*

F#show isis topology level-2
IS-IS paths to level-2 routers
System Id       Metric  Next-Hop          Interface         SNPA
A               10      A                 Se1/0             *HDLC*
F               --
```

All IS-IS routes should be in the routing tables on all the routers as shown in Example 7-15 for Router F.

Example 7-15 IP Routing Table for Router F

```
F#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route
```

Example 7-15 IP Routing Table for Router F

```
Gateway of last resort is not set

     156.26.0.0/24 is subnetted, 4 subnets
i L2    156.26.2.0 [115/21] via 172.16.15.165, Serial1/0
i L2    156.26.3.0 [115/21] via 172.16.15.165, Serial1/0
i L2    156.26.0.0 [115/21] via 172.16.15.165, Serial1/0
i L2    156.26.1.0 [115/21] via 172.16.15.165, Serial1/0
     172.16.0.0/16 is variably subnetted, 16 subnets, 3 masks
i L1    172.16.16.164/30 [115/30] via 172.16.17.2, Ethernet0/0
C       172.16.15.164/30 is directly connected, Serial1/0
i L2    172.16.15.128/27 [115/22] via 172.16.15.165, Serial1/0
i L2    172.16.15.251/32 [115/20] via 172.16.15.165, Serial1/0
i L2    172.16.15.254/32 [115/30] via 172.16.15.165, Serial1/0
i L2    172.16.15.253/32 [115/22] via 172.16.15.165, Serial1/0
i L2    172.16.15.252/32 [115/21] via 172.16.15.165, Serial1/0
i L1    172.16.17.253/32 [115/20] via 172.16.17.2, Ethernet0/0
C       172.16.17.252/32 is directly connected, Loopback0
i L1    172.16.17.254/32 [115/30] via 172.16.17.2, Ethernet0/0
i L1    172.16.17.32/27 [115/20] via 172.16.17.2, Ethernet0/0
i L2    172.16.15.32/27 [115/20] via 172.16.15.165, Serial1/0
C       172.16.17.0/27 is directly connected, Ethernet0/0
i L2    172.16.15.0/27 [115/11] via 172.16.15.165, Serial1/0
i L2    172.16.15.96/27 [115/12] via 172.16.15.165, Serial1/0
i L2    172.16.15.64/27 [115/20] via 172.16.15.165, Serial1/0
```

The routing table on Router F contains both Level 1 and Level 2 routes. The Level 1 routes are those that originate in area 17. The Level 2 routes are those that originate in area 15. The Level 1 only routers have only routes from their own area as shown in Example 7-16 for Router G.

Example 7-16 IP Routing Table for Router G

```
G#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 172.16.17.1 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
i L1    172.16.16.164/30 [115/20] via 172.16.17.34, Ethernet1/2
```

continues

Example 7-16 IP Routing Table for Router G (continued)

