Policy-Based Routing

# CCNP Lab 9

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## 22 April 2019

# Purpose

The purpose of the lab was to introduce policy-based routing and configure it on a simple network configuration consisting of a router, two virtual machines, and an external PC. Our goal was to configure HTTP and HTTPS servers on the virtual machines in a single network such that there is full connectivity within the network but the PC outside the network can only access the HTTP server for one virtual machine and the HTTPS server for the other. While we could have simply used an extended access list, the point of the lab was to study policy-based routing, so we were to create a route-map instead. We then had to demonstrate that our configuration was correct by attempting to reach each of the servers from inside and outside the network.

# Background

Policy-based routing is a tool enabling packets to be forwarded and routed according to policies defined by a network administrator. Policies can be applied to packets that meet pre-defined criteria, such as matching an access-list, next-hop address, protocol, or packet length. Once a packet meets certain criteria, the router is able to modify the next-hop address or interface through which the packet is then sent. This includes the ability to redirect packets to a null interface, effectively denying the packet. Using policy-based routing is like using access-lists, except it has a wider scope due to the additional criteria that can be specified for matching.

Policy-based routing allows network administrators to override default routing done by the router and set custom configurations according to specific needs within the network. In particular, admins are able to prioritize certain applications, load share, or segregate customer traffic according to their profiles or level of service provided. Overall, policy-based routing provides a high level of flexibility in managing traffic in a network, particularly in small scale applications.

# Summary

My partner and I first created two virtual machines running Ubuntu Server and set up an Apache web server with HTTP and HTTPS on each. To set up HTTP, we simply installed Apache and started the service, then navigated to the IP address of the server. For HTTPS, we had to generate and store a private key and self-signed certificate with SSL, and manually modify one of the files. The self-signed certificate allows us to verify our own websites, which is a fundamental part of HTTPS, though web browsers will generate a warning and we will have to manually go on to the website.

We then configured the router to act as a DHCP server for the virtual machines and external PC and set up policy-based routing. We then configured the virtual machines to use a DHCP address, and manually entered a default gateway. In order to know which IP addresses would be assigned by the router beforehand, which we would need for the access-lists in policy-based routing, we limited the address pool to just two addresses. This allowed us to configure policy-based routing for the two IP addresses that we know will eventually be assigned to the two virtual machines. For the computer outside the network, we simply set it to use a DHCP address from the router.

To verify that our configuration was correct, we first made sure that we could access the HTTP and HTTPS web servers within the network. We then demonstrated that external users were only able to access the HTTP web server on one virtual machine and the HTTPS web server on the other virtual machine with the external PC.

# Commands

The key commands used in this lab for the router were:

route-map Routing permit 10 – created a route-map entry for a particular route-map with the specified priority

match ip address 100 – matches any routes that meet the requirements of the specified access-list

set ip next-hop 192.168.10.2 – sets the next-hop address for the packet

set interface Null0 – sets the egress interface for the packet; in this case the interface is Null0, which effectively denies the packet

ip policy route-map Routing - configures the specified route-map for a particular interface

The key commands used in this lab for the virtual machines were:

sudo service apache2 start – starts the Apache web server

a2enmod ssl – enables the SSL module

mkdir /etc/apache2/ssl – creates a subdirectory to place the files that will be created

openssl req -x509 -nodes -days 365 -newkey rsa:2048 -keyout /etc/apache2/ssl/apache.key -out /etc/apache2/ssl/apache.crt – generates a private key file and self-signed X.509 certificate file, and saves them to the specified locations

nano /etc/apache2/sites-available/default-ssl.conf – edits the specified file; two lines need to be manually changed to reference the private key and certificate:

      SSLCertificateFile /etc/apache2/ssl/apache.crt

      SSLCertificateKeyFile /etc/apache2/ssl/apache.key

a2ensite default-ssl.conf – activates the SSL-enabled virtual host

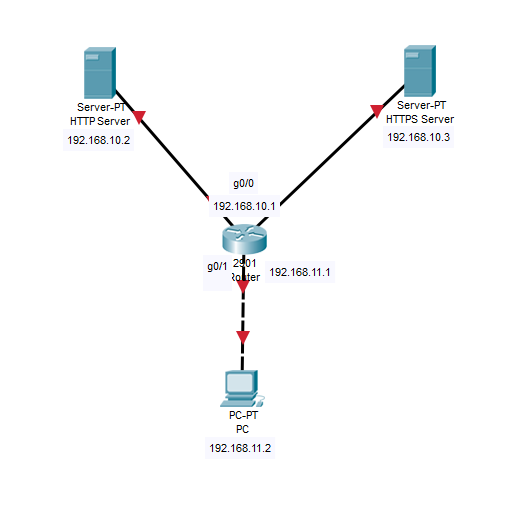
ifconfig – displays relevant network interface information

dhclient ens33 -v – configures the virtual machine to request a DHCP address; the -v makes the virtual machine output relevant information to the command line

dhclient ens33 -r -v – removes the DHCP address currently used by the virtual machine

route add default gw 192.168.10.1 ens33 – manually sets a default gateway for the server

# Tables and Diagrams

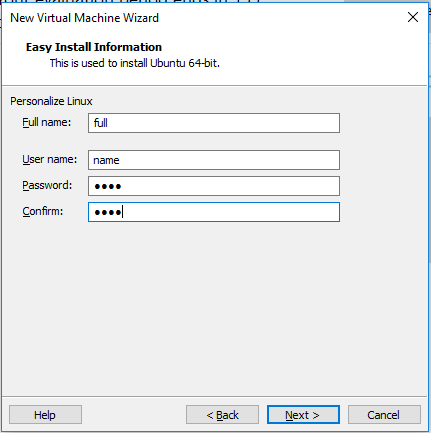


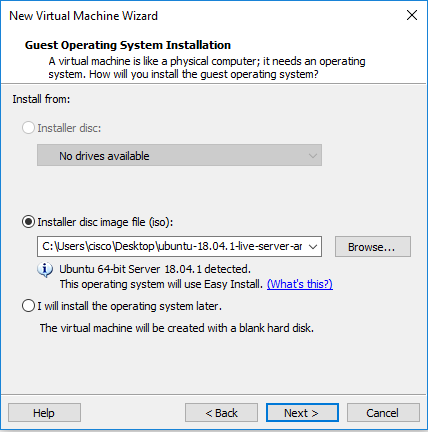
Note that the two virtual machines are on a desktop, which is physically connected to the router. The network connect is bridged and each have their own IP address.

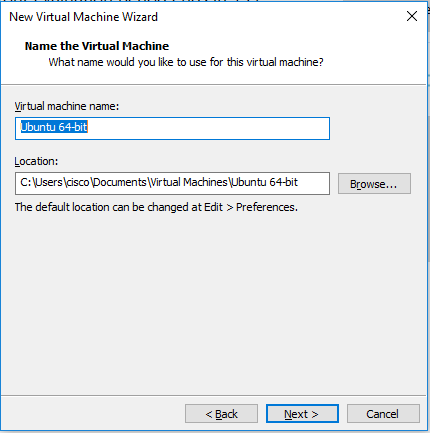
The two servers and the PC are configured to use a DHCP address assigned by the router.

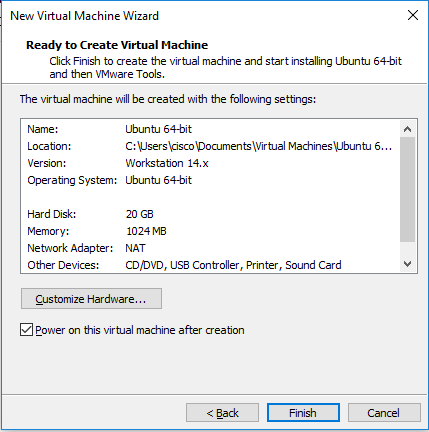
# Configurations

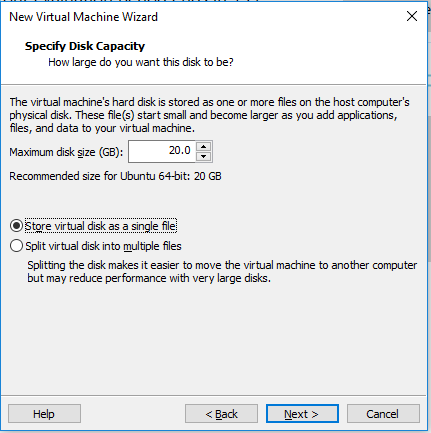
Setting up the Virtual Machines:  

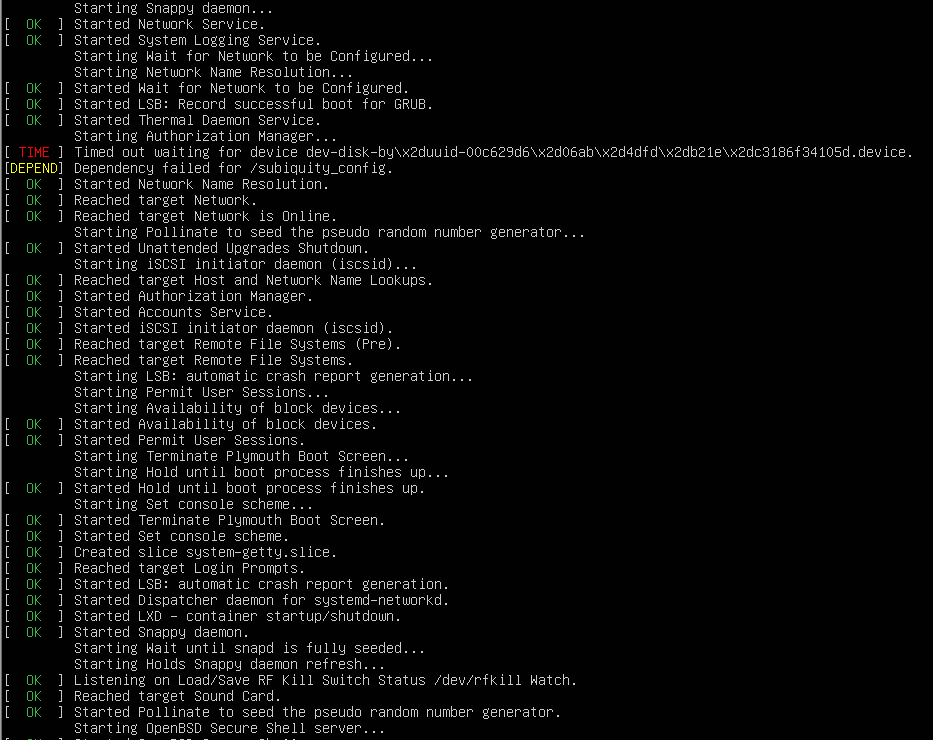


Select the desired image. We will be using Ubuntu Server.

