Contents

Overview .................................................................................................................................................. 3
Objectives ............................................................................................................................................... 3
Lab settings .......................................................................................................................................... 3
Lab roadmap .......................................................................................................................................... 3
1 Introduction ........................................................................................................................................ 3
  1.1 BGP overview ................................................................................................................................... 3
  1.2 BGP route reflectors ..................................................................................................................... 4
2 Lab topology ........................................................................................................................................ 5
  2.1 Lab settings ....................................................................................................................................... 6
  2.2 Open topology and load configuration ......................................................................................... 7
  2.3 Load zebra daemon and Verify IP addresses ............................................................................... 10
3 Configure and verify IBGP ............................................................................................................... 14
  3.1 Configure BGP on routers r2, r3 and r4 ..................................................................................... 14
4 Troubleshoot BGP connectivity between routers r2 and r4 .......................................................... 19
5 Configure and verify EBGP ............................................................................................................. 22
  5.1 Configure EBGP on routers r1 and r2 ......................................................................................... 22
  5.2 Verify the connectivity of the configured topology .................................................................. 26
References .......................................................................................................................................... 27
Overview

This lab introduces Border Gateway Protocol (BGP) route reflection that offers an alternative to the full mesh Internal BGP (IBGP) topology. In this lab, External BGP (EBGP) will be configured and verified among two Autonomous Systems (ASes). Furthermore, IBGP will be configured within an AS, where a route reflector will distribute IBGP routes to all routers within the AS.

Objectives

By the end of this lab, students should be able to:

1. Configure IBGP and EBGP.
2. Understand BGP next hop attribute.
3. Configure BGP route reflectors.
4. Verify the connectivity of the configured topology.

Lab settings

The information in Table 1 provides the credentials to access Client1 machine.

<table>
<thead>
<tr>
<th>Device</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client1</td>
<td>admin</td>
<td>password</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab is organized as follows:

1. Section 1: Introduction.
2. Section 2: Lab topology.
3. Section 3: Configure and verify IBGP on routers r2, r3 and r4.
4. Section 4: Troubleshoot BGP connectivity between routers r2 and r4.
5. Section 5: Configure and verify EBGP on routers r1 and r2.
6. Section 6: Configure and verify full mesh IBGP.

1 Introduction

1.1 BGP overview
BGP is an exterior gateway protocol designed to exchange routing and reachability information among ASes on the Internet. BGP is relevant to network administrators of large organizations which connect to one or more Internet Service Providers (ISPs), as well as to ISPs who connect to other network providers. In terms of BGP, an AS is referred to as a routing domain, where all networked systems operate common routing protocols and are under the control of a single administration.

BGP is a form of distance vector protocol. It requires each router to maintain a table, which stores the distance and the output interface (i.e., vector) to remote networks. BGP makes routing decisions based on paths, network policies, or rule set configured by a network administrator and is involved in making core routing decisions.

Two routers that establish a BGP connection are referred to as BGP peers or neighbors. BGP sessions run over Transmission Control Protocol (TCP). If a BGP session is established between two neighbors in different ASes, the session is referred to as an EBGP session. If the session is established between two neighbors in the same AS, the session is referred to as IBGP. Figure 1 shows a network running BGP protocol. Routers that exchange information within the same AS use IBGP, while routers that exchange information between different ASes use EBGP.

```
Figure 1. Routers that exchange information within the same AS use IBGP, while routers that exchange information between different ASes use EBGP.
```

### 1.2 BGP route reflectors

IBGP routers do not re-advertise routes learned via IBGP to their peers. This behavior is used to prevent routing information cycles, i.e., the circulation of routing information between IBGP peers in a continuous repeated manner. Consider Figure 2, Router r1 sends a route advertisement to its IBGP neighbor (router r2). Router r2 will not advertise the learned route to its IBGP neighbors (router r3) since it was learned from an IBGP peer (router r1).
A topology is called full mesh (fully meshed topology) when there is an IBGP peering relationship between any two routers in the AS. All BGP routers within a single AS must be fully meshed so that any external routing information must be re-distributed to all other routers within that AS. However, when the network topology of the AS is large, it becomes challenging to configure a full mesh IBGP².

A BGP route reflector is an IBGP router that repeats routes learned from IBGP peers to some of its other IBGP peers². Consider Figure 3, instead of having a full mesh IBGP topology, route reflection will be configured. The route reflector (router r2) advertises the route learned from its IBGP neighbors to all its clients. Thus, router r3 receives the advertised routes from router r1, and the way around, without establishing IBGP neighbor relationship.