```
C        172.16.17.253/32 is directly connected, Loopback0
i L1     172.16.17.252/32 [115/20] via 172.16.17.1, Ethernet1/0
i L1     172.16.17.254/32 [115/20] via 172.16.17.34, Ethernet1/2
C        172.16.17.32/27 is directly connected, Ethernet1/2
C        172.16.17.0/27 is directly connected, Ethernet1/0
i*L1 0.0.0.0/0 [115/10] via 172.16.17.1, Ethernet1/0
```

The Level 1 only routers in area 15 have specific routes from area 15 but no specific routes from area 17. The Level 1 only routers in area 17 have specific routes from area 17 but no specific routes from area 15. The Level 1 only routers do have a default route that points to the border router, either A or F. You have seen this behavior in Chapter 6, "Open Shortest Path First—Better, Stronger, Faster," for OSPF stub areas where a default route is advertised into the stub area.

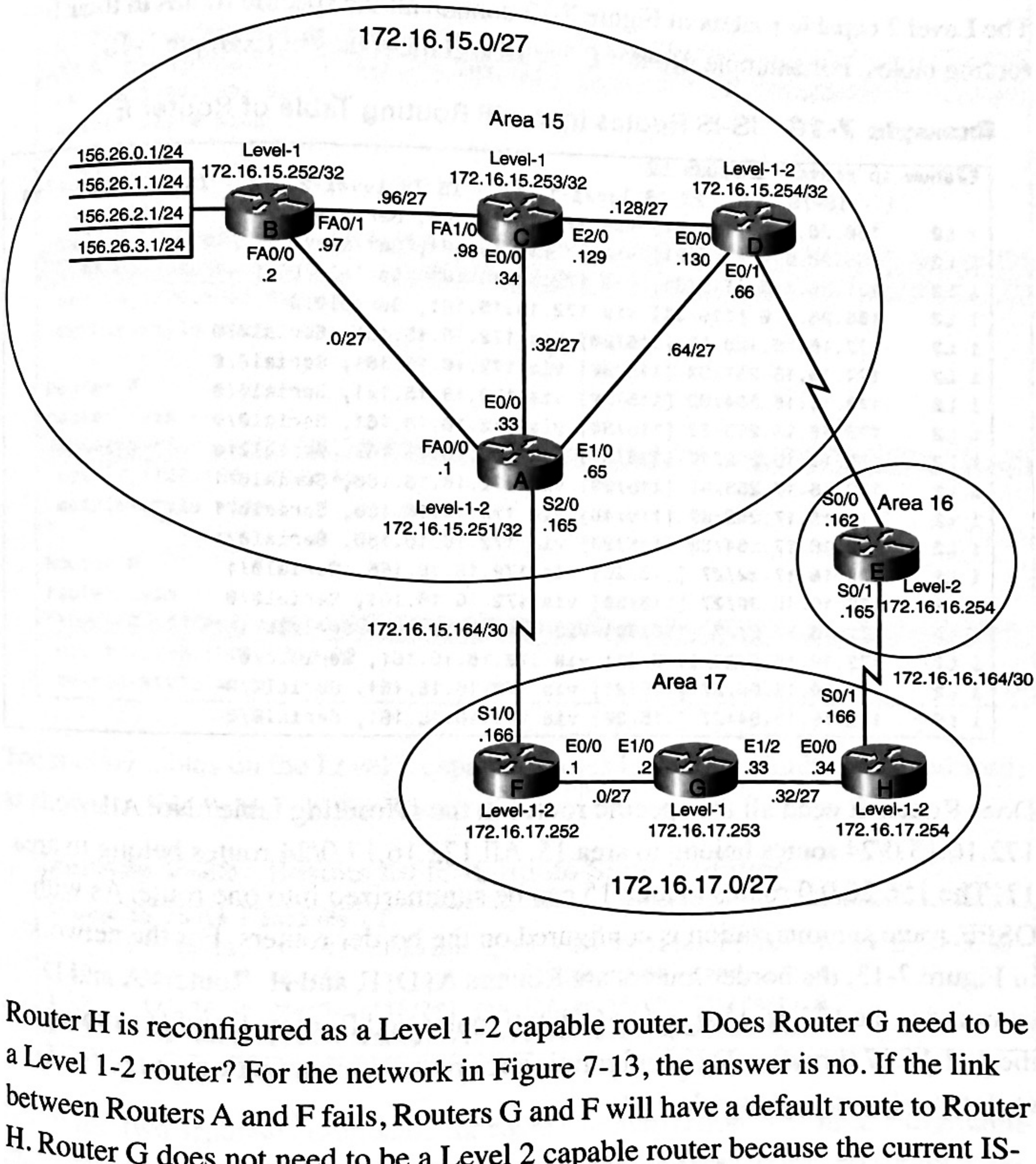
When using a basic OSPF configuration, all routes appear on all routers. Every OSPF router's IP routing table contains all specific intra-area, interarea, and external routes. You could configure an OSPF area as a stub area, blocking the external routes from being advertised into an area. You could further configure an OSPF area as a totally stubby area. In a totally stubby area, both OSPF interarea and external routes are blocked from being advertised into the area. By default, IS-IS treats all areas as totally stubby areas. IS-IS interarea routes are not advertised to Level 1 only routers. The border routers automatically advertise a default route into the area as shown in the routing tables for Router B in Example 7-17.

Example 7-17 IP Routing Table for Router B

```
B#show ip route | include 0.0.0.0
Gateway of last resort is 172.16.15.1 to network 0.0.0.0
i*L1 0.0.0.0/0 [115/1] via 172.16.15.1, FastEthernet0/0
```

If the serial link between Routers A and F in Figure 7-12 fails, areas 15 and 17 will be cut off from each other. For redundancy, a Level 2 capable router is installed so you have another path between the two areas. (See Figure 7-13.)

Figure 7-13 Router E Provides a Redundant Path Between Areas 15 and 16



Router H is reconfigured as a Level 1-2 capable router. Does Router G need to be a Level 1-2 router? For the network in Figure 7-13, the answer is no. If the link between Routers A and F fails, Routers G and F will have a default route to Router H. Router G does not need to be a Level 2 capable router because the current IS-IS backbone is contiguous and it connects all IS-IS areas.

IS-IS Route Summarization

The Level 2 capable routers in Figure 7-13 contain all the specific routes in their IP routing tables. For example, Router E has 18 specific routes in Example 7-18.

Example 7-18 IS-IS Routes in the IP Routing Table of Router E