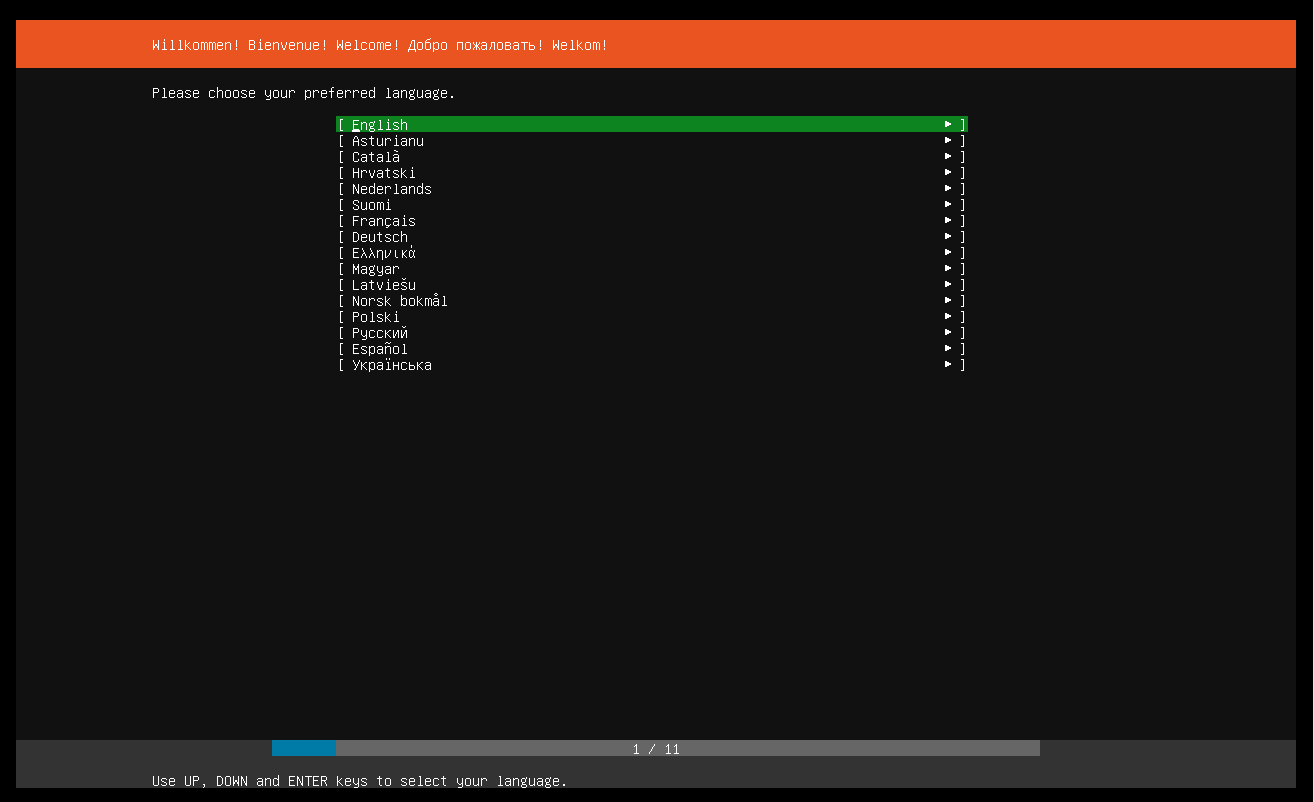


There is no need to change any of the hardware settings. 

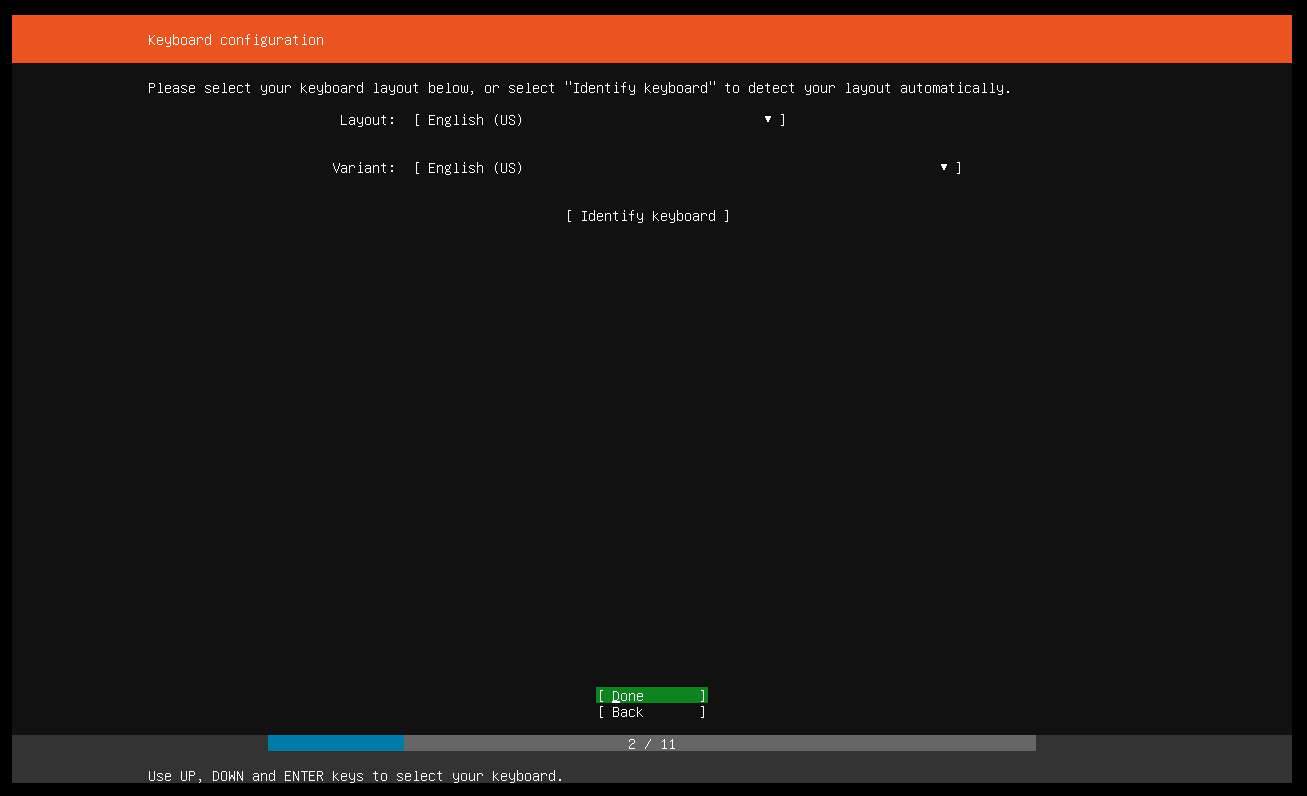
We do not need to split the disk, so we will continue without changing any of the settings.



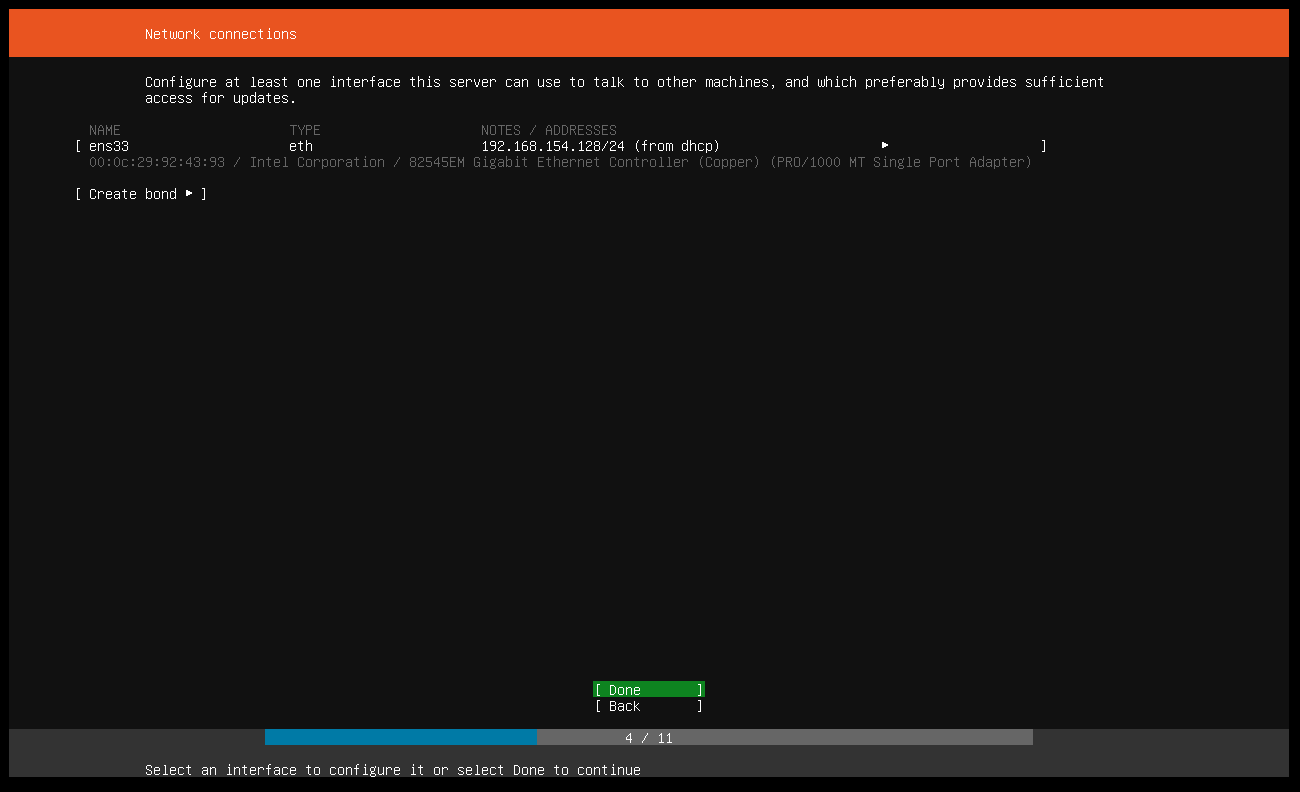
Once we finish, we should see a screen like above.



