

This appendix contains job aids and supplements for the following topics:

- Extending IP Addressing Job Aids
- Supplement 1: Addressing Review
- Supplement 2: IP Access Lists
- Supplement 3: OSPF
- Supplement 4: EIGRP
- Supplement 5: BGP
- Supplement 6: Route Optimization



# Job Aids and Supplements

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The job aids and supplements are provided to give you some background information and additional examples of the concepts covered in this book.

The IP addressing job aids are intended for your use when working with IP addresses. The information in Supplement 1, “Addressing Review,” and Supplement 2, “IP Access Lists,” should be a review of the fundamentals of IP addressing and of the concepts and configuration of access lists, respectively. The other supplements contain examples and additional material on the OSPF, EIGRP, and BGP routing protocols, and on route optimization.

## Extending IP Addressing Job Aids

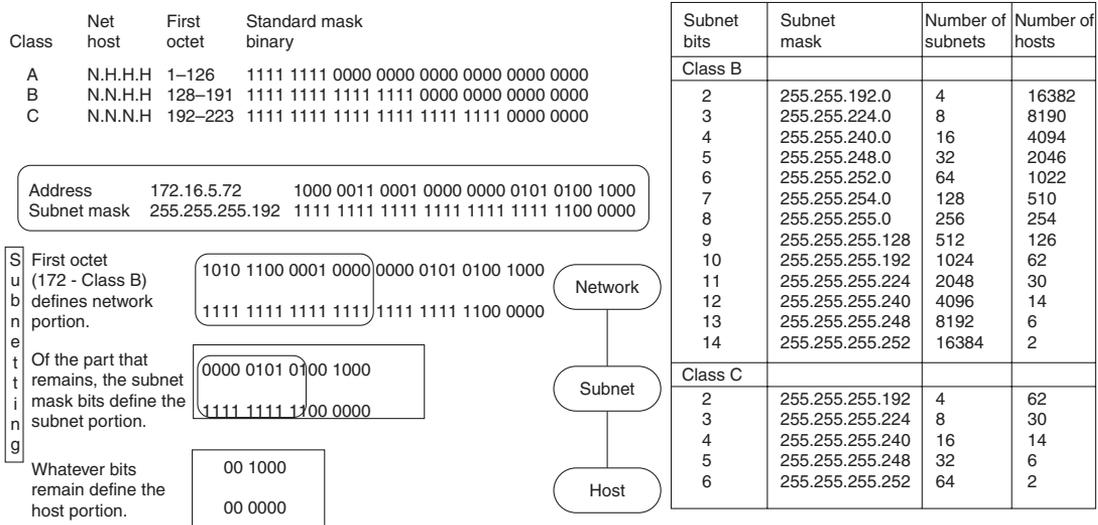
This section includes the following job aids that you may find useful when working with IP addressing:

- IP addresses and subnetting
- Decimal-to-binary conversion chart

### IP Addresses and Subnetting

Figure A-1 is a job aid to help you with various aspects of IP addressing, including how to distinguish address classes, the number of subnets and hosts available with various subnet masks, and how to interpret IP addresses.

**Figure A-1** IP Addresses and Subnetting Job Aid



## Decimal-to-Binary Conversion Chart

The following can be used to convert from decimal to binary, and from binary to decimal:

Decimal	Binary	Decimal	Binary	Decimal	Binary	Decimal	Binary
0	00000000	64	01000000	128	10000000	192	11000000
1	00000001	65	01000001	129	10000001	193	11000001
2	00000010	66	01000010	130	10000010	194	11000010
3	00000011	67	01000011	131	10000011	195	11000011
4	00000100	68	01000100	132	10000100	196	11000100
5	00000101	69	01000101	133	10000101	197	11000101
6	00000110	70	01000110	134	10000110	198	11000110
7	00000111	71	01000111	135	10000111	199	11000111
8	00001000	72	01001000	136	10001000	200	11001000
9	00001001	73	01001001	137	10001001	201	11001001
10	00001010	74	01001010	138	10001010	202	11001010
11	00001011	75	01001011	139	10001011	203	11001011
12	00001100	76	01001100	140	10001100	204	11001100
13	00001101	77	01001101	141	10001101	205	11001101

*(Continued)*

<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>
14	00001110	78	01001110	142	10001110	206	11001110
15	00001111	79	01001111	143	10001111	207	11001111
16	00010000	80	01010000	144	10010000	208	11010000
17	00010001	81	01010001	145	10010001	209	11010001
18	00010010	82	01010010	146	10010010	210	11010010
19	00010011	83	01010011	147	10010011	211	11010011
20	00010100	84	01010100	148	10010100	212	11010100
21	00010101	85	01010101	149	10010101	213	11010101
22	00010110	86	01010110	150	10010110	214	11010110
23	00010111	87	01010111	151	10010111	215	11010111
24	00011000	88	01011000	152	10011000	216	11011000
25	00011001	89	01011001	153	10011001	217	11011001
26	00011010	90	01011010	154	10011010	218	11011010
27	00011011	91	01011011	155	10011011	219	11011011
28	00011100	92	01011100	156	10011100	220	11011100
29	00011101	93	01011101	157	10011101	221	11011101
30	00011110	94	01011110	158	10011110	222	11011110
31	00011111	95	01011111	159	10011111	223	11011111
32	00100000	96	01100000	160	10100000	224	11100000
33	00100001	97	01100001	161	10100001	225	11100001
34	00100010	98	01100010	162	10100010	226	11100010
35	00100011	99	01100011	163	10100011	227	11100011
36	00100100	100	01100100	164	10100100	228	11100100
37	00100101	101	01100101	165	10100101	229	11100101
38	00100110	102	01100110	166	10100110	230	11100110
39	00100111	103	01100111	167	10100111	231	11100111
40	00101000	104	01101000	168	10101000	232	11101000
41	00101001	105	01101001	169	10101001	233	11101001
42	00101010	106	01101010	170	10101010	234	11101010
43	00101011	107	01101011	171	10101011	235	11101011

*continues*

*(Continued)*

<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>	<b>Decimal</b>	<b>Binary</b>
44	00101100	108	01101100	172	10101100	236	11101100
45	00101101	109	01101101	173	10101101	237	11101101
46	00101110	110	01101110	174	10101110	238	11101110
47	00101111	111	01101111	175	10101111	239	11101111
48	00110000	112	01110000	176	10110000	240	11110000
49	00110001	113	01110001	177	10110001	241	11110001
50	00110010	114	01110010	178	10110010	242	11110010
51	00110011	115	01110011	179	10110011	243	11110011
52	00110100	116	01110100	180	10110100	244	11110100
53	00110101	117	01110101	181	10110101	245	11110101
54	00110110	118	01110110	182	10110110	246	11110110
55	00110111	119	01110111	183	10110111	247	11110111
56	00111000	120	01111000	184	10111000	248	11111000
57	00111001	121	01111001	185	10111001	249	11111001
58	00111010	122	01111010	186	10111010	250	11111010
59	00111011	123	01111011	187	10111011	251	11111011
60	00111100	124	01111100	188	10111100	252	11111100
61	00111101	125	01111101	189	10111101	253	11111101
62	00111110	126	01111110	190	10111110	254	11111110
63	00111111	127	01111111	191	10111111	255	11111111

## Supplement 1: Addressing Review

This supplement reviews the basics of IP addresses, including the following:

- Converting IP addresses between decimal and binary
- Determining an IP address class
- Extending an IP classful address using subnet masks
- Calculating a subnet mask
- Calculating the networks for a subnet mask
- Using prefixes to represent a subnet mask
- Review questions

## Converting IP Addresses Between Decimal and Binary

An IP address is a 32-bit, two-level hierarchical number. It is hierarchical because the first portion of the address represents the network, and the second portion of the address represents the node (host).

The 32 bits are grouped into four octets, with 8 bits per octet. The value of each octet ranges from 0 to 255 decimal, or 00000000 to 11111111 binary. IP addresses are usually written in dotted-decimal notation—each of the four octets is written in decimal notation, and dots are put between the octets. Figure A-2 illustrates how you convert an octet of an IP address in binary to decimal notation.

**Figure A-2** *Converting an Octet of an IP Address from Binary to Decimal*

Value for each bit							
1	1	1	1	1	1	1	1
128	64	32	16	8	4	2	1 = 255

Converting from binary to decimal							
0	1	0	0	0	0	0	1
128	64	32	16	8	4	2	1
0 + 64 + 0 + 0 + 0 + 0 + 0 + 1 = 65							

It is important that you understand how this conversion is done because it is used when calculating subnet masks, as discussed later in this section.

Figure A-3 shows three examples of converting IP addresses between binary and decimal.

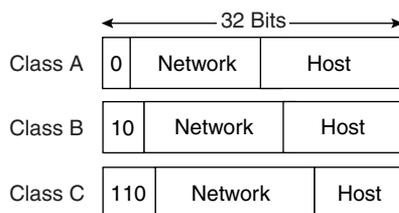
**Figure A-3** *Examples of Converting IP Addresses Between Binary and Decimal*

Binary address:	00001010.00000001.00010111.0001001
Decimal address:	10 . 1 . 23 . 19
Binary address:	10101100.00010010.01000001.10101010
Decimal address:	172 . 18 . 65 . 170
Binary address:	11000000.10101000.00001110.00000110
Decimal address:	192 . 168 . 14 . 6

## Determining an IP Address Class

To accommodate large and small networks, the Network Information Center (NIC) segregated the 32-bit IP address into Classes A through E. The first few bits of the first octet determine the class of an address; this then determines how many network bits and host bits are in the address. This is illustrated for Class A, B, and C addresses in Figure A-4. Each address class therefore allows for a certain number of network addresses and a certain number of host addresses within a network. Table A-1 shows the address range, number of networks, and number of hosts for each of the classes. (Note that Class D and E addresses are used for other purposes, not for addressing hosts.)

**Figure A-4** *Determining an IP Address Class from the First Few Bits of an Address*



**Table A-1** *IP Address Classes*

Class	Address Range	Number of Networks	Number of Hosts
Class A	1.0.0.0 to 126.0.0.0	128 ( $2^7$ )	16,777,214
Class B	128.0.0.0 to 191.255.0.0	16,386 ( $2^{14}$ )	65,532
Class C	192.0.0.0 to 223.255.255.0	Approximately 2 million ( $2^{21}$ )	254
Class D	224.0.0.0 to 239.255.255.254	Reserved for multicast addresses	—
Class E	240.0.0.0 to 254.255.255.255	Reserved for research	—

**NOTE** The network 127.0.0.0 is reserved for loopback.

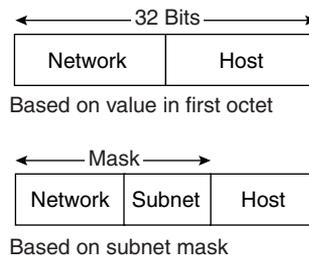
Using classes to denote which portion of the address represents the network number and which portion is the node or host address is referred to as classful addressing. Several issues must be addressed with classful addressing, however. The number of available Class A, B, and C addresses is finite. Another problem is that not all classes are useful for a midsize organization, as illustrated in Table A-1. As can be expected, the Class B range is the most

accommodating to a majority of today's organizational network topologies. To maximize the use of the IP addresses received by an organization regardless of the class, *subnet masks* were introduced.

## Extending an IP Classful Address Using Subnet Masks

RFC 950 was written to address the problem of IP address shortage. It proposed a procedure, called *subnet masking*, for dividing Class A, B, and C addresses into smaller pieces, thus increasing the number of possible networks. A subnet mask is a 32-bit value that identifies which bits in an address represent network bits and which represent host bits. In other words, the router doesn't determine the network portion of the address by looking at the value of the first octet; it looks at the subnet mask associated with the address. In this way, subnet masks enable you to extend the usage of an IP address. This is a way of making an IP address a three-level hierarchy, as shown in Figure A-5.

**Figure A-5** *A Subnet Mask Determines How an IP Address Is Interpreted*



To create a subnet mask for an address, use a 1 for each bit that you want to represent the network or subnet portion of the address, and use a 0 for each bit that you want to represent the node portion of the address. Note that the 1s in the mask are contiguous. The default subnet masks for Class A, B, and C addresses are as shown Table A-2.

**Table A-2** *IP Address Default Subnet Masks*

Class	Default Mask in Binary	Default Mask in Decimal
Class A	11111111.00000000.00000000.00000000	255.0.0.0
Class B	11111111.11111111.00000000.00000000	255.255.0.0
Class C	11111111.11111111.11111111.00000000	255.255.255.0

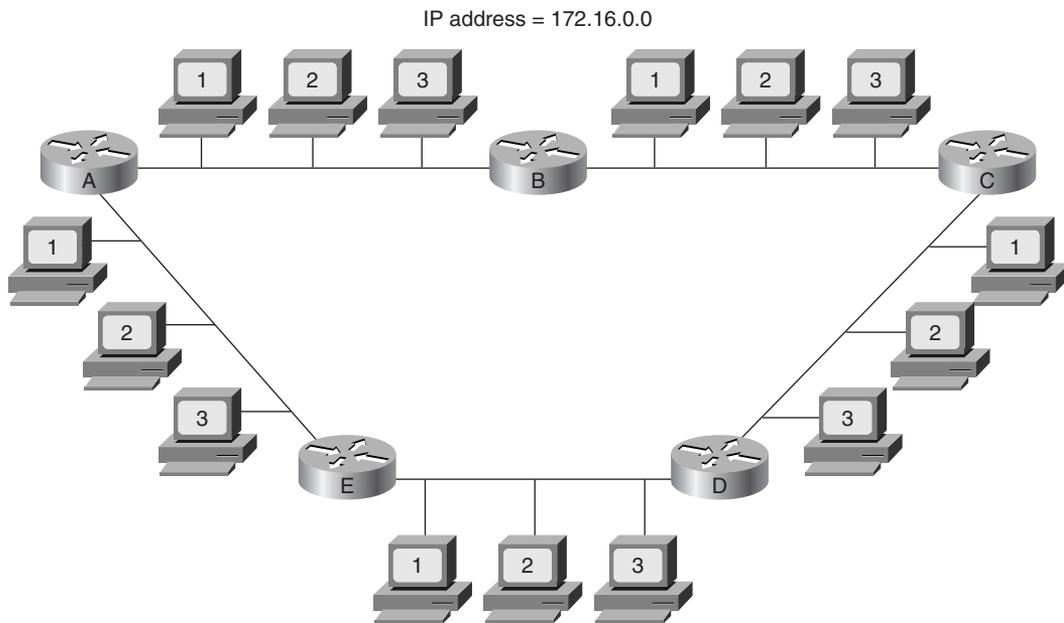
## Calculating a Subnet Mask

Because subnet masks extend the number of network addresses that you can use by using bits from the host portion, you do not want to randomly decide how many additional bits to

use for the network portion. Instead, you want to do some research to determine how many network addresses you need to derive from your NIC-given IP address. For example, consider that you have IP address 172.16.0.0 and want to configure the network shown in Figure A-6. To establish your subnet mask, you would do the following:

- Step 1** Determine the number of networks (subnets) needed. In Figure A-6, for example, there are five networks.
- Step 2** Determine how many nodes per subnet must be defined. This example has five nodes (two routers and three workstations) on each subnet.
- Step 3** Determine future network and node requirements. For example, assume 100 percent growth.
- Step 4** Given the information gathered from Steps 1 through 3, determine the total number of subnets required. For this example, 10 subnets are required. Refer to the “Job Aid: IP Addressing and Subnetting” section, earlier in this appendix, and select the appropriate subnet mask value that can accommodate 10 networks.

**Figure A-6** Network Used in Subnet Mask Example



No mask exactly accommodates 10 subnets. Depending on your network growth trends, you may select 4 subnet bits, resulting in a subnet mask of 255.255.240.0. The binary representation of this subnet mask is as follows:

```
11111111.11111111.11110000.00000000
```

The number of additional subnets given by  $n$  additional bits is  $2^n$ . For example, the additional 4 subnet bits would give you 16 subnets.

## Calculating the Networks for a Subnet Mask

For the example in Figure A-6, after you identify your subnet mask, you must calculate the 10 subnetted network addresses to use with 172.16.0.0 255.255.240.0. One way to do this is as follows:

- Step 1** Write the subnetted address in binary format, as shown at the top of Figure A-7. Use the job aid “Decimal-to-Binary Conversion Chart,” provided earlier in this appendix, if necessary.
- Step 2** On the binary address, draw a line between the 16th and 17th bits, as shown in Figure A-7. Then draw a line between the 20th and 21st bits. Now you can focus on the target subnet bits.
- Step 3** Historically, it was recommended that you begin choosing subnets from highest (from the left-most bit) to lowest so that you could have available network addresses. However, this strategy does not allow you to adequately summarize subnet addresses, so the present recommendation is to choose subnets from lowest to highest (right to left).

When calculating the subnet address, all the host bits are set to zero. To convert back to decimal, it is important to note that you must always convert an entire octet, 8 bits. For the first subnet, your subnet bits are 0000, and the rest of the octet (all host bits) is 0000.

Use the job aid “Decimal-to-Binary Conversion Chart,” provided earlier in this appendix, if necessary, and locate this first subnet number. The first subnet number would be 00000000, or decimal 0.

- Step 4** (Optional) It is recommended that you list each subnet in binary form to reduce the number of errors. In this way, you will not forget where you left off in your subnet address selection.
- Step 5** Locate the second-lowest subnet number. In this case, it would be 0001. When combined with the next 4 bits (the host bits) of 0000, this is subnet binary 00010000, or decimal 16.
- Step 6** Continue locating subnet numbers until you have as many as you need—in this case, 10 subnets, as shown in Figure A-7.

