<u>CMPE 206 LAB</u>

OSPF Network Examination

Learning Objectives

Upon completion of this lab, you will be able to:

- Understand the Mechanism of Link-State Routing Protocol Open Shortest Path First (OSPF).
- Configure Router with Loopback Address
- Configure Router with OSPF and LSAs Message Sending
- Configure Router with OSPF LSAs Message Suppression
- Configure Router with OSPF Reference Bandwidth
- Configure Router with OSPF Route Cost on Interfaces
- Configure Router in OSPF Multi-Area Environment
- Configure Area Border Router with Route Summarization

Task 1: Understand the Mechanism of Link-State Routing Protocol Open Shortest Path First (OSPF). (No screenshot needed, read and study the following content, and complete the quiz)

Link-State Routing Protocols

When using link-state routing protocol, every router creates a ‘connectivity map’ of the network. To achieve this, each router advertises information about its interfaces (connected networks) to its neighbors. These advertisements are passed along to other routers, until all routers in the network develop the same map of the network. Each router independently uses this map to calculate the best routes to each destination.

Link-state protocols use more resources (processing power and memory) on the router, because more information needs to be formed and shared compared to distance-vector routing protocols. However, link-state protocols tend to be faster in reacting to changes in the network than distance-vector protocols.

Open Shortest Path First (OSPF)

OSPF uses the **Shortest Path First (SPF)** algorithm of Dutch computer scientist Edsger Dijkstra (aka Dijkstra’s algorithm), and it has three versions that used by networking:

1. OSPFv1 (1989): It is old and relatively slow version; it is not in use for modern router anymore.
2. OSPFv2 (1998): Used in IPv4 network, it is the most common one used in enterprises.
3. OSPFv3 (2008): Used in IPv6 network, it can be used in IPv4 network as well.

When a router is configured to use OSPF, it stores information about the network in **Link-State Advertisements (LSAs)** which are organized in a structure called the **Link-State Database (LSDB)**. Router will flood LSAs until all routers in the OSPF area develop the same map of the network (shares the same LSDB). Each LSA has an aging timer (30 min by default). The LSA will be flooded again after the timer expires.

In OSPF, there are three main steps in the process of sharing LSAs and determining the best route to each destination in the network:

1. **Become neighbors** with other routers connected to the same segment.
2. **Exchange LSAs** with neighbor routers.
3. **Calculate the best routes** to each destination, and insert them into the routing table.

In OSPF, areas are used to divide up the network. An **area** is a set of routers and links that share the same LSDB. **Backbone area** is an area that all other areas must connect to, and we use area 0 as backbone in common practice for single-area OSPF. There are a few terminologies you need to know:

1. Routers with all interfaces in the same area are called **internal routers (IRs),** and Routers with interfaces in multiple areas are called **area border routers (ABRs)**.
2. **ABRs maintain a separate LSDB for each area they are connected to.** You should connect an ABR to a maximum of 2 areas as connecting to 3+ areas can overburden the router.
3. Routers connected to the backbone area (area 0) are called **backbone routers (BRs)**.
4. An **intra-area route** is a route that the origin and destination are located inside the same OSPF area; and **inter-area route** is a route that the origin and destination are located in a different OSPF area.
5. All OSPF areas must have at least one ABR connected to the backbone area, and all OSPF areas should be **contiguous**, which means that any arbitrary sub-area (area besides area 0) should have only one router that is a BR and ABR at any time, so no areas are split and become non-contiguous.
6. For any OSPF routers, **OSPF interfaces in the same subnet must be in the same area**, otherwise the router will not become OSPF neighbors with the others.
7. An **Autonomous System Boundary router (ASBR)** is an OSPF router that connects the OSPF network to an external network.

Sometimes, small networks can be single-area without any negative effects in performance, but in larger networks, a single-area design can have negative effects:

1. the SPF algorithm takes more time to calculate the best routes
2. the SPF consume exponentially more processing power on the routers.
3. each routers shares a much larger LSDB which takes up more memory on the routers.
4. any small change in the network causes every router to flood LSAs and run the SPF algorithm again, which causes problem 1-3 to every router in the area.

By dividing a large OSPF network into several smaller areas, you can avoid above negative effects.