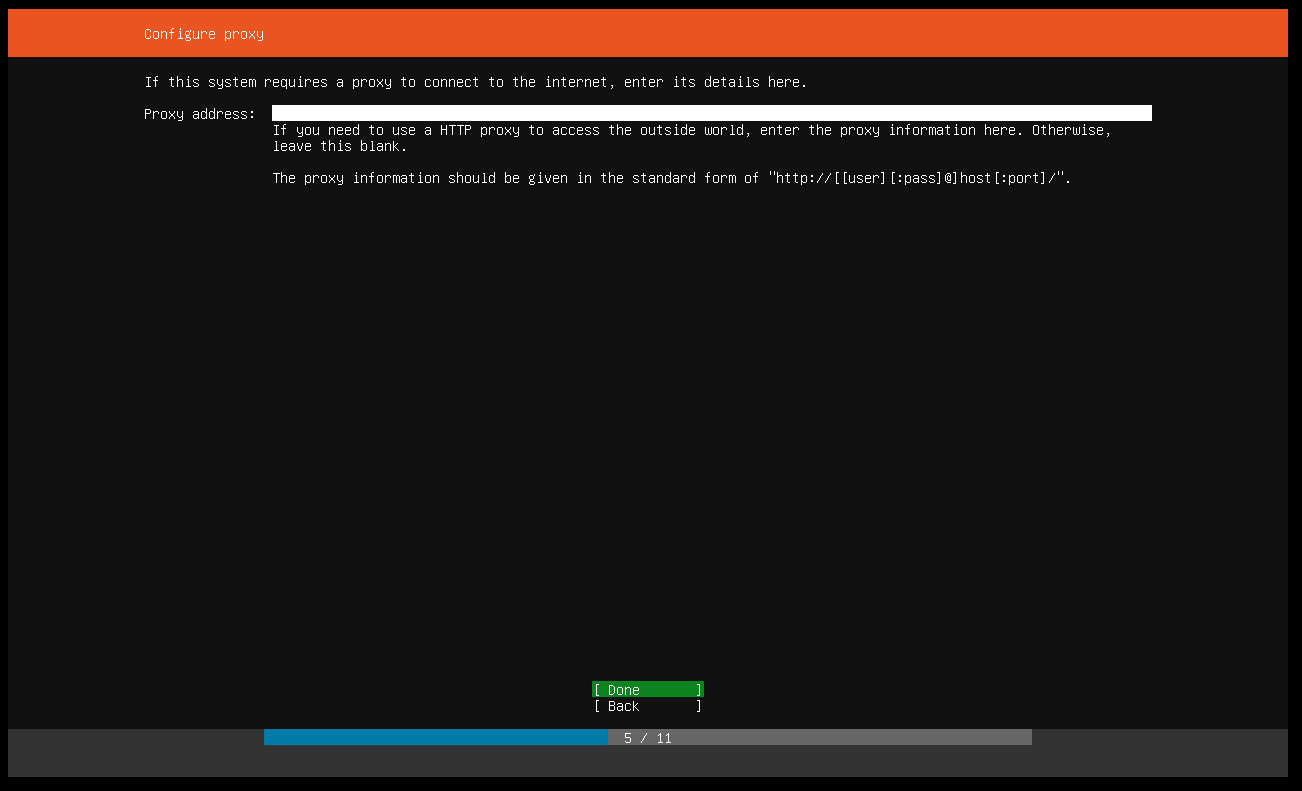
We will use the default language.



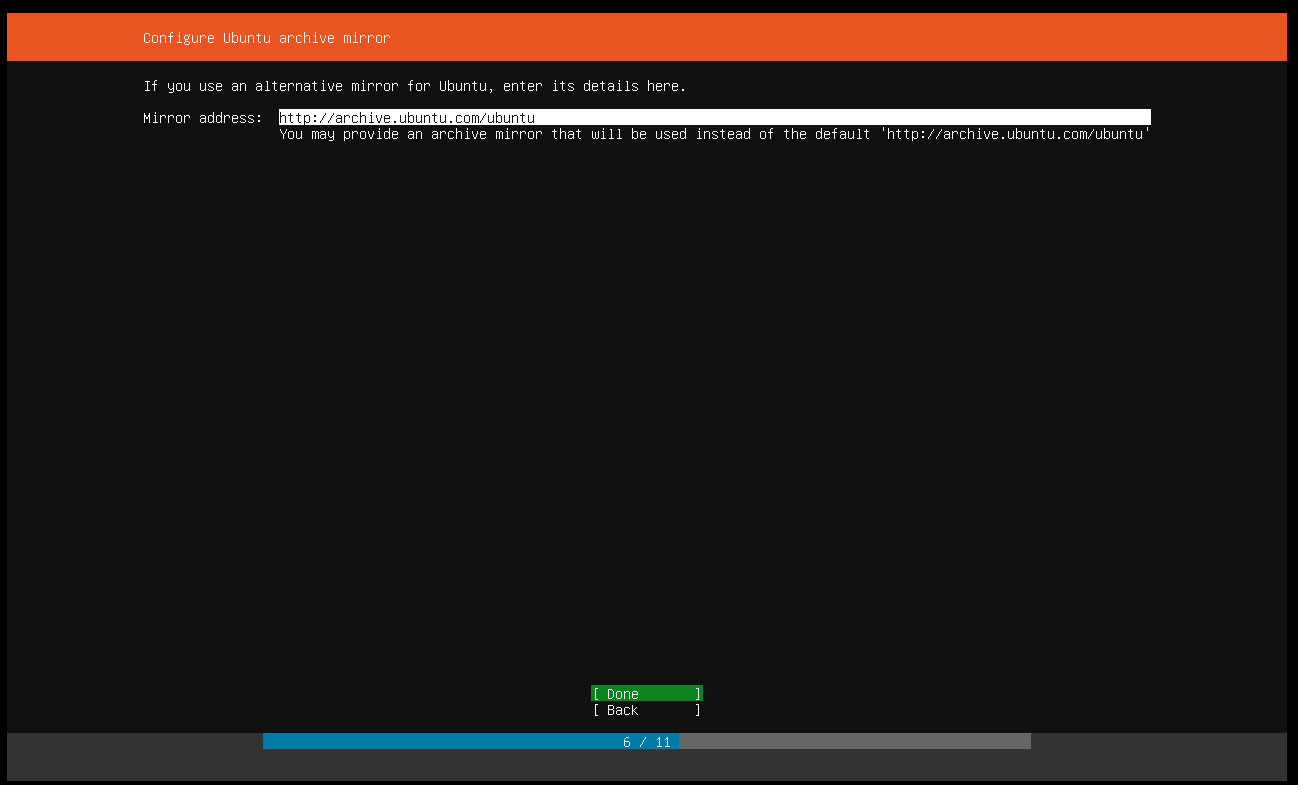
We will use the default keyboard.



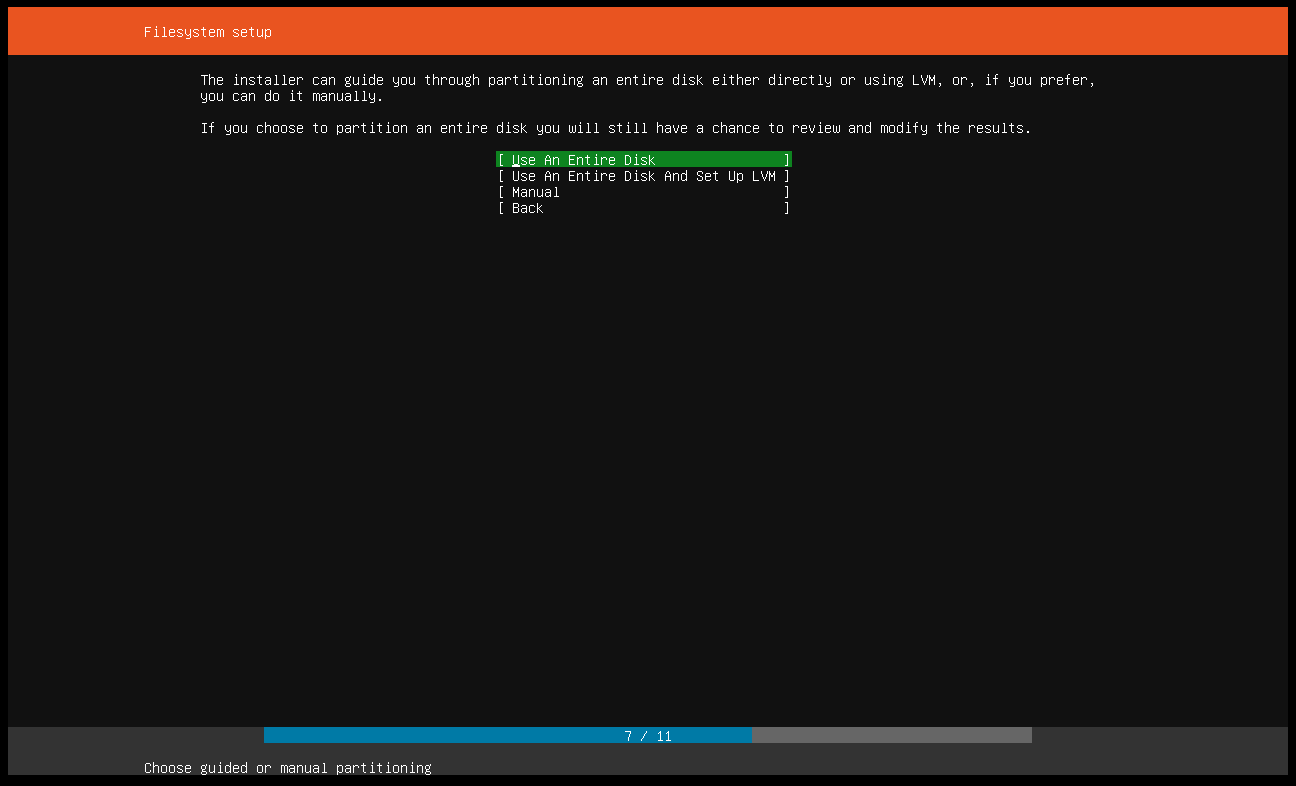
No need to change any settings. It is important to note the name of the interface, as it needs to be referenced later.



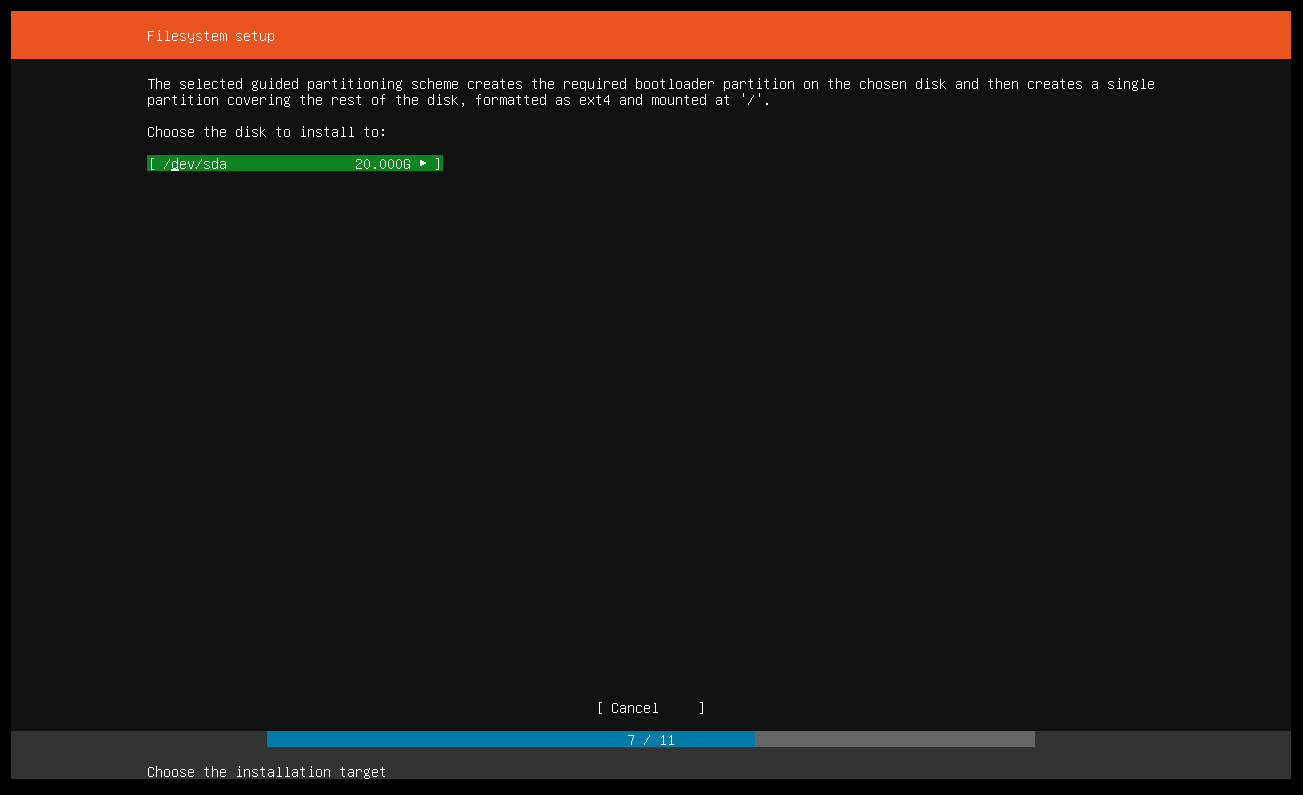
We do not need a proxy address.

