# Configuring Single Area OSPF

OSPF’s basic configuration is very simple. Like with other routing protocols (RIP, EIGRP), you must first enable OSPF on a router using the router ospf PROCESS-ID global configuration command. Next, you need to define which interfaces OSPF will run and what networks will be advertised using the network IP_ADDRESS WILDCARD_MASK AREA_ID command from the OSPF configuration mode.

NOTE

The OSPF process number doesn’t have to be the same on all routers to establish a neighbor relationship, but the Area ID has to be the same on all neighboring routers for routers to become neighbors.

Let’s get started with some basic OSPF routing protocol configuration. We will use the following network topology:

ospf sample topology

Assume that the IP addresses and the basic configurations are already configured on the devices. To configure OSPF, we need to enable OSPF on both routers first. Then we need to define what network will be advertised in OSPF using the following sequence of commands on both routers:

```
R1(config-router)#router ospf 1
R1(config-router)#network 10.0.1.0 0.0.0.255 area 0
R1(config-router)#network 172.16.0.0 0.0.255.255 area 0

R2(config-router)#router ospf 1
R2(config-router)#network 192.168.0.0 0.0.0.255 area 0
R2(config-router)#network 172.16.0.0 0.0.255.255 area 0
```

The network commands entered on both routers include subnets directly connected to both routers. We can verify that the routers have become neighbors by typing the show ip ospf neighbors command on either router:

```
R1#show ip ospf neighbor
Neighbor ID Pri State Date Time Address Interface
192.168.0.2 1 FULL/BDR 00:00:32 172.16.0.2 FastEthernet0/1
```

To verify if the routing updates were exchanged, we can use the show ip route command. All routes marked with the character O are OSPF routes. For example, here is the output of the command on R1:

```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
```

```
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter
area
* - candidate default, U - per-user static route, o - ODR
P - periodic downloaded static route

Gateway of last resort is not set

10.0.0.0/24 is subnetted, 1 subnets
C 10.0.1.0 is directly connected, FastEthernet0/0
C 172.16.0.0/16 is directly connected, FastEthernet0/1
O 192.168.0.0/24 [110/2] via 172.16.0.2, 00:03:44, FastEthernet0/1
```

You can see in the routing table that R1 has learned about the network 192.168.0.0/24 through OSPF.

## Configuring Multiarea OSPF

Although basic OSPF configuration can be straightforward, OSPF provides many extra features that can get really complex. In this example, we will configure a multiarea OSPF network and some other OSPF features.

Consider the following multiarea OSPF network. Assume that the IP address and the basic configurations are already configured on each device.

ospf sample topology areas

In this example, we have two OSPF areas – area 0 and area 1. As you can see from the network topology depicted above, routers R1 and R3 are in area 0 and area 1, respectively. Router 2 connects to both areas, which makes him an ABR (Area Border Router). Our goal is to advertise the subnets directly connected to R1 and R3 by entering the following configurations on R1:

```
R1(config-router)#router ospf 1
R1(config-router)#network 10.0.1.0 0.0.0.255 area 0
R1(config-router)#network 172.16.0.0 0.0.255.255 area 0
R1(config-router)#router-id 1.1.1.1
```

NOTE

We have used the router-id 1.1.1.1 command to specify the router ID of this router manually. The OSPF process will use that RID (router-id) when communicating with other OSPF neighbors.

Because R1 connects only to R2, we only need to establish a neighbor relationship with R2 and advertise directly connected subnet into OSPF.

Configuration of R3 looks similar, but with one difference, namely area number. R3 is in area 1.

```
R3(config-router)#router ospf 1
R3(config-router)#network 192.168.0.0 0.0.0.255 area 1
R3(config-router)#network 90.10.0.0 0.0.0.255 area 1
R3(config-router)#router-id 3.3.3.3
```

What about R2? Because R2 is an ABR, we need to establish neighbor relationships with R1 and R3. To do that, we need to specify different area IDs for each neighbor relationship, 0 for R1 and 1 for R2. We can do that using the following sequence of commands:

```
R2(config-router)#router ospf 1
R2(config-router)#network 172.16.0.0 0.0.0.255 area 0
R2(config-router)#network 192.168.0.0 0.0.0.255 area 1
R2(config-router)#router-id 2.2.2.2
```

Now R2 should have a neighbor relationship with both R1 and R3. We can verify that by using the show ip ospf neighbor command:

```
R2#show ip ospf neighbor
Neighbor ID Pri State Date Time Address Interface
1.1.1.1 1 FULL/BDR 00:00:39 172.16.0.1 FastEthernet0/0
3.3.3.3 1 FULL/DR 00:00:36 192.168.0.2 FastEthernet0/1
```