**Figure A-7** Calculating the Subnets for the Example in Figure A-6

Assigned address: 172.16.0.0/16  
 In binary 10101100.00010000.00000000.00000000

Subnetted address: 172.16.0.0/20  
 In binary 10101100.00010000.xxxx0000.00000000

1 <sup>st</sup> subnet:	10101100 . 00010000 .0000	0000.0000000000	= 172.16.0.0
2 <sup>nd</sup> subnet:	172 . 16 .0001	0000.00000000	= 172.16.16.0
3 <sup>rd</sup> subnet:	172 . 16 .0010	0000.00000000	= 172.16.32.0
4 <sup>th</sup> subnet:	172 . 16 .0011	0000.00000000	= 172.16.48.0
.			
10 <sup>th</sup> subnet:	172 . 16 .1001	0000.00000000	= 172.16.144.0
	Network	Subnet	Host

## Using Prefixes to Represent a Subnet Mask

As already discussed, subnet masks are used to identify the number of bits in an address that represent the network, subnet, and host portions of the address. Another way of indicating this is to use a *prefix*. A prefix is a slash (/) and a numerical value that is the sum of the bits that represent the network and subnet portion of the address. For example, if you were using a subnet mask of 255.255.255.0, the prefix would be /24 for 24 bits.

Table A-3 shows some examples of the different ways that you can represent a prefix and subnet mask.

**Table A-3** Representing Subnet Masks

IP Address/Prefix	Subnet Mask in Decimal	Subnet Mask in Binary
192.168.112.0/21	255.255.248.0	11111111.11111111.11111000.00000000
172.16.0.0/16	255.255.0.0	11111111.11111111.00000000.00000000
10.1.1.0/27	255.255.255.224	11111111.11111111.11111111.11100000

It is important to know how to write subnet masks and prefixes because Cisco routers use both, as shown in Example A-1. You will typically be asked to input a subnet mask when configuring an IP address, but the output generated using **show** commands typically shows an IP address with a prefix.

**Example A-1** *Examples of Subnet Mask and Prefix Use on Cisco Routers*

```

p1r3#show run
<Output Omitted>
interface Ethernet0
 ip address 10.64.4.1 255.255.255.0
!
interface Serial0
 ip address 10.1.3.2 255.255.255.0
<Output Omitted>

p1r3#show interface ethernet0
Ethernet0 is administratively down, line protocol is down
  Hardware is Lance, address is 00e0.b05a.d504 (bia 00e0.b05a.d504)
  Internet address is 10.64.4.1/24
<Output Omitted>

p1r3#show interface serial0
Serial0 is down, line protocol is down
  Hardware is HD64570
  Internet address is 10.1.3.2/24
<Output Omitted>

```

**Supplement 1 Review Questions**

Answer the following questions, and then refer to Appendix G, “Answers to the Review Questions,” for the answers.

- 1 You need to design an IP network for your organization. Your organization’s IP address is 172.16.0.0. Your assessment indicates that the organization needs at least 130 networks of no more than 100 nodes in each network.

As a result, you have decided to use a classful subnetting scheme based on the 172.16.0.0/24 scheme. In the space that follows, write any four IP addresses that are part of the range of subnetwork numbers. Also, write the subnet address and subnet mask for these addresses. One address is provided as an example.

IP Address	Subnet Address and Mask
172.16.1.0/24	172.16.1.0 255.255.255.0

- 2 Your network has the address 172.16.168.0/21. Write eight IP addresses in this network.

- 3 Write the four IP addresses in the range described by the 192.168.99.16/30 address.
- 4 Of the four addresses in question 3, which two could you use as host addresses in a point-to-point connection?

## Supplement 2: IP Access Lists

This supplement covers the following topics:

- IP access list overview
- IP standard access lists
- IP extended access lists
- Restricting virtual terminal access
- Verifying access list configuration
- Review questions

### IP Access List Overview

Packet filtering helps control packet movement through the network, as illustrated in Figure A-8. Such control can help limit network traffic and restrict network use by certain users or devices. To permit or deny packets from crossing specified router interfaces, Cisco provides access lists. An IP access list is a sequential collection of permit and deny conditions that apply to IP addresses or upper-layer IP protocols.

**Figure A-8** *Access Lists Control Packet Movement Through a Network*

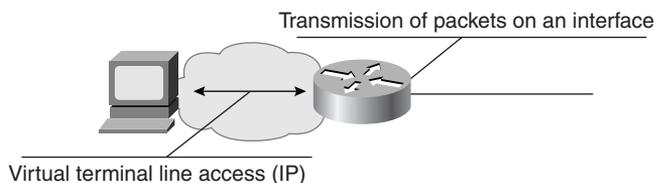


Table A-4 shows some of the available types of access lists on a Cisco router and their access list numbers.

**Table A-4** *Access List Numbers*

Type of Access List	Range of Access List Numbers
IP standard	1 to 99
IP extended	100 to 199

**Table A-4** *Access List Numbers (Continued)*

Type of Access List	Range of Access List Numbers
Bridge type-code	200 to 299
IPX standard	800 to 899
IPX extended	900 to 999
IPX SAP	1000 to 1099

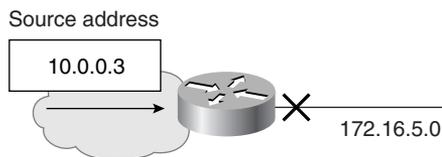
This supplement covers IP standard and extended access lists. For information on other types of access lists, refer to the technical documentation on Cisco's web site at [www.cisco.com](http://www.cisco.com).

**WARNING** The Cisco IOS Release 10.3 introduced substantial additions to IP access lists. These extensions are backward compatible. Migrating from existing releases to the Cisco IOS Release 10.3 or later image will convert your access lists automatically. However, previous releases are not upwardly compatible with these changes. Thus, if you save an access list with the Cisco IOS Release 10.3 or later image and then use older software, the resulting access list will not be interpreted correctly. This incompatibility can cause security problems. Save your old configuration file before booting Cisco IOS Release 10.3 (or later) images in case you need to revert to an earlier version.

## IP Standard Access Lists

This section discusses IP standard access list operation and implementation.

Standard access lists permit or deny packets based only on the source IP address of the packet, as shown in Figure A-9. The access list number range for standard IP access lists is 1 to 99. Standard access lists are easier to configure than their more robust counterparts, extended access lists.

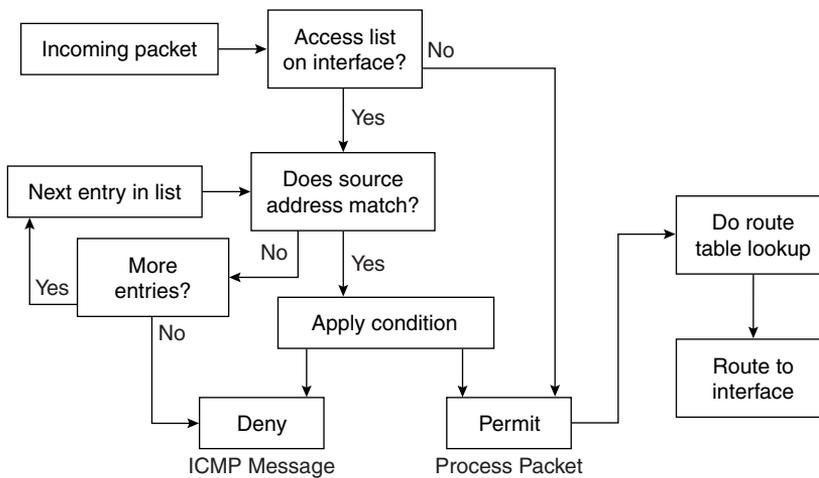
**Figure A-9** *Standard IP Access Lists Filter Based Only on the Source Address*

A standard access list is a sequential collection of permit and deny conditions that apply to source IP addresses. The router tests addresses against the conditions in an access list one

by one. The first match determines whether the router accepts or rejects the packet. Because the router stops testing conditions after the first match, the order of the conditions is critical. If no conditions match, the router rejects the packet.

The processing of inbound standard access lists is illustrated in Figure A-10. After receiving a packet, the router checks the source address of the packet against the access list. If the access list permits the address, the router exits the access list and continues to process the packet. If the access list rejects the address, the router discards the packet and returns an Internet Control Message Protocol (ICMP) administratively prohibited message.

**Figure A-10** *Inbound Standard IP Access List Processing*



Note that the action taken if no more entries are found in the access list is to deny the packet; this illustrates an important concept to remember when creating access lists. The last entry in an access list is what is known as an implicit deny any. All traffic not explicitly permitted will be implicitly denied.

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**NOTE**

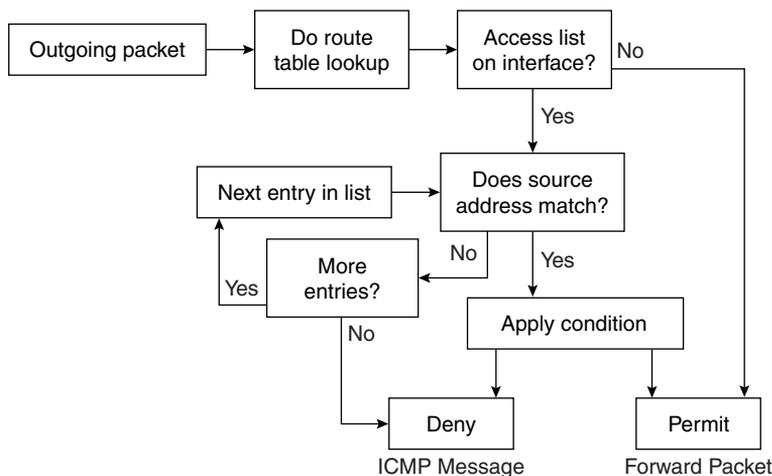
When configuring access lists, order is important. Make sure that you list the entries in order from specific to general. For example, if you want to deny a specific host address and permit all other addresses, make sure that your entry about the specific host appears first.

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The processing of outbound standard IP access lists is illustrated in Figure A-11. After receiving and routing a packet to a controlled interface, the router checks the source address of the packet against the access list. If the access list permits the address, the router

transmits the packet. If the access list denies the address, the router discards the packet and returns an ICMP administratively prohibited message.

**Figure A-11** *Outbound Standard IP Access List Processing*



Both standard and extended IP access lists use a wildcard mask. Like an IP address, a wildcard mask is a 32-bit quantity written in dotted-decimal format. The wildcard mask tells the router which bits of the address to use in comparisons. Address bits corresponding to wildcard mask bits set to 1 are ignored in comparisons; address bits corresponding to wildcard mask bits set to 0 are used in comparisons.

An alternative way to think of the wildcard mask is as follows. If a 0 bit appears in the wildcard mask, then the corresponding bit location in the access list address and the same bit location in the packet address must match (either both must be 0 or both must be 1). If a 1 bit appears in the wildcard mask, then the corresponding bit location in the packet will match (whether it is 0 or 1), and that bit location in the access list address is ignored. For this reason, bits set to 1 in the wildcard mask are sometimes called “don’t care” bits.

Remember that the order of the access list statements is important because the access list is not processed further after a match has been found.

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### Wildcard Masks

The concept of a wildcard mask is similar to the wildcard character used in DOS-based computers. For example, to delete all files on your computer that begin with the letter “f,” you would type:

**delete f\*.\***

The \* character is the wildcard; any files that start with “f,” followed by any other characters, then a dot, and then any other characters, will be deleted.

Instead of using wildcard characters, routers use wildcard masks to implement this concept.

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Examples of addresses and wildcard masks, and what they match, are shown in Table A-5.

**Table A-5** *Access List Wildcard Mask Examples*

<b>Address</b>	<b>Wildcard Mask</b>	<b>Matches</b>
0.0.0.0	255.255.255.255	Any address
172.16.0.0/16	0.0.255.255	Any host on network 172.16.0.0
172.16.7.11/16	0.0.0.0	Host address 172.16.7.11
255.255.255.255	0.0.0.0	Local broadcast address 255.255.255.255
172.16.8.0/21	0.0.7.255	Any host on subnet 172.16.8.0/21

Whether you are creating a standard or extended access list, you will need to complete the following two tasks:

**Step 1** Create an access list in global configuration mode by specifying an access list number and access conditions.

Define a standard IP access list using a source address and wildcard, as shown later in this section.

Define an extended access list using source and destination addresses, as well as optional protocol-type information for finer granularity of control, as shown in the “IP Extended Access Lists” section, later in this supplement.

**Step 2** Apply the access list in interface configuration mode to interfaces or terminal lines.

After an access list is created, you can apply it to one or more interfaces. Access lists can be applied on either outbound or inbound interfaces.

## IP Standard Access List Configuration

Use the **access-list** *access-list-number* { **permit** | **deny** } { *source source-wildcard* | **any** } [**log**] global configuration command to create an entry in a standard traffic filter list, as detailed in Table A-6.

**Table A-6** *Standard IP access-list Command Description*

<b>access-list Command</b>	<b>Description</b>
<i>access-list-number</i>	Identifies the list to which the entry belongs, a number from 1 to 99.
<b>permit   deny</b>	Indicates whether this entry allows or blocks traffic from the specified address.
<i>source</i>	Identifies the source IP address.
<i>source-wildcard</i>	(Optional) Identifies which bits in the address field must match. A 1 in a bit position indicates “don’t care” bits, and a 0 in any bit position indicates that bit must strictly match. If this field is omitted, the wildcard mask 0.0.0.0 is assumed.
<b>any</b>	Use this keyword as an abbreviation for a source and source-wildcard of 0.0.0.0 255.255.255.255.
<b>log</b>	(Optional) Causes an informational logging message about the packet that matches the entry to be sent to the console. Exercise caution when using this keyword because it consumes CPU cycles.

When a packet does not match any of the configured lines in an access list, the packet is denied by default because there is an invisible line at the end of the access list that is equivalent to **deny any**. (**deny any** is the same as denying an address of 0.0.0.0 with a wildcard mask of 255.255.255.255.)

The keyword **host** can also be used in an access list; it causes the address that immediately follows it to be treated as if it were specified with a mask of 0.0.0.0. For example, configuring **host 10.1.1.1** in an access list is equivalent to configuring **10.1.1.1 0.0.0.0**.

Use the **ip access-group access-list-number {in | out}** interface configuration command to link an existing access list to an interface, as shown in Table A-7. Each interface may have both an inbound and an outbound IP access list.

**Table A-7** *ip access-group Command Description*

<b>ip access-group Command</b>	<b>Description</b>
<i>access-list-number</i>	Indicates the number of the access list to be linked to this interface.
<b>in   out</b>	Processes packets arriving on or leaving from this interface. <b>Out</b> is the default.

Eliminate the entire list by typing the **no access-list** *access-list-number* global configuration command. De-apply the access list with the **no ip access-group** *access-list-number* **{in | out}** interface configuration command.

### Implicit Wildcard Masks

Implicit, or default, wildcard masks reduce typing and simplify configuration, but care must be taken when relying on the default mask.

The access list line shown in Example A-2 is an example of a specific host configuration. For standard access lists, if no wildcard mask is specified, the wildcard mask is assumed to be 0.0.0.0. The implicit mask makes it easier to enter a large number of individual addresses.

**Example A-2** *Standard Access List Using the Default Wildcard Mask*

```
access-list 1 permit 172.16.5.17
```

Common errors found in access list lines are illustrated in Example A-3.

**Example A-3** *Standard Access List Using the Default Wildcard Mask*

```
access-list 1 permit 0.0.0.0
access-list 2 permit 172.16.0.0
access-list 3 deny any
access-list 3 deny 0.0.0.0 255.255.255.255
```

The first list in Example A-3—**permit 0.0.0.0**—would exactly match the address 0.0.0.0 and then permit it. In most cases, this address is illegal, so this list would prevent all traffic from getting through (because of the implicit **deny any** at the end of the list).

The second list in Example A-3—**permit 172.16.0.0**—is probably a configuration error. The intention is probably 172.16.0.0 0.0.255.255. The exact address 172.16.0.0 refers to the network and would never be assigned to a host. As a result, nothing would get through with this list, again because of the implicit **deny any** at the end of the list. To filter networks or subnets, use an explicit wildcard mask.

The next two lines in Example A-3—**deny any** and **deny 0.0.0.0 255.255.255.255**—are unnecessary to configure because they duplicate the function of the implicit deny that occurs when a packet fails to match all the configured lines in an access list. Although not necessary, you may want to add one of these entries for record-keeping purposes.

### Configuration Principles

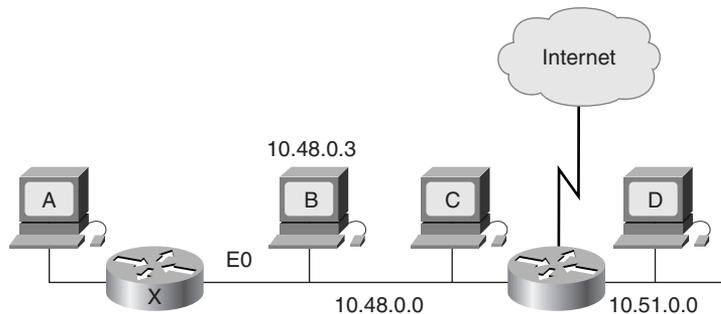
Following these general principles helps ensure that the access lists you create have the intended results:

- Top-down processing
  - Organize your access list so that more specific references in a network or subnet appear before more general ones.
  - Place more frequently occurring conditions before less frequent conditions.
- Implicit **deny any**
  - Unless you end your access list with an explicit **permit any**, it will deny by default all traffic that fails to match any of the access list lines.
- New lines added to the end
  - Subsequent additions are always added to the end of the access list.
  - You cannot selectively add or remove lines when using numbered access lists, but you can when using IP named access lists (a feature available in Cisco IOS Release 11.2 and later).
- Undefined access list = **permit any**
  - If you apply an access list with the **ip access-group** command to an interface before any access list lines have been created, the result will be **permit any**. The list is live, so if you enter only one line, it goes from a **permit any** to a **deny most** (because of the implicit **deny any**) as soon as you press Return. For this reason, you should create your access list before you apply it to an interface.