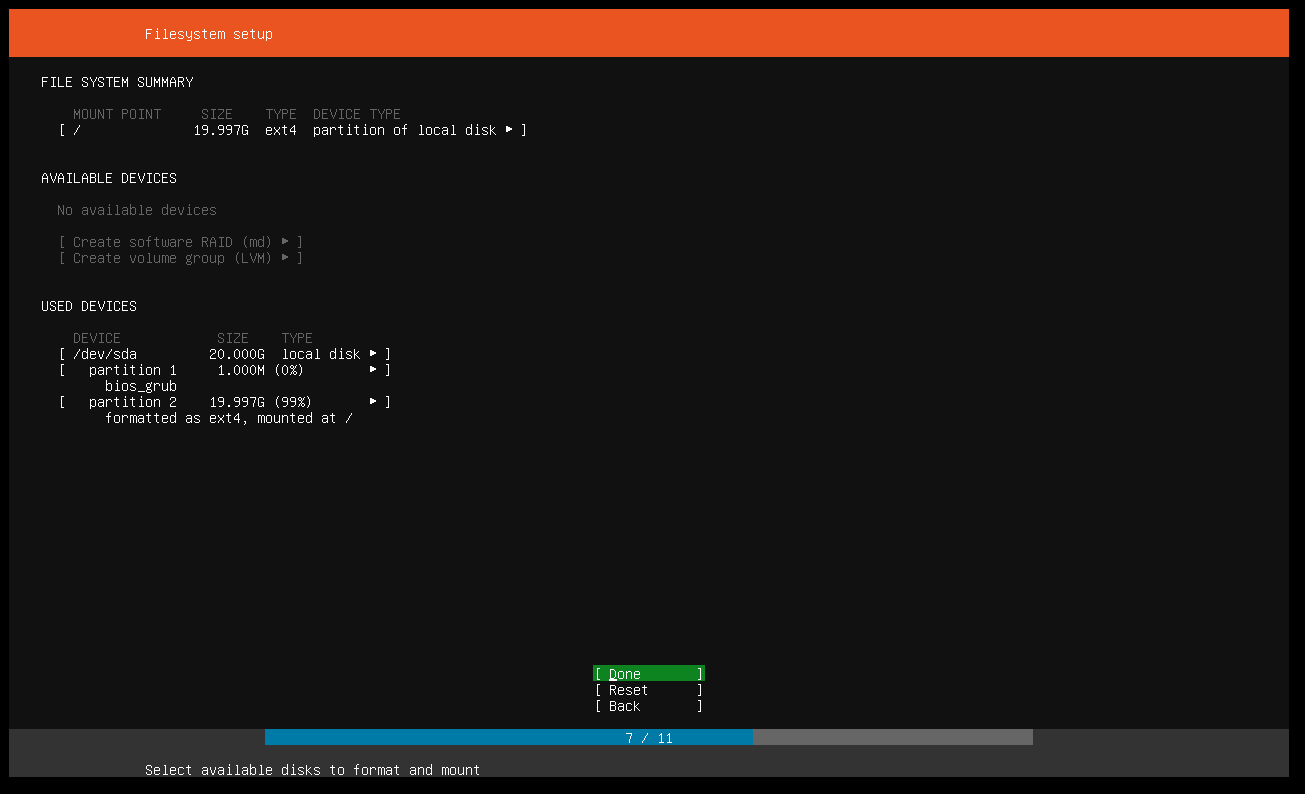


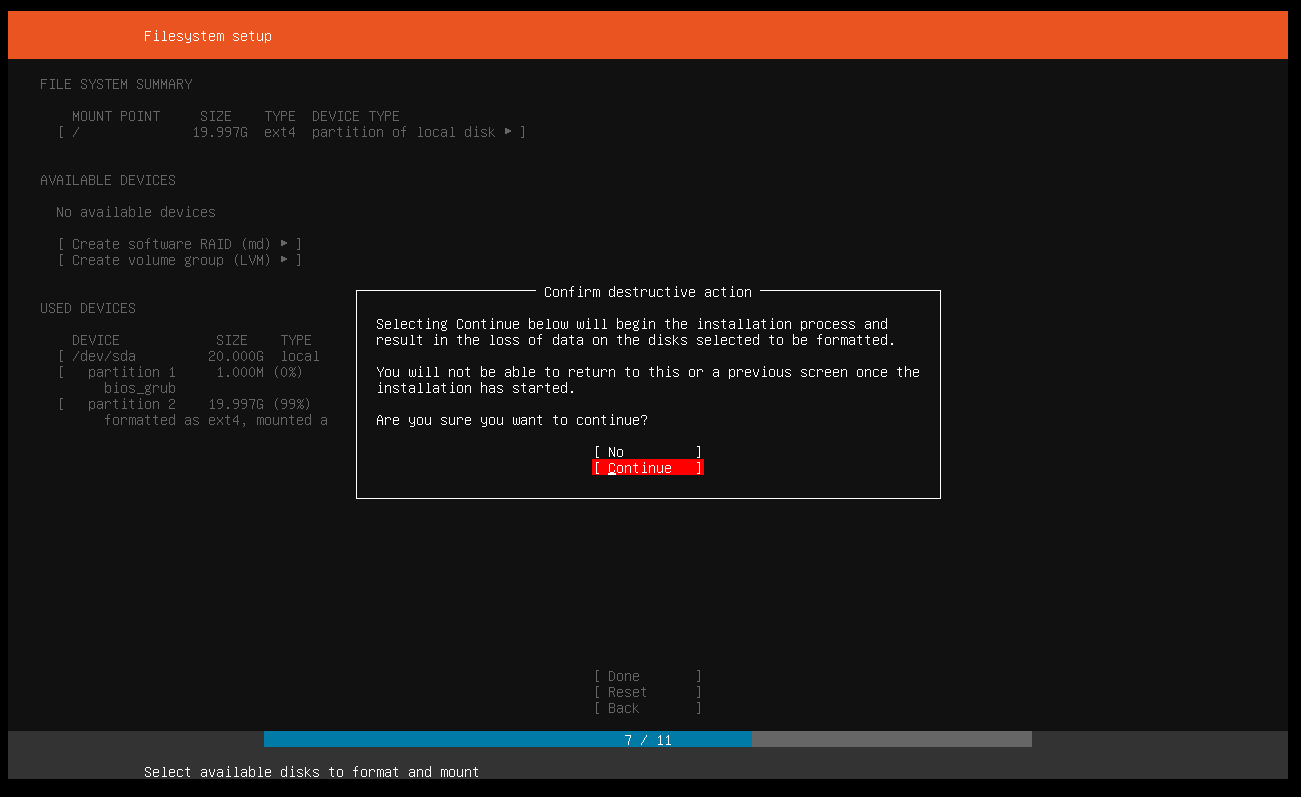
The default archive mirror is sufficient.

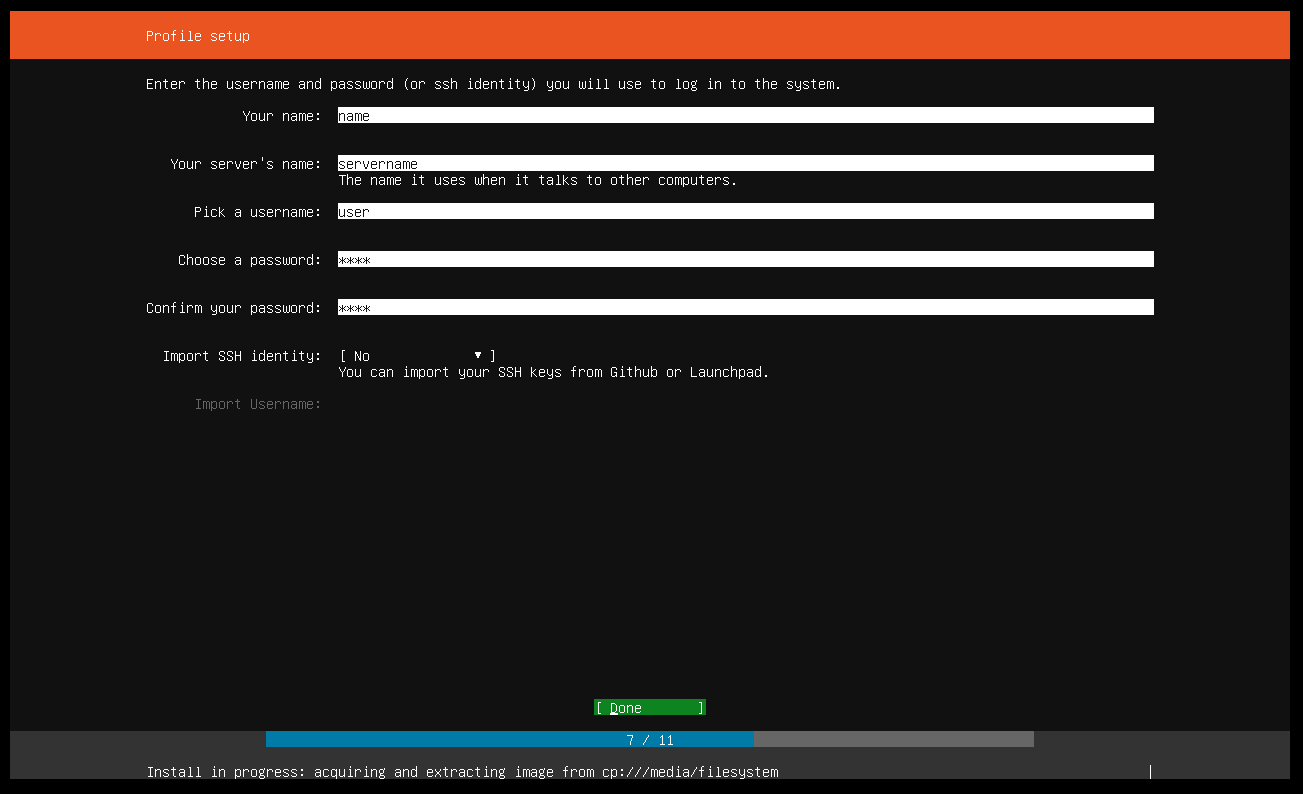


We will use an entire disk; no need for partitions.