To verify if directly connected subnets are really advertised into the different areas, we can use the show ip route ospf command on both R1 and R3:

```
R1#show ip route ospf
90.0.0.0/24 is subnetted, 1 subnets
O IA 90.10.0.0 [110/3] via 172.16.0.2, 00:12:48, FastEthernet0/1
O IA 192.168.0.0 [110/2] via 172.16.0.2, 00:12:48, FastEthernet0/1
R3#show ip route ospf
10.0.0.0/24 is subnetted, 1 subnets
O IA 10.0.1.0 [110/3] via 192.168.0.1, 00:13:47, FastEthernet0/0
O IA 172.168.0.0 [110/2] via 192.168.0.1, 00:13:47, FastEthernet0/0
```

OSPF Cost – OSPF Routing Protocol Metric Explained

OSPF is a dynamic routing protocol that uses Link State Routing (LSR) algorithm. It is one of the Interior Gateway Protocols (IGP) that operates within a single autonomous system. OSPF cost is its metric (the unit used by a router to make routing decisions).

OSPF executes a process using an algorithm developed by Edsger Dijkstra to find the shortest route to the advertising node. The router will then use this output as a candidate path for its routing table. For the OSPF to accurately represent topology, each link of the network must have an associated OSPF cost.

OSPF relies on costs that are inversely proportional to the bandwidth of the link. Therefore, higher bandwidth links are preferred to lower ones. The Cost formula is reference bandwidth divided by interface bandwidth. The default reference bandwidth of 100 Mbps is used for OSPF cost calculation.

For example, if we have an Ethernet interface (10 Mbps), the OSPF path cost value is 100 Mbps / 10 Mbps = 10.

OSPF Default Interface Cost Values

Here are the default Cost values for each interface type:

| | |
|---|---|
| Gigabit Ethernet Interface (1 Gbps) | 1 |
| Fast Ethernet Interface (100 Mbps) | 1 |
| Ethernet Interface (10 Mbps) | 10 |
| DS1 (1.544 Mbps) | 64 |
| DSL (768 Kbps) | 133 |

Cisco routers have three methods to change the OSPF interface cost:

1. By directly using the interface command ‘ip ospf cost <1-65535>’

```
Router#conf t
Router(config)#int gi0/0/0
Router(config-if)#ip ospf cost <1-65535>
```

We can verify this by using the ‘show ip ospf interface’ command.

2. Changing the ‘interface bandwidth’ setting (in kilobits), which changes the calculated value.

```
Router#conf t
Router(config)#int gi0/0/0
Router(config-if)#bandwidth <1-10000000>
```

3. Changing the OSPF reference bandwidth setting, which changes the calculated value.

```
Router#conf t
Router(config)#router ospf 1
```

```
Router(config-router)#auto-cost reference-bandwidth 100000
```

NOTE
Please ensure reference bandwidth is the same across all routers. The reference bandwidth command warns you that you need to make the same change across all your routers. This will allow all routers to make their calculations on the same information.

ospf cost
In our example, R1, R2, and R3 are running OSPF. From R1’s perspective, it installed both paths in its routing table since the links towards R2 and R3 have equal Costs of 1.

```
O       1.1.1.0/24 [110/2] via 10.2.2.2, 00:00:03,
GigabitEthernet0/0
                   [110/2] via 10.3.3.2, 00:00:03,
GigabitEthernet0/1
GigabitEthernet0/0 is up, line protocol is up
  Internet address is 10.2.2.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 1

GigabitEthernet0/1 is up, line protocol is up
  Internet address is 10.3.3.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 1
```

Let’s change R1 Gi0/1’s cost to 20.

```
R1#conf t
R1(config)#int gi0/1
R1(config-if)#ip ospf cost 20
```

For verification, let’s check the cost and the routing table again.

```
R1#sh ip ospf interface

GigabitEthernet0/0 is up, line protocol is up
  Internet address is 10.2.2.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 1


GigabitEthernet0/1 is up, line protocol is up
  Internet address is 10.3.3.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 20
```

Lower cost wins, and R3’s route was removed from our routing table.

```
O       1.1.1.0/24 [110/2] via 10.2.2.2, 00:00:00,
GigabitEthernet0/0
```

Cisco Bandwidth Command vs Clock Rate & Speed Commands
It’s pretty common for individuals, especially new network professionals, to get the two interface commands speed and bandwidth mixed up. Most believe that when applied to an interface, the Cisco bandwidth command and speed command have the same meaning and that the goal is to lower the interface’s throughput to the limit given by bandwidth or speed. The two commands have completely different scopes, and they do not limit the actual speed in any way.