### Standard Access List Example

An example network is shown in Figure A-12, and the configuration on Router X in that figure is shown in Example A-4.

**Figure A-12** Network Used for Standard IP Access List Example



Consider which devices can communicate with Host A in this example:

**Example A-4** *Standard Access List Configuration of Router X in Figure A-12*

```

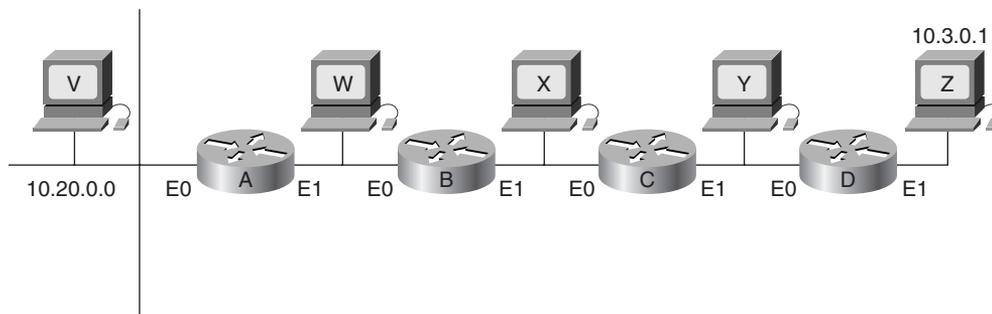
Router(config)#access-list 2 permit 10.48.0.3
Router(config)#access-list 2 deny 10.48.0.0 0.0.255.255
Router(config)#access-list 2 permit 10.0.0.0 0.255.255.255
Router(config)#!(Note: all other access implicitly denied)
Router(config)#interface ethernet 0
Router(config-if)#ip access-group 2 in

```

- Host B can communicate with Host A. It is permitted by the first line of the access list, which uses an implicit host mask.
- Host C cannot communicate with Host A. Host C is in the subnet denied by the second line in the access list.
- Host D can communicate with Host A. Host D is on a subnet that is explicitly permitted by the third line of the access list.
- Users on the Internet cannot communicate with Host A. Users outside of this network are not explicitly permitted, so they are denied by default with the implicit **deny any** at the end of the access list.

**Location of Standard Access Lists**

Access list location can be more of an art than a science, but some general guidelines can be discovered by looking at the simple example illustrated in Figure A-13. An access list configuration for this network is shown in Example A-5. If the policy goal is to deny Host Z access to Host V on another network, and not to change any other access policy, determine on which interface of which router this access list should be configured.

**Figure A-13** *Location of Standard IP Access List Example***Example A-5** *Standard Access List to Be Configured on a Router in Figure A-13*

```

access-list 3 deny 10.3.0.1
access-list 3 permit any

```

The access list should be placed on Router A. The reason is that a standard access list can specify only a source address. No hosts beyond the point in the path that the traffic is denied can connect.

The access list could be configured as an outbound list on E0 of Router A, but it would most likely be configured as an inbound list on E1 so that packets to be denied would not have to be routed through Router A first.

Consider the effect of placing the access list on other routers:

- **Router B**—Host Z could not connect with Host W (and Host V).
- **Router C**—Host Z could not connect with hosts W and X (and Host V).
- **Router D**—Host Z could not connect with hosts W, X, and Y (and Host V).

Thus, for standard access lists, the rule is to place them as close to the *destination* router as possible to exercise the most control. Note, however, that this means that traffic is routed through the network, only to be denied close to its destination.

## IP Extended Access Lists

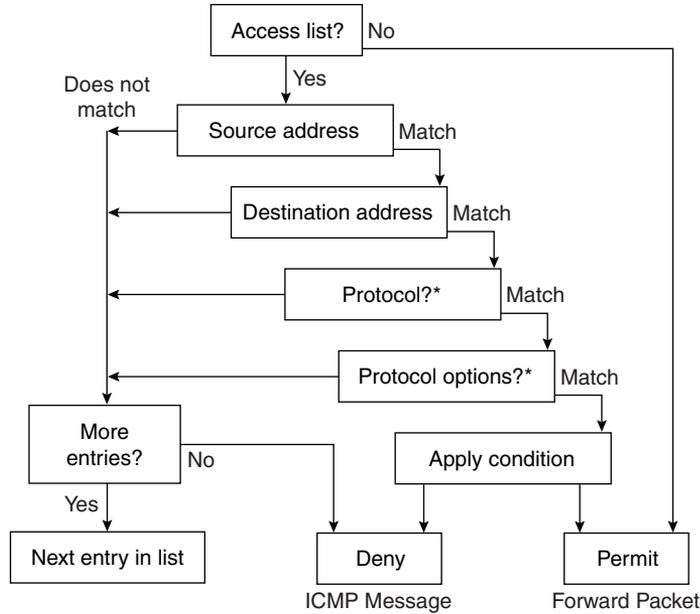
This section discusses extended access list operation and implementation.

Standard access lists offer quick configuration and low overhead in limiting traffic based on source address within a network. Extended access lists provide a higher degree of control by enabling filtering based on the source and destination addresses, transport layer protocol, and application port number. These features make it possible to limit traffic based on the uses of the network.

### Extended Access List Processing

As shown in Figure A-14, every condition tested in a line of an extended access list must match for the line of the access list to match and for the permit or deny condition to be applied. As soon as one parameter or condition fails, the next line in the access list is compared.

**Figure A-14** *Extended IP Access List Processing Flow*



\* If present in access list

The extended access list checks source address, destination address, and protocol. Depending on the protocol configured, there may be more protocol-dependent options tested. For example, a TCP port may be checked, which allows routers to filter at the application layer.

### Extended IP Access List Configuration

Use the **access-list** *access-list-number* { **permit** | **deny** } { *protocol* | *protocol-keyword* } { *source source-wildcard* | **any** } { *destination destination-wildcard* | **any** } [*protocol-specific options*] [**log**] global configuration command to create an entry in an extended traffic filter list, as described in Table A-8.

**Table A-8** *Extended IP access-list Command Description*

<b>access-list Command</b>	<b>Description</b>
<i>access-list-number</i>	Identifies the list to which the entry belongs, a number from 100 to 199.
<b>permit</b>   <b>deny</b>	Indicates whether this entry allows or blocks traffic.

**Table A-8** *Extended IP access-list Command Description (Continued)*

<b>access-list Command</b>	<b>Description</b>
<i>protocol</i>	<b>ip</b> , <b>tcp</b> , <b>udp</b> , <b>icmp</b> , <b>igmp</b> , <b>gre</b> , <b>igrp</b> , <b>eigrp</b> , <b>ospf</b> , <b>nos</b> , or a number in the range of 0 through 255. To match any Internet protocol, use the keyword <b>ip</b> . Some protocols have more options that are supported by an alternate syntax for this command, as shown later in this section.
<i>source and destination</i>	Identifies the source and destination IP addresses.
<i>source-wildcard and destination-wildcard</i>	Identifies which bits in the address field must match. A 1 in a bit position indicates “don’t care” bits, and a 0 in any bit position indicates that the bit must strictly match.
<b>any</b>	Use this keyword as an abbreviation for a source and source-wildcard, or a destination and destination-wildcard of 0.0.0.0 255.255.255.255.
<b>log</b>	(Optional) Causes informational logging messages about a packet that matches the entry to be sent to the console. Exercise caution when using this keyword because it consumes CPU cycles.

The wildcard masks in an extended access list operate the same way as they do in standard access lists. The keyword **any** in either the source or the destination position matches any address and is equivalent to configuring an address of 0.0.0.0 with a wildcard mask of 255.255.255.255. An example of an extended access list is shown in Example A-6.

**Example A-6** *Use of the Keyword any*

```
access-list 101 permit ip 0.0.0.0 255.255.255.255 0.0.0.0 255.255.255.255
! (alternate configuration)
access-list 101 permit ip any any
```

The keyword **host** can be used in either the source or the destination position; it causes the address that immediately follows it to be treated as if it were specified with a mask of 0.0.0.0. An example is shown in Example A-7.

**Example A-7** *Use of the Keyword host*

```
access-list 101 permit ip 0.0.0.0 255.255.255.255 172.16.5.17 0.0.0.0
! (alternate configuration)
access-list 101 permit ip any host 172.16.5.17
```

Use the **access-list** *access-list-number* {**permit** | **deny**} **icmp** {*source source-wildcard* | **any**} {*destination destination-wildcard* | **any**} [*icmp-type [icmp-code]*] | *icmp-message*] global configuration command to filter ICMP traffic. The protocol keyword **icmp** indicates

that an alternate syntax is being used for this command and that protocol-specific options are available, as described in Table A-9.

**Table A-9** *Extended IP access-list icmp Command Description*

<b>access-list icmp Command</b>	<b>Description</b>
<i>access-list-number</i>	Identifies the list to which the entry belongs, a number from 100 to 199.
<b>permit   deny</b>	Indicates whether this entry allows or blocks traffic.
<i>source</i> and <i>destination</i>	Identifies the source and destination IP addresses.
<i>source-wildcard</i> and <i>destination-wildcard</i>	Identifies which bits in the address field must match. A 1 in a bit position indicates “don’t care” bits, and a 0 in any bit position indicates that the bit must strictly match.
<b>any</b>	Use this keyword as an abbreviation for a source and source-wildcard, or a destination and destination-wildcard of 0.0.0.0 255.255.255.255.
<i>icmp-type</i>	(Optional) Packets can be filtered by ICMP message type. The type is a number from 0 to 255.
<i>icmp-code</i>	(Optional) Packets that have been filtered by ICMP message type can also be filtered by ICMP message code. The code is a number from 0 to 255.
<i>icmp-message</i>	(Optional) Packets can be filtered by a symbolic name representing an ICMP message type or a combination of ICMP message type and ICMP message code. A list of these names is provided in Table A-10.

Cisco IOS Release 10.3 and later versions provide symbolic names that make configuration and reading of complex access lists easier. With symbolic names, it is no longer critical to understand the meaning of the ICMP message type and code (for example, message 8 and message 0 can be used to filter the **ping** command). Instead, the configuration can use symbolic names (for example, the **echo** and **echo-reply** symbolic names can be used to filter the **ping** command), as shown in Table A-10. (You can use the Cisco IOS context-sensitive help feature by entering ? when entering the access-list command, to verify the available names and proper command syntax.)

**Table A-10** *ICMP Message and Type Names*

Administratively-prohibited	Information-reply	Precedence-unreachable
Alternate-address	Information-request	Protocol-unreachable
Conversion-error	Mask-reply	Reassembly-timeout
Dod-host-prohibited	Mask-request	Redirect

**Table A-10** *ICMP Message and Type Names (Continued)*

Dod-net-prohibited	Mobile-redirect	Router-advertisement
Echo	Net-redirect	Router-solicitation
Echo-reply	Net-tos-redirect	Source-quench
General-parameter-problem	Net-tos-unreachable	Source-route-failed
Host-isolated	Net-unreachable	Time-exceeded
Host-precedence-unreachable	Network-unknown	Timestamp-reply
Host-redirect	No-room-for-option	Timestamp-request
Host-tos-redirect	Option-missing	Traceroute
Host-tos-unreachable	Packet-too-big	Ttl-exceeded
Host-unknown	Parameter-problem	Unreachable
Host-unreachable	Port-unreachable	

Use the **access-list** *access-list-number* { **permit** | **deny** } **tcp** { *source source-wildcard* | **any** } [*operator source-port* | *source-port*] { *destination destination-wildcard* | **any** } [*operator destination-port* | *destination-port*] [**established**] global configuration command to filter TCP traffic. The protocol keyword **tcp** indicates that an alternate syntax is being used for this command and that protocol-specific options are available, as described in Table A-11.

**Table A-11** *Extended IP access-list tcp Command Description*

<b>access-list tcp Command</b>	<b>Description</b>
<i>access-list-number</i>	Identifies the list to which the entry belongs, a number from 100 to 199.
<b>permit</b>   <b>deny</b>	Indicates whether this entry allows or blocks traffic.
<i>source</i> and <i>destination</i>	Identifies the source and destination IP addresses.
<i>source-wildcard</i> and <i>destination-wildcard</i>	Identifies which bits in the address field must match. A 1 in a bit position indicates “don’t care” bits, and a 0 in any bit position indicates that the bit must strictly match.
<b>any</b>	Use this keyword as an abbreviation for a source and source-wildcard, or a destination and destination-wildcard of 0.0.0.0 255.255.255.255.
<i>operator</i>	(Optional) A qualifying condition. Can be: <b>lt</b> , <b>gt</b> , <b>eq</b> , <b>neq</b> .
<i>source-port</i> and <i>destination-port</i>	(Optional) A decimal number from 0 to 65535 or a name that represents a TCP port number.
<b>established</b>	(Optional) A match occurs if the TCP segment has the ACK or RST bits set. Use this if you want a Telnet or another activity to be established in one direction only.

---

**established Keyword in Extended Access Lists**

When a TCP session is started between two devices, the first segment sent has the SYN (synchronize) code bit set but does not have the ACK (acknowledge) code bit set in the segment header because it is not acknowledging any other segments. All subsequent segments sent do have the ACK code bit set because they are acknowledging previous segments sent by the other device. This is how a router can distinguish between a segment from a device that is attempting to *start* a TCP session and a segment of an ongoing already *established* session. The RST (reset) code bit is set when an established session is being terminated.

When you configure the **established** keyword in a TCP extended access list, it indicates that that access list statement should match only TCP segments in which the ACK or RST code bit is set. In other words, only segments that are part of an already established session will be matched; segments that are attempting to start a session will not match the access list statement.

---

Table A-12 is a list of TCP port names that can be used instead of port numbers. Port numbers corresponding to these protocols can be found by typing a ? in the place of a port number, or by looking at RFC 1700, "Assigned Numbers." (This RFC is available at URL [www.cis.ohio-state.edu/htbin/rfc/rfc1700.html](http://www.cis.ohio-state.edu/htbin/rfc/rfc1700.html).)

**Table A-12** *TCP Port Names*

Bgp	Hostname	Syslog
Chargen	Irc	Tacacs-ds
Daytime	Klogin	Talk
Discard	Kshell	telnet
Domain	Lpd	Time
Echo	nntp	Uucp
Finger	Pop2	Whois
ftp control	Pop3	www
ftp-data	SmtP	
Gopher	Sunrpc	

Other port numbers can also be found in RFC 1700, "Assigned Numbers." A partial list of the assigned TCP port numbers is shown in Table A-13.

**Table A-13** *Some Reserved TCP Port Numbers*

Decimal	Keyword	Description
7	ECHO	Echo
9	DISCARD	Discard
13	DAYTIME	Daytime
19	CHARGEN	Character generator
20	FTP-DATA	File Transfer Protocol (data)
21	FTP-CONTROL	File Transfer Protocol
23	TELNET	Terminal connection
25	SMTP	Simple Mail Transfer Protocol
37	TIME	Time of day
43	WHOIS	Who is
53	DOMAIN	Domain name server
79	FINGER	Finger
80	WWW	World Wide Web HTTP
101	HOSTNAME	NIC host name server

Use the **access-list** *access-list-number* { **permit** | **deny** } **udp** { *source source-wildcard* | **any** } [ *operator source-port* | *source-port* ] { *destination destination-wildcard* | **any** } [ *operator destination-port* | *destination-port* ] global configuration command to filter UDP traffic. The protocol keyword **udp** indicates that an alternate syntax is being used for this command and that protocol-specific options are available, as described in Table A-14.

**Table A-14** *Extended IP access-list udp Command Description*

<b>access-list udp</b> Command	Description
<i>access-list-number</i>	Identifies the list to which the entry belongs, a number from 100 to 199.
<b>permit</b>   <b>deny</b>	Indicates whether this entry allows or blocks traffic.
<i>source</i> and <i>destination</i>	Identifies the source and destination IP addresses.
<i>source-wildcard</i> and <i>destination-wildcard</i>	Identifies which bits in the address field must match. A 1 in a bit position indicates “don’t care” bits, and a 0 in any bit position indicates that bit must strictly match.
<b>any</b>	Use this keyword as an abbreviation for a source and source-wildcard, or a destination and destination-wildcard of 0.0.0.0 255.255.255.255.

*continues*

**Table A-14** *Extended IP access-list udp Command Description (Continued)*

<b>access-list udp Command</b>	<b>Description</b>
<i>operator</i>	(Optional) A qualifying condition. Can be: <b>lt</b> , <b>gt</b> , <b>eq</b> , <b>neq</b> .
<i>source-port</i> and <i>destination-port</i>	(Optional) A decimal number from 0 to 65535 or a name that represents a UDP port number.

Table A-15 is a list of UDP port names that can be used instead of port numbers. Port numbers corresponding to these protocols can be found by typing a ? in the place of a port number, or by looking at RFC 1700, “Assigned Numbers.”

**Table A-15** *UDP Port Names*

Biff	Nameserver	Syslog
Bootpc	NetBios-dgm	Tacads-ds
Bootps	NetBios-ns	Talk
Discard	Ntp	Tftp
Dns	Rip	Time
Dnsix	Snmp	Whois
Echo	Snmptrap	Xdmcp
Mobile-ip	Sunrpc	

Other port numbers can also be found in RFC 1700, “Assigned Numbers.” A partial list of the assigned UDP port numbers is shown in Table A-16.

