WAP Implementation Documentation

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Purpose:

The primary purpose of this lab is to familiarize ourselves with Cisco Access Point configuration. To do so, our task was to configure an access point that broadcasted three unique SSID's. Two of these SSID's were set to be using WPA2 PSK, whereas the other one uses a RADIUS server to provide authentication. All three SSID's were required to be able to connect to the Internet. Throughout this lab, we both learned AP configuration and also reviewed previous concepts such as DHCP, NAT/PAT, and VLAN setup/trunking.

Background Information:

Access Point Technology

With the rise of wireless technologies in recent decades, more network topologies have shifted from traditional, physical ethernet connections to more convenient wireless connections. To do so, most networks utilize a Wireless Access Point (WAP), which enables various clients ranging from laptops to IP phones to connect wirelessly to the network. These access points function on a network topology by continuously broadcasting a Service Set Identifier (SSID) on a certain radio frequency or channel, from which endpoint devices can pick up on and connect to. Devices will send authentication requests to the access point based on the type of wireless connection. After the device is authenticated, the access point will act as an intermediary device between the client and the network topology. This enables wireless communication with minimized hassle, as the access point functions similarly to a router/switch in handling packets.

This lab required us to configure a Cisco Aironet AP, which we would use to create three different SSID's. Before configuring, we needed to ensure that the AP was running latest software. Due to the relatively outdated nature of the AP's, we needed to download new Cisco firmware and flash it onto the device. To do so, we learned how to enter boot recovery on an AP, and from there we transferred a firmware image through TFTP.

Typically, clients on an access point will be assigned addresses from a private network through NAT. In this lab, we assigned each client on a private network, which ran through two layers of NAT in order to get to the internet. First, we needed to run PAT on the one address assigned to us by our upstream DHCP, and then we needed to run NAT on each SSID.

Wireless Security

After successfully loading firmware and configuring basic settings on the AP, we needed to create unique SSID's using WPA2 and WPA2 Enterprise for authentication.

Since WAP's provide wireless capabilities, packets are sent through radio frequencies. However, given that this is the case, attackers have leveraged this to perform packet sniffing. With the right equipment and setup, an attacker can intercept packets between an AP and a client, thus presenting a significant security issue. By sniffing packets, an attacker can intercept potentially critical information, such as login information to websites.

Initially, a protocol called Wired Equivalent Privacy (WEP) was created and used in the early 2000's to provide wireless security. This protocol was aimed at providing security that matched that of wired networks, meaning that attackers would not be able to decrypt packets that were sniffed. However, this protocol has been deprecated for quite a long time now, as numerous different issues were found within its implementation. Due to limited cryptographic advances at the time, the WEP protocol is easy to brute-force and crack with modern computing power, and as such should not be used.

WPA was introduced in order to provide a fix for the faults that WEP had, and presented stronger cryptographic encryption, as well as separate protocols for industry and home use. WPA-Personal is used for home networks and provides a simple solution to network security. On the other hand, WPA-Enterprise is tailored towards corporate use, and it utilizes an external Remote Authentication Dial-In-User Service (RADIUS) to provide login. RADIUS is a protocol which provides an AAA service, consisting of:

1) Authentication: Logging in as various different users, each with unique passwords
2) Authorization: Determining what permissions are granted to logged in users
3) Accounting: Tracking user resource consumption and session history

RADIUS authenticates users using a user/pass scheme. In conjunction with WPA, it enables enterprise use. WPA2 builds off of WPA, however uses AES instead of TKIP for encryption, whereas WPA3 further increases cryptographic strength and adds various other improvements. In this lab, we utilized an external drive to setup RADIUS, mimicking a real server. However, one could also as easily setup RADIUS on a Docker image, which allows for scalability and flexibility.

Lab Summary:

First off, we needed to flash our AP using the appropriate firmware. The AP's that we received were running older firmware, and our task was to put K9W7-JD9 on it. To do so, we used TFTP in order to transfer the file over. After flashing our firmware, we continued with basic AP configuration.

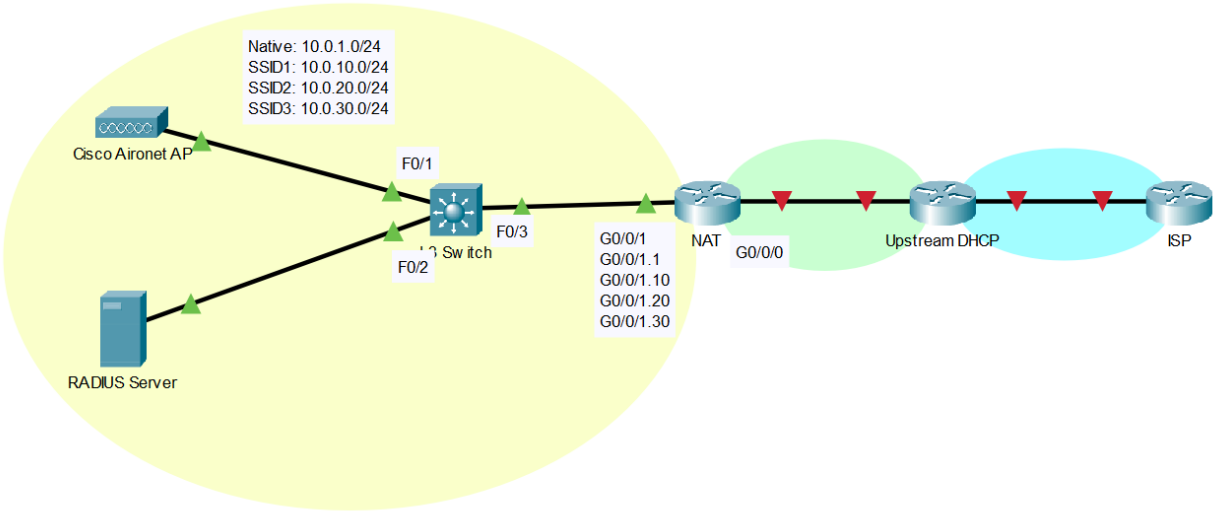
In order to get this lab working, we needed to use both DHCP and PAT in order to retrieve an internet-accessible address, as well as to give addresses to clients connecting to our SSID. To do so, we had to use VLANs to separate our three different

SSID networks. Each had its own subnet, and was trunked to the switch and router. This would allow each VLAN to reach the internet, but avoid security implications while doing so. Each VLAN is separate from the others and cannot ping them.

Finally, we needed to configure some form of a RADIUS server. We settled on using an external Ubuntu drive to do so, mimicking a real server scenario. However, with the rise of virtualization, this could easily have been put in a Docker container to simplify deployment and increase flexibility.

Network Diagram and IP Table:

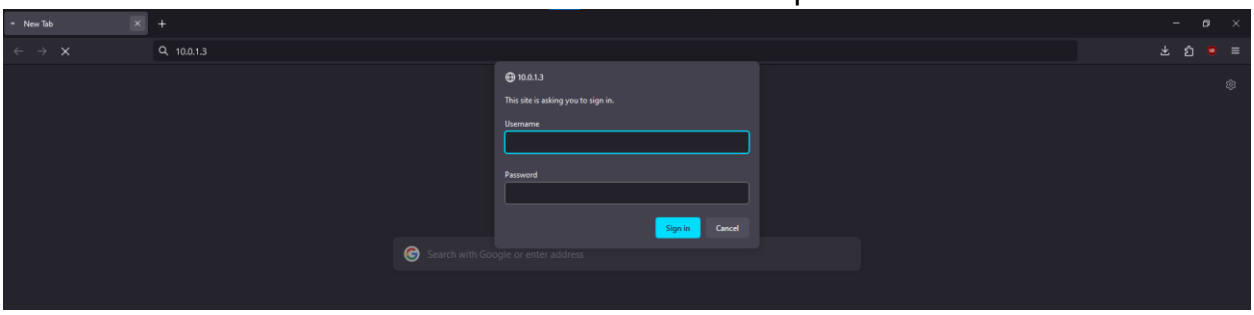
Device	Port	IPv4	Mask
R1	G0/0/0	DHCP (ISP side)	
	G0/0/1.1	10.0.1.1	255.255.255.0
	G0/0/1.10	10.0.10.1	255.255.255.0
	G0/0/1.20	10.0.20.1	255.255.255.0
	G0/0/1.30	10.0.30.1	255.255.255.0
S1	Vlan 1	10.0.1.2	255.255.255.0
AP		10.0.1.3	255.255.255.0
Radius		10.0.1.254	255.255.255.0
PC1	Wireless Adapter	DHCP (from switch)	255.255.255.0
PC2	Wireless Adapter	DHCP (from switch)	255.255.255.0



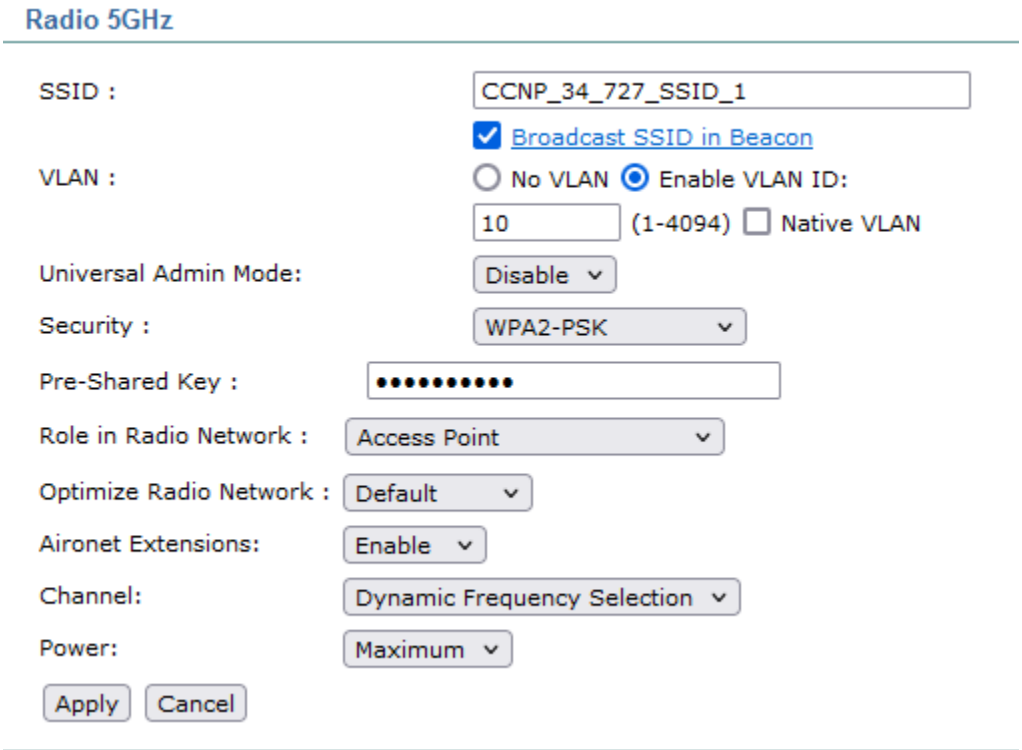
Configurations:

AP WPA2 PSK SSID:

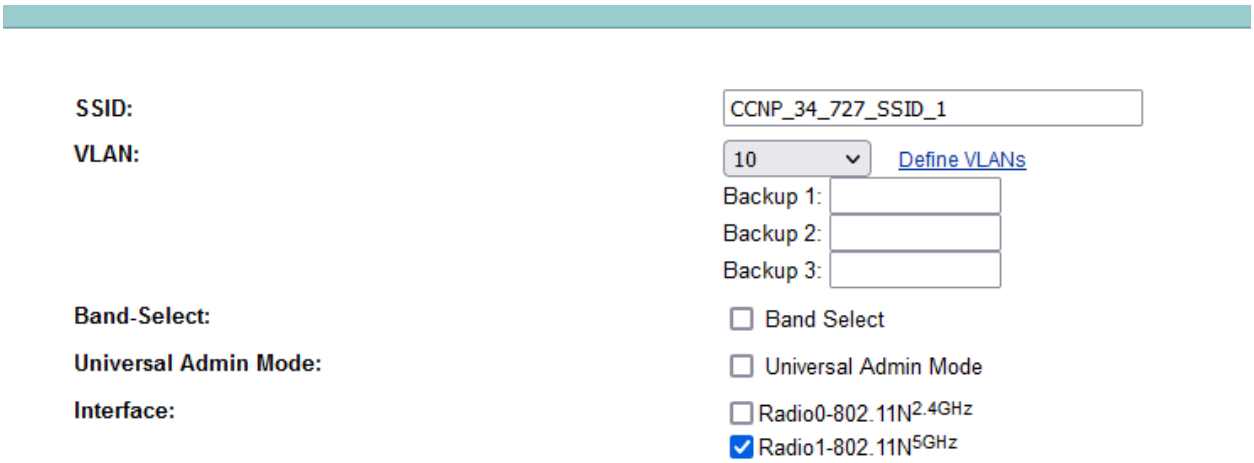
1) Enter the Cisco WAP by typing in the assigned IP address in a computer connected to the same LAN. The default username and password is “Cisco”.