Cisco Bandwidth Command

The Cisco bandwidth command is used to communicate the bandwidth value of an interface to higher-level protocols (Ex. routing protocols).

Set the inherited and received bandwidth values for an interface using the bandwidth statement in interface configuration mode. To restore the default bandwidth settings, use the no form of this command.

```
R1#conf t
R1(config)#int gi0/0
R1(config-if)#bandwidth ?
  <1-10000000>   Bandwidth in kilobits
  inherit        Specify how bandwidth is inherited
  qos-reference  Reference bandwidth for QOS test
  receive        Specify receive-side bandwidth
```

or

```
R1(config-if)#no bandwidth
```

inherit (Optional) Inherited bandwidth. Specifies how a subinterface inherits the bandwidth of its main interface.
receive (Optional) Receiver bandwidth. Entering this option enables asymmetric transmit/receive operations so that the transmitted (inherit [kbps]) and received bandwidth are different.

The Cisco bandwidth command is an optional but frequently used interface command. Despite the name, it is not intended to limit bandwidth, and it cannot be used to change an interface’s actual capacity. The interface bandwidth command is used to inform higher-level protocols about the interface’s speed.

The majority of the time, a routing protocol has to know the interface speed in order to determine the appropriate route. TCP will also change its initial retransmission parameters based on the bandwidth configured on the interface as a result of this operation.

## Speed Command

The explanation for the speed command is actually simpler than the bandwidth command. You can set the speed on some interfaces (hardware dependent). You can set it to 10 Mbps even if the interface is 100 Mbps. This indicates that the interface is allowed to send packets at speeds of up to 10 Mbps. You may ask, “What if we set the interface speed to 10 Mbps, does that mean OSPF or EIGRP will generate metrics based on that value?” Yes, of course.

What will you do, though, if the speed command has a value other than the normal 10 Mbps or 100 Mbps? 1 Mbps, for example. You can’t change the speed to 1. Or if you have a hardware card that won’t let you go faster than 1 Gbps? That’s why the bandwidth command is used to inform the higher-level protocols about the actual bandwidth capacity.

```
R1#conf t
R1(config)#int gi0/0
R1(config-if)#speed ?
  10    Force 10 Mbps operation
  100   Force 100 Mbps operation
  1000  Force 1000 Mbps operation
  auto  Enable AUTO speed configuration
```

or

```
R1(config-if)# no speed
```

## Clock Rate Command

On serial links, this command is used to set the clock rate. While both ends of the serial link can set the clock rate, the router will only accept the command from the DCE end (usually an ISP modem).

```
R1#conf t
R1(config)#int se0/1/0
R1(config-if)#clock rate 64000
```

or

```
R1(config-if)#no clock rate
```

## OSPF Passive Interface – Configuration and Why it is Used

OSPF is a link-state routing protocol that creates and keeps neighbor relationships by sharing routing updates with other OSPF routers. No routing information is exchanged and the only packets they exchange are Hello packets. Hello packets enables dynamic neighbor discovery and preserve neighbor connections. Passive interface command is used to suppress OSPF hello packets on a specified interface. It is also used in other routing protocols like RIP and EIGRP.

Enabling passive interfaces in our network devices mean that:

OSPF continues to announce or advertise the interface’s connected network.
OSPF routers stop sending OSPF Hellos on the interface.
On the interface, OSPF no longer processes any received Hellos.

## Why Do We Use OSPF Passive Interface?

The passive interface should be configured on interfaces that do not have an OSPF router connected to them so that they won’t receive any OSPF information. By silencing routing announcements on network interfaces, we tell the router to “listen but don’t talk.” A protocol’s routing load on the CPU can be reduced by minimizing the number of interfaces with which it must interact. The ‘passive-interface’ command disables OSPF and EIGRP route processing for that interface. If you’re sure the routing protocol won’t need to communicate with anything on the specified interface, use this command.

Another reason to apply passive interface is to increase security. An attacker could start an application that replies with OSPF hello packets then our router will try to establish neighbor relationship. The attacker could then advertise fake routes to misdirect traffic.

## OSPF Passive Interface Configuration

There are two ways to configure OSPF passive interface in our network devices.