**Table A-16** *Some Reserved UDP Port Numbers*

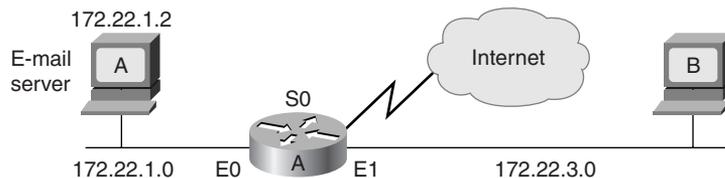
<b>Decimal</b>	<b>Keyword</b>	<b>Description</b>
7	ECHO	Echo
9	DISCARD	Discard
37	TIME	Time of day
42	NAMESERVER	Host name server
43	WHOIS	Who is
53	DNS	Domain name server
67	BOOTPS	Bootstrap protocol server
68	BOOTPC	Bootstrap protocol client
69	TFTP	Trivial File Transfer Protocol
123	NTP	Network Time Protocol
137	NetBios-ns	NetBios Name Service

**Table A-16** *Some Reserved UDP Port Numbers (Continued)*

Decimal	Keyword	Description
138	NetBios-dgm	NetBios Datagram Service
161	SNMP	SNMP
162	SNMPTrap	SNMP Traps
520	RIP	RIP

## Extended Access List Examples

In the example shown in Figure A-15, Router A's interface Ethernet 1 is part of a Class B subnet with the address 172.22.3.0, Router A's interface Serial 0 is connected to the Internet, and the e-mail server's address is 172.22.1.2. The access list configuration applied to Router A is shown in Example A-8.

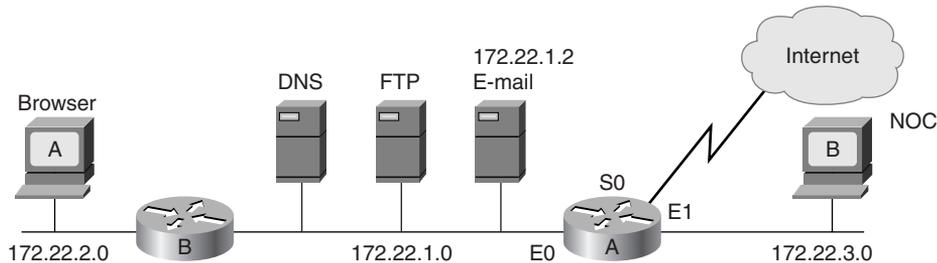
**Figure A-15** *Network Used for Extended IP Access List Example***Example A-8** *Configuration on Router A in Figure A-15*

```
access-list 104 permit tcp any 172.22.0.0 0.0.255.255 established
access-list 104 permit tcp any host 172.22.1.2 eq smtp
access-list 104 permit udp any any eq dns
access-list 104 permit icmp any any echo
access-list 104 permit icmp any any echo-reply
!
interface serial 0
 ip access-group 104 in
```

In Example A-8, access list 104 is applied inbound on Router A's Serial 0 interface. The keyword **established** is used only for the TCP protocol to indicate an established connection. A match occurs if the TCP segment has the ACK or RST bits set, which indicate that the packet belongs to an existing connection. If the session is not already established (the ACK bit is not set and the SYN bit is set), it means that someone on the Internet is attempting to initialize a session, in which case the packet is denied. This configuration also permits SMTP traffic from any address to the e-mail server. UDP domain name server packets and ICMP echo and echo-reply packets are also permitted, from any address to any other address.

Another example is shown in Figure A-16. The access list configuration applied to Router A is shown in Example A-9.

**Figure A-16** *Extended IP Access List Example with Many Servers*



**Example A-9** *Configuration on Router A in Figure A-16*

```
access-list 118 permit tcp any 172.22.0.0 0.0.255.255 eq www established
access-list 118 permit tcp any host 172.22.1.2 eq smtp
access-list 118 permit udp any any eq dns
access-list 118 permit udp 172.22.3.0 0.0.0.255 172.22.1.0 0.0.0.255 eq snmp
access-list 118 deny icmp any 172.22.0.0 0.0.255.255 echo
access-list 118 permit icmp any any echo-reply
!
interface ethernet 0
 ip access-group 118 out
```

In Example A-9, access list 118 is applied outbound on Router A's Ethernet 0 interface. With the configuration shown in Example A-9, *replies* to queries from the Client A browser to the Internet will be allowed back into the corporate network (because they are established sessions). Browser queries *from* external sources are not explicitly allowed and will be discarded by the implicit **deny any** at the end of the access list.

The access list in Example A-9 also allows e-mail (SMTP) to be delivered exclusively to the mail server. The name server is permitted to resolve DNS requests. The 172.22.1.0 subnet is controlled by the network management group located at the NOC server (Client B), so network-management queries (Simple Network Management Protocol [SNMP]) will be allowed to reach these devices in the server farm. Attempts to ping the corporate network from outside or from subnet 172.22.3.0 will fail because the access list blocks the echo requests. However, the replies to echo requests generated from within the corporate network will be allowed to re-enter the network.

## Location of Extended Access Lists

Because extended access lists can filter on more than source address, location is no longer a constraint as it was when considering the location of a standard access list. Frequently, policy decisions and goals are the driving forces behind extended access list placement.

If your goal is to minimize traffic congestion and maximize performance, you might want to push the access lists close to the source to minimize cross-traffic and administratively prohibited ICMP messages. If your goal is to maintain tight control over access lists as part of your network security strategy, you might want to have them more centrally located. Notice how changing network goals will affect access list configuration.

Some things to consider when placing extended access lists include the following:

- Minimize distance traveled by traffic that will be denied (and ICMP unreachable messages).
- Keep denied traffic off the backbone.
- Select the router to receive CPU overhead from access lists.
- Consider the number of interfaces affected.
- Consider access list management and security.
- Consider network growth impacts on access list maintenance.

## Restricting Virtual Terminal Access

This section discusses how standard access lists can be used to limit virtual terminal access.

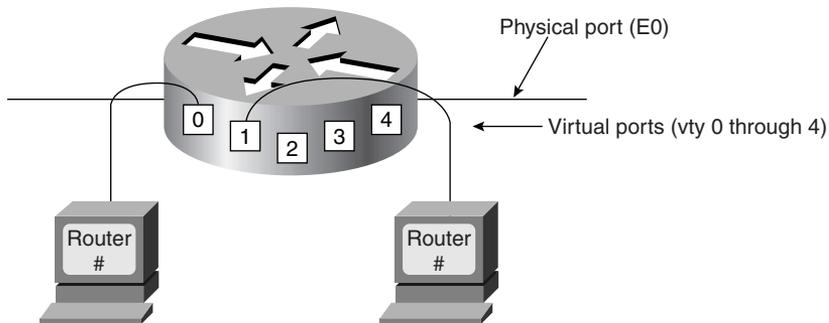
Standard and extended access lists will block packets from going *through* the router. They are not designed to block packets that originate within the router. An outbound Telnet extended access list does not prevent router-initiated Telnet sessions, by default.

For security purposes, users can be denied virtual terminal (vty) access to the router, or users can be permitted vty access to the router but denied access to destinations from that router. Restricting virtual terminal access is less a traffic control mechanism than one technique for increasing network security.

Because vty access is accomplished using the Telnet protocol, there is only one type of vty access list.

## How to Control vty Access

Just as a router has physical ports or interfaces such as Ethernet 0 and Ethernet 1, it also has virtual ports. These virtual ports are called virtual terminal lines. By default, there are five such virtual terminal lines, numbered vty 0 through 4, as shown in Figure A-17.

**Figure A-17** A Router Has Five Virtual Terminal Lines (Virtual Ports) by Default

You should set identical restrictions on all virtual terminal lines because you cannot control on which virtual terminal line a user will connect.

**NOTE**

Some experts recommend that you configure one of the vty terminal lines differently than the others. This way you will have a “back door” into the router.

## Virtual Terminal Line Access Configuration

Use the **line vty** {*vtv-number* | *vtv-range*} global configuration command to place the router in line configuration mode, as described in Table A-17.

**Table A-17** *line vty* Command Description

line vty Command	Description
<i>vtv-number</i>	Indicates the number of the vty line to be configured.
<i>vtv-range</i>	Indicates the range of vty lines to which the configuration will apply.

Use the **access-class** *access-list-number* {**in** | **out**} line configuration command to link an existing access list to a terminal line or range of lines, as described in Table A-18.

**Table A-18** *access-class* Command Description

access-class Command	Description
<i>access-list-number</i>	Indicates the number of the standard access list to be linked to a terminal line. This is a decimal number from 1 to 99.
<b>in</b>	Prevents the router from receiving incoming connections <i>from</i> the addresses in the access list.
<b>out</b>	Prevents someone from initiating a Telnet <i>to</i> addresses defined in the access list.

---

**NOTE** When using the **out** keyword in the access-class command, the addresses in the specified standard access list are treated as *destination* addresses rather than source addresses.

---

In the example configuration in Example A-10, any device on network 192.168.55.0 is permitted to establish a virtual terminal (Telnet) session with the router. Of course, the user must know the appropriate passwords to enter user mode and privileged mode.

**Example A-10** *Configuration to Restrict Telnet Access to a Router*

```
access-list 12 permit 192.168.55.0 0.0.0.255
!
line vty 0 4
  access-class 12 in
```

Notice that in this example, identical restrictions have been set on all virtual terminal lines (0 to 4) because you cannot control on which virtual terminal line a user will connect. (Note that the implicit **deny any** still applies to this alternate application of access lists.)

## Verifying Access List Configuration

This section describes how to verify access list configuration.

Use the **show access-lists** [*access-list-number* | *name*] privileged EXEC command to display access lists from all protocols, as described in Table A-19. If no parameters are specified, all access lists will be displayed.

**Table A-19** *show access-list Command Description*

<b>show access-lists</b>	
<b>Command</b>	<b>Description</b>
<i>access-list-number</i>	(Optional) Number of the access list to display
<i>name</i>	(Optional) Name of the access list to display

The system counts how many packets match each line of an extended access list; the counters are displayed by the **show access-lists** command.

Example A-11 illustrates an example output from the **show access-lists** command. In this example, the first line of the access list has been matched three times, and the last line has been matched 629 times. The second line has not been matched.

**Example A-11** *Output of the show access-lists Command*

```
p1r1#show access-lists
Extended IP access list 100
  deny tcp host 10.1.1.2 host 10.1.1.1 eq telnet (3 matches)
  deny tcp host 10.1.2.2 host 10.1.2.1 eq telnet
  permit ip any any (629 matches)
```

Use the **show ip access-list** [*access-list-number* | *name*] EXEC command to display IP access lists, as described in Table A-20. If no parameters are specified, all IP access lists will be displayed.

**Table A-20** *show ip access-list Command Description*

<b>show ip access-list Command</b>	<b>Description</b>
<i>access-list-number</i>	(Optional) Number of the IP access list to display
<i>name</i>	(Optional) Name of the IP access list to display

Use the **clear access-list counters** [*access-list-number* | *name*] EXEC command to clear the counters for the number of matches in an extended access list, as described in Table A-21. If no parameters are specified, the counters will be cleared for all access lists.

**Table A-21** *clear access-list counters Command Description*

<b>clear access-list counters Command</b>	<b>Description</b>
<i>access-list-number</i>	(Optional) Number of the access list for which to clear the counters
<i>name</i>	(Optional) Name of the access list for which to clear the counters

Use the **show line** [*line-number*] EXEC command to display information about terminal lines. The *line-number* is optional and indicates the absolute line number of the line for which you want to list parameters. If a line number is not specified, all lines are displayed.

## Supplement 2 Review Questions

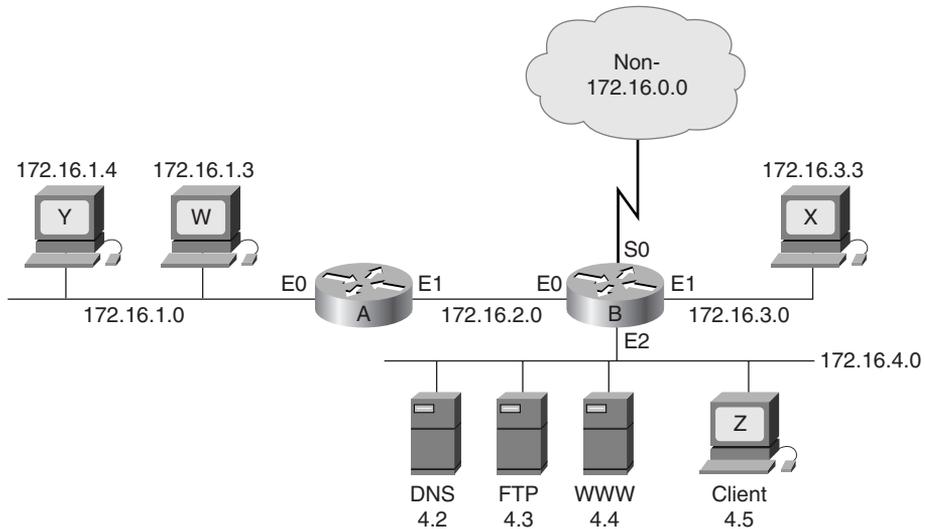
Answer the following questions, and then refer to Appendix G for the answers.

- 1 Figure A-18 shows the network for this question.

Create an access list and place it in the proper location to satisfy the following requirements:

- Prevent all hosts on subnet 172.16.1.0/24, except host 172.16.1.3, from accessing the web server on subnet 172.16.4.0. Allow all other hosts, including from the outside world, to access the web server.

**Figure A-18** Network for Review Question 1



- Prevent the outside world from pinging subnet 172.16.4.0.
- Allow all hosts on all subnets of network 172.16.0.0 (using subnet mask 255.255.255.0) to send queries to the DNS server on subnet 172.16.4.0. The outside world is not allowed to access the DNS server.
- Prevent host 172.16.3.3 from accessing subnet 172.16.4.0 for any reason.
- Prevent all other access to the 172.16.4.0 subnet.

Write your configuration in the spaces that follow. Be sure to include the router name (A or B), interface name (E0, E1, or E2), and access list direction (in or out).

**Global commands:**

---



---



---



---



---



---

**Interface commands:**

---



---



---

- 2 What do bits set to 1 in a wildcard mask indicate when matching an address?
- 3 By default, what happens to all traffic in an access list?
- 4 Where should an extended access list be placed to save network resources?
- 5 Using the keyword **host** in an access list is a substitute for using what value of a wildcard mask?

## Supplement 3: OSPF

This supplement covers the following OSPF-related topics:

- Not-so-stubby areas
- OSPF single-area configuration example
- OSPF multiarea configuration example

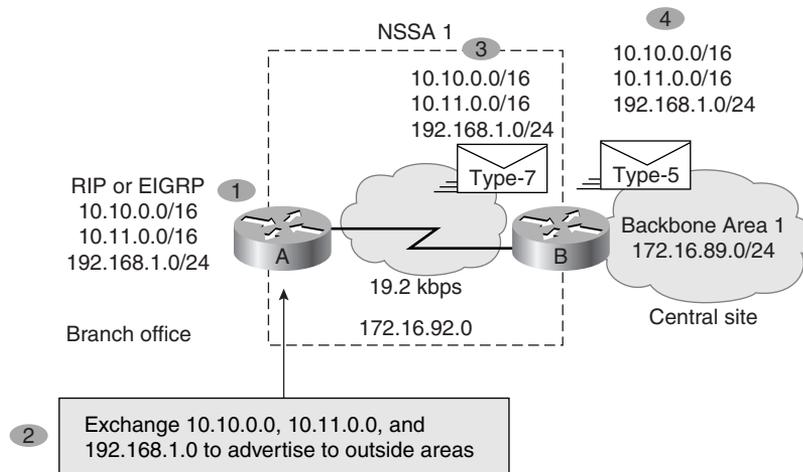
### OSPF Not-So-Stubby Areas

Not-so-stubby areas (NSSAs) were first introduced in Cisco IOS Release 11.2. NSSAs are based on RFC 1587, “The OSPF NSSA Option.” NSSAs enable you to make a hybrid stub area that can accept some autonomous system external routes, referred to as type 7 LSAs. Type 7 LSAs may be originated by and advertised throughout an NSSA. Type 7 LSAs are advertised only within a single NSSA; they are not flooded into the backbone area or any other area by border routers, although the information that they contain can be propagated into the backbone area by being translated into type 5 LSAs by the ABR. As with stub areas, NSSAs do not receive or originate type 5 LSAs.

Use an NSSA if you are an Internet service provider (ISP) or a network administrator that must connect a central site using Open Shortest Path First (OSPF) to a remote site using a different protocol, such as the Routing Information Protocol (RIP) or Enhanced Interior Gateway Routing Protocol (EIGRP), as shown in Figure A-19. You can use NSSA to simplify the administration of this kind of topology.

Prior to NSSA, the limitation that a stub area cannot import external routes meant that the connection between Router A and Router B in Figure A-19 could not be a stub area. Therefore, if the connection ran OSPF, it would be a standard area and would import the routes learned from RIP or EIGRP as type 5 LSAs. Because it is likely not desirable for the branch office to get all the type 5 routes from the central site, Router B would be forced to run OSPF and RIP or EIGRP.

Now, with NSSA you can extend OSPF to cover the remote connection by defining the area between the corporate router and the remote router as an NSSA, as shown in Figure A-19.

**Figure A-19** Example of a Topology Where an NSSA Is Used

In Figure A-19, Router A is defined as an autonomous system boundary router (ASBR). It is configured to exchange any routes within the RIP/EIGRP domain to the NSSA. The following is what happens when using an NSSA:

- 1 Router A receives RIP or EIGRP routes for networks 10.10.0.0/16, 10.11.0.0/16, and 192.168.1.0/24.
- 2 Router A, connected to the NSSA, imports the non-OSPF routes as type 7 LSAs into the NSSA.
- 3 Router B, an ABR between the NSSA and the backbone area 0, receives the type 7 LSAs.
- 4 After the SPF calculation on the forwarding database, Router B translates the type 7 LSAs into type 5 LSAs and then floods them throughout backbone area 0.

At this point Router B could have summarized routes 10.10.0.0/16 and 10.11.0.0/16 as 10.0.0.0/8, or could have filtered one or more of the routes.