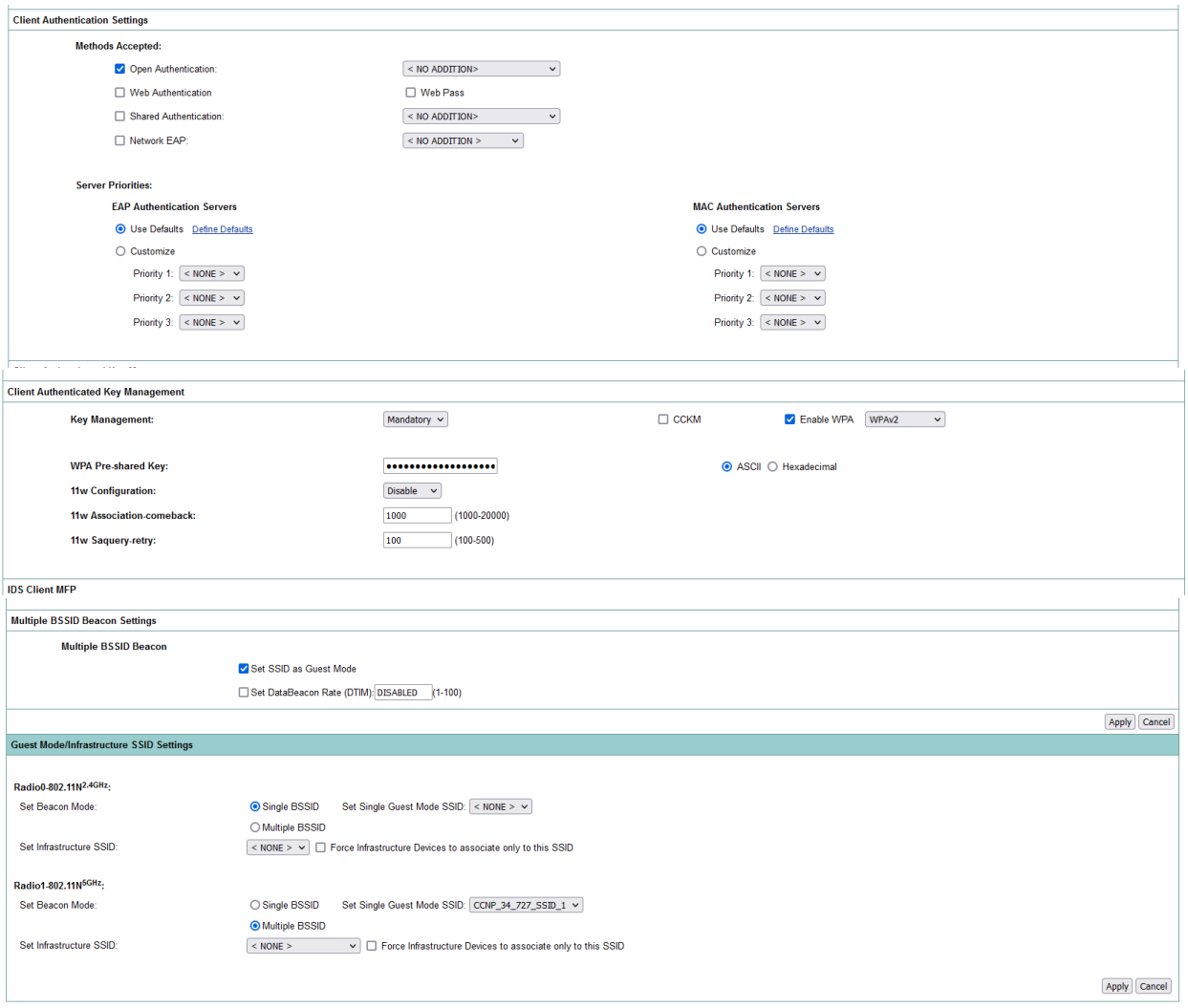
2) Using the SSID setup under “Network Configuration”, configure a new SSID with WPA2-PSK. The VLAN ID should in best practice correspond to the SSID value. For our purposes, SSID 1 was on VLAN 10, SSID 2 on VLAN 20, etc.



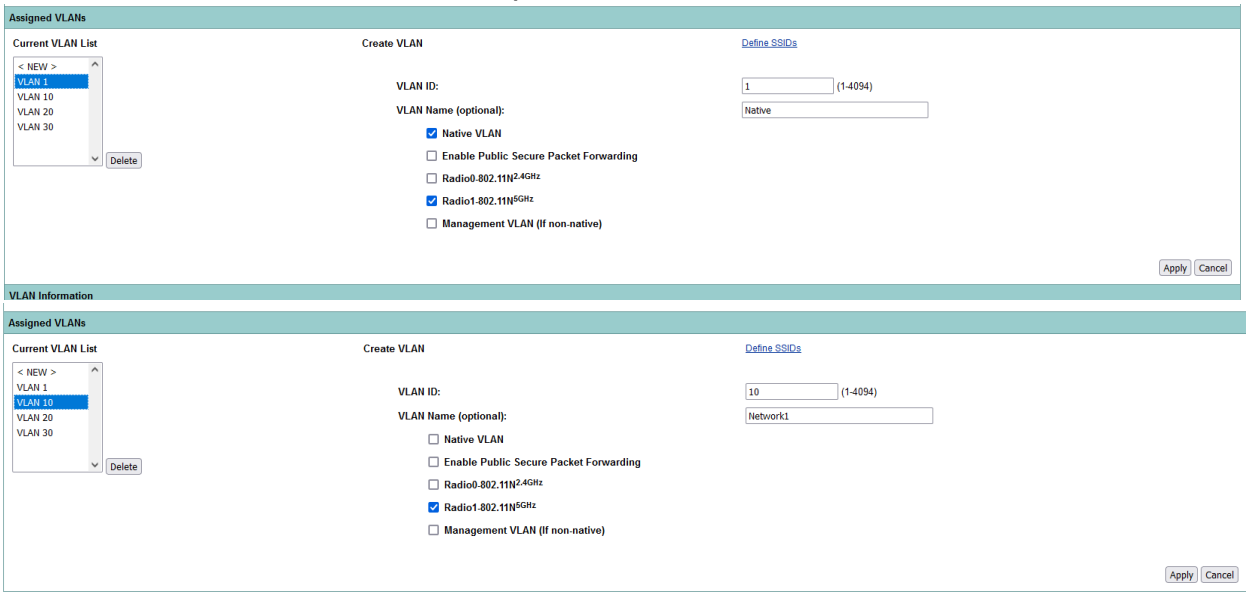
3) Navigate to “Security>SSID Manager” and select the newly created SSID. Ensure the SSID is on Radio1-5Ghz.



4) Ensure the Authentication settings is set to none. This is only used for RADIUS servers. Verify WPA2 is configured and that Guest Mode is on. This allows clients to connect to the SSID by broadcast. Furthermore, set Radio1 interface to be Multiple BSSID, allowing more than one SSID to be broadcasted.



5) Create a corresponding VLAN for your new SSID. Ensure that there is already a Native VLAN in order for the access point and switch to communicate.

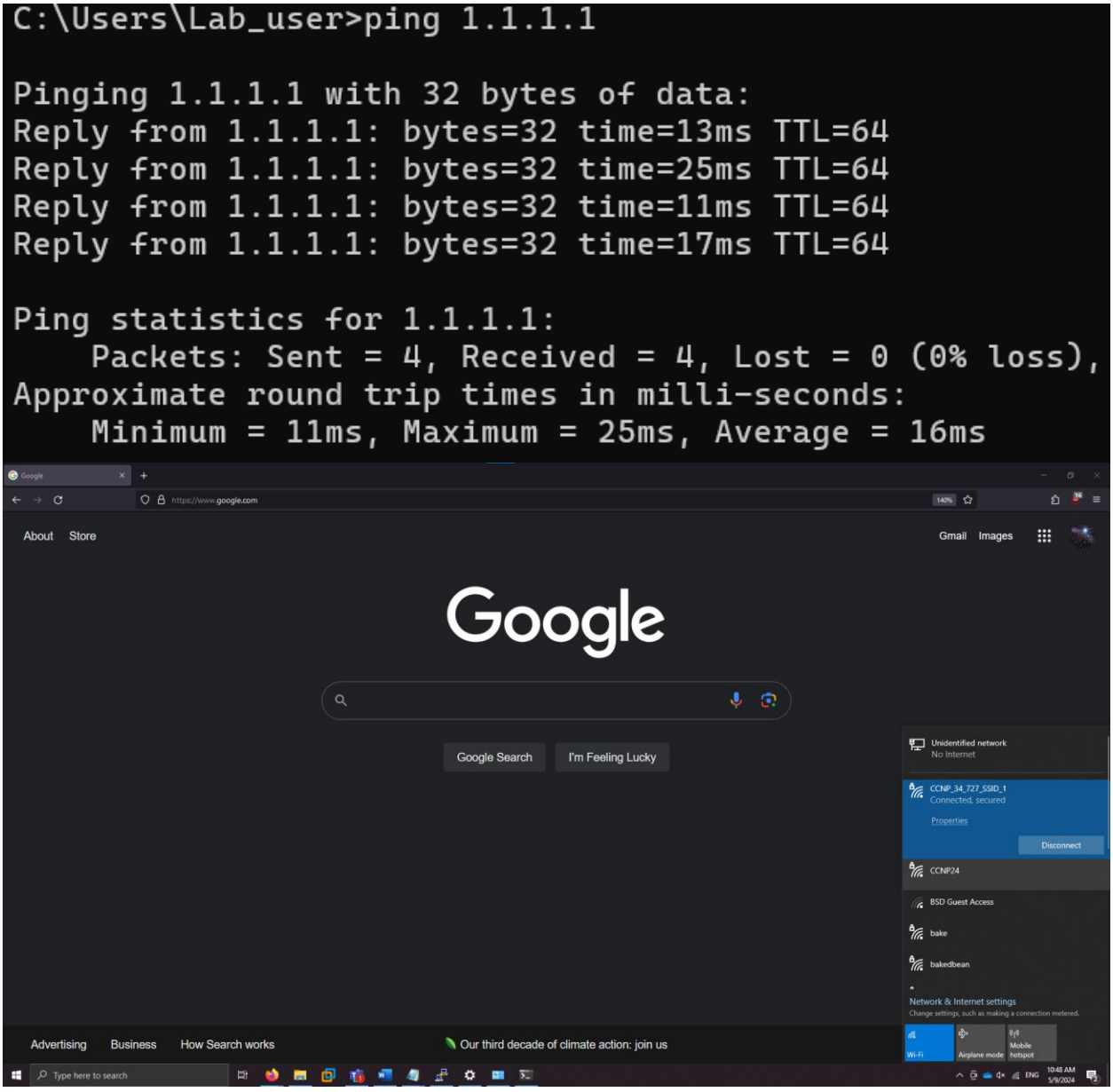


6) Setup the VLAN on the switch side. Console into the switch through PuTTY and enter the interface of the port connected to the access point. Then, set the port as a trunk using:
   switchport trunk encapsulation dot1q
   switchport mode trunk
7) Now enter the router that the switch connects to. Enter the sub-interface corresponding to the VLAN on the interface connecting to the switch. Set the VLAN on this sub-interface.
   interface GigabitEthernet0/0/1.10
   encapsulation dot1Q 10
   ip address 10.0.10.1 255.255.255.0
8) Finally, ensure that the native VLAN is up by configuring the same process on the native VLAN interface, usually G0/0/1.1:
   interface GigabitEthernet0/0/1.1
   encapsulation dot1Q 1 native
   ip address 10.0.1.1 255.255.255.0
9) Now that internet connectivity is open, we must assign addresses and DNS to each of the clients connecting on an SSID. To do so, we must use DHCP. Configure DHCP on the Switch as follows:
   ip dhcp pool vPool1
   network 10.0.1.0 255.255.255.0
   default-router 10.0.1.1
   dns-server 8.8.8.8

10) Check for network connectivity by connecting to the configured SSID. It should show up as an available network on any device with WiFi. After connecting, verify that DHCP is correctly assigning addresses and the DNS server is working.