1. If we only need to configure passive interface on a single or a couple of interfaces, we can individually configure them using the ‘passive-interface’ command:

```
Router#conf t
Router(config)#router ospf 1
Router(config-router)#passive-interface gi0/0/0
Router(config-router)#passive-interface gi0/0/1
```

2. If we need all interfaces to be passive interfaces and leaving a single or a couple of interfaces non-passive, we can set passive interface as the default configuration by using the ‘passive-interface default’ command:

```
Router#conf t
Router(config)#router ospf 1
Router(config-router)#passive-interface default
Router(config-router)#no passive-interface gi0/0/0
```

To verify our passive interface configuration, we can use the ‘show ip ospf interface command’:

```
Router#sh ip ospf interface

GigabitEthernet0/0/0 is up, line protocol is up
  Internet address is 10.10.10.10/24, Area 0
  Process ID 1, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State WAITING, Priority 1
  No designated router on this network
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit
5
    No Hellos (Passive interface)
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
```

Take note that this interface is no longer sending OSPF Hellos or processing any received Hellos in our OSPF domain.

OSPF Default-Information Originate and the Default Route
The default route or the Gateway of Last Resort is used to forward packets if our destination IP address does not have a match in our routing table. In IPv4, the CIDR notation is 0.0.0.0/0, whereas, in IPv6, it is ::/0. And because the prefix length is 0, it is also the shortest possible match. Using the ‘default-information originate’ command enables our default routes to be injected in our routing protocol, such as OSPF, and be propagated in our network.

What is a Default Route?

In networks where learning all of the more specific routes is not desirable, such as stub networks, default routes are beneficial. A default route is very useful when a router is connected to the Internet because, without it, the router must have all the routing entries of the Internet’s networks, which can reach hundreds of thousands. Consider the massive CPU load; if the router is unable to handle it, it will degrade or crash.

With a static default route, the router only needs to know the destinations within the internal organization and will use the default route to forward IP packets for any other address to the

Internet.

OSPF Default-Information Originate Command

Any OSPF router can originate default routes injected into a normal area. The OSPF router does not create a default route into the OSPF domain by default. The ‘default-information originate’ command is required for OSPF to generate a default route.

```
default-information originate
```

In our example above, router R1 is directly connected to the Internet. It’s a common enterprise setup where all Internet traffic breaks out from a single site. In R1, we have a static route configured pointing to the ISP/Internet next hop device.

```
S* 0.0.0.0/0 [1/0] via 1.1.1.2
```

We are running the OSPF routing protocol, and R1 is peering with both R2 and R3.

```
R1#sh ip ospf neighbor


Neighbor ID     Pri   State           Dead Time   Address
Interface
10.30.30.33       1   FULL/DR         00:00:30    10.30.30.33
GigabitEthernet0/2
10.20.20.22       1   FULL/DR         00:00:30    10.20.20.22
GigabitEthernet0/1
```

Before we proceed, let’s check the routing tables of R2 and R3.

```
R2#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter
area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type
2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set
```

```
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.20.20.20/30 is directly connected, GigabitEthernet0/1
L       10.20.20.22/32 is directly connected, GigabitEthernet0/1
O       10.30.30.32/30 [110/2] via 10.20.20.21, 00:05:10,
GigabitEthernet0/1
R3#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter
area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type
2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O       10.20.20.20/30 [110/2] via 10.30.30.34, 00:05:20,
GigabitEthernet0/1
C       10.30.30.32/30 is directly connected, GigabitEthernet0/1
L       10.30.30.33/32 is directly connected, GigabitEthernet0/1
```

As we can see, we're only learning internal routes (directly connected networks in this case). Now, let's inject the default route into the OSPF domain.

```
R1#conf t
R1(config)#router ospf 1
R1(config-router)#default-information originate
```

As simple as that, default route exists in R2 and R3 as well.

```
R2#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter
area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type
2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 10.20.20.21 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
```

```
C       10.20.20.20/30 is directly connected, GigabitEthernet0/1
L       10.20.20.22/32 is directly connected, GigabitEthernet0/1
O       10.30.30.32/30 [110/2] via 10.20.20.21, 00:16:22,
GigabitEthernet0/1
O*E2 0.0.0.0/0 [110/1] via 10.20.20.21, 00:00:28, GigabitEthernet0/1
R3#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B
- BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter
area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type
2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 10.30.30.34 to network 0.0.0.0

     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O       10.20.20.20/30 [110/2] via 10.30.30.34, 00:16:39,
GigabitEthernet0/1
C       10.30.30.32/30 is directly connected, GigabitEthernet0/1
L       10.30.30.33/32 is directly connected, GigabitEthernet0/1
O*E2 0.0.0.0/0 [110/1] via 10.30.30.34, 00:00:45, GigabitEthernet0/1
```

OSPF Load Balancing – Explanation and Configuration
Open Shortest Path First or OSPF is an open standard Interior Gateway Protocol (IGP) that is used in an IP network to exchange routing table information within a single Autonomous System (AS). Like other dynamic routing protocols, OSPF does equal cost load balancing, and if you have routes with equal cost paths to the same destination, then OSPF will do load sharing. Unlike Enhanced Interior Gateway Routing Protocol (EIGRP), OSPF can’t do unequal cost load balancing.