Another important OSPF's metric is the **cost of a route**. It is automatically calculated based on the bandwidth (speed) of the interface, it is calculated by dividing a **reference bandwidth** value by the **interface's bandwidth**. The default reference bandwidth is 100 Mbps, which is the same as Fast Ethernet's bandwidth.

1. Reference: 100 Mbps / Interface: 1 Mbps = 100 route cost
2. Reference: 100 Mbps / Interface: 10 Mbps = 10 route cost
3. Reference: 100 Mbps / Interface: 100 Mbps = 1 route cost
4. Reference: 100 Mbps / Interface: 1000 Mbps = 1 route cost (why?)

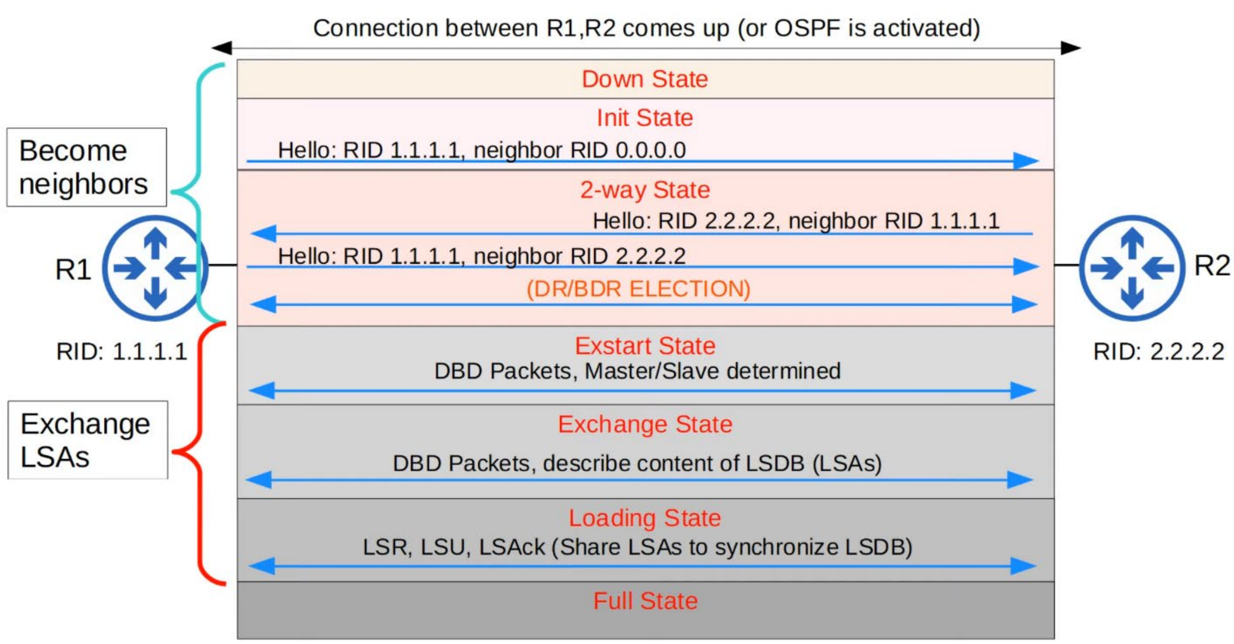
    a. All values obtain form route cost computation that are lees than 1 will be converted to 1.
    b. Therefore, it is important to set up an appropriate reference bandwidth to avoid incorrect route cost computation, which is critical for OSPF to select the best route to forward message.
5. Reference: 100 Mbps / Interface: 10000 Mbps = 1 route cost (why?)
    a. Same as above

OSPF neighbors' connectivity is critical to OSPF's routing construction. If routers cannot become OSPF neighbors, OSPF cannot operate at all. Making sure that routers successfully become OSPF neighbors is the main task in configuring and troubleshooting OSPF. Once routers become neighbors, they automatically do the work of sharing network information, calculating routes, etc.

When OSPF is activated on an interface:

1. The router starts sending OSPF 'hello' message out of the interface at regular intervals (determined by the hello timer). These are used to introduce the router to potential OSPF neighbors. The default hello timer is 10 seconds and dead timer is 40 seconds on an Ethernet connection, and 'hello' messages are multicast to 224.0.0.5 (multicast address for all OSPF routers).
    a. RIP's multicast address is 224.0.0.9, and EIGRP's multicast address is 224.0.0.10.
2. 'Hello' messages are encapsulated in an IP header, with a value of 89 in the protocol field. By exchanging 'hello' messages, routers check that they are compatible to become OSPF neighbors, and then negotiate their neighbor relationship.