## Configuring NSSA

The steps used to configure OSPF NSSA are as follows:

- Step 1** On the ABR connected to the NSSA, configure OSPF, as described in Chapter 3, “Configuring OSPF in a Single Area,” and Chapter 4, “Interconnecting Multiple OSPF Areas.”
- Step 2** Configure an area as NSSA using the following command, explained in Table A-22:

```
router(config-router)#area area-id nssa [no-redistribution]
[default-information-originate]
```

**Table A-22** *area nssa Command*

Command	Description
<i>area-id</i>	Identifier of the area that is to be an NSSA. The identifier can be specified as either a decimal value or an IP address.
<b>no-redistribution</b>	(Optional) Used when the router is an NSSA ABR and you want the <b>redistribute</b> command to import routes only into the normal areas, but not into the NSSA area.
<b>default-information-originate</b>	(Optional) Used to generate a type 7 default into the NSSA area. This argument takes effect only on the NSSA ABR.

**Step 3** Every router within the same area must agree that the area is NSSA; otherwise, the routers will not be capable of communicating with each other. Therefore, configure this command on every router in the NSSA area.

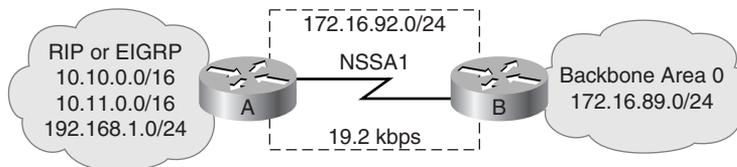
**Step 4** (Optional) Control the summarization or filtering during the translation, using the following command explained in Table A-23:

```
router(config-router)#summary-address address mask [prefix mask] [not-advertise]
[tag tag]
```

**Table A-23** *summary-address Command*

Command	Description
<i>address</i>	Summary address designated for a range of addresses
<i>prefix</i>	(Optional) IP route prefix for the destination
<i>mask</i>	(Optional) IP subnet mask used for the summary route
<b>not-advertise</b>	(Optional) Used to suppress routes that match the prefix/mask pair
<i>tag</i>	(Optional) Tag value that can be used as a match value for controlling redistribution via route maps

Figure A-20 and Example A-12 provide an example of NSSA configuration.

**Figure A-20** Example of NSSA Topology**Example A-12** Configuring NSSA on the Routers in Figure A-20

```

Router A Configuration:
router ospf 1
 redistribute rip subnets
 network 172.16.92.0.0.0.255 area 1
 area 1 nssa

Router B Configuration:
router ospf 1
 summary-address 10.0.0.0.255.0.0.0
 network 172.16.89.0.0.0.255 area 0
 network 172.16.92.0.0.0.255 area 1
 area 1 nssa

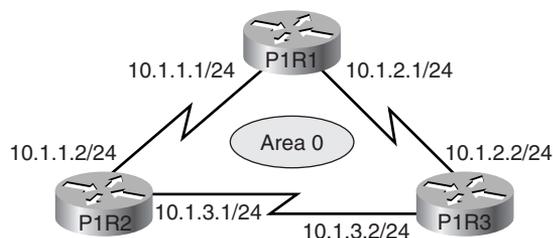
```

**NOTE**

The **redistribute** command shown in Example A-12 instructs the router to import RIP packets into the OSPF network. Redistribution is discussed in detail in Chapter 8, “Optimizing Routing Update Operation.”

## OSPF Single-Area Configuration Example

This section includes configuration and **show** command output examples that result from configuring the network shown in Figure A-21.

**Figure A-21** OSPF Single-Area Topology

Example A-13 shows a typical configuration for single-area OSPF, for P1R3.

**Example A-13** P1R3 in *Figure A-21 Configuration*

```
P1R3#show run
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname P1R3
!
interface Ethernet0
 no ip address
 shutdown
!
interface Ethernet1
 no ip address
 shutdown
!
interface Serial0
 ip address 10.1.3.2 255.255.255.0
 no fair-queue
 clockrate 64000
!
interface Serial1
 ip address 10.1.2.2 255.255.255.0
!

router ospf 1
 network 10.1.2.0 0.0.0.255 area 0
 network 10.1.3.0 0.0.0.255 area 0
!
no ip classless
!
!
line con 0
 exec-timeout 0 0
line aux 0
line vty 0 4
 login
!
end
```

As shown in Example A-13, OSPF is activated on both Serial 0 and Serial 1 interfaces.

Example A-14 provides output of some **show commands** on P1R3. From the **show ip route** output, you can confirm that OSPF is receiving OSPF routing information. From the **show ip ospf neighbor detail** output, you can confirm that P1R3 has reached the full state with

its two neighbors. From the **show ip ospf database** output, you can confirm that P1R3 is receiving only type 1 LSAs—router link states LSA. No type 2 LSAs are received because all the connections are point-to-point and, therefore, no designated router (DR) was elected.

**Example A-14** P1R3 in Figure A-21 Output for **show ip route**, **show ip ospf neighbor detail**, and **show ip ospf database** Commands

```
P1R3#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, * - candidate default
       U - per-user static route, o - ODR

Gateway of last resort is not set

    10.0.0.0/24 is subnetted, 3 subnets
C       10.1.3.0 is directly connected, Serial0
C       10.1.2.0 is directly connected, Serial1
O       10.1.1.0 [110/128] via 10.1.3.1, 00:01:56, Serial0
        [110/128] via 10.1.2.1, 00:01:56, Serial1

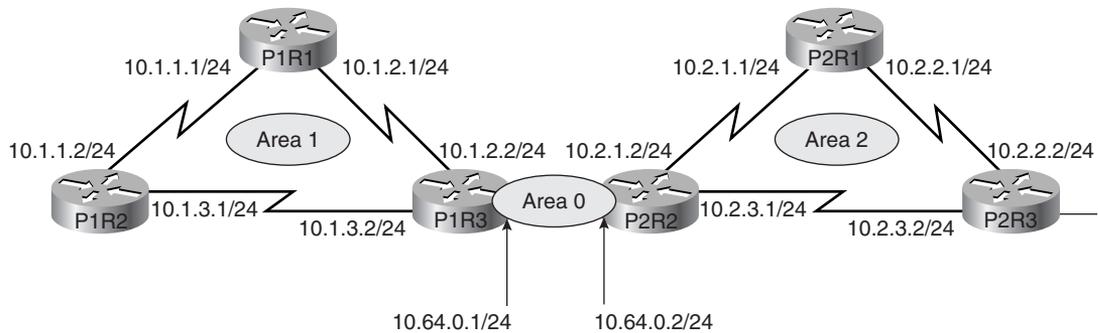
P1R3#show ip ospf neighbor detail
Neighbor 10.1.3.1, interface address 10.1.3.1
  In the area 0 via interface Serial0
Neighbor priority is 1, State is FULL
Options 2
  Dead timer due in 00:00:34
Neighbor 10.1.2.1, interface address 10.1.2.1
  In the area 0 via interface Serial1
Neighbor priority is 1, State is FULL
Options 2
  Dead timer due in 00:00:36

P1R3#show ip ospf database
      OSPF Router with ID (10.1.3.2) (Process ID 1)
      Router Link States (Area 0)

Link ID        ADV Router    Age           Seq#           Checksum Link count
10.1.2.1       10.1.2.1     301          0x80000004    0x4A49   4
10.1.3.1       10.1.3.1     292          0x80000004    0x1778   4
10.1.3.2       10.1.3.2     288          0x80000004    0x5D2E   4
P1R3#
```

## OSPF Multiarea Configuration Example

This section includes configuration and **show** command output examples that result from configuring the network shown in Figure A-22.

**Figure A-22** OSPF Multiarea Topology

Example A-15 provides output for P1R3 before any areas are configured for stub and route summarization. You can observe that the OSPF database is quite large and has multiple entries from type 1 (Router Link States), type 2 (Net Link States), and type 3 (Summary Net Link States) LSAs.

**Example A-15** P1R3 in Figure A-22 Output Prior to Stub and Route Summarization

```
P1R3#show ip ospf database

      OSPF Router with ID (10.64.0.1) (Process ID 1)

          Router Link States (Area 0)

Link ID      ADV Router   Age         Seq#         Checksum Link count
10.64.0.1    10.64.0.1   84          0x80000009  0x6B87   1
10.64.0.2    10.64.0.2   85          0x8000000C  0x6389   1

          Net Link States (Area 0)

Link ID      ADV Router   Age         Seq#         Checksum
10.64.0.2    10.64.0.2   85          0x80000001  0x7990

          Summary Net Link States (Area 0)

Link ID      ADV Router   Age         Seq#         Checksum
10.1.1.0     10.64.0.1   128         0x80000001  0x92D2
10.1.2.0     10.64.0.1   129         0x80000001  0x59F
10.1.3.0     10.64.0.1   129         0x80000001  0xF9A9
10.2.1.2     10.64.0.2   71          0x80000001  0x716F
10.2.2.1     10.64.0.2   41          0x80000001  0x7070
10.2.3.1     10.64.0.2   51          0x80000001  0x657A

          Router Link States (Area 1)

Link ID      ADV Router   Age         Seq#         Checksum Link count
10.1.2.1     10.1.2.1    859         0x80000004  0xD681   4
```

**Example A-15** PIR3 in Figure A-22 Output Prior to Stub and Route Summarization (Continued)

10.1.3.1	10.1.3.1	868	0x80000004	0xEB68	4
10.64.0.1	10.64.0.1	133	0x80000007	0xAF61	4
Summary Net Link States (Area 1)					
Link ID	ADV Router	Age	Seq#	Checksum	
10.2.1.2	10.64.0.1	74	0x80000001	0xDBFB	
10.2.2.1	10.64.0.1	45	0x80000001	0xDAFC	
10.2.3.1	10.64.0.1	55	0x80000001	0xCF07	
10.64.0.0	10.64.0.1	80	0x80000003	0x299	
P1R3#					

Example A-16 shows the configuration output for P1R3, a router that is an ABR for a stub area and that is doing route summarization.

**Example A-16** PIR3 in Figure A-22 Configuration

```
P1R3#show run
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname P1R3
!
interface Ethernet0
 ip address 10.64.0.1 255.255.255.0
!
interface Ethernet1
 no ip address
 shutdown
!
interface Serial0
 ip address 10.1.3.2 255.255.255.0
 no fair-queue
 clockrate 64000
!
interface Serial1
 ip address 10.1.2.2 255.255.255.0
!
router ospf 1
 network 10.64.0.0 0.0.0.255 area 0
 network 10.1.2.0 0.0.0.255 area 1
 network 10.1.3.0 0.0.0.255 area 1
 area 1 stub no-summary
 area 1 range 10.1.0.0 255.255.0.0
```

*continues*

**Example A-16** PIR3 in Figure A-22 Configuration (Continued)

```

!
no ip classless
!
!
line con 0
  exec-timeout 0 0
line aux 0
line vty 0 4
  login
!
end

```

Example A-17 provides output from PIR3, after the network is configured with stub areas and route summarization. The number of entries in the OSPF topology database is reduced.

**Example A-17** PIR3 in Figure A-22 *show ip ospf database* Output After Stub and Route Summarization Were Configured

```

P1R3#show ip ospf database

      OSPF Router with ID (10.64.0.1) (Process ID 1)

          Router Link States (Area 0)

Link ID        ADV Router    Age         Seq#          Checksum Link count
10.64.0.1     10.64.0.1    245        0x80000009   0x6B87   1
10.64.0.2     10.64.0.2    246        0x8000000C   0x6389   1

          Net Link States (Area 0)

Link ID        ADV Router    Age         Seq#          Checksum
10.64.0.2     10.64.0.2    246        0x80000001   0x7990

          Summary Net Link States (Area 0)

Link ID        ADV Router    Age         Seq#          Checksum
10.1.0.0      10.64.0.1    54         0x80000001   0x1B8B
10.2.0.0      10.64.0.2    25         0x80000001   0x9053

          Router Link States (Area 1)

Link ID        ADV Router    Age         Seq#          Checksum Link count
10.1.2.1     10.1.2.1    1016       0x80000004   0xD681   4
10.1.3.1     10.1.3.1    1026       0x80000004   0xEB68   4
10.64.0.1     10.64.0.1    71         0x80000009   0xE9FF   2

          Summary Net Link States (Area 1)

Link ID        ADV Router    Age         Seq#          Checksum
0.0.0.0      10.64.0.1    76         0x80000001   0x4FA3
P1R3#

```

## Supplement 4: EIGRP

This supplement covers the following EIGRP-related topics:

- IPX and EIGRP
- AppleTalk and EIGRP
- EIGRP configuration examples

### IPX and EIGRP

The following section provides information on EIGRP for Novell IPX networks.

EIGRP for a Novell IPX network has the same fast routing and partial update capabilities as EIGRP for IP. In addition, EIGRP has several capabilities that are designed to facilitate the building of large, robust Novell IPX networks.

The first capability is support for incremental SAP updates. Novell IPX RIP routers send out large RIP and SAP updates every 60 seconds. This can consume substantial amounts of bandwidth. EIGRP for IPX sends out SAP updates only when changes occur and sends only changed information.

The second capability that EIGRP adds to IPX networks is the capability to build large networks. IPX RIP networks have a diameter limit of 15 hops. EIGRP networks can have a diameter of 224 hops.

The third capability that EIGRP for Novell IPX provides is optimal path selection. The RIP metric for route determination is based on ticks, with hop count used as a tie-breaker. If more than one route has the same value for the tick metric, the route with the least number of hops is preferred. Instead of ticks and hop count, IPX EIGRP uses a combination of these metrics: delay, bandwidth, reliability, and load.

To add EIGRP to a Novell RIP and SAP network, configure EIGRP on the Cisco router interfaces that connect to other Cisco routers also running EIGRP. Configure RIP and SAP on the interfaces that connect to Novell hosts and or Novell routers that do not support EIGRP. With EIGRP configured, periodic SAP updates are replaced with EIGRP incremental updates when an EIGRP peer is found. However, note that unless RIP is explicitly disabled for an IPX network number, both RIP and EIGRP will be active on the interface associated with that network number.

### Route Selection

IPX EIGRP routes are automatically preferred over RIP routes regardless of metrics unless a RIP route has a hop count less than the external hop count carried in the EIGRP update—for example, a server advertising its own internal network.

## Redistribution and Metric Handling

Redistribution is automatic between RIP and EIGRP, and vice versa. Automatic redistribution can be turned off using the **no redistribute** command. Redistribution is not automatic between different EIGRP autonomous systems.

## Reducing SAP Traffic

Novell IPX RIP routers send out large RIP and SAP updates every 60 seconds regardless of whether a change has occurred. These updates can consume a substantial amount of bandwidth. You can reduce SAP update traffic by configuring EIGRP to do incremental SAP updates. When EIGRP is configured for incremental SAP updates, the updates consist only of information that has changed, and the updates are sent out only when a change occurs, thus saving bandwidth.

When you configure EIGRP for incremental SAP updates, you can do the following:

- Retain RIP, in which case only the reliable transport of EIGRP is used for sending incremental SAP updates. (This is the preferred configuration over bandwidth-sensitive connections.)
- Turn off RIP, in which case EIGRP replaces RIP as the routing protocol.

## AppleTalk and EIGRP

The following section provides information on EIGRP for AppleTalk network.

Cisco routers support AppleTalk Phase 1 and AppleTalk Phase 2. For AppleTalk Phase 2, Cisco routers support both extended and nonextended networks.

To add EIGRP to an AppleTalk network, configure EIGRP on the Cisco router interfaces that connect to other Cisco routers also running EIGRP. Do not disable Routing Table Maintenance Protocol (RTMP) on the interfaces that connect to AppleTalk hosts or that connect to AppleTalk routers that do not support EIGRP. RTMP is enabled by default when AppleTalk routing is enabled and when an interface is assigned an AppleTalk cable range.

## Route Selection

AppleTalk EIGRP routes are automatically preferred over RTMP routes. Whereas the AppleTalk metric for route determination is based on hop count only, AppleTalk EIGRP uses a combination of these configurable metrics: delay, bandwidth, reliability, and load.

## Metric Handling

The formula for converting RTMP metrics to AppleTalk EIGRP metrics is hop count multiplied by 252,524,800. This is a constant based on the bandwidth for a 9.6-kbps serial line and includes an RTMP factor. An RTMP hop distributed into EIGRP appears as a slightly worse path than an EIGRP-native, 9.6-kbps serial link. The formula for converting EIGRP to RTMP is the value of the EIGRP external metric plus 1.

## Redistribution

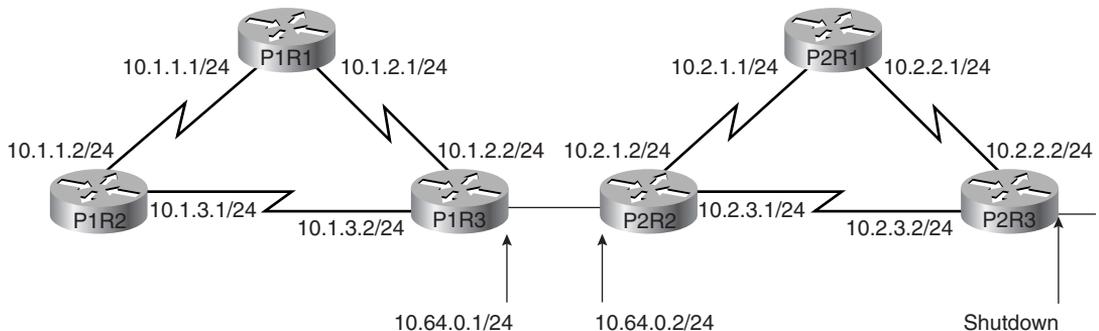
Redistribution between AppleTalk and EIGRP, and vice versa, is automatic by default. Redistribution involves converting the EIGRP metric back into an RTMP hop count metric. In reality, there is no conversion of an EIGRP composite metric into an RTMP metric. Because a hop count is carried in an EIGRP metric tuple as the EIGRP route spreads through the network, 1 is added to the hop count carried in the EIGRP metric blocks through the network and put into any RTMP routing tuple generated.