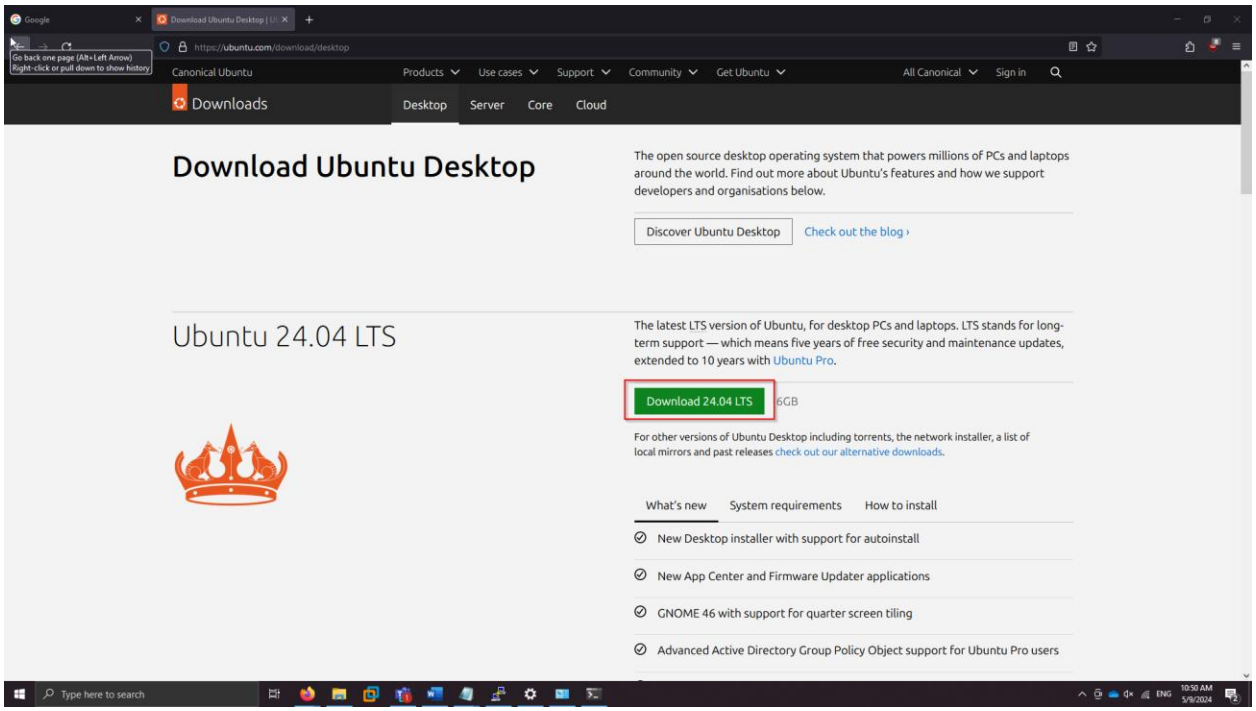
```
Wireless LAN adapter Wi-Fi 2:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) Dual Band Wireless-AC 8260 #2
   Physical Address. . . . . . . . . : AC-ED-5C-3E-57-6A
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv4 Address. . . . . . . . . . . : 10.0.10.4(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Thursday, May 9, 2024 10:32:21 AM
   Lease Expires . . . . . . . . . . : Friday, May 10, 2024 10:46:52 AM
   Default Gateway . . . . . . . . . : 10.0.10.1
   DHCP Server . . . . . . . . . . . : 10.0.10.2
   DNS Servers . . . . . . . . . . . : 127.0.2.2
                                       127.0.2.3
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

11) Finally, verify full internet connectivity by pinging any given address.

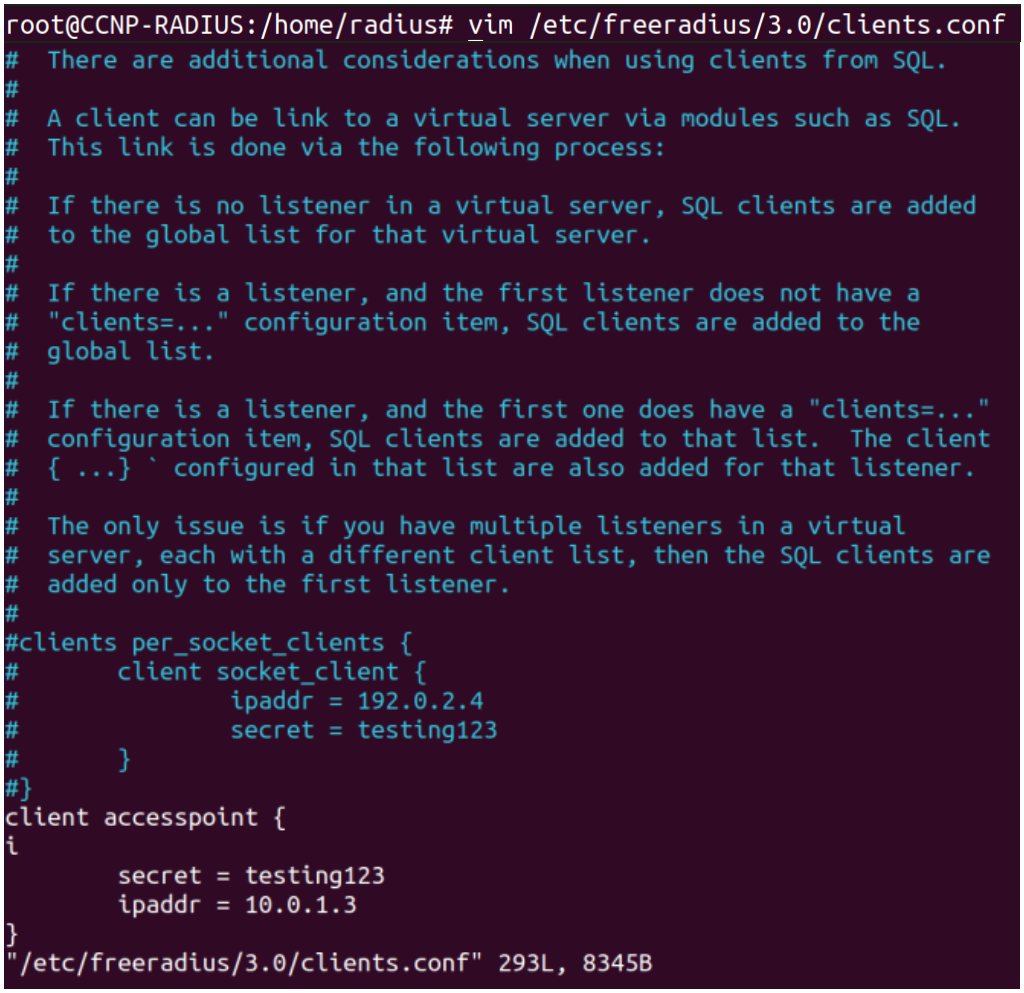


AP WPA2 Enterprise SSID (RADIUS Configuration):

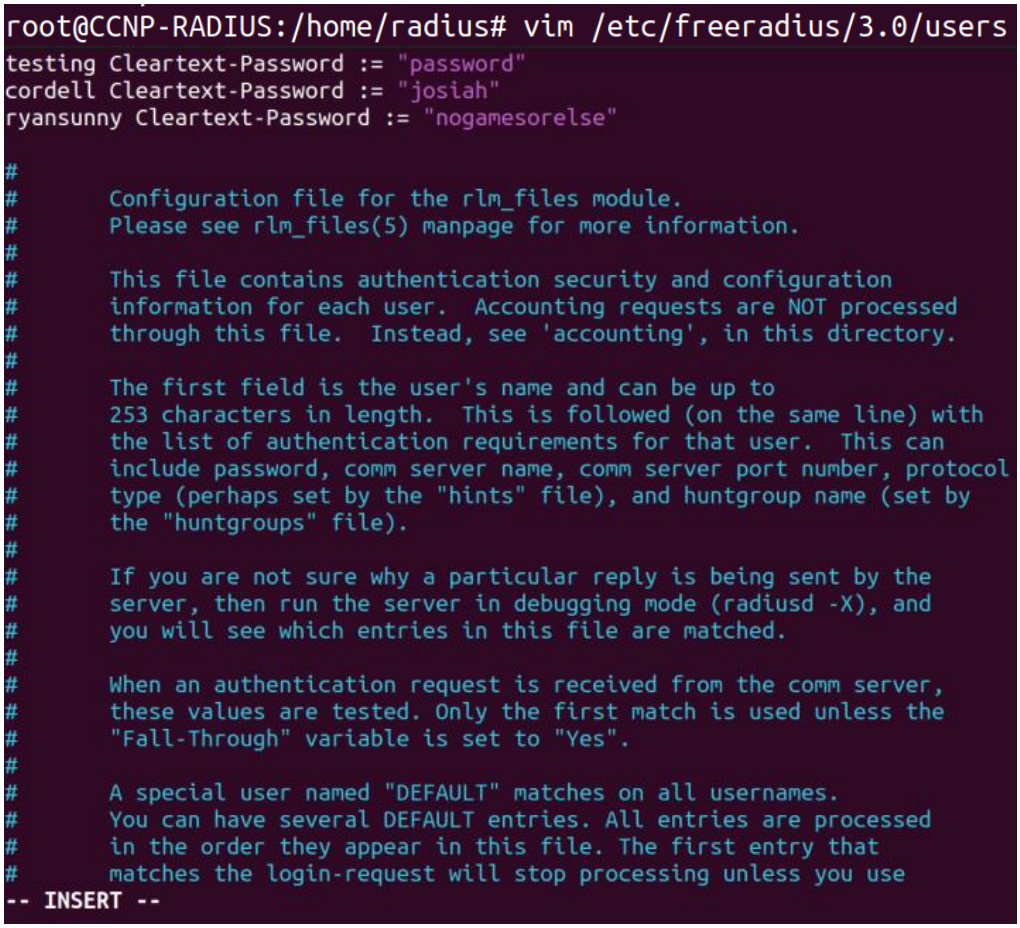
1) Download Ubuntu desktop, or alternatively create an Ubuntu Docker container or operating system of your choice. The RADIUS server should function on virtualized software, but for our purposes we used a physical drive.



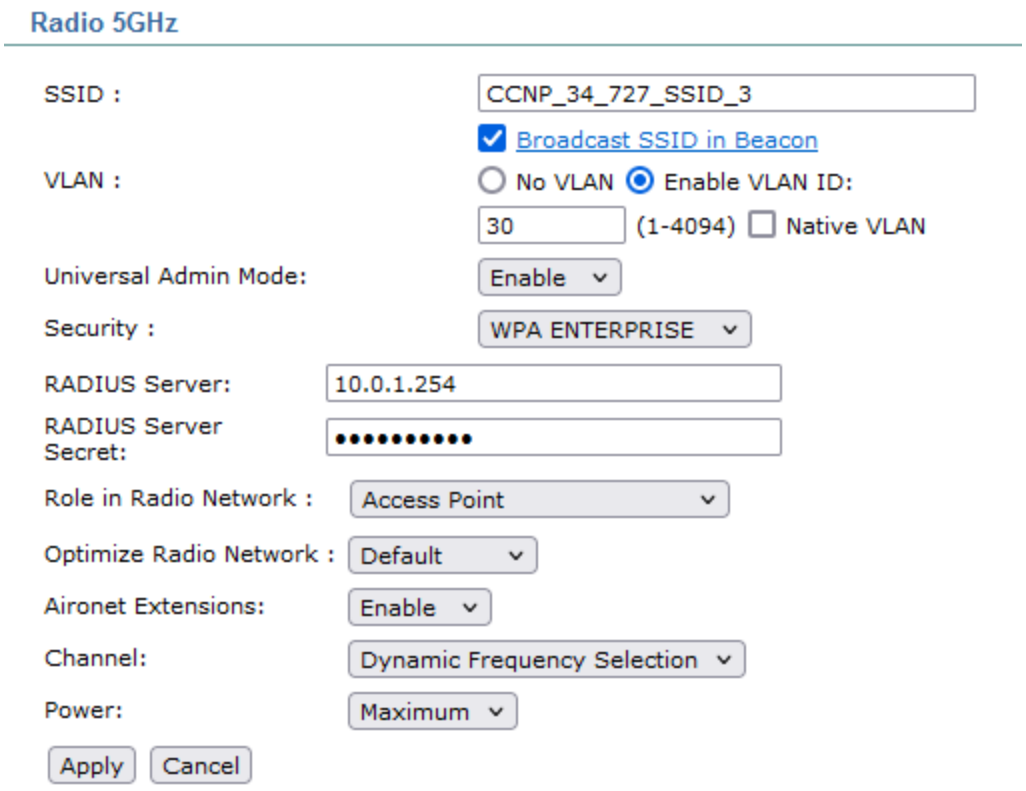
2) Complete basic setup and boot into Ubuntu, then download FreeRADIUS following the instructions on the website. For convenience and updates later, we used a package manager (apt) in order to install FreeRADIUS.
   sudo apt update
   sudo apt install freeradius freeradius-utils
3) Temporarily switch into the root user to configure FreeRADIUS. From here, you can edit FreeRADIUS configuration files.
   sudo su
4) First, edit the *clients.conf* file, which is responsible for setting the IP and shared secret of a client server utilizing the RADIUS service. In this case, we set the IP to be the access point, which will communicate with the RADIUS server in order to login users for SSID3.



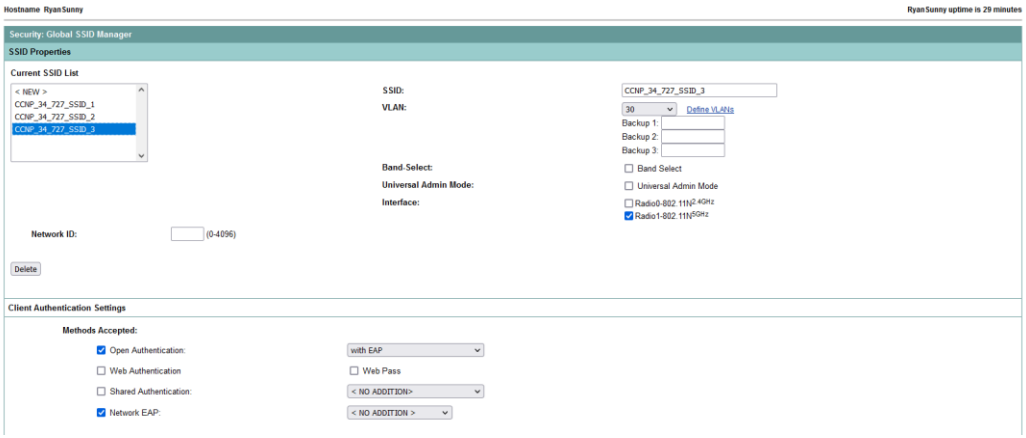
5) Next, edit the users file and follow the default template to add a new user. In this case, our user is “ryansunny” and the password is “nogamesorelse”. We will be using these credentials to sign in when accessing our SSID.

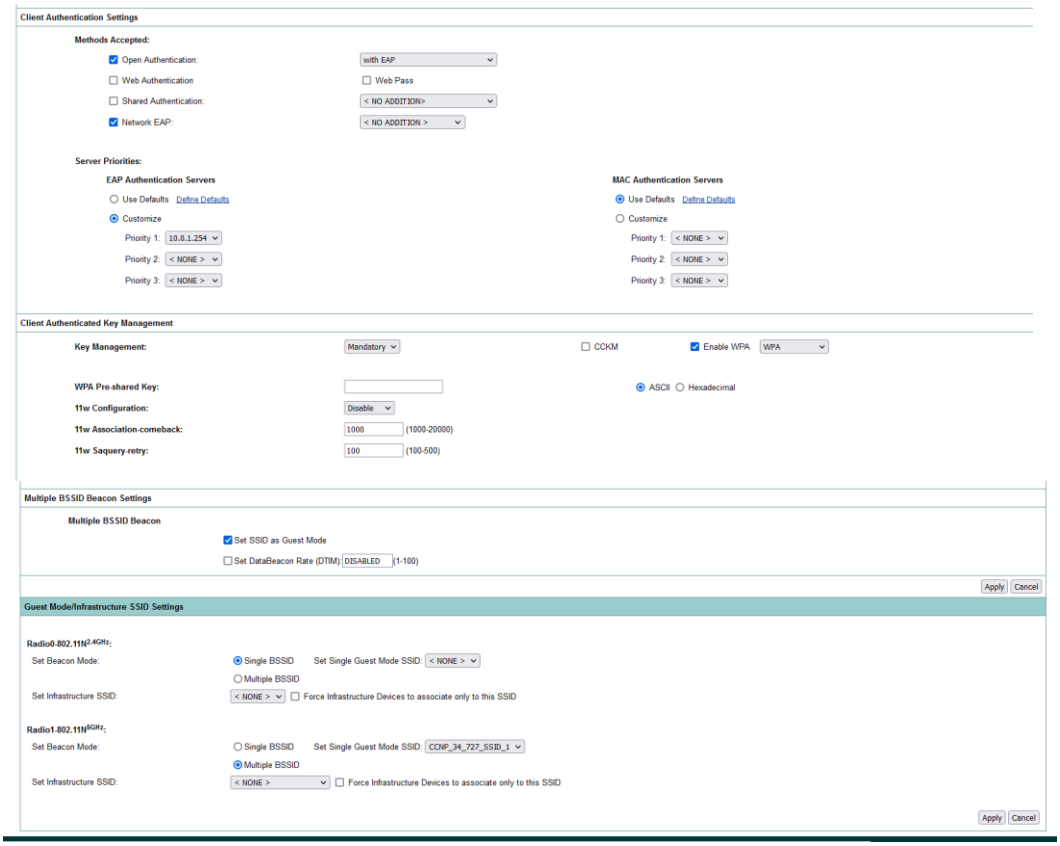


6) Configure the IP on Ubuntu to be an address within the subnet range. For our purposes, we configured the RADIUS server to be 10.0.1.254, in order to be consistent with our scheme.
7) Next, configure the AP to use the RADIUS server. On the interface, add a new SSID and configure it to use WPA Enterprise. Fill in the fields with the preconfigured values.

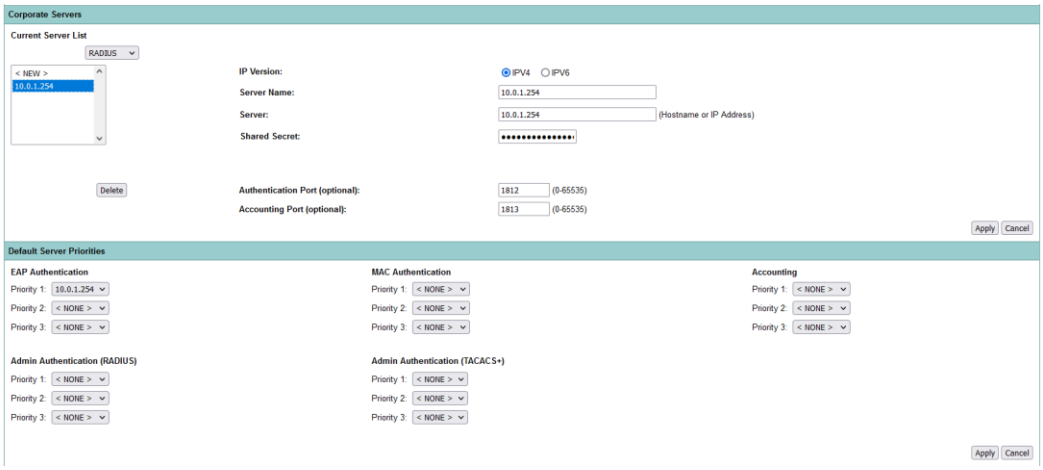


8) Next, verify the SSID is created correctly and enable WPA security. Also, enable Guest SSID so the network will be broadcast to nearby devices.



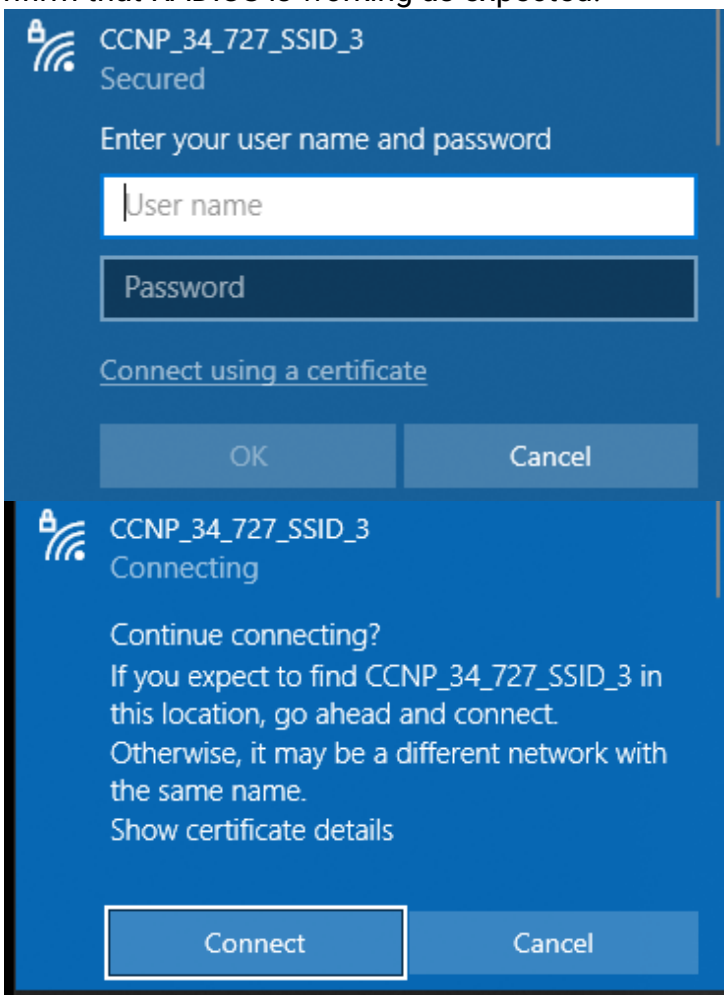


9) Finally, go into Server Manager and add the RADIUS server as a new server on the AP. This allows the SSID to forward all AAA traffic to the RADIUS server, which in turn handles the requests. Ensure that the RADIUS server is set as the default EAP authentication server, and that Authentication is 1812 and Accounting is 1813. The shared secret continues to be the default one configured in FreeRADIUS, “testing123”.
NOTE: The shared secret should be changed if the RADIUS server is going to be used.



10) Confirm that the SSID is using the configured server, and then boot the FreeRADIUS process on the Ubuntu machine using:
sudo freeradius -X

11) Confirm that RADIUS is working as expected!



AP Config:

```
hostname RyanSunny


logging rate-limit console 9
enable secret 5 $1$Uca.$wqB9Ug2Lu/O2SPHQD/G34/


aaa new-model


aaa group server tacacs+ tac_admin


aaa group server radius rad_eap
 server name 10.0.1.254
```

```
aaa group server radius rad_mac

aaa group server radius rad_acct

aaa group server radius rad_admin

aaa group server radius rad_pmip

aaa group server radius dummy

aaa group server radius rad_eap3
 server name 10.0.1.254

aaa authentication login eap_methods group rad_eap
aaa authentication login mac_methods local
aaa authentication login eap_methods3 group rad_eap3
aaa authorization exec default local
aaa accounting network acct_methods start-stop group rad_acct

aaa session-id common
no ip source-route
no ip cef

dot11 pause-time 100
dot11 syslog
dot11 vlan-name Native vlan 1
dot11 vlan-name Network1 vlan 10
dot11 vlan-name Network2 vlan 20
dot11 vlan-name Network3 vlan 30

dot11 ssid CCNP_34_727_SSID_1
   vlan 10
```

```
   authentication open
   authentication key-management wpa version 2
   guest-mode
   mbssid guest-mode
   wpa-psk ascii 7 123A0C0411042F0D39282B

dot11 ssid CCNP_34_727_SSID_2
   vlan 20
   authentication open
   authentication key-management wpa version 2
   mbssid guest-mode
   wpa-psk ascii 7 13261E0108032723382727

dot11 ssid CCNP_34_727_SSID_3
   vlan 30
   authentication open eap eap_methods3
   authentication network-eap eap_methods3
   authentication key-management wpa
   mbssid guest-mode

no ipv6 cef

username Cisco password 7 01300F175804

bridge irb

interface Dot11Radio0
 no ip address
 shutdown
 antenna gain 0
 station-role root
 bridge-group 1
```

```
 bridge-group 1 subscriber-loop-control
 bridge-group 1 spanning-disabled
 bridge-group 1 block-unknown-source
 no bridge-group 1 source-learning
 no bridge-group 1 unicast-flooding

interface Dot11Radio1
 no ip address

 encryption vlan 1 mode ciphers aes-ccm

 encryption vlan 2 mode ciphers aes-ccm

 encryption vlan 10 mode ciphers aes-ccm

 encryption vlan 20 mode ciphers aes-ccm

 encryption key 2 size 128bit 7 FD719385EC0CEE0A351C749FB410 transmit-key

 encryption vlan 30 mode ciphers aes-ccm tkip

 ssid CCNP_34_727_SSID_1

 ssid CCNP_34_727_SSID_2

 ssid CCNP_34_727_SSID_3

 antenna gain 0
 peakdetect
 dfs band 3 block
 mbssid
 channel dfs
```

```
 station-role root

interface Dot11Radio1.1
 encapsulation dot1Q 1 native
 bridge-group 1
 bridge-group 1 subscriber-loop-control
 bridge-group 1 spanning-disabled
 bridge-group 1 block-unknown-source
 no bridge-group 1 source-learning
 no bridge-group 1 unicast-flooding

interface Dot11Radio1.10
 encapsulation dot1Q 10
 ip address 10.0.10.3 255.255.255.0
 bridge-group 10
 bridge-group 10 subscriber-loop-control
 bridge-group 10 spanning-disabled
 bridge-group 10 block-unknown-source
 no bridge-group 10 source-learning
 no bridge-group 10 unicast-flooding

interface Dot11Radio1.11

interface Dot11Radio1.20
 encapsulation dot1Q 20
 bridge-group 20
 bridge-group 20 subscriber-loop-control
 bridge-group 20 spanning-disabled
 bridge-group 20 block-unknown-source
 no bridge-group 20 source-learning
 no bridge-group 20 unicast-flooding
```