The complete workflow of OSPF exchanging messages which change the interfaces from down state to full state between two arbitrary routers is fairly long and complicated, the following figure is the OSPF state changing procedure and message types for your knowledge. Although we will not be examining this procedure in this lab, you are encouraged to know more about them by reading article Understand OSPF Neighbor States provide by Cisco.



Type	Name	Purpose
1	**Hello**	Neighbor discovery and maintenance.
2	**Database Description (DBD)**	Summary of the LSDB of the router. Used to check if the LSDB of each router is the same.
3	**Link-State Request (LSR)**	Requests specific LSAs from the neighbor.
4	**Link-State Update (LSU)**	Sends specific LSAs to the neighbor.
5	**Link-State Acknowledgement (LSAck)**	Used to acknowledge that the router received a message.

OSPF basic configuration in CLI

1. Command 'router ospf'
    a. This command enables you to enter OSPF configuration mode, you use the command **router ospf,** followed by a **process ID**.
        i. Example: R1(config)#router ospf 1
        ii. It assigned the current OSPF process with ID 1 for router R1 and enter OSPF configuration mode.
    b. A router can run multiple OSPF processes at once, and this ID is used in the router to identify each of them. Typically, you will just use a single OSPF process, but you can use more in a multiple areas OSPF network. The OSPF process ID is **locally significant**, which is unrelated to areas configurations, and routers with different process IDs can become OSPF neighbors.
2. Command 'network'
    a. This command tells OSPF to look for any interfaces with an IP address contained in the range specified in the network command, activates OSFP on the interfaces in the specified area, and the router will then try to become OSPF neighbors with other OSPF-activated neighbor routers. To configure it, you use command **network**, followed by the **network address**, **network wildcard mask** (inverse subnet mask), and **OSPF area.**
        i. Example: R1(config-router)#network 10.0.12.0 0.0.0.3 area 0
        ii. If R1 has an active G1/0 interface (Gigabit Ethernet Interface 0/1) that has an IP address of 10.0.12.1, which is contained in 10.0.12.0/28. The above command will activate OSPF on R1'G1/0 interface in area 0.
    b. In short, the **network** command is simply used to tell the router which interfaces to activate OSPF on, it does not tell the router to 'advertise these networks'.
3. Command 'passive-interface'

a. This command tells the router to stop sending OSPF 'hello' messages out of the interface. OSPF uses 'hello' messages to tell other routers about itself. To configure it, you use command **passive-interface**, followed by the **interface**(s) that you intended to make it passive.
    i. Example: R1(config-router)#passive-interface g2/0.
    ii. It makes interface g2/0 passive on router R1.

b. The router will continue to send LSAs informing its neighbors about the subnet configure on the interface, so you should always use this command on interfaces which do not have any OSPF neighbors because it is a waste to continuously send hello messages out of an interface with no other routers connected to it.

4. Command 'auto-cost reference-bandwidth'
    a. This command enables you to manually update the reference bandwidth for route cost computations. To configure it, you use command **auto-cost reference-bandwidth**, followed by the **reference bandwidth** in megabits-per-second.
    b. You should always check the interfaces that are used in the network and get to know their corresponding bandwidth, and configure the reference bandwidth (much) greater than the fastest links in your network to maintain OSPF's route cost computation correctness and to allow for future link upgrades.
5. Command 'ip ospf cost'
    a. This command enables you to manually configure the route cost of a specific interface. To configure it, you use command **ip ospf cost**, followed by the **cost** you intended to assign.
    b. This cost will take priority over the auto-calculated cost, and we mainly use to manipulate the best route selection of OSPF on a specific interface/link to achieve **customized routing**. Make sure you assign an appropriate cost to maintain OSPF's performance.
    c. This cost does not physically affect the bandwidth of the actual interface/link. If you want to change the actual speed, use the **speed** command (you can only set the intend speed to equal or lower original speed)
6. Command 'show ip ospf interface brief'
    a. This command gives a convenient overview of each OSPF-enable interface on the current router.
    b. It is very useful if you want to have a quick overview on each interface's state, cost, neighbor, area, OSPF process ID, etc.
7. Command 'default-information originate'
    a. This command will cause the current router to create a new LSA and flood it to the network within its area.
    b. If the current router is connected to the internet, by using this command, the current router becomes an ASBR.
8. Command 'show ip protocols'
    a. This command will show you a list of routing information that is available in the current router.
9. Command 'router-id'
    a. This command enables you to manually configure the router ID for the current router. To configure it, you use command **router-id,** followed by the **router ID** you want to assign in the network address form
        i. Example: R1(config-router)#router-id 1.1.1.1