Configure OSPF Load Balancing

By default, OSPF allows the installation of up to 4 multiple paths of a single network with identical metrics. This number may be increased to a maximum of 16.

NOTE
Maximum-paths default setting varies depending on router platform.

ospf load balancing

In our example above, the ‘show ip route’ command output will show four different equal cost routes to our host 100.100.100.1/24.

```
R1#sh ip route
O       100.100.100.0 [110/2] via 5.5.5.5, 00:14:30,
GigabitEthernet0/3
                      [110/2] via 4.4.4.4, 00:15:24,
GigabitEthernet0/2
                      [110/2] via 3.3.3.3, 00:17:08,
GigabitEthernet0/1
                      [110/2] via 2.2.2.2, 00:13:06,
GigabitEthernet0/0
```

Let’s try installing only two routes by using the ‘maximum-paths’ command.

```
R1(config)#router ospf 1
R1(config-router)#maximum-paths 2
```

In our routing table, the original four entries were reduced to two.

```
O       100.100.100.0 [110/2] via 5.5.5.5, 00:00:43,
GigabitEthernet0/3
                      [110/2] via 4.4.4.4, 00:00:43,
GigabitEthernet0/2
```

An OSPF router could load balance the packets on a per-packet or per-destination basis. The default configuration uses per-destination load balancing. The router’s load balancing configuration determines the new or subsequent traffic.

Per-Destination Load Balancing – packets for a given source and destination host pairs are guaranteed to take the same path, even if multiple OSPF paths are available (Per-flow load balancing).

Per-Packet Load Balancing – it uses the round-robin method to determine which path each packet takes to the destination IP. This is inappropriate for certain types of traffic, such as Voice over IP (VoIP), which depends on the packets arriving at the destination in sequence.

We can check which OSPF load balancing method is in effect by using the ‘show ip cef’ command:

```
R1#sh ip cef 100.100.100.1 detail
100.100.100.0/24, epoch 0, per-destination sharing
```

```
  nexthop 4.4.4.4 GigabitEthernet0/2
  nexthop 5.5.5.5 GigabitEthernet0/3
```

We can change how OSPF load balancing works on the interface configuration mode:

```
R1(config)#int gi0/3
R1(config-if)#ip load-sharing ?
  per-destination  Deterministic distribution
  per-packet       Random distribution
```

OSPF Summarization
Route summarization helps reduce OSPF traffic and route computation. OSPF, unlike EIGRP, doesn’t support automatic summarization. Also, unlike EIGRP, where you can summarize routes on every router in an EIGRP network, OSFP can summarize routes only on ABRs and ASBRs.

The following command is used for OSPF summarization:

```
(config-router) area AREA_ID range IP_ADDRESS MASK
```

To better understand OSPF summarization, consider the following example network:

ospf summarization topology

All three routers are running OSPF and exchanging routes. Before OSPF summarization is configured, the router R1 inside the backbone area has two entries for the networks 11.0.0.0/24 and 11.0.1.0/24 in its routing table.

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

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 1 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
     11.0.0.0/24 is subnetted, 2 subnets
O IA    11.0.0.0 [110/3] via 10.0.0.2, 00:00:40, FastEthernet0/0
O IA    11.0.1.0 [110/3] via 10.0.0.2, 00:00:40, FastEthernet0/0
O IA 172.16.0.0/16 [110/2] via 10.0.0.2, 00:00:40, FastEthernet0/0
```

We could summarize these two subnets on R2, so that R1 receives only one routing update for both subnets. To do that, the following command can be used on R2:

```
Router(config)#router ospf 1
Router(config-router)#area 1 range 11.0.0.0 255.255.0.0
```

Now, R1 has only one entry in its routing table for R3’s directly connected subnets:

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

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 1 subnets
C       10.0.0.0 is directly connected, FastEthernet0/0
     11.0.0.0/16 is subnetted, 1 subnets
O IA    11.0.0.0 [110/3] via 10.0.0.2, 00:00:30, FastEthernet0/0
O IA 172.16.0.0/16 [110/2] via 10.0.0.2, 00:02:52, FastEthernet0/0
```