There is no conversion of an EIGRP metric back into an RTMP metric because, in reality, what RTMP uses as a metric (the hop count) is carried along the EIGRP metric all the way through the network. This is true of EIGRP-derived routes and routes propagated through the network that were originally derived from an RTMP route.

## EIGRP Configuration Examples

This section includes configuration and **show** command output examples that result from configuring the network shown in Figure A-23.

**Figure A-23** *Topology for the EIGRP Configuration Examples*



Example A-18 provides the configuration output for router P1R3 while running EIGRP.

**Example A-18** P1R3 in Figure A-23 Configured for EIGRP

```
P1R3#show run
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname P1R3
!
enable password san-fran
!
no ip domain-lookup
ipx routing 0000.0c01.3333
ipx maximum-paths 2
!
interface Loopback0
no ip address
ipx network 1013
!
interface Ethernet0
ip address 10.64.0.1 255.255.255.0
!
interface Serial0
ip address 10.1.3.2 255.255.255.0
ipx input-sap-filter 1000
ipx network 1003
!
interface Serial1
ip address 10.1.2.2 255.255.255.0
ipx input-sap-filter 1000
ipx network 1002
clockrate 56000
!
<Output Omitted>
!
router eigrp 200
network 10.0.0.0
!
no ip classless
!
!
line con 0
exec-timeout 0 0
line aux 0
line vty 0 4
login
!
end
```

Example A-19 shows the topology database of P1R3 running EIGRP before modifying the bandwidth—in other words, all links are equal bandwidth. You can see that in the case of equal-cost paths to the same network (10.1.1.0), both routes appear in the topology table as successors.

**Example A-19** P1R3 in Figure A-23 EIGRP Topology Database Prior to Changing the *bandwidth* Value

```
P1R3#show ip eigrp topology
IP-EIGRP Topology Table for process 200
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - Reply status
 P 10.1.3.0/24, 1 successors, FD is 2169856
     via Connected, Serial0
 P 10.1.2.0/24, 1 successors, FD is 2169856
     via Connected, Serial1
 P 10.1.1.0/24, 2 successors, FD is 2681856
     via 10.1.3.1 (2681856/2169856), Serial0
     via 10.1.2.1 (2681856/2169856), Serial1
```

Example A-20 shows the configuration output for P1R3 running EIGRP with **bandwidth** and **ip summary-address** commands configured. The bandwidth on Serial 0 is changed from its default of 1.544 Mbps to 64 kbps.

**Example A-20** P1R3 in Figure A-23 Configuration for EIGRP with *bandwidth* and *ip summary-address* Commands

```
P1R3#show run
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname P1R3
!
enable password san-fran
!
no ip domain-lookup
ipx routing 0000.0c01.3333
ipx maximum-paths 2
!
interface Loopback0
no ip address
ipx network 1013
!
interface Ethernet0
ip address 10.64.0.1 255.255.255.0
ip summary-address eigrp 200 10.1.0.0 255.255.0.0
!
```

*continues*

**Example A-20** *PIR3 in Figure A-23 Configuration for EIGRP with **bandwidth** and **ip summary-address** Commands (Continued)*

```
interface Serial0
 ip address 10.1.3.2 255.255.255.0
 ipx input-sap-filter 1000
 ipx network 1003
 bandwidth 64
!
interface Serial1
 ip address 10.1.2.2 255.255.255.0
 ipx input-sap-filter 1000
 ipx network 1002
 clockrate 56000
!
<Output Omitted>
!
router eigrp 200
 network 10.0.0.0
!
no ip classless
!
!
line con 0
 exec-timeout 0 0
line aux 0
line vty 0 4
 login
!
end
```

Example A-21 shows the topology database of P1R3 running EIGRP, after modifying the bandwidth on interface Serial 0 and summarizing addresses. You will notice that for network 10.1.1.0, only one route appears as a successor.

**Example A-21** *PIR3 in Figure A-23 EIGRP Topology Database After Applying the **bandwidth** and **ip summary-address** Commands*

```
P1R3#show ip eigrp topology
IP-EIGRP Topology Table for process 200
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply, r - Reply status
 P 10.1.3.0/24, 1 successors, FD is 40512000
     via Connected, Serial0
     via 10.1.2.1 (3193856/2681856), Serial1
 P 10.1.2.0/24, 1 successors, FD is 2169856
     via Connected, Serial1
 P 10.1.1.0/24, 1 successors, FD is 2681856
     via 10.1.2.1 (2681856/2169856), Serial1
```

## Supplement 5: BGP

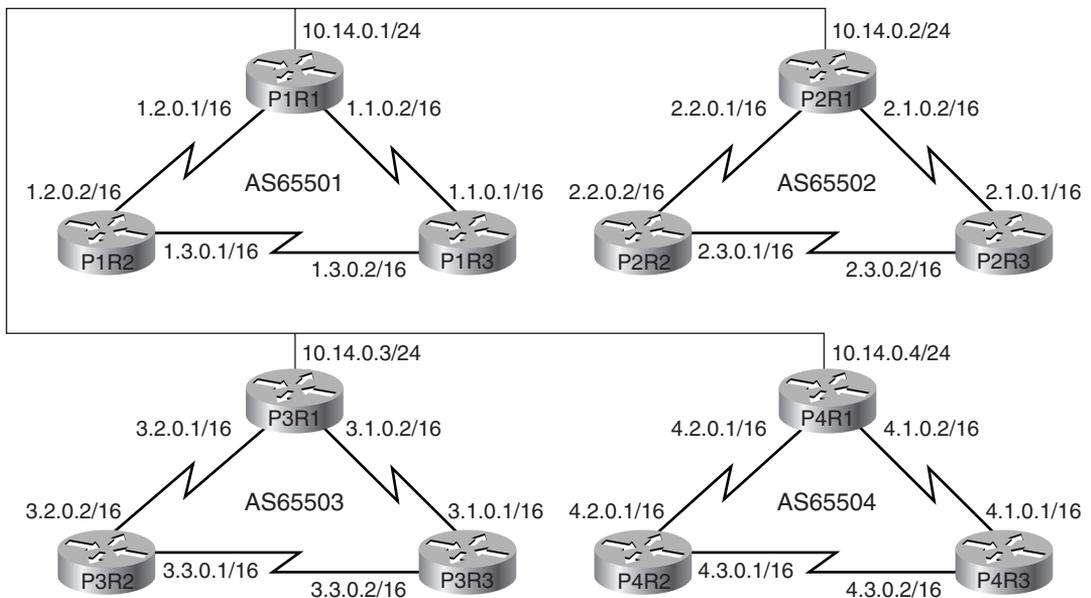
This supplement covers the following BGP-related topics:

- BGP configuration output examples
- Distribute lists
- Route maps
- Communities
- Peer groups

### BGP Configuration Output Examples

This section includes configuration and **show** command output examples that result from configuring the network shown in Figure A-24. RIP is configured as the internal routing protocol within the autonomous systems, and BGP is the external protocol between the autonomous systems. BGP routes are redistributed into RIP.

**Figure A-24** Example BGP/RIP Network



## Example of BGP/RIP Configuration for P1R1

Example A-22 shows part of the configuration for P1R1 in Figure A-24, running both RIP and BGP.

### Example A-22 Configuration of P1R1 in Figure A-24

```
P1R1#show run
<output omitted>
!
interface Ethernet0
 ip address 10.14.0.1 255.255.255.0
!
interface Serial0
 ip address 1.1.0.2 255.255.0.0
!

interface Serial1
 ip address 1.2.0.1 255.255.0.0
!
router rip
 network 10.0.0.0
 network 1.0.0.0
 passive-interface e0
 redistribute bgp 65501 metric 3
!
router bgp 65501
 network 1.0.0.0
 neighbor 10.14.0.2 remote-as 65502
 neighbor 10.14.0.3 remote-as 65503
 neighbor 10.14.0.4 remote-as 65504
!
no ip classless
!
<output omitted>
```

In Example A-22, the **network 10.0.0.0** command advertises network 10.0.0.0 in RIP so that internal routers can see network 10.0.0.0. The **passive-interface e0** command does not allow RIP to advertise any routes on the backbone. The **redistribute bgp 65501 metric 3** command redistributes BGP information into RIP, with a hop count of 3. The **network 1.0.0.0** command under the BGP configuration advertises network 1.0.0.0 to each of Router P1R1's three BGP neighbors.

## Example of RIP Configuration for P1R2

Example A-23 shows part of the configuration for P1R2 in Figure A-24, one of the routers running only RIP.

### Example A-23 Configuration of P1R2 in Figure A-24

```
P1R2#show run
<output omitted>
!
interface Ethernet0
 shutdown
!
interface Serial0
 ip address 1.2.0.2 255.255.0.0
!
interface Serial1
 ip address 1.3.0.1 255.255.0.0

!
router rip
network 1.0.0.0
!
no ip classless
!
<output omitted>
```

In Example A-23, the **network 1.0.0.0** command starts up RIP on all interfaces that P1R2 has in network 1.0.0.0 and allows the router to advertise network 1.0.0.0.

## Example Output of **show ip route** for P1R1

Example A-24 displays the output of the **show ip route** command on P1R1 in Figure A-24.

### Example A-24 **show ip route** Command Output on P1R1 in Figure A-24

```
P1R1#show ip route
<output omitted>

    1.0.0.0/16 is subnetted, 3 subnets
C       1.1.0.0 is directly connected, Serial0
R       1.3.0.0 [120/1] via 1.2.0.2, 00:00:25, Serial1
        [120/1] via 1.1.0.1, 00:00:22, Serial0
C       1.2.0.0 is directly connected, Serial1

B       2.0.0.0/8 [20/0] via 10.14.0.2, 00:03:26
B       3.0.0.0/8 [20/0] via 10.14.0.3, 00:03:26
B       4.0.0.0/8 [20/0] via 10.14.0.4, 00:03:26
    10.0.0.0/24 is subnetted, 1 subnets
C       10.14.0.0 is directly connected, Ethernet0
P1R1#
```

The shaded lines in Example A-24 indicate the routes that P1R1 has learned from its BGP neighbors.

### Example Output of **show ip route** for P1R2

Example A-25 displays the output of the **show ip route** command on P1R2 in Figure A-24.

#### Example A-25 *show ip route* Command Output on P1R2 in Figure A-24

```
P1R2#show ip route
<output omitted>

    1.0.0.0/16 is subnetted, 3 subnets
R       1.1.0.0 [120/1] via 1.2.0.1, 00:00:17, Serial0
        [120/1] via 1.3.0.2, 00:00:26, Serial1
C       1.3.0.0 is directly connected, Serial1

C       1.2.0.0 is directly connected, Serial0
R 2.0.0.0/8 [120/3] via 1.2.0.1, 00:00:17, Serial0
R 3.0.0.0/8 [120/3] via 1.2.0.1, 00:00:17, Serial0
R 4.0.0.0/8 [120/3] via 1.2.0.1, 00:00:17, Serial0
R 10.0.0.0/8 [120/1] via 1.2.0.1, 00:00:17, Serial0
P1R2#
```

The shaded lines in Example A-25 indicate the routes that P1R2 has learned from P1R1, by P1R1 redistributing them into RIP from BGP.

## Distribute Lists

This section details the configuration of distribute lists for filtering BGP information.

The **neighbor distribute-list** *{ip-address | peer-group-name}* **distribute-list** *access-list-number in | out* router configuration command is used to distribute BGP neighbor information as specified in an access list. The parameters for this command are detailed in Table A-24.

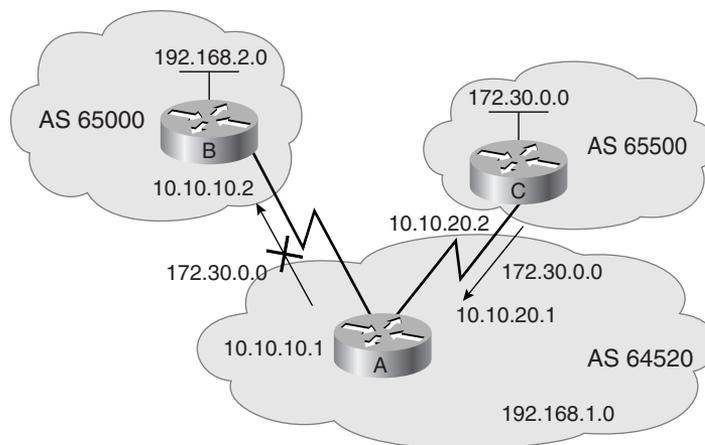
**Table A-24** *neighbor distribute-list* Command Description

<b>neighbor distribute-list Command</b>	<b>Description</b>
<i>ip address</i>	Gives the IP address of the BGP neighbor for which routes will be filtered.
<i>peer-group-name</i>	Gives the name of a BGP peer group. (Peer groups are detailed in the “Peer Groups” section later in this supplement.)

**Table A-24** *neighbor distribute-list Command Description (Continued)*

<b>neighbor distribute-list Command</b>	<b>Description</b>
<i>access-list-number</i>	Gives the number of a standard or extended access list. It can be an integer from 1 to 199. (A named access list can also be referenced.)
<b>in</b>	Indicates that the access list is applied to incoming advertisements from the neighbor.
<b>out</b>	Indicates that the access list is applied to outgoing advertisements to the neighbor.

Example A-26 provides a configuration for Router A in Figure A-25.

**Figure A-25** *Network for BGP Distribute List Example***Example A-26** *Configuration of Router A in Figure A-25*

```
RtrA(config)#router bgp 64520
RtrA(config-router)# network 192.168.1.0
RtrA(config-router)# neighbor 10.10.10.2 remote-as 65000
RtrA(config-router)# neighbor 10.10.20.2 remote-as 65500
RtrA(config-router)# neighbor 10.10.10.2 distribute-list 1 out
RtrA(config-router)# exit
RtrA(config)# access-list 1 deny 172.30.0.0 0.0.255.255
RtrA(config)# access-list 1 permit 0.0.0.0 255.255.255.255
```

In this example, Router A has two neighbors, Router B (10.10.10.2 in AS 65000) and Router C (10.10.20.2 in AS 65500). When Router A sends updates to neighbor Router B,

the **neighbor distribute-list** statement specifies that it will use the **access-list 1** to determine which updates are to be sent.

Access list 1 specifies that any route starting with 172.30—in this case, the route to 172.30.0.0—should not be sent (it is denied in the access list). All other routes will be sent to Router B. (Recall that because access lists have an implicit deny any at the end, the permit statement is required in the access list for the other routes to be sent.)

As shown in Example A-26, a standard IP access list can be used to control the sending of updates about a specific network number. However, if you need to control updates about subnets and supernets of a network with a distribute list, extended access lists would be required.

## Extended Access List Use in a Distribute List

When an IP extended access list is used with a distribute list, the parameters have different meanings than when the extended access list is used in other ways. The syntax of the IP extended access list is the same as usual, with a source address and wildcard, and a destination address and wildcard. However, the meanings of these parameters are different.

The *source* parameters of the extended access list are used to indicate the *address of the network* whose updates are to be permitted or denied. The *destination* parameters of the extended access list are used to indicate the *subnet mask of that network*.

The *wildcard* parameters indicate, for the network and subnet mask, which bits are relevant. Network and subnet mask bits corresponding to wildcard bits set to 1 are ignored during comparisons, and network and subnet mask bits corresponding to wildcard bits set to 0 are used in comparisons.

The following example shows an extended access list:

```
access-list 101 ip permit 172.0.0.0 0.255.255.255 255.0.0.0 0.0.0.0
```

The interpretation of the previous **access-list** when used with a **neighbor distribute-list** command is to permit only a route to network 172.0.0.0/255.0.0.0. Therefore, the list would allow only the supernet 172.0.0.0/8 to be advertised. For example, assume that Router A had routes to networks 172.20.0.0/16 and 172.30.0.0/16, and also had an aggregated route to 172.0.0.0/8. The use of this **access-list** would allow only the supernet 172.0.0.0/8 to be advertised; networks 172.20.0.0/16 and 172.30.0.0/16 would not be advertised.

## Route Maps

Route maps were introduced in Chapter 8. They are reviewed here in the context of BGP and for use in communities, discussed in the next section.

A route map is a method used to control and modify routing information. This is done by defining conditions for redistributing routes from one routing protocol to another or controlling routing information when injected into and out of BGP.

Route maps are complex access lists that allow some conditions to be tested against the route in question using **match** commands. If the conditions match, some actions can be taken to modify the route. These actions are specified by **set** commands.

If the **match** criteria are met and the route map specifies **permit**, then the routes will be controlled as specified by the **set** actions, and the rest of the route map list will be ignored.

If the **match** criteria are met and the route map specifies **deny**, then the routes will not be controlled and the rest of the route-map list will be ignored.

If all sequences in the list are checked without a match, then the route will not be accepted nor forwarded (this is the implicit **deny any** at the end of the route map).

**match** commands include the following:

- **match as-path**
- **match community**
- **match clns**
- **match interface**
- **match ip address**
- **match ip next-hop**
- **match ip route-source**
- **match metric**
- **match route-type**
- **match tag**

**set** commands include the following:

- **set as-path**
- **set clns**
- **set automatic-tag**
- **set community**
- **set interface**
- **set default interface**
- **set ip default next-hop**
- **set level**
- **set local-preference**
- **set metric**
- **set metric-type**
- **set next-hop**

- **set origin**
- **set tag**
- **set weight**

For example, the **set local-preference** *value* route map command is used to specify a preference value for the autonomous system path. The *value* is the local preference value from 0 to 4,294,967,295; a higher value is more preferred.