ii. It assigned router ID 1.1.1.1 to router R1.

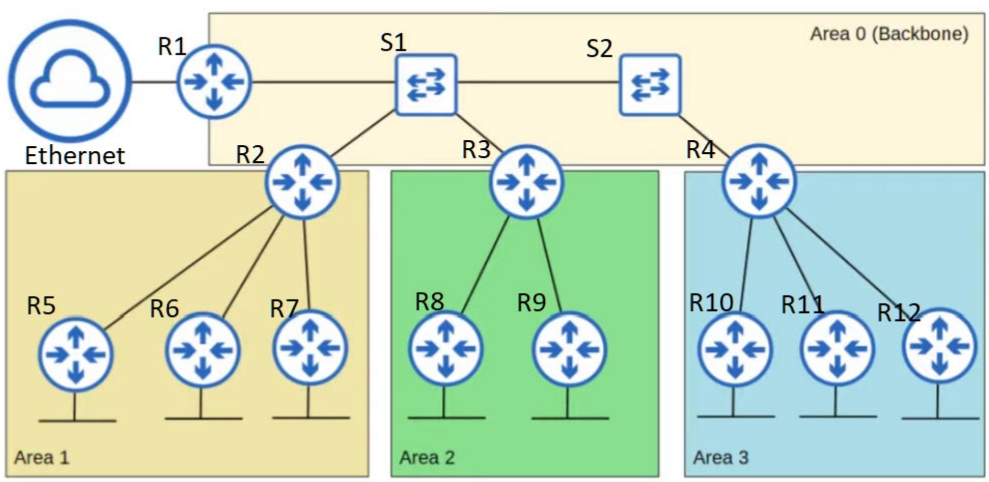
b. The router ID order of priority is as follows:
   i. Manual configuration using ‘router-id’
   ii. If no manual configuration, use the highest IP address on a loopback interface.
   iii. If no loopback interface, use the highest IP address on a physical interface.
c. After you manually assigned the router ID, remember to reload the router, or use the command **clear ip ospf process** in EXEC mode to clear the OSPF process and reset it.
   i. It is generally a bad idea to reload an in-service router in a real network as the router will lose all of its OSPF routes for a short time and will not be able to forward traffic to those destinations. However, in a lab like this, it is not a problem.

10. Command ‘maximum-paths’
    a. This command enables you to change the maximum-paths (4 by default) that is managed and load-balanced by the current router.
11. Command ‘distance’
    a. This command enables you to change the administrative distance/cost (110 by default) for the route.
    b. This is the measure of trustworthiness of the source of the route. If a router learns about a destination from more than one routing protocol, the administrative distance is compared and the preference is given to the routes with lower administrative distance.

OSPF Quiz

Answer the following questions with valid reasoning. For multiple choices questions, each question could have more than one correct answer.

1. Answer the following questions about the OSPF network below:



A. Which routers are IRs?

B. Which routers are ABRs?

C. Which routers are BRs?

D. Which routers are ASBRs?

E. Will the OSPF network still be valid if we disconnect R2 from S1 and connect R2 to R3? Why?

F. Will the OSPF network still be valid if we re-assign R4, R10, R11, R12 from area 3 to area 1? Why?

2. Which of the following statements about OSPF are not true?

A. In multi-area OSPF networks, all non-backbone areas must have an ABR connected to area 0.

B. Signal-area OSPF must use area 0.

C. Two OSPF routers with different process IDs can become OSPF neighbors.

D. The OSPF area must be specified in the network command.

E. An ASBR connects the internal OSPF network to networks outside of the OSPF domain.

F. The OSPF process ID must match the area number.

Answer:

Reasons:

3. You want to activate OSPF on R1's G0/1 and G0/2 interfaces with a single command.

G0/1 IP: 10.0.12.1/28

G0/2 IP: 10.0.13.1/26

Which of the following commands should you use in R1?