```
interface Dot11Radio1.30
 encapsulation dot1Q 30
 bridge-group 30
 bridge-group 30 subscriber-loop-control
 bridge-group 30 spanning-disabled
 bridge-group 30 block-unknown-source
 no bridge-group 30 source-learning
 no bridge-group 30 unicast-flooding

interface Dot11Radio1.301

interface GigabitEthernet0
 no ip address
 duplex auto
 speed auto

interface GigabitEthernet0.1
 encapsulation dot1Q 1 native
 bridge-group 1
 bridge-group 1 spanning-disabled
 no bridge-group 1 source-learning

interface GigabitEthernet0.10
 encapsulation dot1Q 10
 bridge-group 10
 bridge-group 10 spanning-disabled
 no bridge-group 10 source-learning

interface GigabitEthernet0.11

interface GigabitEthernet0.20
 encapsulation dot1Q 20
```

```
 bridge-group 20
 bridge-group 20 spanning-disabled
 no bridge-group 20 source-learning

interface GigabitEthernet0.30
 encapsulation dot1Q 30
 bridge-group 30
 bridge-group 30 spanning-disabled
 no bridge-group 30 source-learning

interface GigabitEthernet0.301

interface BVI1
 mac-address 0007.7df5.4710
 ip address 10.0.1.3 255.255.255.0
 ipv6 address dhcp
 ipv6 address autoconfig
 ipv6 enable

ip forward-protocol nd
ip http server
no ip http secure-server
ip http help-path
http://www.cisco.com/warp/public/779/smbiz/prodconfig/help/eag
ip radius source-interface BVI1

radius-server attribute 32 include-in-access-req format %h

radius server 10.0.1.254
 address ipv4 10.0.1.254 auth-port 1812 acct-port 1813
 key 7 111D1C16031B050B557878

bridge 1 route ip
```

```
line con 0
line vty 0 4
 transport input all

end
```

R1 Config:

```
hostname R1

boot-start-marker
boot-end-marker

vrf definition Mgmt-intf

 address-family ipv4
 exit-address-family

 address-family ipv6
 exit-address-family

no aaa new-model

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO214420QQ
license accept end user agreement
license boot level securityk9

spanning-tree extend system-id
```

```
redundancy
 mode none

vlan internal allocation policy ascending

interface GigabitEthernet0/0/0
 ip address dhcp
 ip nat outside
 negotiation auto

interface GigabitEthernet0/0/1
 no ip address
 ip nat inside
 negotiation auto

interface GigabitEthernet0/0/1.1
 encapsulation dot1Q 1 native
 ip address 10.0.1.1 255.255.255.0
 ip nat inside

interface GigabitEthernet0/0/1.10
 encapsulation dot1Q 10
 ip address 10.0.10.1 255.255.255.0
 ip nat inside

interface GigabitEthernet0/0/1.20
 encapsulation dot1Q 20
 ip address 10.0.20.1 255.255.255.0
 ip nat inside

interface GigabitEthernet0/0/1.30
 encapsulation dot1Q 30
```

```
 ip address 10.0.30.1 255.255.255.0
 ip nat inside

interface Serial0/1/0
 no ip address
 shutdown

interface Serial0/1/1
 no ip address
 shutdown

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto

interface Vlan1
 no ip address
 shutdown

ip nat inside source list 10 interface GigabitEthernet0/0/0 overload
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0/0/0

access-list 10 permit 10.0.0.0 0.255.255.255

control-plane

line con 0
```

```
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

ntp server pool.ntp.org

end
```

S1 Config:

```
hostname S1

boot-start-marker
boot-end-marker

no aaa new-model
system mtu routing 1500
authentication mac-move permit
ip subnet-zero
ip dhcp excluded-address 10.0.1.1
ip dhcp excluded-address 10.0.10.1
ip dhcp excluded-address 10.0.20.1
ip dhcp excluded-address 10.0.30.1
ip dhcp excluded-address 10.0.1.2
ip dhcp excluded-address 10.0.1.3
ip dhcp excluded-address 10.0.10.2
ip dhcp excluded-address 10.0.10.3
ip dhcp excluded-address 10.0.20.2
ip dhcp excluded-address 10.0.20.3
ip dhcp excluded-address 10.0.30.2
ip dhcp excluded-address 10.0.30.3
```

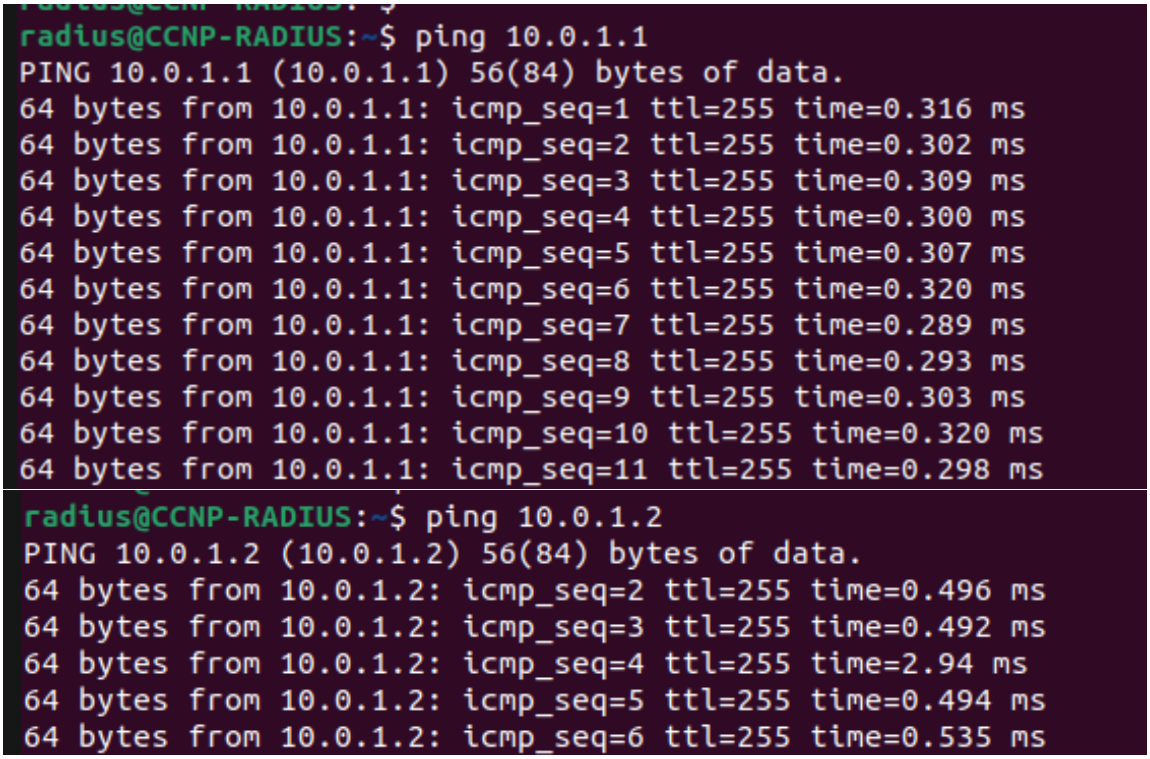
```
ip dhcp pool vPool1
   network 10.0.1.0 255.255.255.0
   default-router 10.0.1.1
   dns-server 8.8.8.8

ip dhcp pool vPool10
   network 10.0.10.0 255.255.255.0
   default-router 10.0.10.1
   dns-server 8.8.8.8

ip dhcp pool vPool20
   network 10.0.20.0 255.255.255.0
   default-router 10.0.20.1
   dns-server 8.8.8.8

ip dhcp pool vPool30
   network 10.0.30.0 255.255.255.0
   default-router 10.0.30.1
   dns-server 8.8.8.8

spanning-tree mode pvst
spanning-tree etherchannel guard misconfig
spanning-tree extend system-id

vlan internal allocation policy ascending

interface FastEthernet0/1
 switchport trunk encapsulation dot1q
 switchport mode trunk

interface FastEthernet0/2
```

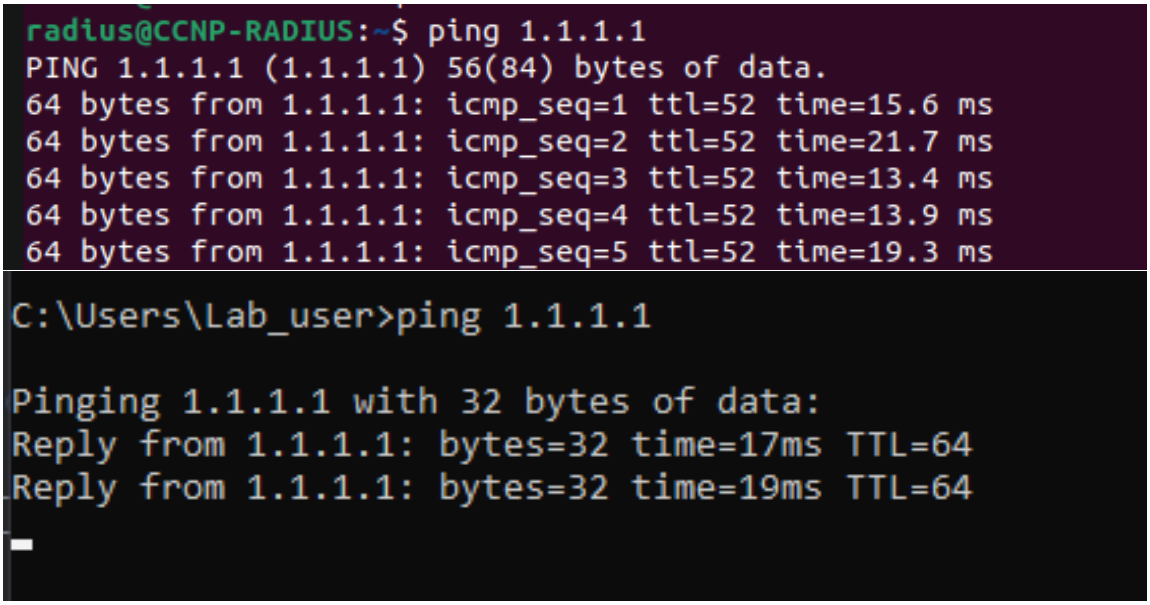
```
 switchport trunk encapsulation dot1q
 switchport mode trunk

interface FastEthernet0/3

interface FastEthernet0/4

interface FastEthernet0/5

interface FastEthernet0/6

interface FastEthernet0/7

interface FastEthernet0/8

interface FastEthernet0/9

interface FastEthernet0/10

interface FastEthernet0/11

interface FastEthernet0/12

interface FastEthernet0/13

interface FastEthernet0/14

interface FastEthernet0/15

interface FastEthernet0/16

interface FastEthernet0/17
```

```
interface FastEthernet0/18

interface FastEthernet0/19

interface FastEthernet0/20

interface FastEthernet0/21

interface FastEthernet0/22

interface FastEthernet0/23

interface FastEthernet0/24

interface GigabitEthernet0/1

interface GigabitEthernet0/2

interface Vlan1
 ip address 10.0.1.2 255.255.255.0

interface Vlan10
 ip address 10.0.10.2 255.255.255.0

interface Vlan20
 ip address 10.0.20.2 255.255.255.0

interface Vlan30
 ip address 10.0.30.2 255.255.255.0

ip default-gateway 10.0.1.1
```

```
ip classless
ip http server

ip sla enable reaction-alerts

line con 0
 login
line vty 0 4
 login
line vty 5 15
 login

end
```

Pings and Traceroute:





Radius Handshake:

```
Ready to process requests
(10) Received Access-Request Id 17 from 10.0.1.3:1645 to 10.0.1.254:1812
length 227
(10)   User-Name = "testing"
(10)   Framed-MTU = 1400
(10)   Called-Station-Id = "d0c2.822e.4392:CCNP_34_727_SSID_3"
(10)   Calling-Station-Id = "14ab.c53c.0807"
(10)   Cisco-AVPair = "ssid=CCNP_34_727_SSID_3"
(10)   Service-Type = Login-User
(10)   Cisco-AVPair = "service-type=Login"
(10)   Message-Authenticator = 0x6cf676848da5e109f7cb8e56615e7760
(10)   EAP-Message = 0x020700061900
(10)   NAS-Port-Type = Wireless-802.11
(10)   NAS-Port = 277
(10)   NAS-Port-Id = "277"
(10)   State = 0x1dfcd08519fbc9db5e3d878bc6e70d5e
(10)   NAS-IP-Address = 10.0.1.3
(10)   NAS-Identifier = "RyanSunny"
(10) Restoring &session-state
(10)   &session-state:Framed-MTU = 994
(10)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.3
Handshake, ClientHello"
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHello"
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Certificate"
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerKeyExchange"
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHelloDone"
(10)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, ClientKeyExchange"
(10)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, Finished"
```

```
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
ChangeCipherSpec"
(10)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Finished"
(10)   &session-state:TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-
SHA384"
(10)   &session-state:TLS-Session-Version = "TLS 1.2"
(10) # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/default
(10)   authorize {
(10)     policy filter_username {
(10)       if (&User-Name) {
(10)       if (&User-Name)  -> TRUE
(10)       if (&User-Name)  {
(10)         if (&User-Name =~ / /) {
(10)         if (&User-Name =~ / /)  -> FALSE
(10)         if (&User-Name =~ /@[^@]*@/ ) {
(10)         if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(10)         if (&User-Name =~ /\.\./ ) {
(10)         if (&User-Name =~ /\.\./ )  -> FALSE
(10)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(10)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))   ->
FALSE
(10)         if (&User-Name =~ /\.$/)  {
(10)         if (&User-Name =~ /\.$/)   -> FALSE
(10)         if (&User-Name =~ /@\./)  {
(10)         if (&User-Name =~ /@\./)   -> FALSE
(10)       } # if (&User-Name)  = notfound
(10)     } # policy filter_username = notfound
(10)     [preprocess] = ok
(10)     [chap] = noop
(10)     [mschap] = noop
(10)     [digest] = noop
(10) suffix: Checking for suffix after "@"
(10) suffix: No '@' in User-Name = "testing", looking up realm NULL
(10) suffix: No such realm "NULL"
(10)     [suffix] = noop
(10) eap: Peer sent EAP Response (code 2) ID 7 length 6
(10) eap: Continuing tunnel setup
(10)     [eap] = ok
(10)   } # authorize = ok
(10) Found Auth-Type = eap
(10) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(10)   authenticate {
(10) eap: Expiring EAP session with state 0x0275a0c70672b940
(10) eap: Finished EAP session with state 0x1dfcd08519fbc9db
(10) eap: Previous EAP request found for state 0x1dfcd08519fbc9db, released
from the list
(10) eap: Peer sent packet with method EAP PEAP (25)
(10) eap: Calling submodule eap_peap to process data
(10) eap_peap: (TLS) Peer ACKed our handshake fragment.  handshake is
finished
(10) eap_peap: Session established.  Decoding tunneled attributes
(10) eap_peap: PEAP state TUNNEL ESTABLISHED
(10) eap: Sending EAP Request (code 1) ID 8 length 40
(10) eap: EAP session adding &reply:State = 0x1dfcd08518f4c9db
(10)     [eap] = handled
```

```
(10)   } # authenticate = handled
(10) Using Post-Auth-Type Challenge
(10) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(10)   Challenge { ... } # empty sub-section is ignored
(10) session-state: Saving cached attributes
(10)   Framed-MTU = 994
(10)   TLS-Session-Information = "(TLS) recv TLS 1.3 Handshake, ClientHello"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, ServerHello"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Certificate"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerKeyExchange"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerHelloDone"
(10)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake,
ClientKeyExchange"
(10)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake, Finished"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 ChangeCipherSpec"
(10)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Finished"
(10)   TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-SHA384"
(10)   TLS-Session-Version = "TLS 1.2"
(10) Sent Access-Challenge Id 17 from 10.0.1.254:1812 to 10.0.1.3:1645 length
98
(10)   EAP-Message =
0x0108002819001703030001de0c487f4aa2d57ae38b8a190800558dd4d2ecf52e8ed6f30a489c
5be57
(10)   Message-Authenticator = 0x00000000000000000000000000000000
(10)   State = 0x1dfcd08518f4c9db5e3d878bc6e70d5e
(10) Finished request
Waking up in 4.9 seconds.
(11) Received Access-Request Id 18 from 10.0.1.3:1645 to 10.0.1.254:1812
length 264
(11)   User-Name = "testing"
(11)   Framed-MTU = 1400
(11)   Called-Station-Id = "d0c2.822e.4392:CCNP_34_727_SSID_3"
(11)   Calling-Station-Id = "14ab.c53c.0807"
(11)   Cisco-AVPair = "ssid=CCNP_34_727_SSID_3"
(11)   Service-Type = Login-User
(11)   Cisco-AVPair = "service-type=Login"
(11)   Message-Authenticator = 0xc164bbae234660c9bf262f5f073aedac
(11)   EAP-Message =
0x0208002b19001703030020000000000000001660e925184947aac2e3e23b831ac450a37354
ab1eeda6670
(11)   NAS-Port-Type = Wireless-802.11
(11)   NAS-Port = 277
(11)   NAS-Port-Id = "277"
(11)   State = 0x1dfcd08518f4c9db5e3d878bc6e70d5e
(11)   NAS-IP-Address = 10.0.1.3
(11)   NAS-Identifier = "RyanSunny"
(11) Restoring &session-state
(11)   &session-state:Framed-MTU = 994
(11)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.3
Handshake, ClientHello"
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHello"
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Certificate"
```

```
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerKeyExchange"
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHelloDone"
(11)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, ClientKeyExchange"
(11)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, Finished"
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
ChangeCipherSpec"
(11)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Finished"
(11)   &session-state:TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-
SHA384"
(11)   &session-state:TLS-Session-Version = "TLS 1.2"
(11) # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/default
(11)   authorize {
(11)     policy filter_username {
(11)       if (&User-Name) {
(11)       if (&User-Name)  -> TRUE
(11)       if (&User-Name)  {
(11)         if (&User-Name =~ / /) {
(11)         if (&User-Name =~ / /)  -> FALSE
(11)         if (&User-Name =~ /@[^@]*@/ ) {
(11)         if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(11)         if (&User-Name =~ /\.\./ ) {
(11)         if (&User-Name =~ /\.\./ )  -> FALSE
(11)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(11)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))   ->
FALSE
(11)         if (&User-Name =~ /\.$/)  {
(11)         if (&User-Name =~ /\.$/)   -> FALSE
(11)         if (&User-Name =~ /@\./)  {
(11)         if (&User-Name =~ /@\./)   -> FALSE
(11)       } # if (&User-Name)  = notfound
(11)     } # policy filter_username = notfound
(11)     [preprocess] = ok
(11)     [chap] = noop
(11)     [mschap] = noop
(11)     [digest] = noop
(11) suffix: Checking for suffix after "@"
(11) suffix: No '@' in User-Name = "testing", looking up realm NULL
(11) suffix: No such realm "NULL"
(11)     [suffix] = noop
(11) eap: Peer sent EAP Response (code 2) ID 8 length 43
(11) eap: Continuing tunnel setup
(11)     [eap] = ok
(11)   } # authorize = ok
(11) Found Auth-Type = eap
(11) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(11)   authenticate {
(11) eap: Expiring EAP session with state 0x0275a0c70672b940
(11) eap: Finished EAP session with state 0x1dfcd08518f4c9db
(11) eap: Previous EAP request found for state 0x1dfcd08518f4c9db, released
from the list
(11) eap: Peer sent packet with method EAP PEAP (25)
```

```
(11) eap: Calling submodule eap_peap to process data
(11) eap_peap: (TLS) EAP Done initial handshake
(11) eap_peap: Session established.  Decoding tunneled attributes
(11) eap_peap: PEAP state WAITING FOR INNER IDENTITY
(11) eap_peap: Identity - testing
(11) eap_peap: Got inner identity 'testing'
(11) eap_peap: Setting default EAP type for tunneled EAP session
(11) eap_peap: Got tunneled request
(11) eap_peap:   EAP-Message = 0x0208000c0174657374696e67
(11) eap_peap: Setting User-Name to testing
(11) eap_peap: Sending tunneled request to inner-tunnel
(11) eap_peap:   EAP-Message = 0x0208000c0174657374696e67
(11) eap_peap:   FreeRADIUS-Proxied-To = 127.0.0.1
(11) eap_peap:   User-Name = "testing"
(11) Virtual server inner-tunnel received request
(11)   EAP-Message = 0x0208000c0174657374696e67
(11)   FreeRADIUS-Proxied-To = 127.0.0.1
(11)   User-Name = "testing"
(11) WARNING: Outer and inner identities are the same.  User privacy is
compromised.
(11) server inner-tunnel {
(11)   # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/inner-tunnel
(11)     authorize {
(11)       policy filter_username {
(11)         if (&User-Name) {
(11)         if (&User-Name)  -> TRUE
(11)         if (&User-Name)  {
(11)           if (&User-Name =~ / /) {
(11)           if (&User-Name =~ / /)  -> FALSE
(11)           if (&User-Name =~ /@[^@]*@/ ) {
(11)           if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(11)           if (&User-Name =~ /\.\./ ) {
(11)           if (&User-Name =~ /\.\./ )  -> FALSE
(11)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(11)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))
-> FALSE
(11)           if (&User-Name =~ /\.$/)  {
(11)           if (&User-Name =~ /\.$/)   -> FALSE
(11)           if (&User-Name =~ /@\./)  {
(11)           if (&User-Name =~ /@\./)   -> FALSE
(11)         } # if (&User-Name)  = notfound
(11)       } # policy filter_username = notfound
(11)       [chap] = noop
(11)       [mschap] = noop
(11) suffix: Checking for suffix after "@"
(11) suffix: No '@' in User-Name = "testing", looking up realm NULL
(11) suffix: No such realm "NULL"
(11)       [suffix] = noop
(11)       update control {
(11)         &Proxy-To-Realm := LOCAL
(11)       } # update control = noop
(11) eap: Peer sent EAP Response (code 2) ID 8 length 12
(11) eap: EAP-Identity reply, returning 'ok' so we can short-circuit the rest
of authorize
(11)       [eap] = ok
(11)     } # authorize = ok
```

```
(11)   Found Auth-Type = eap
(11)   # Executing group from file /etc/freeradius/3.0/sites-enabled/inner-
tunnel
(11)     authenticate {
(11) eap: Peer sent packet with method EAP Identity (1)
(11) eap: Calling submodule eap_mschapv2 to process data
(11) eap_mschapv2: Issuing Challenge
(11) eap: Sending EAP Request (code 1) ID 9 length 43
(11) eap: EAP session adding &reply:State = 0x733052da733948b5
(11)       [eap] = handled
(11)     } # authenticate = handled
(11) } # server inner-tunnel
(11) Virtual server sending reply
(11)   EAP-Message =
0x0109002b1a0109002610ca1234749e59c0acac8f17fa5fc8086166726565726164697573 2d3
32e302e3236
(11)   Message-Authenticator = 0x00000000000000000000000000000000
(11)   State = 0x733052da733948b52b4f2886441d1cfe
(11) eap_peap: Got tunneled reply code 11
(11) eap_peap:   EAP-Message =
0x0109002b1a0109002610ca1234749e59c0acac8f17fa5fc8086166726565726164697573 2d3
32e302e3236
(11) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(11) eap_peap:   State = 0x733052da733948b52b4f2886441d1cfe
(11) eap_peap: Got tunneled reply RADIUS code 11
(11) eap_peap:   EAP-Message =
0x0109002b1a0109002610ca1234749e59c0acac8f17fa5fc8086166726565726164697573 2d3
32e302e3236
(11) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(11) eap_peap:   State = 0x733052da733948b52b4f2886441d1cfe
(11) eap_peap: Got tunneled Access-Challenge
(11) eap: Sending EAP Request (code 1) ID 9 length 74
(11) eap: EAP session adding &reply:State = 0x1dfcd0851bf5c9db
(11)     [eap] = handled
(11)   } # authenticate = handled
(11) Using Post-Auth-Type Challenge
(11) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(11)   Challenge { ... } # empty sub-section is ignored
(11) session-state: Saving cached attributes
(11)   Framed-MTU = 994
(11)   TLS-Session-Information = "(TLS) recv TLS 1.3 Handshake, ClientHello"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, ServerHello"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Certificate"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerKeyExchange"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerHelloDone"
(11)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake,
ClientKeyExchange"
(11)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake, Finished"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 ChangeCipherSpec"
(11)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Finished"
(11)   TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-SHA384"
(11)   TLS-Session-Version = "TLS 1.2"
(11) Sent Access-Challenge Id 18 from 10.0.1.254:1812 to 10.0.1.3:1645 length
132
```