Consider Figure 4. The lab topology consists of two ASes, each identified by an Autonomous System Number (ASN). The ISP, i.e., router r1, provides Internet service to the Campus network (routers r2, r3 and r4). The ASN assigned to the ISP and the Campus network are 100 and 200, respectively. The ISP communicates with the Campus via EBGP routing protocol, and the routers within the Campus network communicate using IBGP, where router r3 is a route reflector, and routers r1 and r2 are the clients.
2.1 Lab settings

Routers and hosts are already configured according to the IP addresses shown in Table 2.

<table>
<thead>
<tr>
<th>Device</th>
<th>Interface</th>
<th>IPv4 Address</th>
<th>Subnet</th>
<th>Default gateway</th>
</tr>
</thead>
<tbody>
<tr>
<td>r1 (ISP)</td>
<td>r1-eth0</td>
<td>192.168.1.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r1-eth1</td>
<td>192.168.1.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td>r2 (Campus network)</td>
<td>r2-eth0</td>
<td>192.168.2.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r2-eth1</td>
<td>192.168.2.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r2-eth2</td>
<td>192.168.2.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td>r3 (Campus network)</td>
<td>r3-eth0</td>
<td>192.168.3.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r3-eth1</td>
<td>192.168.3.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r3-eth2</td>
<td>192.168.3.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td>r4 (Campus network)</td>
<td>r4-eth0</td>
<td>192.168.4.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r4-eth1</td>
<td>192.168.4.1</td>
<td>/24</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### 2.2 Open topology and load configuration

**Step 1.** Start by launching Miniedit by clicking on Desktop’s shortcut. When prompted for a password, type `password`.

![MiniEdit shortcut](image)

**Figure 5.** MiniEdit shortcut.

**Step 2.** On Miniedit’s menu bar, click on *File* then *open* to load the lab’s topology. Locate the `Lab10.mn` topology file in the default directory, `/home/frr/BGP_Labs/lab10` and click on *Open*.

![MiniEdit open dialog](image)

**Figure 6.** MiniEdit’s open dialog.
At this point the topology is loaded with all the required network components. You will execute a script that will load the configuration of the routers.

**Step 3.** Open the Linux terminal.

**Step 4.** Click on the Linux’s terminal and navigate into \textit{BGP\_Labs/lab10} directory by issuing the following command. This folder contains a configuration file and the script responsible for loading the configuration. The configuration file will assign the IP addresses to the routers’ interfaces. The \texttt{cd} command is short for change directory followed by an argument that specifies the destination directory.

```
cd BGP\_Labs/lab10
```

**Step 5.** To execute the shell script, type the following command. The argument of the program corresponds to the configuration zip file that will be loaded in all the routers in the topology.

```
./config\_loader.sh lab10\_conf.zip
```

**Step 6.** Type the following command to exit the Linux terminal.

```
exit
```
Step 7. At this point hosts h1, h2, h3 and h4 interfaces are configured. To proceed with the emulation, click on the *Run* button located in lower left-hand side.

Step 8. Click on Mininet’s terminal, i.e., the one launched when MiniEdit was started.

Step 9. Issue the following command to display the interface names and connections.

```
links
```

Figure 10. Exiting from the terminal.

Figure 11. Starting the emulation.

Figure 12. Opening Mininet’s terminal.

Figure 13. Displaying network interfaces.
In Figure 13, the link displayed within the gray box indicates that interface eth0 of host h1 connects to interface eth1 of switch s1 (i.e., h1-eth0<->s1-eth1).

### 2.3 Load zebra daemon and Verify IP addresses

You will verify the IP addresses listed in Table 2 and inspect the routing table of routers r1, r2, r3 and r4.

**Step 1.** Hold right-click on host h1 and select *Terminal*. This opens the terminal of host h1 and allows the execution of commands on that host.

![Terminal](image)

Figure 14. Opening terminal on host h1.

**Step 2.** In host h1 terminal, type the command shown below to verify that the IP address was assigned successfully. You will verify that host h1 has an interface, h1-eth0 configured with the IP address 192.168.1.10 and the subnet mask 255.255.255.0.

```
ifconfig
```
Step 3. In host h1 terminal, type the command shown below to verify that the default gateway IP address is 192.168.1.1.

```
route
```

Step 4. In order to verify hosts h2, h3 and h4, proceed similarly by repeating from step 1 to step 3 on host h2, h3 and h4 terminals. Similar results should be observed.