A. R1(config-router)# network 10.0.12.0 0.0.0.255 area 0

B. R1(config-router)# network 10.0.12.0 0.0.0.254 area 0

C. R1(config-router)# network 10.0.12.0 0.0.1.255 area 0

D. R1(config-router)# network 10.0.8.0 0.0.3.255 area 0

Answer:

Reasons:

4. Which of the following commands will make R1 an OSPF ASBR?

A. R1(config-router)# network 10.0.0.0 0.0.0.255 area 0

   R1(config-router)# network 10.0.1.0 0.0.0.255 area 1

B. R1(config)# ip route 0.0.0.0 0.0.0.0 203.0.113.2

   R1(config)# router ospf 1

   R1(config-router)# default-information originate

C. R1(config-router)# network 0.0.0.0 255.255.255.255 area 0

D. R1(config-router)# default-route originate

Answer:

Reasons:

5. Which command can be used to manually configure the OSPF router ID?

A. R1(config-router)# router-id 1.1.1.1

B. R1(config-router)# ospf router-id 1.1.1.1

C. R1(config)# interface loopback0

   R1(config-router)# ip address 1.1.1.1 255.255.255.255

D. R1(config-router)# ospf router id 1.1.1.1

Answer:

Reasons:

6. Put the OSPF neighbor states in the correct order. (Format: Down -> Init -> … etc.)

Answer:

7. Which statement about OSPF’s default cost is correct?

A. All interfaces have the same cost.

B. Ethernet and Fast Ethernet interfaces have the same cost.

C. Fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet interfaces have the same cost.

C. Ethernet, Fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet interfaces have the same cost.

Answer:

Reasons:

8. Which of these commands can be used to make a Fast Ethernet interface have an OSPF cost of 100?

A. R1(config-router)# auto-cost reference bandwidth 100

B. R1(config-router)# auto-cost reference bandwidth 1000

C. R1(config-router)# auto-cost reference bandwidth 10000

D. R1(config-router)# auto-cost reference bandwidth 100000

Answer:

Reasons:

9. Which are the default OSPF hello and dead timers on an ethernet connections?

A. 2 secs, 20 secs

B. 10 secs, 40 secs

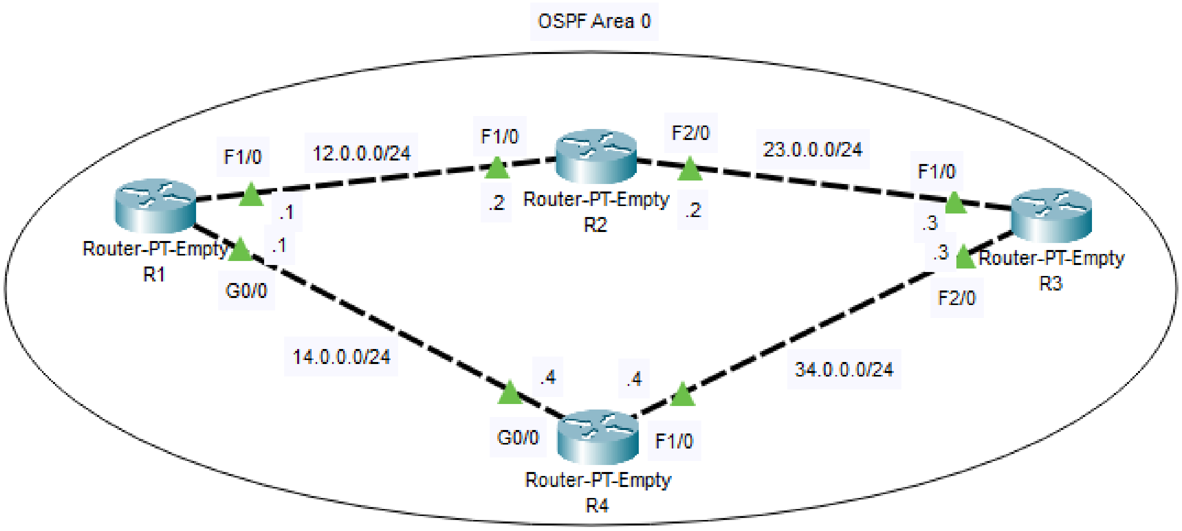
C. 30 secs, 120 secs

D. 60 secs, 180 secs

Answer:

Reasons:

Network Topology (Single-Area) Diagram for Task 2 – 6



Task 2: Configure Router with Loopback Address(Perform below steps and provide corresponding screenshot)

1. Configure a loopback address 1.1.1.1/32 for R1 following the guidelines:
    a. Enter R1's EXEC mode.
        i. Enter Switch1 CLI, type **enable** to enter EXEC mode.
    b. Enter R1's global configuration mode.
        i. In EXEC mode, type **configure terminal** to enter global configuration mode.
    c. Turn on R1's interface loopback 0.
        i. In global configuration mode, type **interface l0** to change the loopback 0 state to up.
    d. Configure R1's loopback 0 address with 1.1.1.1/32.
        i. In loopback 0 interface configuration mode, type **ip address 1.1.1.1 255.255.255.255** to assign 1.1.1.1/32 as R1's loopback 0 address.
2. Configure a loopback address 2.2.2.2/32 for R2 following guidelines 2.1.a – 2.1.d similarly.
3. Configure a loopback address 3.3.3.3/32 for R2 following guidelines 2.1.a – 2.1.d similarly.
4. Configure a loopback address 4.4.4.4/32 for R4 following guidelines 2.1.a – 2.1.d similarly.

Task 3: Configure Router with OSPF and LSAs Message Sending (Perform below steps and provide corresponding screenshot)

1. Configure R1 with OSPF and enable LSAs message sending following the guidelines:
    a. Enable OSPF on R1 with process ID 1.
        i. In global configuration mode, type **router ospf 1** to set up the OSPF with process ID 1 and enter router configuration mode.
        ii. For R2, R3, R4, use process ID 2, 3, 4.
    b. Advertise R1's routes to the network using LSAs, including its loopback.

i. In router configuration mode, type **network 12.0.0.0 0.0.0.255 area 0** to set up LSA for F1/0, then type **network 14.0.0.0 0.0.0.255 area 0** to set up LSA for G1/0, then **type network 1.1.1.1 0.0.0.0 area 0** to set up LSA for its loopback l0 interface.

ii. For R2, R3, R4, check the network topology and use the right network address and wildcard mask to set up the correct LSAs for their interfaces, including their loopback interface.

2. Configure R2 with OSPF and enable LSAs message sending following the guidelines 3.1.a – 3.1.b similarly.
3. Configure R3 with OSPF and enable LSAs message sending following the guidelines 3.1.a – 3.1.b similarly.
4. Configure R4 with OSPF and enable LSAs message sending following the guidelines 3.1.a – 3.1.b similarly.
5. After all routers has been configured with OSPF and sent LSAs, examine their current OSPF neighbor and route information.
   a. On each router's router configuration mode, type **do show ip ospf neighbor** to verify they are all interconnected as OSPF neighbors, then type **do show ip route** to verify they shares the same LSDB.
   b. Do NOT process to the next task if any router failed to be interconnected or does not share the same LSDB.

Task 4: Configure Router with OSPF LSAs Message Suppression (Perform below steps and provide corresponding screenshot)

1. Suppress the LSA message sending on R1's loopback interface following the guidelines:
   a. Turn R1's loopback interface from active to passive.
      i. In router configuration mode, type **passive-interface l0** to make its loopback interface passive and stop sending the LSAs.
2. Suppress the LSA message sending on R2's loopback interface following the guidelines 4.1.a similarly.
3. Suppress the LSA message sending on R3's loopback interface following the guidelines 4.1.a similarly.
4. Suppress the LSA message sending on R4's loopback interface following the guidelines 4.1.a similarly.