```
(11)   EAP-Message =
0x0109004a1900170303003fe0c487f4aa2d57af8d86fbd3b602c6d146381a04252eeb1f7bc7a
8a247a268e90dd4fa6495bc216a6334a709a1ca504b426edcbae34bd2c985e673d876b143
(11)   Message-Authenticator = 0x00000000000000000000000000000000
(11)   State = 0x1dfcd0851bf5c9db5e3d878bc6e70d5e
(11) Finished request
Waking up in 4.9 seconds.
(12) Received Access-Request Id 19 from 10.0.1.3:1645 to 10.0.1.254:1812
length 318
(12)   User-Name = "testing"
(12)   Framed-MTU = 1400
(12)   Called-Station-Id = "d0c2.822e.4392:CCNP_34_727_SSID_3"
(12)   Calling-Station-Id = "14ab.c53c.0807"
(12)   Cisco-AVPair = "ssid=CCNP_34_727_SSID_3"
(12)   Service-Type = Login-User
(12)   Cisco-AVPair = "service-type=Login"
(12)   Message-Authenticator = 0x3dc2f227b77299b6c1ac95aeb9e7553d
(12)   EAP-Message =
0x020900611900170303005600000000000000029e9c2e15379526228c4960fcc0f9551ef02d5
fb1d46487d335bbb4084c9a9166052b70e54d4971b3cbc5e14f4de3b973452b509c53fa8abd2d
10b423a49657ef2fc3ea23854dfa06ae36a5f04373
(12)   NAS-Port-Type = Wireless-802.11
(12)   NAS-Port = 277
(12)   NAS-Port-Id = "277"
(12)   State = 0x1dfcd0851bf5c9db5e3d878bc6e70d5e
(12)   NAS-IP-Address = 10.0.1.3
(12)   NAS-Identifier = "RyanSunny"
(12) Restoring &session-state
(12)   &session-state:Framed-MTU = 994
(12)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.3
Handshake, ClientHello"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHello"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Certificate"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerKeyExchange"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHelloDone"
(12)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, ClientKeyExchange"
(12)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, Finished"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
ChangeCipherSpec"
(12)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Finished"
(12)   &session-state:TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-
SHA384"
(12)   &session-state:TLS-Session-Version = "TLS 1.2"
(12) # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/default
(12)   authorize {
(12)     policy filter_username {
(12)       if (&User-Name) {
(12)       if (&User-Name)  -> TRUE
(12)       if (&User-Name)  {
```

```
(12)         if (&User-Name =~ / /) {
(12)         if (&User-Name =~ / /)  -> FALSE
(12)         if (&User-Name =~ /@[^@]*@/ ) {
(12)         if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(12)         if (&User-Name =~ /\.\./ ) {
(12)         if (&User-Name =~ /\.\./ )  -> FALSE
(12)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(12)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))   ->
FALSE
(12)         if (&User-Name =~ /\.$/)  {
(12)         if (&User-Name =~ /\.$/)   -> FALSE
(12)         if (&User-Name =~ /@\./)  {
(12)         if (&User-Name =~ /@\./)   -> FALSE
(12)       } # if (&User-Name)  = notfound
(12)     } # policy filter_username = notfound
(12)     [preprocess] = ok
(12)     [chap] = noop
(12)     [mschap] = noop
(12)     [digest] = noop
(12) suffix: Checking for suffix after "@"
(12) suffix: No '@' in User-Name = "testing", looking up realm NULL
(12) suffix: No such realm "NULL"
(12)     [suffix] = noop
(12) eap: Peer sent EAP Response (code 2) ID 9 length 97
(12) eap: Continuing tunnel setup
(12)     [eap] = ok
(12)   } # authorize = ok
(12) Found Auth-Type = eap
(12) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(12)   authenticate {
(12) eap: Expiring EAP session with state 0x0275a0c70672b940
(12) eap: Finished EAP session with state 0x1dfcd0851bf5c9db
(12) eap: Previous EAP request found for state 0x1dfcd0851bf5c9db, released
from the list
(12) eap: Peer sent packet with method EAP PEAP (25)
(12) eap: Calling submodule eap_peap to process data
(12) eap_peap: (TLS) EAP Done initial handshake
(12) eap_peap: Session established.  Decoding tunneled attributes
(12) eap_peap: PEAP state phase2
(12) eap_peap: EAP method MSCHAPv2 (26)
(12) eap_peap: Got tunneled request
(12) eap_peap:   EAP-Message =
0x020900421a0209003d311fcc349d2063c23ba8c84813ebcd4a6e0000000000000000fe131f5
5fa15f12f9ef7df1e17cb976347f94361dc9cfef90074657374696e67
(12) eap_peap: Setting User-Name to testing
(12) eap_peap: Sending tunneled request to inner-tunnel
(12) eap_peap:   EAP-Message =
0x020900421a0209003d311fcc349d2063c23ba8c84813ebcd4a6e0000000000000000fe131f5
5fa15f12f9ef7df1e17cb976347f94361dc9cfef90074657374696e67
(12) eap_peap:   FreeRADIUS-Proxied-To = 127.0.0.1
(12) eap_peap:   User-Name = "testing"
(12) eap_peap:   State = 0x733052da733948b52b4f2886441d1cfe
(12) Virtual server inner-tunnel received request
(12)   EAP-Message =
0x020900421a0209003d311fcc349d2063c23ba8c84813ebcd4a6e0000000000000000fe131f5
5fa15f12f9ef7df1e17cb976347f94361dc9cfef90074657374696e67
(12)   FreeRADIUS-Proxied-To = 127.0.0.1
```

```
(12)   User-Name = "testing"
(12)   State = 0x733052da733948b52b4f2886441d1cfe
(12) WARNING: Outer and inner identities are the same.  User privacy is
compromised.
(12) server inner-tunnel {
(12)   session-state: No cached attributes
(12)   # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/inner-tunnel
(12)     authorize {
(12)       policy filter_username {
(12)         if (&User-Name) {
(12)         if (&User-Name)  -> TRUE
(12)         if (&User-Name)  {
(12)           if (&User-Name =~ / /) {
(12)           if (&User-Name =~ / /)  -> FALSE
(12)           if (&User-Name =~ /@[^@]*@/ ) {
(12)           if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(12)           if (&User-Name =~ /\.\./ ) {
(12)           if (&User-Name =~ /\.\./ )  -> FALSE
(12)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(12)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))
-> FALSE
(12)           if (&User-Name =~ /\.$/)  {
(12)           if (&User-Name =~ /\.$/)   -> FALSE
(12)           if (&User-Name =~ /@\./)  {
(12)           if (&User-Name =~ /@\./)   -> FALSE
(12)         } # if (&User-Name)  = notfound
(12)       } # policy filter_username = notfound
(12)       [chap] = noop
(12)       [mschap] = noop
(12) suffix: Checking for suffix after "@"
(12) suffix: No '@' in User-Name = "testing", looking up realm NULL
(12) suffix: No such realm "NULL"
(12)       [suffix] = noop
(12)       update control {
(12)         &Proxy-To-Realm := LOCAL
(12)       } # update control = noop
(12) eap: Peer sent EAP Response (code 2) ID 9 length 66
(12) eap: No EAP Start, assuming it's an on-going EAP conversation
(12)       [eap] = updated
(12) files: users: Matched entry testing at line 1
(12)       [files] = ok
(12)       [expiration] = noop
(12)       [logintime] = noop
(12) pap: WARNING: Auth-Type already set.  Not setting to PAP
(12)       [pap] = noop
(12)     } # authorize = updated
(12)   Found Auth-Type = eap
(12)   # Executing group from file /etc/freeradius/3.0/sites-enabled/inner-
tunnel
(12)     authenticate {
(12) eap: Expiring EAP session with state 0x0275a0c70672b940
(12) eap: Finished EAP session with state 0x733052da733948b5
(12) eap: Previous EAP request found for state 0x733052da733948b5, released
from the list
(12) eap: Peer sent packet with method EAP MSCHAPv2 (26)
(12) eap: Calling submodule eap_mschapv2 to process data
```

```
(12) eap_mschapv2: # Executing group from file /etc/freeradius/3.0/sites-
enabled/inner-tunnel
(12) eap_mschapv2:   authenticate {
(12) mschap: Found Cleartext-Password, hashing to create NT-Password
(12) mschap: Creating challenge hash with username: testing
(12) mschap: Client is using MS-CHAPv2
(12) mschap: Adding MS-CHAPv2 MPPE keys
(12) eap_mschapv2:     [mschap] = ok
(12) eap_mschapv2:   } # authenticate = ok
(12) eap_mschapv2: MSCHAP Success
(12) eap: Sending EAP Request (code 1) ID 10 length 51
(12) eap: EAP session adding &reply:State = 0x733052da723a48b5
(12)       [eap] = handled
(12)     } # authenticate = handled
(12) } # server inner-tunnel
(12) Virtual server sending reply
(12)   EAP-Message =
0x010a00331a0309002e533d3843393334354235383337334433443442333731414142434533
4343734423131323033033373933
(12)   Message-Authenticator = 0x00000000000000000000000000000000
(12)   State = 0x733052da723a48b52b4f2886441d1cfe
(12) eap_peap: Got tunneled reply code 11
(12) eap_peap:   EAP-Message =
0x010a00331a0309002e533d3843393334354235383337334433443442333731414142434533
4343734423131323033033373933
(12) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(12) eap_peap:   State = 0x733052da723a48b52b4f2886441d1cfe
(12) eap_peap: Got tunneled reply RADIUS code 11
(12) eap_peap:   EAP-Message =
0x010a00331a0309002e533d3843393334354235383337334433443442333731414142434533
4343734423131323033033373933
(12) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(12) eap_peap:   State = 0x733052da723a48b52b4f2886441d1cfe
(12) eap_peap: Got tunneled Access-Challenge
(12) eap: Sending EAP Request (code 1) ID 10 length 82
(12) eap: EAP session adding &reply:State = 0x1dfcd0851af6c9db
(12)     [eap] = handled
(12)   } # authenticate = handled
(12) Using Post-Auth-Type Challenge
(12) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(12)   Challenge { ... } # empty sub-section is ignored
(12) session-state: Saving cached attributes
(12)   Framed-MTU = 994
(12)   TLS-Session-Information = "(TLS) recv TLS 1.3 Handshake, ClientHello"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, ServerHello"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Certificate"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerKeyExchange"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerHelloDone"
(12)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake,
ClientKeyExchange"
(12)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake, Finished"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 ChangeCipherSpec"
(12)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Finished"
(12)   TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-SHA384"
(12)   TLS-Session-Version = "TLS 1.2"
```

```
(12) Sent Access-Challenge Id 19 from 10.0.1.254:1812 to 10.0.1.3:1645 length
140
(12)   EAP-Message =
0x010a00521900170303004 7e0c487f4aa2d57b05efd44ddaf69b13cf6dfd07add935d8649931
f3bdeff4a7013a7a581348e5361d8acf09a236d7edbc016172e88c7e3be4dad79fb299a09f804
f2b29f9e9845
(12)   Message-Authenticator = 0x00000000000000000000000000000000
(12)   State = 0x1dfcd0851af6c9db5e3d878bc6e70d5e
(12) Finished request
Waking up in 4.9 seconds.
(13) Received Access-Request Id 20 from 10.0.1.3:1645 to 10.0.1.254:1812
length 258
(13)   User-Name = "testing"
(13)   Framed-MTU = 1400
(13)   Called-Station-Id = "d0c2.822e.4392:CCNP_34_727_SSID_3"
(13)   Calling-Station-Id = "14ab.c53c.0807"
(13)   Cisco-AVPair = "ssid=CCNP_34_727_SSID_3"
(13)   Service-Type = Login-User
(13)   Cisco-AVPair = "service-type=Login"
(13)   Message-Authenticator = 0x0af8a0a20654c00fedda5a8e2ee2a165
(13)   EAP-Message =
0x020a00251900170303001a0000000000000003f5a01b4555235082f99ca25bc91201efe22c
(13)   NAS-Port-Type = Wireless-802.11
(13)   NAS-Port = 277
(13)   NAS-Port-Id = "277"
(13)   State = 0x1dfcd0851af6c9db5e3d878bc6e70d5e
(13)   NAS-IP-Address = 10.0.1.3
(13)   NAS-Identifier = "RyanSunny"
(13) Restoring &session-state
(13)   &session-state:Framed-MTU = 994
(13)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.3
Handshake, ClientHello"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHello"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Certificate"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerKeyExchange"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHelloDone"
(13)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, ClientKeyExchange"
(13)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, Finished"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
ChangeCipherSpec"
(13)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Finished"
(13)   &session-state:TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-
SHA384"
(13)   &session-state:TLS-Session-Version = "TLS 1.2"
(13) # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/default
(13)   authorize {
(13)     policy filter_username {
(13)       if (&User-Name) {
(13)       if (&User-Name)  -> TRUE
```