```
E#show ip route | include L2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
i L2     156.26.2.0 [115/31] via 172.16.15.161, Serial0/0
i L2     156.26.3.0 [115/31] via 172.16.15.161, Serial0/0
i L2     156.26.0.0 [115/31] via 172.16.15.161, Serial0/0
i L2     156.26.1.0 [115/31] via 172.16.15.161, Serial0/0
i L2     172.16.15.128/27 [115/20] via 172.16.15.161, Serial0/0
i L2     172.16.15.251/32 [115/30] via 172.16.15.161, Serial0/0
i L2     172.16.15.254/32 [115/20] via 172.16.15.161, Serial0/0
i L2     172.16.15.253/32 [115/30] via 172.16.15.161, Serial0/0
i L2     172.16.15.252/32 [115/31] via 172.16.15.161, Serial0/0
i L2     172.16.17.253/32 [115/30] via 172.16.16.166, Serial0/1
i L2     172.16.17.252/32 [115/40] via 172.16.16.166, Serial0/1
i L2     172.16.17.254/32 [115/20] via 172.16.16.166, Serial0/1
i L2     172.16.17.32/27 [115/20] via 172.16.16.166, Serial0/1
i L2     172.16.15.32/27 [115/30] via 172.16.15.161, Serial0/0
i L2     172.16.17.0/27 [115/30] via 172.16.16.166, Serial0/1
i L2     172.16.15.0/27 [115/21] via 172.16.15.161, Serial0/0
i L2     172.16.15.96/27 [115/21] via 172.16.15.161, Serial0/0
i L2     172.16.15.64/27 [115/20] via 172.16.15.161, Serial0/0
```

Does Router E need all the specific routes in the IP routing table? No. All 172.16.15.0/24 routes belong to area 15. All 172.16.17.0/24 routes belong to area 17. The 156.26.0.0 routes in area 15 can be summarized into one route. As with OSPF, route summarization is configured on the border routers. For the network in Figure 7-13, the border routers are Routers A, D, F, and H. Routers A and D summarize the 172.16.15.0 and 156.26.0.0 routes and Routers F and H summarize the 172.16.17.0 routes. The configuration for route summarization on the border routers is shown in Example 7-19.

Example 7-19 Configuring IS-IS Route Summarization

```
Router A
router isis
 summary-address 156.26.0.0 255.255.252.0
 summary-address 172.16.15.0 255.255.255.0
 net 15.1720.1601.5251.00
 metric-style wide

Router D
router isis
 summary-address 156.26.0.0 255.255.252.0
 summary-address 172.16.15.0 255.255.255.0
 net 15.1720.1601.5254.00
 metric-style wide

Router F
router isis
 summary-address 172.16.17.0 255.255.255.0
 net 17.1720.1601.7252.00
 metric-style wide

Router H
router isis
 summary-address 172.16.17.0 255.255.255.0
 net 17.1720.1601.7254.00
 metric-style wide
```

The routing tables on the Level 2 capable routers have been significantly reduced, as shown in Example 7-20 for Router A.

Example 7-20 Results for IS-IS Route Summarization

```
A#show ip route | include L2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
i L2     172.16.16.164/30 [115/30] via 172.16.15.66, Ethernet1/0
i L2     172.16.16.254/32 [115/30] via 172.16.15.66, Ethernet1/0
i L2     172.16.17.0/24 [115/40] via 172.16.15.66, Ethernet1/0
```

OSPF has two separate commands for route summarization. The **area range** command summarizes OSPF routes and the **summary-address** command summarizes external routes. With IS-IS, the **summary-address** command is used for all route summarization.

Table 7-4 IS-IS and OSPF Comparison

	IS-IS	OSPF
Protocol Type	Link State	Link State
Routing Types	Interarea Intra Area	Level 1 Level 2
Routes	IP, ISO	IP Only
Backbone	Contiguous chain of L2 routers	Area 0
Area Significance	Router	Interface
Router ID	System ID	IP Address
Default Area Type	Totally Stubby	All routes in all areas
Router Types	Level 1 Level 2 Level 1-2	Internal No counterpart ABR, ASBR
Default Metric	10	Based on the interface bandwidth Metric = 100,000,000/bandwidth

Summary

Like OSPF, IS-IS has many complexities. The following list summarizes the fundamental properties of IS-IS:

- One or more IS-IS areas.
- If more than one IS-IS area is used, a backbone must be configured. An IS-IS backbone consists of a contiguous line of Level 2 capable IS-IS routers.
- Level 1 only routers maintain one database for their area. A default route is used to reach the nearest Level 2 router.

Example 7-23 Results of IS-IS Route Leaking