Task 5: Configure Router with OSPF Reference Bandwidth (Perform below steps and provide corresponding screenshot)

1. There is an issue with the OSPF reference bandwidth in the network that we need to fix, but first let us examine the problem: (instead of screenshots, answer the questions in this step)
   a. Check R1's routing info (use command **do show ip route**), what are the routes that we can take to forward messages from R1 to R3?
      i. Example: one of the routes that R3 can take to forward message to R1 can be written as follows:
      ii. 1.1.1.1 [110/3] via 23.0.0.2, 00:00:30, FastEthernet1/0

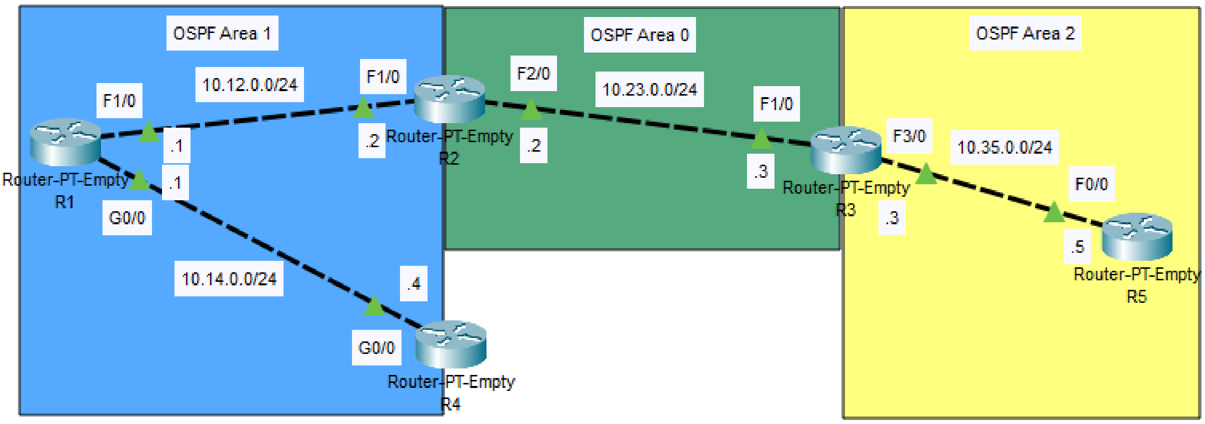
b. Noticed that R1 uses both Gigabit Ethernet Interface 0/0 (G0/0) and Fast Ethernet Interface 1/0 (Fa1/0) to forward message, and Gigabit Ethernet's bandwidth is 1000 Mbps and Fast Ethernet's bandwidth is 100 Mbps, yet it has the same cost on routing based on the current R1's routing table. Why?
c. How to fix it so that R1 can use the best route when forwarding message to R3?

2. Fix the wrong reference bandwidth issue in the network following the guideline:
   a. Auto calculate the reference metric by configuring the proper bandwidth number on R1.
      i. In router configuration mode, type **auto-cost reference-bandwidth 10000** so that a 10-Gigabit Ethernet interface would have an OSPF cost of 1 (a 10000 Mbps interface would have cost of 1).
   b. Use the same command on R2, R3, R4 to ensure reference bandwidth is consistent across all routers.
3. Check if the wrong reference bandwidth issue in the network has been fixed.
   a. Examine the routing table on R1 again to check if it only uses the best route to forward message to R3.
      i. On R1's router configuration mode, type **do show ip route** and see if the routing reference metric are correctly calculated based on the new bandwidth number and R1 only uses the G0/0 interface to forward message to R3.

Task 6: Configure Router with OSPF Route Cost on interfaces (Perform below steps and provide corresponding screenshot)

1. In Task 4, we made R1 forward message to R3 taking the route on R4 exclusively, now assume R4 is overwhelmed by the traffic, and we would like to manually update the routing cost metric on R1 so that R1 no long take the route on R4. Instead, it takes the route on R2 when forwarding the message to R3. Therefore, we need to adjust OSPF cost with an appropriate metric.
   a. Adjust OSPF interface cost where appropriate to cause R1 to send traffic to R3's loopback interface via R2 rather than R4.
      i. On R1's router configuration mode, type **interface g0/0** to enter interface configuration mode for Gigabit Ethernet interface G0/0, then type **ip ospf cost 10000** to manually assign OSPF cost 10000 to the G0/0 interface.
   b. Do the same for R4 to make the cost consistent across the Gigabit Ethernet link between R1 and R4, following the guidelines 5.1.a similarly.
2. Check if the manual update of OSPF route cost on the G0/0 interface is successful.
   a. Examine the routing table on R1 again to check if it only uses the best route to forward message to R3.
      i. On R1's router configuration mode, type **do show ip route** and see if R1 only uses the Fa1/0 interface to forward message to R3.