Step 5. You will validate that the router interfaces are configured correctly according to Table 2. In order to verify router r1, hold right-click on router r1 and select Terminal.
Step 6. Start zebra daemon, which is a multi-server routing software that provides TCP/IP based routing protocols. The configuration will not be working if you do not enable zebra daemon initially. In order to start the zebra, type the following command:

```
zebra
```

Step 7. After initializing zebra, vtysh should be started in order to provide all the CLI commands defined by the daemons. To proceed, issue the following command:

```
vtysh
```

Step 8. Type the following command on router r1 terminal to verify the routing table of router r1. It will list all the directly connected networks. The routing table of router r1 does not contain any route to the networks attached to routers r2 (192.168.2.0/24), r3 (192.168.3.0/24) and r4 (192.168.4.0/24) as there is no routing protocol configured yet.

```
show ip route
```
Step 9. Router r2 is configured similarly to router r1 but, with different IP addresses (see Table 2). Those steps are summarized in the following figure. To proceed, in router r2 terminal issue the commands depicted below. At the end, you will verify all the directly connected networks of router r2.

Step 10. Router r3 is configured similarly to router r1 but, with different IP addresses (see Table 2). Those steps are summarized in the following figure. To proceed, in router r3 terminal issue the commands depicted below. At the end, you will verify all the directly connected networks of router r3.
Step 11. Router r4 is configured similarly to router r1 but, with different IP addresses (see Table 2). Those steps are summarized in the following figure. To proceed, in router r4 terminal issue the commands depicted below. At the end, you will verify all the directly connected networks of router r4.

Configure and verify IBGP

3.1 Configure BGP on routers r2, r3 and r4

In this section, you will configure IBGP on routers r2, r3 and r4. IBGP peering relationship will occur between routers r2 and r3, as well as routers r3 and r4. Additionally, routers r2, r3, and r4 will advertise the networks 192.168.2.0/24, 192.168.3.0/24, and 192.168.4.0/24, respectively.

Step 1. To configure BGP routing protocol, you need to enable the BGP daemon first. In router r2 terminal, type the following command to exit the vtysh session:
Step 2. Type the following command on r2 terminal to enable and start BGP routing protocol.

```
bgpd
```

Figure 25. Starting BGP daemon.

Step 3. In order to enter to router r1 terminal, type the following command:

```
vtysh
```

Figure 26. Starting vtysh in router r2.

Step 4. To enable router r1 into configuration mode, issue the following command:

```
configure terminal
```

Figure 27. Enabling configuration mode in router r2.
Step 5. The ASN assigned for router r2 is 200. In order to configure BGP, type the following command:

```
router bgp 200
```

![Figure 28. Configuring BGP on router r2.](image)

Step 6. To configure a BGP neighbor to router r2 (AS 200), type the command shown below. This command specifies the neighbor IP address (192.168.23.2) and the ASN of the remote BGP peer (AS 200).

```
neighbor 192.168.23.2 remote-as 200
```

![Figure 29. Assigning BGP neighbor to router r2.](image)

Step 7. In this step, router r2 will advertise the Local Area Network (LAN) 192.168.2.0/24 to its BGP peers. To do so, issue the following command:

```
network 192.168.2.0/24
```
Step 8. Type the following command to exit from configuration mode.

```
end
```

Step 9. Type the following command to verify BGP networks. Verify the LAN network of router r2.

```
show ip bgp
```
**Step 10.** Follow from step 1 to step 8 but with different metrics in order to configure BGP on router r3. All the steps are summarized in the following figure.

![Figure 33. Configuring BGP on router r3.](image)

**Step 11.** Follow from step 1 to step 8 but with different metrics in order to configure BGP on router r4. All the steps are summarized in the following figure.

![Figure 34. Configuring BGP in router r4.](image)

**Step 12.** In router r2 terminal, type the following command to verify BGP networks. The network of router r3 (192.168.3.0/24) has been added to the BGP table.

```
show ip bgp
```
4 Troubleshoot BGP connectivity between routers r2 and r4

In this section, you will verify the connectivity between routers r2 and r4.

**Step 1.** Type the following command to verify the routing table of router r4. The routing table does not contain any route to the network 192.168.2.0/24.

```
show ip route
```

Consider Figure 36. The routing table of router r4 does not contain any route to the network 192.168.2.0/24. This result is expected since router r4 does not have a BGP peering relationship with router r2. Furthermore, router r3 will not advertise the network 192.168.2.0/24 to its IBGP neighbor router r4 since this route is learned via IBGP (router r2). To solve this issue, router r3 will be configured as a route reflector so that it advertises IBGP learned routes to IBGP neighbors.