---

**NOTE** A prefix list can be used as an alternative to an access list in the **match {ip address | next-hop | route-source}** *access-list* command of a route map. The configuration of prefix lists and access lists are mutually exclusive within the same sequence of a route map.

---

## Configuring Route Maps for BGP Updates

The **neighbor** {*ip-address* | *peer-group-name*} **route-map** *map-name* {**in** | **out**} router configuration command is used to apply a route map to incoming or outgoing BGP routes, as detailed in Table A-25.

**Table A-25** *neighbor route-map* Command Description

---

<b>neighbor route-map Command</b>	<b>Description</b>
<i>ip-address</i>	Gives the IP address of the BGP neighbor for which routes will be filtered.
<i>peer-group-name</i>	Gives the name of a BGP peer group. (Peer groups are detailed in the “Peer Groups” section, later in this supplement.)
<i>map-name</i>	Gives the name of the route map to apply.
<b>in</b>	Apply route map to incoming routes from the neighbor.
<b>out</b>	Apply route map to outgoing routes to the neighbor.

---

**NOTE** When used for filtering BGP updates, route maps *cannot* be used to filter inbound updates when using a match on the IP address. Filtering outbound updates is permitted.

---

Example A-27 shows BGP running on a router. A route map named *changemetric* is being used when routes are sent out to neighbor 172.20.1.1.

**Example A-27** Configuration Filtering BGP Updates Using a Route Map

```
RtrA(config)# router bgp 64520
RtrA(config-router)# neighbor 172.20.1.1 route-map changemetric out
RtrA(config)# route-map changemetric permit 10
RtrA(config-route-map)# match ip address 1
RtrA(config-route-map)# set metric 2
RtrA(config-route-map)# exit
RtrA(config)# route-map changemetric permit 20
RtrA(config-route-map)# set metric 5
RtrA(config-route-map)# exit
RtrA(config)# access-list 1 permit 172.16.0.0 0.0.255.255
```

---

**NOTE** Other **router bgp** configuration commands have been omitted from the commands in Example A-27.

---

In this example, two instances of `changemetric` have been defined. Sequence number 10 will be checked first. If a route's IP address matches access list 1—in other words, if the IP address starts with 172.16—the route will have its metric (MED) set to 2, and the rest of the list will be ignored. If there is no match, then sequence number 20 will be checked. Because there is no match statement in this instance, the metric (MED) on all other routes will be set to 5.

---

**NOTE** It is always very important to plan what will happen to routes that do not match any of the route map instances because they will be dropped by default.

---

## Communities

This section discusses BGP communities and how to configure them.

As discussed in Chapter 6, “Configuring Basic Border Gateway Protocol,” BGP communities are another way to filter incoming or outgoing BGP routes. Distribute lists and prefix lists (discussed in the previous section in this supplement, “Distribute Lists,” and in Chapter 7, “Implementing BGP in Scalable Networks,” respectively) would be cumbersome to configure for a large network with a complex routing policy. For example, individual neighbor statements and access lists or prefix lists would need to be configured for each neighbor on each router that was involved in the policy.

The BGP communities function allows routers to tag routes with an indicator (the *community*) and allows other routers to make decisions (filter) based upon that tag. BGP communities are used for destinations (routes) that share some common properties and that therefore share common policies; routers, therefore, act on the community rather than on

individual routes. Communities are not restricted to one network or one autonomous system (AS), and they have no physical boundaries.

If a router does not understand the concept of communities, it will pass it on to the next router. However, if the router does understand the concept, it must be configured to propagate the community; otherwise, communities are dropped by default.

## Community Attribute

The community attribute is an optional transitive attribute that can have a value in the range 0 to 4,294,967,200. Each network can be a member of more than one community.

The community attribute is a 32-bit number, with the upper 16 bits indicating the AS number of the AS that defined the community. The lower 16 bits are the community number and have local significance. The community value can be entered as one decimal number or in the format *AS:nn* (where *AS* is the AS number and *nn* is the lower 16-bit local number). The community value is displayed as one decimal number by default.

## Setting and Sending Communities Configuration

Route maps can be used to set the community attributes.

The **set community** {*community-number* [**additive**]} | **none** route map configuration command is used within a route map to set the BGP communities attribute, as described in Table A-26.

**Table A-26** *set community* Command Description

---

<b>set community</b> Command	Description
<i>community-number</i>	Is the community number; values are 1 to 4,294,967,200.
<b>additive</b>	(Optional) Specifies that the community is to be added to the already existing communities.
<b>none</b>	Removes the community attribute from the prefixes that pass the route map.

---

Predefined well-known community numbers that can be used in the **set community** command are as follows:

- **no-export**—Do not advertise to EBGp peers.
- **no-advertise**—Do not advertise this route to any peer.
- **local-AS**—Do not send outside local AS.

**NOTE** The **set community** command is used along with the **neighbor route-map** command to apply the route map to updates.

The **neighbor** {*ip-address* | *peer-group-name*} **send-community** router configuration command is used to specify that the BGP communities attribute should be sent to a BGP neighbor. This command is detailed in Table A-27.

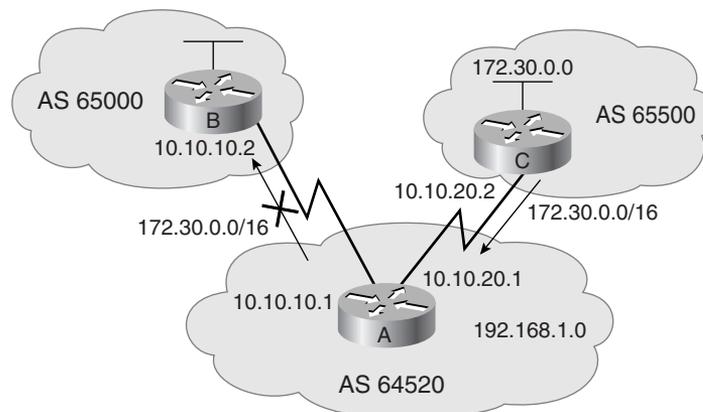
**Table A-27** *neighbor send-community Command Description*

<b>neighbor send-community Command</b>	<b>Description</b>
<i>ip address</i>	IP address of the BGP neighbor to which the communities attribute will be sent.
<i>peer-group-name</i>	Name of a BGP peer group. (Peer groups are detailed in the “Peer Groups” section, later in this supplement.)

By default, the communities attribute is not sent to any neighbor (communities are stripped in outgoing BGP updates).

In the example shown in Figure A-26, Router C is sending BGP updates to Router A, but it does not want Router A to propagate these routes to Router B.

**Figure A-26** *Network for BGP Communities Example*



The configuration for Router C in this example is provided in Example A-28. Router C sets the community attribute in the BGP routes that it is advertising to Router A. The **no-export**

community attribute is used to indicate that Router A should not send the routes to its external BGP peers.

**Example A-28** Configuration of Router C in Figure A-26

```

router bgp 65500
  network 172.30.0.0
  neighbor 10.10.20.1 remote-as 64520
  neighbor 10.10.20.1 send-community
  neighbor 10.10.20.1 route-map SETCOMM out
!
route-map SETCOMM permit 10
  match ip address 1
  set community no-export
!
access-list 1 permit 0.0.0.0 255.255.255.255

```

In this example, Router C has one neighbor, 10.10.20.1 (Router A). When communicating with Router A, the community attribute is sent, as specified by the **neighbor send-community** command. The route map SETCOMM is used when sending routes to Router A, to set the community attribute. Any route that matches **access-list 1** will have the community attribute set to **no-export**. Access list 1 permits any routes; therefore, all routes will have the community attribute set to **no-export**.

In this example, Router A will receive all of Router C's routes but will not pass them on to Router B.

## Using Communities Configuration

The **ip community-list community-list-number permit | deny community-number** global configuration command is used to create a community list for BGP and to control access to it, as described in Table A-28.

**Table A-28** *ip community-list Command Description*

<b>ip community-list Command</b>	<b>Description</b>
<i>community-list-number</i>	Community list number, in the range 1 to 99
<i>community-number</i>	Community number, configured by a <b>set community</b> command

Some predefined well-known community numbers that can be used with the **ip community-list** command are as follows:

- **no-export**—Do not advertise to EBGp peers.
- **no-advertise**—Do not advertise this route to any peer.

- **local-AS**—Do not send outside local AS.
- **internet**—Advertise this route to the Internet community and any router that belongs to it.

The **match community** *community-list-number* [**exact**] route map configuration command is used to match a BGP community attribute to a value in a community list, as described in Table A-29.

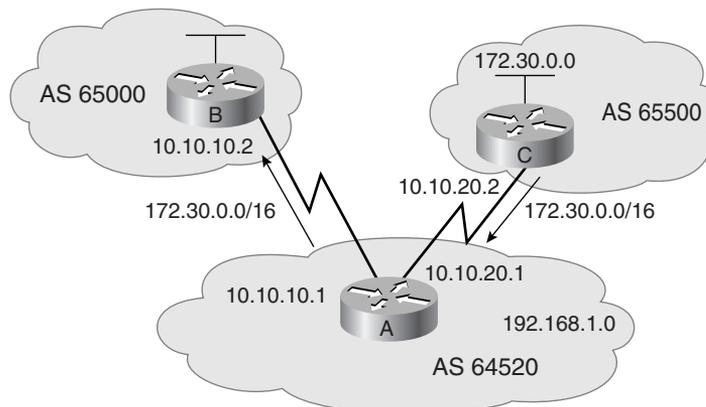
**Table A-29** *match community Command Description*

<b>match community Command</b>	<b>Description</b>
<i>community-list-number</i>	Community list number, in the range 1 to 99, that will be used to compare the community attribute.
<b>exact</b>	(Optional) Indicates that an exact match is required. All the communities and only those communities in the community list must be present in the community attribute.

**NOTE** The **match community** command appears in the documentation as the **match community-list** command; however, only **match community** actually works on the routers.

In the example shown in Figure A-27, Router C is sending BGP updates to Router A. Router A will set the weight of these routes based on the community value set by Router C.

**Figure A-27** *Network for BGP Communities Example Using Weight*



The configuration for Router C in Figure A-27 is shown in Example A-29. Router C has one neighbor, 10.10.20.1 (Router A).

**Example A-29** *Configuration of Router C in Figure A-27*

```
router bgp 65500
  network 172.30.0.0
  neighbor 10.10.20.1 remote-as 64520
  neighbor 10.10.20.1 send-community
  neighbor 10.10.20.1 route-map SETCOMM out
!
route-map SETCOMM permit 10
  match ip address 1
  set community 100 additive
!
access-list 1 permit 0.0.0.0 255.255.255.255
```

In this example, the community attribute will be sent to Router A, as specified by the **neighbor send-community** command. The route map SETCOMM is used when sending routes to Router A to set the community attribute. Any route that matches access-list 1 will have community 100 added to the existing communities in the community attribute of the route. In this example, access list 1 permits any routes; therefore, all routes will have 100 added to the list of communities. If the **additive** keyword in the **set community** command was not set, 100 will replace any old community that already exists; because the keyword **additive** is used, the 100 will be added to the list of communities that the route is part of.

The configuration for Router A in Figure A-27 is shown in Example A-30.

**Example A-30** *Configuration of Router A in Figure A-27*

```
router bgp 64520
  neighbor 10.10.20.2 remote-as 65500
  neighbor 10.10.20.2 route-map CHKCOMM in
!
route-map CHKCOMM permit 10
  match community 1
  set weight 20
route-map CHKCOMM permit 20
  match community 2
!
ip community-list 1 permit 100
ip community-list 2 permit internet
```

---

**NOTE**

Other **router bgp** configuration commands for Router A are not shown in Example A-30.

---

In this example, Router A has a neighbor, 10.10.20.2 (Router C). The route map CHKCOMM is used when receiving routes from Router C to check the community attribute. Any route whose community attribute matches community list 1 will have its weight attribute set to 20. Community list 1 permits routes with a community attribute of 100; therefore, all routes from Router C (which all have 100 in their list of communities) will have their weight set to 20.

In this example, any route that did not match community list 1 would be checked against community list 2. Any route matching community list 2 would be permitted but would not have any of its attributes changed. Community list 2 specifies the **internet** keyword, which means all routes.

The example output shown in Example A-31 is from Router A in Figure A-27. The output shows the details about the route 172.30.0.0 from Router C, including that its community attribute is 100 and its weight attribute is now 20.

**Example A-31** Output from Router A in Figure A-27

```
RtrA #show ip bgp 172.30.0.0/16
BGP routing table entry for 172.30.0.0/16, version 2
Paths: (1 available, best #1)
  Advertised to non peer-group peers:
    10.10.10.2
  65500
    10.10.20.2 from 10.10.20.2 (172.30.0.1)
      Origin IGP, metric 0, localpref 100, weight 20, valid, external, best, ref 2
      Community: 100
```

## Peer Groups

This section discusses peer groups and how to configure them.

In BGP, many neighbors often are configured with the same update policies (that is, the same outbound route maps, distribute lists, filter lists, update source, and so on). On Cisco routers, neighbors with the same update policies can be grouped into peer groups to simplify configuration and, more importantly, to make updating more efficient. When you have many peers, this approach is highly recommended.

A BGP peer group is a group of BGP neighbors with the same update policies. Instead of separately defining the same policies for each neighbor, a peer group can be defined with these policies assigned to the peer group. Individual neighbors are then made members of the peer group.

Members of the peer group inherit all the configuration options of the peer group. Members can also be configured to override these options if these options do not affect outbound updates; in other words, only options that affect the inbound updates can be overridden.

Peer groups are useful to simplify configurations when many neighbors have the same policy. They are also more efficient because updates are generated only once per peer group rather than once for each neighbor.

The peer group name is local only to the router it is configured on; it is not passed to any other router.

## Peer Group Configuration

The **neighbor *peer-group-name* peer-group** router configuration command is used to create a BGP peer group. The *peer-group-name* is the name of the BGP peer group to be created.

Another syntax of the **neighbor peer-group** command is used to assign neighbors as part of the group; use the **neighbor *ip-address* peer-group *peer-group-name*** router configuration command. The details of this command are shown in Table A-30.

**Table A-30** *neighbor peer-group* Command Description

---

<b>neighbor peer-group Command</b>	<b>Description</b>
<i>ip-address</i>	IP address of the neighbor that is to be assigned as a member of the peer group
<i>peer-group-name</i>	Name of the BGP peer group

---

The **clear ip bgp peer-group *peer-group-name* EXEC** command is used to clear the BGP connections for all members of a BGP peer group. The *peer-group-name* is the name of the BGP peer group for which connections are to be cleared.

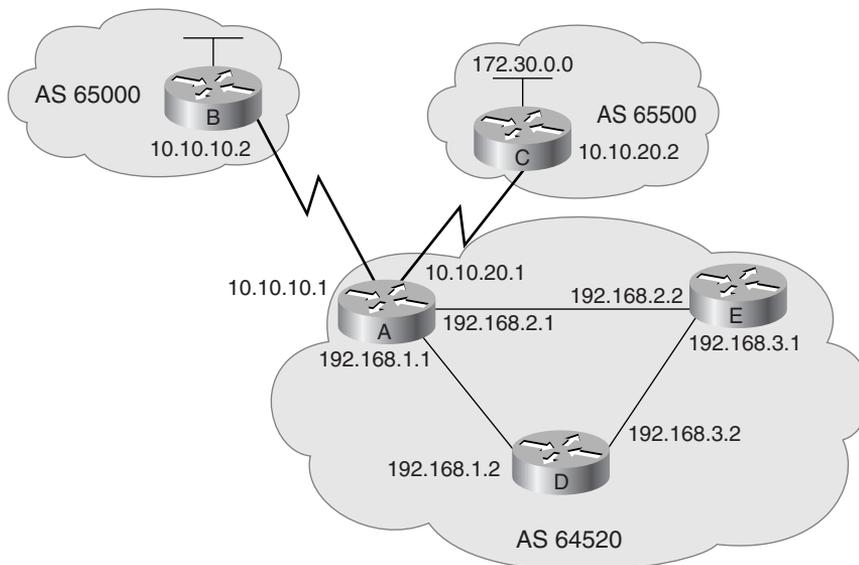
---

**NOTE** The Cisco documentation says that the **clear ip bgp peer-group** command is used to *remove* all the members of a BGP peer group; however, it actually clears the connections.

---

## Peer Group Example

In the example shown in Figure A-28, Router A has two internal neighbors, routers D and E, and two external neighbors, routers B and C. The routing policies for routers D and E are the same, and the routing policies for routers B and C are the same.

**Figure A-28** Network for BGP Peer Group Example

Router A is configured with two peer groups, one for internal neighbors and one for external neighbors, rather than individual neighbor configurations. Example A-32 shows part of the configuration for Router A, for the internal neighbors.

**Example A-32** Router A in Figure A-28 Configuration for Internal Neighbors

```
router bgp 64520
 neighbor INTERNALMAP peer-group
 neighbor INTERNALMAP remote-as 64520
 neighbor INTERNALMAP prefix-list PREINTIN in
 neighbor INTERNALMAP prefix-list PREINTOUT out
 neighbor INTERNALMAP route-map SETINTERNAL out
 neighbor 192.168.2.2 peer-group INTERNALMAP
 neighbor 192.168.1.2 peer-group INTERNALMAP
 neighbor 192.168.2.2 prefix-list JUST2 in
```

This configuration creates a peer group called INTERNALMAP. All members of this peer group are in AS 64520. A prefix list called PREINTIN will be applied to all routes from members of this peer group, and a prefix list called PREINTOUT will be applied to all routes going to members of this peer group. A route map called SETINTERNAL will be applied to all routes going to members of this peer group.

Router E (192.168.2.2) and Router D (192.168.1.2) are members of the peer group INTERNALMAP.

A prefix list called JUST2 will be applied to all routes from Router E (192.168.2.2). Recall that you can override only peer group options that affect inbound updates.