Network Topology (Multi-Area) Diagram for Task 7 – 8



Task 7: Configure Router in OSPF Multi-Area Environment (Perform below steps and provide corresponding screenshot)

1. Configure R1 in OSPF Multi-Area Environment following the guidelines:
    a. Enter R1's EXEC mode.
        i. Enter Switch1 CLI, type **enable** to enter EXEC mode.
    b. Enter R1's global configuration mode.
        i. In EXEC mode, type **configure terminal** to enter global configuration mode.
    c. Enable OSPF on R1 with process ID 1.
        i. In global configuration mode, type **router ospf 1** to set up the OSPF with process ID 1 and enter router configuration mode.
        ii. Use the same process ID for all other routers.
    d. Advertise R1's routes to the network using LSAs, including its loopback.
        i. In router configuration mode, type **network 10.12.0.0 0.0.0.255 area 1** to set up LSA for F1/0, then type **network 10.14.0.0 0.0.0.255 area 1** to set up LSA for G1/0, then **type network 1.1.1.1 0.0.0.0 area 1** to set up LSA for its loopback l0 interface.
        ii. For all other routers, check the network topology and use the right network address and wildcard mask to set up the correct LSAs for their interfaces, including their loopback interface. For ABRs, set up their loopback interface with the backbone area.
    e. Turn R1's loopback interface from active to passive.
        i. In router configuration mode, type **passive-interface l0** to make its loopback interface passive and stop sending the LSAs.
    f. Auto calculate the reference metric by configuring the proper bandwidth number on R1.
        i. In router configuration mode, type **auto-cost reference-bandwidth 100000** so that a 100-Gigabit Ethernet interface would have an OSPF cost of 1 (a 100000 Mbps interface would have cost of 1).
2. Configure R2 in OSPF Multi-Area Environment following the guidelines 6.1.a – 6.1.d similarly.
3. Configure R3 in OSPF Multi-Area Environment following the guidelines 6.1.a – 6.1.d similarly.
4. Configure R4 in OSPF Multi-Area Environment following the guidelines 6.1.a – 6.1.d similarly.

5. Configure R5 in OSPF Multi-Area Environment following the guidelines 6.1.a – 6.1.d similarly.
6. After all routers has been configured in OSPF Multi-Area Environment, examine their current OSPF neighbor and route information.
    a. On each router's router configuration mode, type **do show ip ospf neighbor** to verify their OSPF neighbor connectivity, then type **do show ip route** to verify that the routers in the same area shares the same LSDB.
    b. Do NOT process to the next task if any router failed to be interconnected or does not share the same LSDB with routers in the same are

Task 8: Configure Area Border Router with Route Summarization (Perform below steps and provide corresponding screenshot)

1. In Task 6, we examined the LSDB for all routers, and notice that for IRs like R1, R4, and R5, they store many redundant routing information just to match a single route for each network, where all the routes are the same. Such redundant routing information could exponentially consume the RAM of IRs in a large network, and it happens because its ABRs are sending all LSAs without summarization. Therefore, we need to perform route summarizations on all ABRs so each IRs can store summarized route information instead, so RAM can be saved with no performance cost.
    a. Perform route summarization on R2 to optimize the LSDB of R1 and R4.
        i. On R2's router configuration mode, type **area 0 range 10.0.0.0 255.0.0.0** to configure LSAs that received in area 0 to be summarized within network 10.0.0.0/8, which matches all routes from network 10.23.0.0/24, 10.12.0.0/24, and 10.14.0.0/24.
        ii. It could take a few seconds for R1 and R4 to learn the summarized routing information. Instead of waiting, you can use the fast forward time function to make the network converge right away.
    b. Perform route summarization on R3 to optimize the LSDB of R5, following the guidelines 7.1.a similarly.
2. Check if the route summarization is successful and the LSDB of IRs are optimized.
    a. Examine the routing table on R1 again to see if the routing information has been summarized.
        i. On R1's router configuration mode, type **do show ip route** and see if R1 use a single route with a board network address to match all routes for each network.
    b. Do the same for R3 and R5 to see if they use a single route with a board network address to match all routes for each network, following the guidelines 7.2.a similarly.