```
G#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 172.16.17.34 to network 0.0.0.0

     156.26.0.0/22 is subnetted, 1 subnets
i ia    156.26.0.0 [115/31] via 172.16.17.1, Ethernet1/0
     172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
i L1    172.16.16.164/30 [115/20] via 172.16.17.34, Ethernet1/2
C       172.16.17.253/32 is directly connected, Loopback0
i L1    172.16.17.252/32 [115/20] via 172.16.17.1, Ethernet1/0
i L1    172.16.17.254/32 [115/20] via 172.16.17.34, Ethernet1/2
C       172.16.17.32/27 is directly connected, Ethernet1/2
C       172.16.17.0/27 is directly connected, Ethernet1/0
i*L1 0.0.0.0/0 [115/10] via 172.16.17.34, Ethernet1/2
               [115/10] via 172.16.17.1, Ethernet1/0
```

Router G will choose the specific 156.26.0.0 route over the default route because of the longest match property of IP routing.

Comparing IS-IS and OSPF

IS-IS and OSPF are similar protocols. Both are hierarchical link-state interior routing protocols. Table 7-4 is a comparison of the major properties of IS-IS and OSPF.

Both IS-IS and OSPF are widely used in networks today. Usually IS-IS is deployed by Internet service providers (ISPs), whereas OSPF is typically used in enterprise networks.

Route Leaking

Router G has two default routes in its IP routing table. One default route is from Router F and one is from Router H, as shown in Example 7-21.

Example 7-21 IS-IS Default Routes

```
G#show ip route
     172.16.0.0/16 is variably subnetted, 6 subnets, 3 masks
i L1    172.16.16.164/30 [115/20] via 172.16.17.34, Ethernet1/2
C       172.16.17.253/32 is directly connected, Loopback0
i L1    172.16.17.252/32 [115/20] via 172.16.17.1, Ethernet1/0
i L1    172.16.17.254/32 [115/20] via 172.16.17.34, Ethernet1/2
C       172.16.17.32/27 is directly connected, Ethernet1/2
C       172.16.17.0/27 is directly connected, Ethernet1/0
i*L1 0.0.0.0/0 [115/10] via 172.16.17.34, Ethernet1/2
               [115/10] via 172.16.17.1, Ethernet1/0
```

What is the shortest path from Router G to one of the 156.26 networks in area 15? The shortest path is through Router F to Router A. Router G does not know this is the shortest path. Both default routes in the routing table on Router G have the same IS-IS cost. You would like Router G to use the path through Router F to reach the 156.26 networks. This can be accomplished by leaking specific Level 2 routes into area 17. ***Route leaking*** is the process of redistributing selected Level 2 routes into an area as Level 1 routes. (See Example 7-22).

Example 7-22 Configuring Route Leaking on Router F

```
Router F
router isis
 summary-address 172.16.17.0 255.255.255.0
 redistribute isis ip level-2 into level-1 distribute-list 100
 net 17.1720.1601.7252.00
 metric-style wide

access-list 100 permit ip 156.26.0.0 0.0.255.255 any
```

The access-list identifies the routes that are allowed to be leaked into the area as Level 1 routes. In this case, you are only allowing 156.26 routes. The routing table on Router G now contains a specific route to the 156.26 networks. (See Example 7-23.)

- Level 2 capable routers maintain a database for routes to reach all IS-IS areas.
- Link-state packets (LSPs) flood information about a router's interfaces throughout an IS-IS area.
- IS-IS databases within an area must be identical before a router can calculate the routes that are installed in the IP routing table.
- The Shortest Path First (SPF) algorithm is run on each area database maintained by a router. SPF determines the routes that are installed in the IP routing table.
- Routes can be summarized only between areas, not within an area.
- There are three types of IS-IS routers: Level 1 only, Level 2 only, and Level 1-2 capable.
- External routes can be summarized only on an ASBR.
- IS-IS routes can be summarized only on an IS-IS border router.

Chapter Review Questions

You can find the answers to these questions in Appendix A.

1. Describe the structure and format of an NSAP address.
2. Assume a router has a loopback address of 135.77.9.254. Convert the loopback address to an IS-IS system ID.
3. Describe the difference between an OSPF and IS-IS backbone.
4. In IS-IS, what does Level 1 routing mean?
5. What is the OSPF counterpart to Level 1 routing?
6. In IS-IS, what is the function of a Level 1-2 router?
7. What is the OSPF counterpart to a Level 1-2 IS-IS router?