**Step 2.** To enable router r3 into configuration mode, issue the following command:

```
configure terminal
```
**Step 3.** In order to configure BGP, type the following command:

```
router bgp 200
```

**Step 4.** In order to configure router r3 so that it advertises IBGP learned routes to its IBGP neighbor router r2 (192.168.23.1), type the following command:

```
neighbor 192.168.23.1 route-reflector-client
```

**Step 5.** In order to configure router r3 so that it advertises IBGP learned routes to its IBGP neighbor router r4 (192.168.34.2), type the following command:

```
neighbor 192.168.34.2 route-reflector-client
```

At this point, router r2 receives route advertisements from router r4, and router r4 receives route advertisements from router r2, all via router r3. However, router r4 does not have a route to the next hop IP address 192.168.23.1 (router r2), and router r2 does not have a route to the next hop IP address 192.168.34.2 (router r4). Thus, hindering the routing process between routers r2 and r4. To solve this issue, router r3 will be configured to advertise the networks 192.168.23.0/30 and 192.168.34.0/30.

**Step 6.** In router r3 terminal, type the following command to advertise the network 192.168.23.0/30:
Step 7. In router r3 terminal, type the following command to advertise the network 192.168.34.0/30:

```
network 192.168.34.0/30
```

Figure 42. Displaying the routing table of router r3.

Step 8. Type the following command to exit from configuration mode.

```
end
```

Figure 43. exiting from configuration mode.

Step 9. Type the following command to verify the routing table of router r4.

```
show ip route
```
Consider Figure 44. The routing table of router r4 has a route to the network 192.168.2.0/24. This route was advertised by the route reflector router r3.

**Step 10.** In host h4 terminal, perform a connectivity test between host h4 and host h2 by issuing the command shown below. To stop the test, press Ctrl+c. The result will show a successful connectivity test.

```
ping 192.168.2.10
```

5 Configure and verify EBGP

In this section, you will configure and verify EBGP on routers r1 and r2.

5.1 Configure EBGP on routers r1 and r2

**Step 1.** To configure BGP routing protocol, you need to enable the BGP daemon first. In router r1 terminal, type the following command to exit the vtysh session:

```
exit
```
Step 2. Type the following command on r1 terminal to enable and start BGP routing protocol.

```
bgpd
```

Step 3. In order to enter to router r1 terminal, type the following command:

```
vtysh
```

Step 4. To enable router r1 into configuration mode, issue the following command:

```
configure terminal
```

Step 5. The ASN assigned for router r1 is 100. In order to configure BGP, type the following command:

```
router bgp 100
```
Step 6. To configure a BGP neighbor to router r1 (AS 100), type the command shown below. This command specifies the neighbor IP address (192.168.12.2) and the ASN of the remote BGP peer (AS 200).

```
neighbor 192.168.12.2 remote-as 200
```

Step 7. In this step, router r1 will advertise the LAN 192.168.1.0/24 to its BGP peers. To do so, issue the following command:

```
network 192.168.1.0/24
```

Step 8. Type the following command to exit from configuration mode.

```
end
```
Step 9. Follow from step 4 to step 6 but with different metrics in order to configure EBGP on router r2. All the steps are summarized in the following figure.

At this point, routers r1 and r2 are EBGP neighbors and the network 192.168.1.0/24 should be advertised from router r1 to router r2. Additionally, router r2 should advertise EBGP learned routes to its IBGP neighbor routers (router r3).

Step 10. In router r3 terminal, type the following command to verify BGP networks.

```
show ip bgp
```
Consider Figure 55. The BGP table of router r3 has a route to the network 192.168.1.0/24. The code $\rightarrow$ is not shown next to this network, which means that it is not reachable. Router r3 uses the next hop 192.168.12.1 to reach the network 192.168.1.0/24, however, router r3 does not have a route to the network 192.168.12.0/30. Router r2 will be configured so that it updates the next hop to itself when it advertises EBGP routes to IBGP neighbors.

**Step 11.** In router r2 terminal, configure BGP so that the IBGP neighbor 192.168.23.2 (router r3) uses router r2 as the next hop to the network 192.168.1.0/24. To do so, type the following command:

```
neighbor 192.168.23.2 next-hop-self
```

![Figure 56. Configuring BGP in router r2.](image)

### 5.2 Verify the connectivity of the configured topology

**Step 1.** Type the following command to verify the BGP table of router r3. You will notice that the BGP table contains a route to the network 192.168.1.0/24 via the next hop 192.168.23.1 (router r2).

```
show ip route
```

![Figure 57. Displaying the routing table of router r3.](image)
**Step 2.** In host h4 terminal, perform a connectivity between host h4 and host h1 by issuing the command shown below. To stop the test, press `Ctrl+c`. The result will show a successful connectivity test.

```plaintext
ping 192.168.1.10
```

![Figure 58. Connectivity test using `ping` command.](image)

This concludes Lab 10. Stop the emulation and then exit out of MiniEdit.

**References**