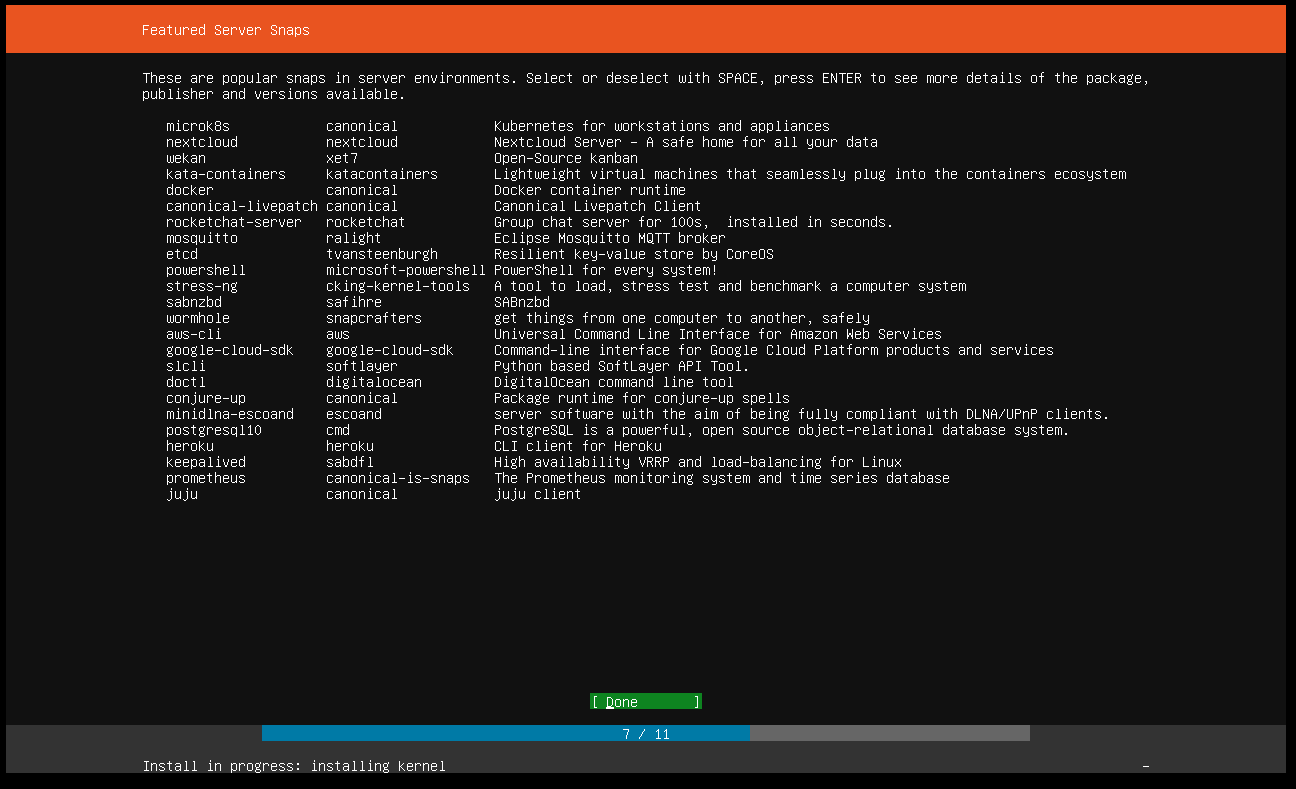




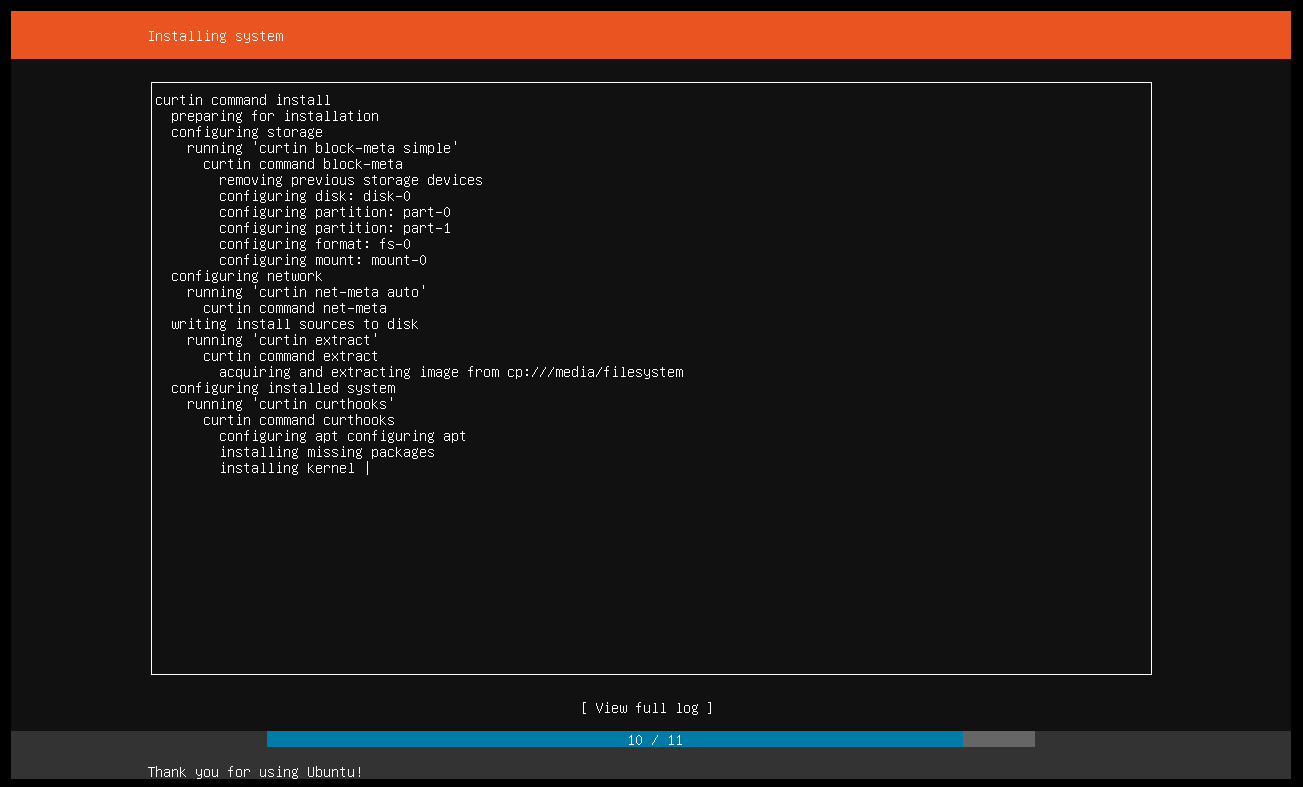


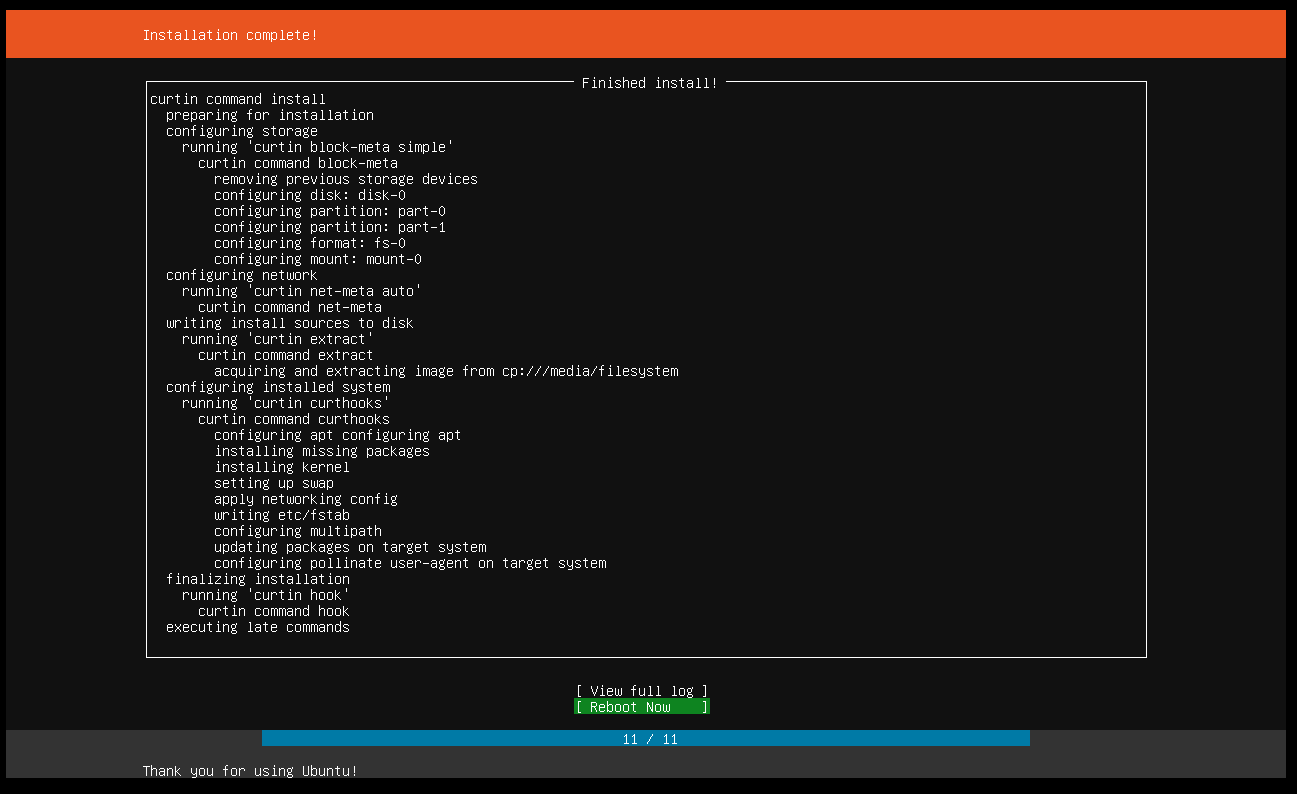


Configure the username and password here. The server name and personal name is not significant to this lab.

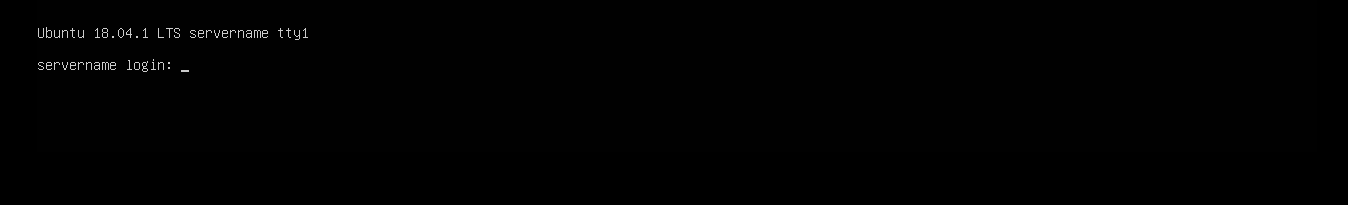


We will not need anything on this screen.





After restarting, the virtual machine should now be successfully created and you should get the following screen:



Router Show Commands:

**Router# show run**

Building configuration...