---

**NOTE** **Router bgp** configuration commands for Router A not related to peer groups are not shown in Example A-32.

---

Example A-33 shows part of the configuration for Router A in Figure A-28, for the external neighbors.

**Example A-33** *Router A in Figure A-28 Configuration for External Neighbors*

```
router bgp 64520
  neighbor EXTERNALMAP peer-group
  neighbor EXTERNALMAP prefix-list PREEXTIN in
  neighbor EXTERNALMAP prefix-list PREEXTOUT out
  neighbor EXTERNALMAP route-map SETEXTERNAL out
  neighbor 10.10.10.2 remote-as 65000
  neighbor 10.10.10.2 peer-group EXTERNALMAP
  neighbor 10.10.10.2 prefix-list JUSTEXT2 in
  neighbor 10.10.20.2 remote-as 65500
  neighbor 10.10.20.2 peer-group EXTERNALMAP
```

This configuration creates a peer group called EXTERNALMAP. A prefix list called PREEXTIN will be applied to all routes from members of this peer group, and a prefix list called PREEXTOUT will be applied to all routes going to members of this peer group. A route map called SETEXTERNAL will be applied to all routes going to members of this peer group.

Router B (10.10.10.2) is in AS 65000 and is a member of the peer group EXTERNALMAP. Router C (10.10.20.2) is in AS 65500 and is a member of the peer group EXTERNALMAP.

A prefix list called JUSTEXT2 will be applied to all routes from Router B (10.10.10.2). Recall that you can override only peer group options that affect inbound updates.

---

**NOTE** **Router bgp** configuration commands for Router A not related to peer groups are not shown in Example A-33.

---

## Supplement 6: Route Optimization

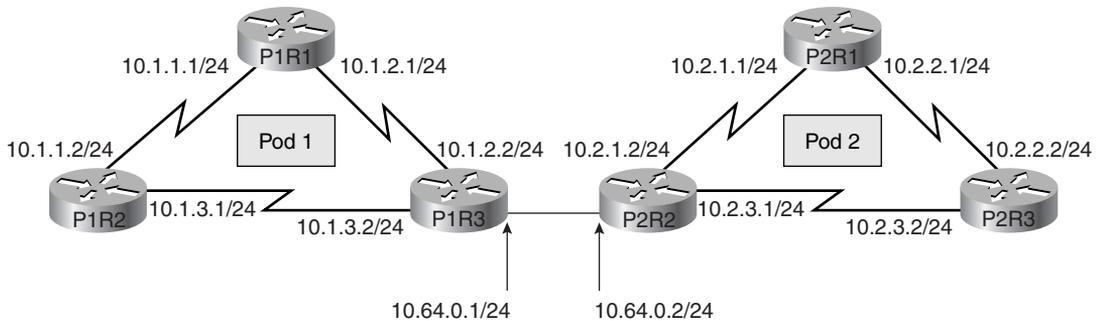
This supplement reviews the following topics:

- Examples of redistribution in a nonredundant configuration
- Miscellaneous redistribution configuration examples

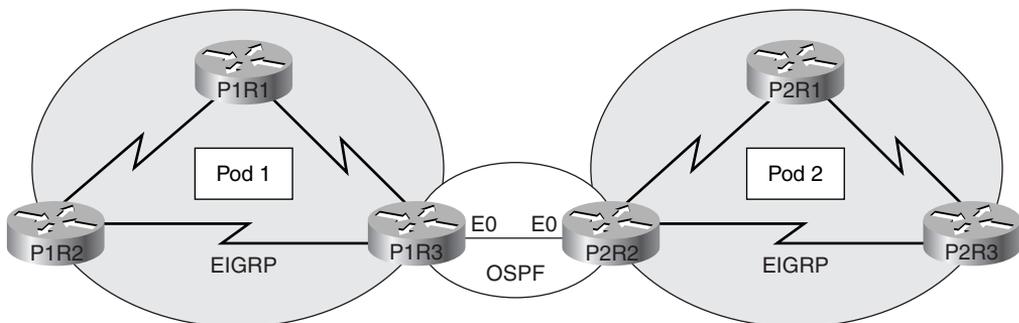
### Examples of Redistribution in a Nonredundant Configuration

This section includes configuration and **show** command output examples that result from configuring the network shown in Figure A-29. The addresses for this configuration are also shown in Figure A-29; protocols for the example are shown in Figure A-30.

**Figure A-29** Addressing for Redistribution Configuration Example



**Figure A-30** Example Nonredundant Redistribution Configuration



## Example of Redistribution Between EIGRP and OSPF

Example A-34 shows the configuration output for P1R3, an ASBR supporting EIGRP and OSPF.

**Example A-34** *ASBR in Figures A-29 and A-30, Redistributing Between EIGRP and OSPF*

```
P1R3#show run
Building configuration...
Current configuration:
!
version 11.2
hostname P1R3
!
enable password san-fran
!
no ip domain-lookup
ipx routing 0000.0c01.3333
ipx maximum-paths 2
!
interface Loopback0
 no ip address
 ipx network 1013
!
interface Ethernet0
 ip address 10.64.0.1 255.255.255.0
!
interface Serial0
 ip address 10.1.3.2 255.255.255.0
 bandwidth 64
 ipx input-sap-filter 1000
 ipx network 1003
!
interface Serial1
 ip address 10.1.2.2 255.255.255.0
 ipx input-sap-filter 1000
 ipx network 1002
 clockrate 56000
<Output Omitted>
!

router eigrp 200

 redistribute ospf 300 metric 10000 100 255 1 1500
 passive-interface Ethernet0
 network 10.0.0.0
!

router ospf 300

 redistribute eigrp 200 subnets
 network 10.64.0.0 0.0.255.255 area 0
!
no ip classless
```

**Example A-34** ASBR in Figures A-29 and A-30, Redistributing Between EIGRP and OSPF (Continued)

```

line con 0
exec-timeout 20 0
password cisco
!
line aux 0
line vty 0 4
password cisco
!
end

```

In Example A-34, EIGRP in AS 200 is configured for all interfaces in network 10.0.0.0. The **passive-interface** command is used to disable EIGRP on the ethernet (because OSPF will be running there). Routes from OSPF are redistributed into EIGRP with the **redistribute** command, using the defined metrics. OSPF is configured to run on the ethernet 0 interface, in area 0. Routes from EIGRP are redistributed into OSPF; the **subnets** keyword is included so that subnetted routes (in this case, subnets of network 10.0.0.0) will be redistributed. If this keyword were omitted, no routes would be redistributed from OSPF to EIGRP in this example.

Example A-35 shows outputs verifying that external routes are learned by OSPF and EIGRP, respectively, on an ASBR.

**Example A-35** OSPF and EIGRP Topology Databases of P1R3 in Figures A-29 and A-30

```

P1R3#show ip ospf database

      OSPF Router with ID (10.64.0.1) (Process ID 300)

          Router Link States (Area 0)

Link ID        ADV Router    Age         Seq#          Checksum Link count
10.64.0.1     10.64.0.1    280        0x80000005   0x767F   1
10.64.0.2     10.64.0.2    274        0x80000004   0x767D   1

          Net Link States (Area 0)

Link ID        ADV Router    Age         Seq#          Checksum
10.64.0.2     10.64.0.2    274        0x80000002   0x7791

Type-5 AS External Link States

Link ID        ADV Router    Age         Seq#          Checksum Tag
10.1.1.0       10.64.0.1    202        0x80000002   0xE95E   0
10.1.2.0       10.64.0.1    202        0x80000002   0xDE68   0
10.1.3.0       10.64.0.1    202        0x80000002   0xD372   0
10.2.1.0       10.64.0.2    1686       0x80000001   0xD96D   0
10.2.2.0       10.64.0.2    1686       0x80000001   0xCE77   0

```

*continues*

**Example A-35 OSPF and EIGRP Topology Databases of P1R3 in Figures A-29 and A-30 (Continued)**

10.2.3.0	10.64.0.2	1686	0x80000001	0xC381	0
10.64.0.0	10.64.0.1	204	0x80000002	0xFD0C	0
10.64.0.0	10.64.0.2	1688	0x80000001	0xF910	0
P1R3#					
P1R3# <b>show ip eigrp topology</b>					
IP-EIGRP Topology Table for process 200					
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,					
r - Reply status					
P 10.1.3.0/24, 1 successors, FD is 40512000					
via Connected, Serial0					
via 10.1.2.1 (3193856/2681856), Serial1					
P 10.2.1.0/24, 1 successors, FD is 281600					
via Redistributed (281600/0)					
P 10.1.2.0/24, 1 successors, FD is 2169856					
via Connected, Serial					
P 10.2.2.0/24, 1 successors, FD is 281600					
via Redistributed (281600/0)					
P 10.1.1.0/24, 1 successors, FD is 2681856					
via 10.1.2.1 (2681856/2169856), Serial1					
P 10.2.3.0/24, 1 successors, FD is 281600					
via Redistributed (281600/0)					
P 10.64.0.0/24, 1 successors, FD is 281600					
via Connected, Ethernet0					

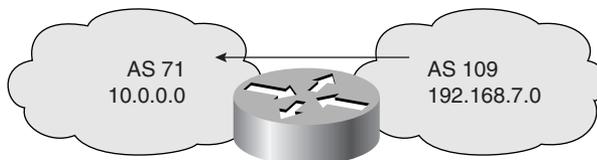
In Example A-35, you can see from the **show ip ospf database** command output that P1R3 learns external routes (type 5 LSAs) in OSPF. Note that subnetted networks are included. EIGRP also learns external routes, shown as redistributed routes in the **show ip eigrp topology** command output.

## Miscellaneous Redistribution Configuration Examples

This section presents examples of one-way redistribution.

### IGRP Redistribution Example

Cisco IOS software supports multiple IGRP autonomous systems. Each autonomous system maintains its own routing database. You can redistribute routing information among these routing databases. Table A-31 describes some of the commands seen in Example A-36. Refer to Figure A-31 for the topology used in Example A-36.

**Figure A-31** *Figure A-31 IGRP Redistribution Configuration Example***Example A-36** *Routes Redistributed from AS 109 into AS 71 in Figure A-31*

```
router igrp 71
 redistribute igrp 109
 distribute-list 3 out igrp 109
 access-list 3 permit 192.168.7.0 0.0.0.255
```

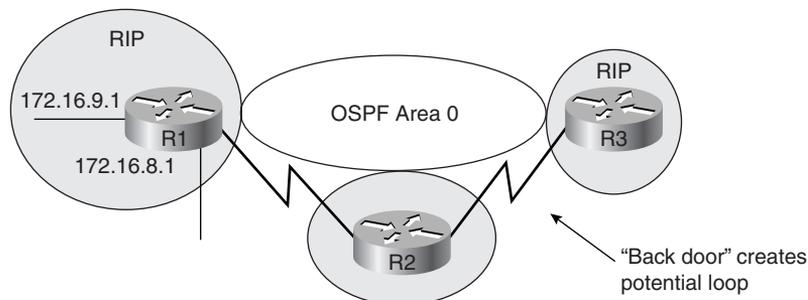
**Table A-31** *Redistribution Commands in Example A-36*

Command	Description
<b>redistribute igrp 109</b>	Redistributes routes from IGRP 109 into IGRP 71.
<b>distribute list 3 out igrp 109</b>	Uses access list 3 to define which routes will be redistributed from IGRP 109 into IGRP 71.
<b>3</b>	Redistributes per access list 3.
<b>out</b>	Applies the access list to outgoing routing updates.
<b>igrp 109</b>	Identifies the IGRP routing process to filter.
<b>access-list 3 permit 192.168.7.0 0.0.0.255</b>	Permits routes from only network 192.168.7.0.

In Example A-36, only routing updates from the 192.168.7.0 network are redistributed into autonomous system 71. Updates from other networks are denied.

## RIP/OSPF Redistribution Example

In Example A-37 and Figure A-32, there is an additional path connecting the RIP clouds. These paths, or “back doors,” frequently exist, allowing the potential for feedback loops. You can use access lists to determine the routes that are advertised and accepted by each router.

**Figure A-32** *Blocking Paths to Avoid Looping***Example A-37** *Avoiding Loops While Redistributing on Router R1 in Figure A-32*

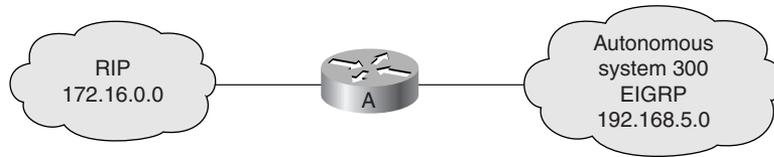
```
hostname R1
!
router ospf 109
 network 172.16.62.0 0.0.0.255 area 0
 network 172.16.63.0 0.0.0.255 area 0
 redistribute rip subnets metric-type 1 metric 20
 distribute-list 11 out rip

access-list 11 permit 172.16.8.0 0.0.7.255
```

For example, access list 11 in the configuration file for Router R1 allows OSPF to redistribute information learned from RIP only for networks 172.16.8.0 through 172.16.15.0. These commands prevent Router R1 from advertising networks in other RIP domains onto the OSPF backbone, thereby preventing other boundary routers from using false information and forming a loop. You would configure similar access lists on R2 and R3.

## Redistribution Example Using Default Metric

In Figure A-33 and Example A-38, the router is redistributing IP RIP and EIGRP routes. The 192.168.5.0 network is redistributed to the IP RIP network with a metric of three hops. EIGRP in autonomous system 300 learns routes from IP RIP.

**Figure A-33** *Redistributing RIP and EIGRP***Example A-38** *Redistribution Using Default Metric in Figure A-33*

```

router rip
  network 172.16.0.0
  redistribute eigrp 300
  default-metric 3
router eigrp 300
  network 192.168.5.0
  redistribute rip
  default-metric 56 2000 255 1 1500

```

Table A-32 describes some of the commands seen in Example A-38.

**Table A-32** *Redistribution Commands in Example A-38*

Command	Description
<b>redistribute eigrp 300</b>	Enables redistribution of routes learned from EIGRP autonomous system 300 into the IP RIP network.
<b>default-metric 3</b>	Specifies that EIGRP-learned routes are three hops away.
<b>redistribute rip</b>	Enables redistribution of routes learned from the IP RIP network into EIGRP autonomous system 300.
<b>default-metric 56 2000 255 1 1500</b>	Indicates that the RIP-derived network is being redistributed with the following EIGRP metric values:
<b>56</b>	Bandwidth is 56 kbps.
<b>2000</b>	Delay is 2000 tens of microseconds.
<b>255</b>	Reliability is 100 percent (255 of 255).
<b>1</b>	Loading is less than 1 percent (1 of 255).
<b>1500</b>	MTU is 1500 bytes.

## Redistribution Example Using Filtering

Figure A-34 and Example A-39 provide an example of a redistribution filtering.

**Figure A-34** *Redistribution Using Filtering and Default Metric***Example A-39** *R1 in Figure A-34 Hides Network 10.0.0.0 Using Redistribution Filtering*

```
hostname R1
!
router rip
 network 192.168.5.0
 redistribute eigrp 1
 default-metric 3
 distribute-list 7 out eigrp 1
!
router eigrp 1
 network 172.16.0.0
 redistribute rip
 default-metric 56 2000 255 1 1500
!
access-list 7 deny 10.0.0.0 0.255.255.255
access-list 7 permit 0.0.0.0 255.255.255.255
```

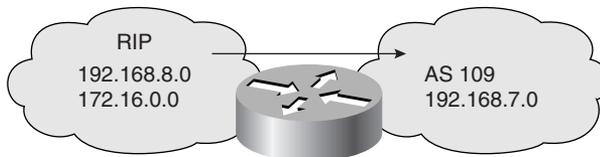
Table A-33 describes some of the commands seen in Example A-39.

**Table A-33** *R6 Redistribution Filtering Commands in Example A-39*

Command	Description
<b>redistribute eigrp 1</b>	Enables routes learned from EIGRP autonomous system 1 to be redistributed into IP RIP.
<b>default-metric 3</b>	Specifies that all routes learned from EIGRP will be advertised by RIP as reachable in three hops.
<b>distribute-list 7 out eigrp 1</b>	Defines that routes defined by access-list 7 leaving the EIGRP process will be filtered before being given to the RIP process.

## Redistribution Example Using Filtering and Default Metric

Figure A-35 and Example A-40 provide an example of a redistribution filtering and default metric.

**Figure A-35** *Figure A-35 Redistribution Filtering and Default Metric***Example A-40** *Redistributing RIP and IGRP*

```

router rip
  network 192.168.8.0
  network 172.16.0.0
  redistribute igrp 109
  default-metric 4
  distribute-list 11 out igrp 109
!
router igrp 109
  network 192.168.7.0
  redistribute rip
  default-metric 10000 100 255 1 1500
  distribute-list 10 out rip

access-list 10 permit 172.16.0.0 0.0.255.255
access-list 11 permit 192.168.7.0 0.0.0.255

```

Table A-34 describes some of the commands seen in Example A-40.

**Table A-34** *Redistribution and Route Filtering Commands in Example A-40*

Command	Description
<b>redistribute igrp 109</b>	Redistributes IGRP routes into RIP.
<b>default-metric 4</b>	Sets the metric for IGRP-derived routes to four hops.
<b>redistribute rip</b>	Redistributes RIP routes into IGRP.
<b>default-metric</b>	Sets the metric for IGRP for all redistributed routes.
<b>10000</b>	Sets the minimum bandwidth of the route to 10,000 kbps.
<b>100</b>	Sets the delay to 100 tens of microseconds.
<b>255</b>	Sets the reliability, in this case, to the maximum.
<b>1</b>	Sets the loading to 1.
<b>1500</b>	Sets the MTU to 1500 bytes.
<b>distribute list 10 out rip</b>	Uses access list 10 to limit updates going out of RIP into IGRP.