Current configuration : 2475 bytes

Last configuration change at 19:29:19 UTC Wed Apr 24 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

ip dhcp excluded-address 192.168.10.1

ip dhcp excluded-address 192.168.10.4 192.168.10.255

ip dhcp pool Bot

network 192.168.11.0 255.255.255.0

default-router 192.168.10.1

ip dhcp pool Top

network 192.168.10.0 255.255.255.0

default-router 192.168.11.1

lease infinite

interface GigabitEthernet0/0

ip address 192.168.10.1 255.255.255.0

duplex auto

speed auto

interface GigabitEthernet0/1

ip address 192.168.11.1 255.255.255.0

ip policy route-map Routing

duplex auto

speed auto

access-list 100 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.2 eq www

access-list 101 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.3 eq 443

access-list 102 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.2 eq 443

access-list 103 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.3 eq www

route-map Routing permit 10

match ip address 100

set ip next-hop 192.168.10.2

route-map Routing permit 20

match ip address 101

set ip next-hop 192.168.10.3

route-map Routing permit 30

match ip address 102

set interface Null0

route-map Routing permit 40

match ip address 103

set interface Null0

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

**Router# show ip dhcp binding**

Bindings from all pools not associated with VRF:

IP address       Client-ID/           Lease expiration     Type

                Hardware address/

                User name

192.168.10.2     000c.29ea.75fb       Infinite             Automatic

192.168.10.3     000c.2903.d98c       Infinite             Automatic

192.168.11.2     014c.cc6a.388e.e3    Apr 25 2019 07:20 PM Automatic

**Router# show route-map**

route-map Routing, permit, sequence 10

 Match clauses:

ip address (access-lists): 100

 Set clauses:

ip next-hop 192.168.10.2

 Policy routing matches: 12 packets, 1107 bytes

route-map Routing, permit, sequence 20

 Match clauses:

ip address (access-lists): 101

 Set clauses:

ip next-hop 192.168.10.3

 Policy routing matches: 18 packets, 2081 bytes

route-map Routing, permit, sequence 30

 Match clauses:

ip address (access-lists): 102

 Set clauses:

interface Null0

 Policy routing matches: 9 packets, 594 bytes

route-map Routing, permit, sequence 40

 Match clauses:

ip address (access-lists): 103

 Set clauses:

interface Null0

 Policy routing matches: 6 packets, 396 bytes

**Router# show ip access-lists**

Extended IP access list 100

10 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.2 eq www (12 matches)

Extended IP access list 101

10 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.3 eq 443 (18 matches)

Extended IP access list 102

10 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.2 eq 443 (18 matches)

Extended IP access list 103

10 permit tcp 192.168.11.0 0.0.0.255 host 192.168.10.3 eq www (12 matches)

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# Problems

We had a variety of minor problems throughout the lab, some of which shouldn’t really have happened. One such issue was simply forgetting to turn off internet access, as the computers would attempt to connect to websites via the wireless connection if we did not turn it off.

In configuring DHCP, we initially forgot to configure the “default-router” command for our DHCP pools, which caused the external PC to not have a gateway address. A related issue was on the virtual machines, which did not seem to receive a gateway address even with the “default-router” command. This caused pings to and from the virtual machines to outside the network to fail, which was puzzling. We eventually solved this by using the “route” command in the command line interface, which allowed us to see that there was no default gateway, and manually setting one ourselves.

Another thing we did not realize was that the network interface of the virtual machines was “ens33,” which is different from the typical “eth0” that we saw on online guides. This caused us a lot of grief as we were unable to figure out why we couldn’t configure a manual IP address (which we used for testing). It wasn’t until we looked closely at the output printed by the “ifconfig” command did we realize that the name of the interface was different.

# Conclusion

This lab was a gentle introduction to using policy-based routing on a network. The commands were fairly intuitive, and we were able to reference several good guides, so the lab overall went fairly smoothly. Through the process of completing the lab, we were able to learn important basics to policy-based routing and how it can be used to allow for custom management of a network.

MPLS

# CCNP Lab 10

## Axel Li

## 30 May 2019

# Purpose

The purpose of this lab was to learn the basics of Multiprotocol Label Switching (MPLS) and how to create a simple configuration. Our task was to configure MPLS on the backbone of a WAN consisting of three switches in a chain with two routers at either end. To complete the lab, we had to demonstrate pings between routers across the network and show that the switches were transmitting Label Distribution Protocol labels via Wireshark and show commands within the router. It was not necessary to prevent routers from different organizations (denoted by their letter in the topology below) from pinging each other, only that they could ping their corresponding router on the other side of the network.

# Background

MPLS is a routing technique that uses labels rather than network addresses to direct traffic within a network. This helps avoid delays in lookups in a routing table, thus speeding up traffic. In addition, MPLS utilizes paths between distant nodes, changing the label at each hop, which is different from the use of only endpoints in IP routing. MPLS is considered to be a layer 2.5 protocol under the OSI model, and “Multiprotocol” in the name refers to the ability to encapsulate packets from different routing protocols due to only using labels when making packet forwarding decisions. MPLS is similar to ATM and Frame Relay, which also use labels to move data through a network, but has evolved in response to the pros and cons of those previous technologies.

To communicate label information and establish paths, MPLS devices use Label Distribution Protocol (LDP). When a packet passes through a MPLS router, the topmost label is referenced and the router can either push (add a label), pop (remove the label), or swap (exchange the label for another) before sending out the packet based on label-switched paths in prebuilt lookup tables. Once the last label is popped at the egress router, the router forwards the encapsulated data according to its routing protocol.

# Summary

We started with creating a basic WAN with eBGP between the routers and switches, and OSPF as the backbone routing protocol between the switches, putting it aside in a text file to make quick changes until the configuration was correct. For iBGP, we configured loopback interfaces for each of the switches. At this point, we checked to make sure that there was connectivity throughout the entire network, which we did by pinging across the network between the routers. Afterwards, we added MPLS with LDP on the interfaces between the switches and configured port monitoring on the switches, sending all packets that went through the switch to desktop computer. To confirm that MPLS was now being used, we then used Wireshark to examine the packets being sent and found MPLS labels within the packets.

# Commands

The major commands specific to this lab are as follows:

router bgp [AS-number] - Creates an BGP routing process and enters routing configuration mode for this process

neighbor [Ip address] remote-as [AS number] - Establishes connection with the specified neighbor

neighbor [Ip address] update-source [Interface ID] - Configures an interface for use in establishing BGP peer connections with an internal BGP session

neighbor [Ip address] default-originate - Originates a default route for the specified neighbor

network [ip address] mask [subnet mask] - Configures the advertisement of networks in BGP

ip cef distributed - Enables distributed Cisco Express Forwarding operation to line cards where express forwarding is performed

mpls ip - Implemented by default, configures MPLS hop-by-hop forwarding globally (needs to be entered both in router configuration and in each interface)

mpls label protocol ldp - Configures the use of LDP on all interfaces (If global, can be overridden on specific interface configurations)

mpls label range [minimum label] [maximum label] - Specifies the range of labels for use with MPLS label assignments

mpls ldp router-id Loopback0 force - Specifies the preferred interface for use as the LDP router ID

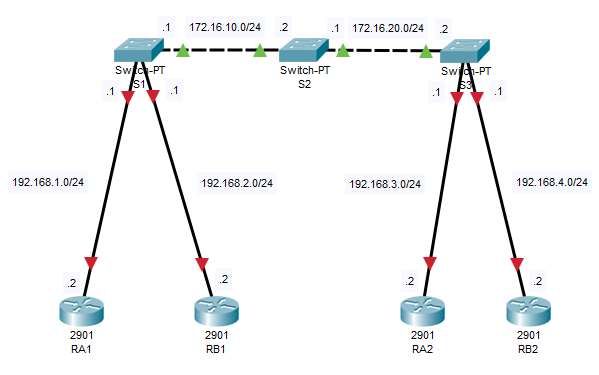
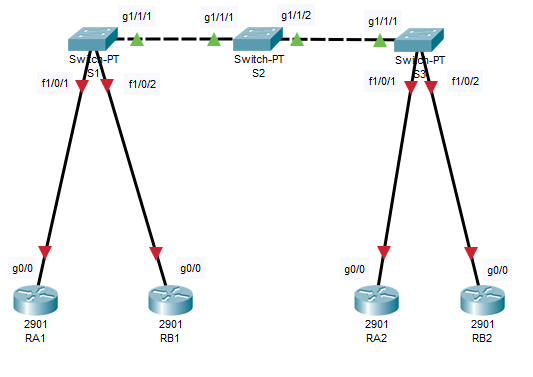
redistribute bgp [AS number] subnets - Redistributes BGP routes into OSPF processes

monitor session [session number] source interface [interface | interface range] – Specifies source interface for the specified SPAN session

monitor session [session number] destination interface [interface] - Specifies destination interface for specified SPAN session

# Tables and Diagrams

Topology Diagrams:



# Configurations

Show Commands:

**Router B2:**

RB2#show ip route

Gateway of last resort is 192.168.4.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.4.1, 00:38:55

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.4.1, 00:32:20

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.4.1, 00:31:49

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.4.1, 00:31:49

4.0.0.0/32 is subnetted, 1 subnets

C 4.4.4.4 is directly connected, Loopback0

B 192.168.1.0/24 [20/0] via 192.168.4.1, 00:38:55

B 192.168.2.0/24 [20/0] via 192.168.4.1, 00:38:55

B 192.168.3.0/24 [20/0] via 192.168.4.1, 00:38:55

192.168.4.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.4.0/24 is directly connected, GigabitEthernet0/0

L 192.168.4.2/32 is directly connected, GigabitEthernet0/0

RB2#show run

Building configuration...

Current configuration : 1672 bytes

Last configuration change at 17:58:12 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RB2

ip cef

interface Loopback0

ip address 4.4.4.4 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.4.2 255.255.255.0

duplex auto

speed auto

router bgp 4

bgp log-neighbor-changes

network 4.4.4.4 mask 255.255.255.255

network 192.168.4.0

neighbor 192.168.4.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

**Router A2:**

RA2#show ip route

Gateway of last resort is 192.168.3.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.3.1, 00:38:00

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.3.1, 00:31:25

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.3.1, 00:30:54

3.0.0.0/32 is subnetted, 1 subnets

C 3.3.3.3 is directly connected, Loopback0

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.3.1, 00:30:54

B 192.168.1.0/24 [20/0] via 192.168.3.1, 00:38:00

B 192.168.2.0/24 [20/0] via 192.168.3.1, 00:38:00

192.168.3.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.3.0/24 is directly connected, GigabitEthernet0/0

L 192.168.3.2/32 is directly connected, GigabitEthernet0/0

B 192.168.4.0/24 [20/0] via 192.168.3.1, 00:38:00

RA2#show run

Building configuration...

Current configuration : 1755 bytes

Last configuration change at 18:25:24 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RA2

ip cef

interface Loopback0

ip address 3.3.3.3 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.3.2 255.255.255.0

duplex auto

speed auto

router bgp 3

bgp log-neighbor-changes

network 3.3.3.3 mask 255.255.255.255

network 192.168.3.0

neighbor 192.168.3.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

**Router B1:**

RB1#show ip route

Gateway of last resort is 192.168.2.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.2.1, 00:37:23

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.2.1, 00:30:15

2.0.0.0/32 is subnetted, 1 subnets

C 2.2.2.2 is directly connected, Loopback0

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.2.1, 00:29:45

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.2.1, 00:29:14

B 192.168.1.0/24 [20/0] via 192.168.2.1, 00:37:23

192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.2.0/24 is directly connected, GigabitEthernet0/0

L 192.168.2.2/32 is directly connected, GigabitEthernet0/0

B 192.168.3.0/24 [20/0] via 192.168.2.1, 00:36:51

B 192.168.4.0/24 [20/0] via 192.168.2.1, 00:36:51

RB1#show run

Building configuration...

Current configuration : 1969 bytes

Last configuration change at 18:24:19 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RB1

ip cef

interface Loopback0

ip address 2.2.2.2 255.255.255.255

ip broadcast-address 2.2.2.2

interface GigabitEthernet0/0

ip address 192.168.2.2 255.255.255.0

ip broadcast-address 192.168.2.0

duplex auto

speed auto

router bgp 2

bgp log-neighbor-changes

network 2.2.2.2 mask 255.255.255.255

network 192.168.2.0

neighbor 192.168.2.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

**Router A1:**

RA1#show ip route

Gateway of last resort is 192.168.1.1 to network 0.0.0.0

B\* 0.0.0.0/0 [20/0] via 192.168.1.1, 00:36:29

1.0.0.0/32 is subnetted, 1 subnets

C 1.1.1.1 is directly connected, Loopback0

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.1.1, 00:28:51

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.1.1, 00:28:51

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.1.1, 00:28:20

192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.1.0/24 is directly connected, GigabitEthernet0/0

L 192.168.1.2/32 is directly connected, GigabitEthernet0/0

B 192.168.2.0/24 [20/0] via 192.168.1.1, 00:36:29

B 192.168.3.0/24 [20/0] via 192.168.1.1, 00:35:56

B 192.168.4.0/24 [20/0] via 192.168.1.1, 00:35:56

RA1#show run

Building configuration...

Current configuration : 1754 bytes

Last configuration change at 19:13:58 UTC Wed Jun 5 2019

version 15.2

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname RA1

ip cef

interface Loopback0

ip address 1.1.1.1 255.255.255.255

interface GigabitEthernet0/0

ip address 192.168.1.2 255.255.255.0

duplex auto

speed auto

router bgp 1

bgp log-neighbor-changes

network 1.1.1.1 mask 255.255.255.255

network 192.168.1.0

neighbor 192.168.1.1 remote-as 100

line con 0

line aux 0

line 2

no activation-character

no exec

transport preferred none

transport output lat pad telnet rlogin lapb-ta mop udptn v120 ssh

stopbits 1

line vty 0 4

login

transport input all

scheduler allocate 20000 1000

end

**Switch 3:**

S3#show mpls ldp bindings

lib entry: 1.1.1.1/32, rev 20

local binding: label: 205

remote binding: lsr: 20.20.20.20:0, label: 206

lib entry: 2.2.2.2/32, rev 22

local binding: label: 206

remote binding: lsr: 20.20.20.20:0, label: 207

lib entry: 3.3.3.3/32, rev 24

local binding: label: 207

remote binding: lsr: 20.20.20.20:0, label: 208

lib entry: 4.4.4.4/32, rev 26

local binding: label: 208

remote binding: lsr: 20.20.20.20:0, label: 209

lib entry: 10.10.10.10/32, rev 2

local binding: label: 200

remote binding: lsr: 20.20.20.20:0, label: 200

lib entry: 20.20.20.20/32, rev 4

local binding: label: 201

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 30.30.30.30/32, rev 6

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 203

lib entry: 172.16.10.0/24, rev 8

local binding: label: 202

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 172.16.20.0/24, rev 10

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 192.168.1.0/24, rev 12

local binding: label: 203

remote binding: lsr: 20.20.20.20:0, label: 201

lib entry: 192.168.2.0/24, rev 14

local binding: label: 204

remote binding: lsr: 20.20.20.20:0, label: 202

lib entry: 192.168.3.0/24, rev 18

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 205

lib entry: 192.168.4.0/24, rev 16

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 204

S3#show mpls ldp neighbors

Peer LDP Ident: 20.20.20.20:0; Local LDP Ident 30.30.30.30:0

TCP connection: 20.20.20.20.646 - 30.30.30.30.53728

State: Oper; Msgs sent/rcvd: 58/57; Downstream

Up time: 00:35:50

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.20.1

Addresses bound to peer LDP Ident:

20.20.20.20 172.16.10.2 172.16.20.1

S3#show mpls forwarding-table

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 200 10.10.10.10/32 0 Gi1/1/1 172.16.20.1

201 Pop Label 20.20.20.20/32 0 Gi1/1/1 172.16.20.1

202 Pop Label 172.16.10.0/24 0 Gi1/1/1 172.16.20.1

203 201 192.168.1.0/24 0 Gi1/1/1 172.16.20.1

204 202 192.168.2.0/24 0 Gi1/1/1 172.16.20.1

205 206 1.1.1.1/32 0 Gi1/1/1 172.16.20.1

206 207 2.2.2.2/32 0 Gi1/1/1 172.16.20.1

207 No Label 3.3.3.3/32 0 Fa1/0/1 192.168.3.2

208 No Label 4.4.4.4/32 610 Fa1/0/2 192.168.4.2

S3#show ip route

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

O E2 1.1.1.1 [110/1] via 172.16.20.1, 00:27:44, GigabitEthernet1/1/1

2.0.0.0/32 is subnetted, 1 subnets

O E2 2.2.2.2 [110/1] via 172.16.20.1, 00:27:14, GigabitEthernet1/1/1

3.0.0.0/32 is subnetted, 1 subnets

B 3.3.3.3 [20/0] via 192.168.3.2, 00:27:14

4.0.0.0/32 is subnetted, 1 subnets

B 4.4.4.4 [20/0] via 192.168.4.2, 00:27:14

10.0.0.0/32 is subnetted, 1 subnets

O 10.10.10.10 [110/3] via 172.16.20.1, 00:35:32, GigabitEthernet1/1/1

20.0.0.0/32 is subnetted, 1 subnets

O 20.20.20.20 [110/2] via 172.16.20.1, 00:35:32, GigabitEthernet1/1/1

S3#show run

Building configuration...

Current configuration : 2541 bytes

Last configuration change at 00:12:30 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname S3

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 30.30.30.30 255.255.255.255

interface FastEthernet1/0/1

no switchport

ip address 192.168.3.1 255.255.255.0

interface FastEthernet1/0/2

no switchport

ip address 192.168.4.1 255.255.255.0

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.20.2 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

redistribute bgp 100 subnets

network 30.30.30.30 0.0.0.0 area 0

network 172.16.20.0 0.0.0.255 area 0

router bgp 100

bgp log-neighbor-changes

network 192.168.3.0

network 192.168.4.0

neighbor 10.10.10.10 remote-as 100

neighbor 10.10.10.10 update-source Loopback0

neighbor 192.168.3.2 remote-as 3

neighbor 192.168.3.2 default-originate

neighbor 192.168.4.2 remote-as 4

neighbor 192.168.4.2 default-originate

no auto-summary

mpls ldp router-id Loopback0 force

line con 0

line vty 5 15

monitor session 1 source interface Fa1/0/1 - 2

monitor session 1 source interface Gi1/1/1

monitor session 1 destination interface Fa1/0/3

end

**Switch 2:**

S2#show mpls ldp bindings

lib entry: 1.1.1.1/32, rev 20

local binding: label: 206

remote binding: lsr: 10.10.10.10:0, label: 205

remote binding: lsr: 30.30.30.30:0, label: 205

lib entry: 2.2.2.2/32, rev 22

local binding: label: 207

remote binding: lsr: 30.30.30.30:0, label: 206

remote binding: lsr: 10.10.10.10:0, label: 206

lib entry: 3.3.3.3/32, rev 24

local binding: label: 208

remote binding: lsr: 30.30.30.30:0, label: 207

remote binding: lsr: 10.10.10.10:0, label: 207

lib entry: 4.4.4.4/32, rev 26

local binding: label: 209

remote binding: lsr: 30.30.30.30:0, label: 208

remote binding: lsr: 10.10.10.10:0, label: 208

lib entry: 10.10.10.10/32, rev 2

local binding: label: 200

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 200

lib entry: 20.20.20.20/32, rev 4

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 200

remote binding: lsr: 30.30.30.30:0, label: 201

lib entry: 30.30.30.30/32, rev 14

local binding: label: 203

remote binding: lsr: 30.30.30.30:0, label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 202

lib entry: 172.16.10.0/24, rev 6

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 202

lib entry: 172.16.20.0/24, rev 8

local binding: label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 201

remote binding: lsr: 30.30.30.30:0, label: imp-null

lib entry: 192.168.1.0/24, rev 10

local binding: label: 201

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 203

lib entry: 192.168.2.0/24, rev 12

local binding: label: 202

remote binding: lsr: 10.10.10.10:0, label: imp-null

remote binding: lsr: 30.30.30.30:0, label: 204

lib entry: 192.168.3.0/24, rev 18

local binding: label: 205

remote binding: lsr: 10.10.10.10:0, label: 204

remote binding: lsr: 30.30.30.30:0, label: imp-null

lib entry: 192.168.4.0/24, rev 16

local binding: label: 204

remote binding: lsr: 30.30.30.30:0, label: imp-null

remote binding: lsr: 10.10.10.10:0, label: 203

S2#show mpls ldp neighbors

Peer LDP Ident: 10.10.10.10:0; Local LDP Ident 20.20.20.20:0

TCP connection: 10.10.10.10.646 - 20.20.20.20.47613

State: Oper; Msgs sent/rcvd: 55/55; Downstream

Up time: 00:34:21

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.10.1

Addresses bound to peer LDP Ident:

10.10.10.10 192.168.1.1 192.168.2.1 172.16.10.1

Peer LDP Ident: 30.30.30.30:0; Local LDP Ident 20.20.20.20:0

TCP connection: 30.30.30.30.53728 - 20.20.20.20.646

State: Oper; Msgs sent/rcvd: 55/56; Downstream

Up time: 00:34:06

LDP discovery sources:

GigabitEthernet1/1/2, Src IP addr: 172.16.20.2

Addresses bound to peer LDP Ident:

30.30.30.30 192.168.4.1 172.16.20.2 192.168.3.1

S2#show mpls forwarding-table

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 Pop Label 10.10.10.10/32 5747 Gi1/1/1 172.16.10.1

201 Pop Label 192.168.1.0/24 590 Gi1/1/1 172.16.10.1

202 Pop Label 192.168.2.0/24 590 Gi1/1/1 172.16.10.1

203 Pop Label 30.30.30.30/32 5824 Gi1/1/2 172.16.20.2

204 Pop Label 192.168.4.0/24 590 Gi1/1/2 172.16.20.2

205 Pop Label 192.168.3.0/24 0 Gi1/1/2 172.16.20.2

206 205 1.1.1.1/32 0 Gi1/1/1 172.16.10.1

207 206 2.2.2.2/32 0 Gi1/1/1 172.16.10.1

208 207 3.3.3.3/32 0 Gi1/1/2 172.16.20.2

209 208 4.4.4.4/32 610 Gi1/1/2 172.16.20.2

S2#show ip route

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

O E2 1.1.1.1 [110/1] via 172.16.10.1, 00:26:01, GigabitEthernet1/1/1

2.0.0.0/32 is subnetted, 1 subnets

O E2 2.2.2.2 [110/1] via 172.16.10.1, 00:25:30, GigabitEthernet1/1/1

3.0.0.0/32 is subnetted, 1 subnets

O E2 3.3.3.3 [110/1] via 172.16.20.2, 00:25:30, GigabitEthernet1/1/2

4.0.0.0/32 is subnetted, 1 subnets

O E2 4.4.4.4 [110/1] via 172.16.20.2, 00:25:30, GigabitEthernet1/1/2

10.0.0.0/32 is subnetted, 1 subnets

O 10.10.10.10 [110/2] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

20.0.0.0/32 is subnetted, 1 subnets

C 20.20.20.20 is directly connected, Loopback0

30.0.0.0/32 is subnetted, 1 subnets

O 30.30.30.30 [110/2] via 172.16.20.2, 00:33:48, GigabitEthernet1/1/2

172.16.0.0/16 is variably subnetted, 4 subnets, 2 masks

C 172.16.10.0/24 is directly connected, GigabitEthernet1/1/1

L 172.16.10.2/32 is directly connected, GigabitEthernet1/1/1

C 172.16.20.0/24 is directly connected, GigabitEthernet1/1/2

L 172.16.20.1/32 is directly connected, GigabitEthernet1/1/2

O E2 192.168.1.0/24 [110/1] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

O E2 192.168.2.0/24 [110/1] via 172.16.10.1, 00:34:04, GigabitEthernet1/1/1

O E2 192.168.3.0/24 [110/1] via 172.16.20.2, 00:33:33, GigabitEthernet1/1/2

O E2 192.168.4.0/24 [110/1] via 172.16.20.2, 00:33:45, GigabitEthernet1/1/2

S2#show run

Building configuration...

Current configuration : 2280 bytes

Last configuration change at 02:15:04 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug datetime msec

service timestamps log datetime msec

no service password-encryption

hostname S2

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 20.20.20.20 255.255.255.255

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.10.2 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

interface GigabitEthernet1/1/2

no switchport

ip address 172.16.20.1 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

network 20.20.20.20 0.0.0.0 area 0

network 172.16.10.0 0.0.0.255 area 0

network 172.16.20.0 0.0.0.255 area 0

ip http server

ip http secure-server

mpls ldp router-id Loopback0 force

line con 0

line vty 5 15

monitor session 1 source interface Gi1/1/1 - 2

monitor session 1 destination interface Fa1/0/3

end

**Switch 1:**

S1#show mpls ldp bindings

lib entry: 1.1.1.1/32, rev 20

local binding: label: 205

remote binding: lsr: 20.20.20.20:0, label: 206

lib entry: 2.2.2.2/32, rev 22

local binding: label: 206

remote binding: lsr: 20.20.20.20:0, label: 207

lib entry: 3.3.3.3/32, rev 24

local binding: label: 207

remote binding: lsr: 20.20.20.20:0, label: 208

lib entry: 4.4.4.4/32, rev 26

local binding: label: 208

remote binding: lsr: 20.20.20.20:0, label: 209

lib entry: 10.10.10.10/32, rev 2

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 200

lib entry: 20.20.20.20/32, rev 10

local binding: label: 200

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 30.30.30.30/32, rev 15

local binding: label: 202

remote binding: lsr: 20.20.20.20:0, label: 203

lib entry: 172.16.10.0/24, rev 4

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 172.16.20.0/24, rev 12

local binding: label: 201

remote binding: lsr: 20.20.20.20:0, label: imp-null

lib entry: 192.168.1.0/24, rev 6

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 201

lib entry: 192.168.2.0/24, rev 8

local binding: label: imp-null

remote binding: lsr: 20.20.20.20:0, label: 202

lib entry: 192.168.3.0/24, rev 18

local binding: label: 204

remote binding: lsr: 20.20.20.20:0, label: 205

lib entry: 192.168.4.0/24, rev 16

local binding: label: 203

remote binding: lsr: 20.20.20.20:0, label: 204

S1#show mpls ldp neighbors

Peer LDP Ident: 20.20.20.20:0; Local LDP Ident 10.10.10.10:0

TCP connection: 20.20.20.20.47613 - 10.10.10.10.646

State: Oper; Msgs sent/rcvd: 53/53; Downstream

Up time: 00:32:50

LDP discovery sources:

GigabitEthernet1/1/1, Src IP addr: 172.16.10.2

Addresses bound to peer LDP Ident:

20.20.20.20 172.16.10.2 172.16.20.1

S1#show mpls forwarding-table

Local Outgoing Prefix Bytes Label Outgoing Next Hop

Label Label or Tunnel Id Switched interface

200 Pop Label 20.20.20.20/32 0 Gi1/1/1 172.16.10.2

201 Pop Label 172.16.20.0/24 0 Gi1/1/1 172.16.10.2

202 203 30.30.30.30/32 0 Gi1/1/1 172.16.10.2

203 204 192.168.4.0/24 0 Gi1/1/1 172.16.10.2

204 205 192.168.3.0/24 0 Gi1/1/1 172.16.10.2

205 No Label 1.1.1.1/32 0 Fa1/0/1 192.168.1.2

206 No Label 2.2.2.2/32 0 Fa1/0/2 192.168.2.2

207 208 3.3.3.3/32 0 Gi1/1/1 172.16.10.2

208 209 4.4.4.4/32 0 Gi1/1/1 172.16.10.2

S1#show ip route

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets

B 1.1.1.1 [20/0] via 192.168.1.2, 00:24:26

2.0.0.0/32 is subnetted, 1 subnets

B 2.2.2.2 [20/0] via 192.168.2.2, 00:23:55

3.0.0.0/32 is subnetted, 1 subnets

O E2 3.3.3.3 [110/1] via 172.16.10.2, 00:23:55, GigabitEthernet1/1/1

4.0.0.0/32 is subnetted, 1 subnets

O E2 4.4.4.4 [110/1] via 172.16.10.2, 00:23:55, GigabitEthernet1/1/1

10.0.0.0/32 is subnetted, 1 subnets

C 10.10.10.10 is directly connected, Loopback0

20.0.0.0/32 is subnetted, 1 subnets

O 20.20.20.20 [110/2] via 172.16.10.2, 00:32:29, GigabitEthernet1/1/1

30.0.0.0/32 is subnetted, 1 subnets

O 30.30.30.30 [110/3] via 172.16.10.2, 00:32:03, GigabitEthernet1/1/1

172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks

C 172.16.10.0/24 is directly connected, GigabitEthernet1/1/1

L 172.16.10.1/32 is directly connected, GigabitEthernet1/1/1

O 172.16.20.0/24

[110/2] via 172.16.10.2, 00:32:13, GigabitEthernet1/1/1

192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.1.0/24 is directly connected, FastEthernet1/0/1

L 192.168.1.1/32 is directly connected, FastEthernet1/0/1

192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks

C 192.168.2.0/24 is directly connected, FastEthernet1/0/2

L 192.168.2.1/32 is directly connected, FastEthernet1/0/2

O E2 192.168.3.0/24 [110/1] via 172.16.10.2, 00:31:58, GigabitEthernet1/1/1

O E2 192.168.4.0/24 [110/1] via 172.16.10.2, 00:32:03, GigabitEthernet1/1/1

S1#show run

Building configuration...

Current configuration : 4775 bytes

Last configuration change at 02:14:49 UTC Mon Mar 1 1993

version 12.2

no service pad

service timestamps debug uptime

service timestamps log uptime

no service password-encryption

hostname S1

ip routing

mpls label range 200 299

mpls label protocol ldp

interface Loopback0

ip address 10.10.10.10 255.255.255.255

interface FastEthernet1/0/1

no switchport

ip address 192.168.1.1 255.255.255.0

interface FastEthernet1/0/2

no switchport

ip address 192.168.2.1 255.255.255.0

interface GigabitEthernet1/1/1

no switchport

ip address 172.16.10.1 255.255.255.0

speed auto 1000

mpls label protocol ldp

mpls ip

router ospf 1

redistribute bgp 100 subnets

network 10.10.10.10 0.0.0.0 area 0

network 172.16.10.0 0.0.0.255 area 0

router bgp 100

bgp log-neighbor-changes

network 192.168.1.0

network 192.168.2.0

neighbor 30.30.30.30 remote-as 100

neighbor 30.30.30.30 update-source Loopback0

neighbor 192.168.1.2 remote-as 1

neighbor 192.168.1.2 default-originate

neighbor 192.168.2.2 remote-as 2

neighbor 192.168.2.2 default-originate

no auto-summary

mpls ldp router-id Loopback0 force

line con 0

line vty 0 4

login

line vty 5 15

login

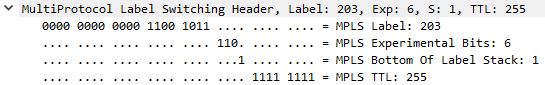
monitor session 1 source interface Fa1/0/1 - 2

monitor session 1 source interface Gi1/1/1

monitor session 1 destination interface Fa1/0/3

end

Wireshark Proof of MPLS Labels:



We found this by putting “MPLS” as the filter and searching the MPLS header.

Traceroute Proof of MPLS Labels:

RB2#traceroute 1.1.1.1

Type escape sequence to abort.

Tracing the route to 1.1.1.1

VRF info: (vrf in name/id, vrf out name/id)

1 192.168.4.1 0 msec 4 msec 4 msec

2 172.16.20.1 [AS 100] [MPLS: Label 206 Exp 0] 0 msec 4 msec 0 msec

3 172.16.10.1 [AS 100] [MPLS: Label 205 Exp 0] 0 msec 0 msec 0 msec

4 192.168.1.2 [AS 100] 4 msec \* 0 msec

# Problems

My partner and I struggled a lot with this lab due to making things more complicated than it should be. For instance, while researching MPLS we became quickly confused with which aspects of MPLS were necessary for completion of this lab. In addition, our colleagues all had different approaches towards the lab, making the process significantly more overwhelming. Online guides were especially unhelpful, as they did not explain which commands were actually necessary for just a basic configuration, and often gave vague explanations for what the commands did.

As we were told that at least one portion of the network must have MPLS configured manually, we spent a significant amount of time attempting to make static labels work. No matter what we tried, we just couldn’t get it to work. It turns out that we simply were not supposed to use an autoconfiguration command, and all our work ended up being useless. The MPLS portion of the lab turned out to be quite simple, with only a couple of commands on each switch, but we only figured out about this at the very end.

# Conclusion

This lab was a difficult introduction to configuring basic MPLS due to the many distractors that we ran into. The commands itself, however, were extremely simple, so the latter portion of the lab when we knew exactly what to do went incredibly smoothly. With completing this lab, we learned the theory of how MPLS operates and its general uses as well as how to configure one ourselves, which is especially useful as MPLS is an industry relevant protocol.