```
(13)       if (&User-Name)  {
(13)         if (&User-Name =~ / /) {
(13)         if (&User-Name =~ / /)  -> FALSE
(13)         if (&User-Name =~ /@[^@]*@/ ) {
(13)         if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(13)         if (&User-Name =~ /\.\./ ) {
(13)         if (&User-Name =~ /\.\./ )  -> FALSE
(13)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(13)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))   ->
FALSE
(13)         if (&User-Name =~ /\.$/)  {
(13)         if (&User-Name =~ /\.$/)   -> FALSE
(13)         if (&User-Name =~ /@\./)  {
(13)         if (&User-Name =~ /@\./)   -> FALSE
(13)       } # if (&User-Name)  = notfound
(13)     } # policy filter_username = notfound
(13)     [preprocess] = ok
(13)     [chap] = noop
(13)     [mschap] = noop
(13)     [digest] = noop
(13) suffix: Checking for suffix after "@"
(13) suffix: No '@' in User-Name = "testing", looking up realm NULL
(13) suffix: No such realm "NULL"
(13)     [suffix] = noop
(13) eap: Peer sent EAP Response (code 2) ID 10 length 37
(13) eap: Continuing tunnel setup
(13)     [eap] = ok
(13)   } # authorize = ok
(13) Found Auth-Type = eap
(13) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(13)   authenticate {
(13) eap: Expiring EAP session with state 0x0275a0c70672b940
(13) eap: Finished EAP session with state 0x1dfcd0851af6c9db
(13) eap: Previous EAP request found for state 0x1dfcd0851af6c9db, released
from the list
(13) eap: Peer sent packet with method EAP PEAP (25)
(13) eap: Calling submodule eap_peap to process data
(13) eap_peap: (TLS) EAP Done initial handshake
(13) eap_peap: Session established.  Decoding tunneled attributes
(13) eap_peap: PEAP state phase2
(13) eap_peap: EAP method MSCHAPv2 (26)
(13) eap_peap: Got tunneled request
(13) eap_peap:   EAP-Message = 0x020a00061a03
(13) eap_peap: Setting User-Name to testing
(13) eap_peap: Sending tunneled request to inner-tunnel
(13) eap_peap:   EAP-Message = 0x020a00061a03
(13) eap_peap:   FreeRADIUS-Proxied-To = 127.0.0.1
(13) eap_peap:   User-Name = "testing"
(13) eap_peap:   State = 0x733052da723a48b52b4f2886441d1cfe
(13) Virtual server inner-tunnel received request
(13)   EAP-Message = 0x020a00061a03
(13)   FreeRADIUS-Proxied-To = 127.0.0.1
(13)   User-Name = "testing"
(13)   State = 0x733052da723a48b52b4f2886441d1cfe
(13) WARNING: Outer and inner identities are the same.  User privacy is
compromised.
(13) server inner-tunnel {
```

```
(13)   session-state: No cached attributes
(13)   # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/inner-tunnel
(13)     authorize {
(13)       policy filter_username {
(13)         if (&User-Name) {
(13)         if (&User-Name)  -> TRUE
(13)         if (&User-Name)  {
(13)           if (&User-Name =~ / /) {
(13)           if (&User-Name =~ / /)  -> FALSE
(13)           if (&User-Name =~ /@[^@]*@/ ) {
(13)           if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(13)           if (&User-Name =~ /\.\./ ) {
(13)           if (&User-Name =~ /\.\./ )  -> FALSE
(13)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(13)           if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))
-> FALSE
(13)           if (&User-Name =~ /\.$/)  {
(13)           if (&User-Name =~ /\.$/)   -> FALSE
(13)           if (&User-Name =~ /@\./)  {
(13)           if (&User-Name =~ /@\./)   -> FALSE
(13)         } # if (&User-Name)  = notfound
(13)       } # policy filter_username = notfound
(13)       [chap] = noop
(13)       [mschap] = noop
(13) suffix: Checking for suffix after "@"
(13) suffix: No '@' in User-Name = "testing", looking up realm NULL
(13) suffix: No such realm "NULL"
(13)       [suffix] = noop
(13)       update control {
(13)         &Proxy-To-Realm := LOCAL
(13)       } # update control = noop
(13) eap: Peer sent EAP Response (code 2) ID 10 length 6
(13) eap: No EAP Start, assuming it's an on-going EAP conversation
(13)       [eap] = updated
(13) files: users: Matched entry testing at line 1
(13)       [files] = ok
(13)       [expiration] = noop
(13)       [logintime] = noop
(13) pap: WARNING: Auth-Type already set.  Not setting to PAP
(13)       [pap] = noop
(13)     } # authorize = updated
(13)   Found Auth-Type = eap
(13)   # Executing group from file /etc/freeradius/3.0/sites-enabled/inner-
tunnel
(13)     authenticate {
(13) eap: Expiring EAP session with state 0x0275a0c70672b940
(13) eap: Finished EAP session with state 0x733052da723a48b5
(13) eap: Previous EAP request found for state 0x733052da723a48b5, released
from the list
(13) eap: Peer sent packet with method EAP MSCHAPv2 (26)
(13) eap: Calling submodule eap_mschapv2 to process data
(13) eap: Sending EAP Success (code 3) ID 10 length 4
(13) eap: Freeing handler
(13)       [eap] = ok
(13)     } # authenticate = ok
```

```
(13)   # Executing section post-auth from file /etc/freeradius/3.0/sites-
enabled/inner-tunnel
(13)     post-auth {
(13)       if (0) {
(13)       if (0)  -> FALSE
(13)     } # post-auth = noop
(13) } # server inner-tunnel
(13) Virtual server sending reply
(13)   MS-MPPE-Encryption-Policy = Encryption-Allowed
(13)   MS-MPPE-Encryption-Types = RC4-40or128-bit-Allowed
(13)   MS-MPPE-Send-Key = 0x131754fa87cdb097689864f121ea9f7d
(13)   MS-MPPE-Recv-Key = 0xbb7892aa92e0522b086574bddaf60e68
(13)   EAP-Message = 0x030a0004
(13)   Message-Authenticator = 0x00000000000000000000000000000000
(13)   User-Name = "testing"
(13) eap_peap: Got tunneled reply code 2
(13) eap_peap:   MS-MPPE-Encryption-Policy = Encryption-Allowed
(13) eap_peap:   MS-MPPE-Encryption-Types = RC4-40or128-bit-Allowed
(13) eap_peap:   MS-MPPE-Send-Key = 0x131754fa87cdb097689864f121ea9f7d
(13) eap_peap:   MS-MPPE-Recv-Key = 0xbb7892aa92e0522b086574bddaf60e68
(13) eap_peap:   EAP-Message = 0x030a0004
(13) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(13) eap_peap:   User-Name = "testing"
(13) eap_peap: Got tunneled reply RADIUS code 2
(13) eap_peap:   MS-MPPE-Encryption-Policy = Encryption-Allowed
(13) eap_peap:   MS-MPPE-Encryption-Types = RC4-40or128-bit-Allowed
(13) eap_peap:   MS-MPPE-Send-Key = 0x131754fa87cdb097689864f121ea9f7d
(13) eap_peap:   MS-MPPE-Recv-Key = 0xbb7892aa92e0522b086574bddaf60e68
(13) eap_peap:   EAP-Message = 0x030a0004
(13) eap_peap:   Message-Authenticator = 0x00000000000000000000000000000000
(13) eap_peap:   User-Name = "testing"
(13) eap_peap: Tunneled authentication was successful
(13) eap_peap: SUCCESS
(13) eap: Sending EAP Request (code 1) ID 11 length 46
(13) eap: EAP session adding &reply:State = 0x1dfcd08515f7c9db
(13)     [eap] = handled
(13)   } # authenticate = handled
(13) Using Post-Auth-Type Challenge
(13) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(13)   Challenge { ... } # empty sub-section is ignored
(13) session-state: Saving cached attributes
(13)   Framed-MTU = 994
(13)   TLS-Session-Information = "(TLS) recv TLS 1.3 Handshake, ClientHello"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, ServerHello"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Certificate"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerKeyExchange"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake,
ServerHelloDone"
(13)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake,
ClientKeyExchange"
(13)   TLS-Session-Information = "(TLS) recv TLS 1.2 Handshake, Finished"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 ChangeCipherSpec"
(13)   TLS-Session-Information = "(TLS) send TLS 1.2 Handshake, Finished"
(13)   TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-SHA384"
(13)   TLS-Session-Version = "TLS 1.2"
```

```
(13) Sent Access-Challenge Id 20 from 10.0.1.254:1812 to 10.0.1.3:1645 length
104
(13)   EAP-Message =
0x010b002e19001703030023e0c487f4aa2d57b13408ce713d0693c8a1aa926d50b780e92ff6f
ef36181a99bf260dc
(13)   Message-Authenticator = 0x00000000000000000000000000000000
(13)   State = 0x1dfcd08515f7c9db5e3d878bc6e70d5e
(13) Finished request
Waking up in 4.9 seconds.
(14) Received Access-Request Id 21 from 10.0.1.3:1645 to 10.0.1.254:1812
length 267
(14)   User-Name = "testing"
(14)   Framed-MTU = 1400
(14)   Called-Station-Id = "d0c2.822e.4392:CCNP_34_727_SSID_3"
(14)   Calling-Station-Id = "14ab.c53c.0807"
(14)   Cisco-AVPair = "ssid=CCNP_34_727_SSID_3"
(14)   Service-Type = Login-User
(14)   Cisco-AVPair = "service-type=Login"
(14)   Message-Authenticator = 0x4f32d493bd6893ce08aa9b8f2254b8b6
(14)   EAP-Message =
0x020b002e190017030300230000000000000042ed1a9d8b5f207ef498bb4c0850a47564b00b
009dfc346afa31a7f
(14)   NAS-Port-Type = Wireless-802.11
(14)   NAS-Port = 277
(14)   NAS-Port-Id = "277"
(14)   State = 0x1dfcd08515f7c9db5e3d878bc6e70d5e
(14)   NAS-IP-Address = 10.0.1.3
(14)   NAS-Identifier = "RyanSunny"
(14) Restoring &session-state
(14)   &session-state:Framed-MTU = 994
(14)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.3
Handshake, ClientHello"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHello"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Certificate"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerKeyExchange"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, ServerHelloDone"
(14)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, ClientKeyExchange"
(14)   &session-state:TLS-Session-Information = "(TLS) recv TLS 1.2
Handshake, Finished"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
ChangeCipherSpec"
(14)   &session-state:TLS-Session-Information = "(TLS) send TLS 1.2
Handshake, Finished"
(14)   &session-state:TLS-Session-Cipher-Suite = "ECDHE-RSA-AES256-GCM-
SHA384"
(14)   &session-state:TLS-Session-Version = "TLS 1.2"
(14) # Executing section authorize from file /etc/freeradius/3.0/sites-
enabled/default
(14)   authorize {
(14)     policy filter_username {
(14)       if (&User-Name) {
(14)       if (&User-Name)  -> TRUE
```

```
(14)       if (&User-Name)  {
(14)         if (&User-Name =~ / /) {
(14)         if (&User-Name =~ / /)  -> FALSE
(14)         if (&User-Name =~ /@[^@]*@/ ) {
(14)         if (&User-Name =~ /@[^@]*@/ )  -> FALSE
(14)         if (&User-Name =~ /\.\./ ) {
(14)         if (&User-Name =~ /\.\./ )  -> FALSE
(14)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))  {
(14)         if ((&User-Name =~ /@/) && (&User-Name !~ /@(.+)\.(.+)$/))   ->
FALSE
(14)         if (&User-Name =~ /\.$/)  {
(14)         if (&User-Name =~ /\.$/)   -> FALSE
(14)         if (&User-Name =~ /@\./)  {
(14)         if (&User-Name =~ /@\./)   -> FALSE
(14)       } # if (&User-Name)  = notfound
(14)     } # policy filter_username = notfound
(14)     [preprocess] = ok
(14)     [chap] = noop
(14)     [mschap] = noop
(14)     [digest] = noop
(14) suffix: Checking for suffix after "@"
(14) suffix: No '@' in User-Name = "testing", looking up realm NULL
(14) suffix: No such realm "NULL"
(14)     [suffix] = noop
(14) eap: Peer sent EAP Response (code 2) ID 11 length 46
(14) eap: Continuing tunnel setup
(14)     [eap] = ok
(14)   } # authorize = ok
(14) Found Auth-Type = eap
(14) # Executing group from file /etc/freeradius/3.0/sites-enabled/default
(14)   authenticate {
(14) eap: Expiring EAP session with state 0x0275a0c70672b940
(14) eap: Finished EAP session with state 0x1dfcd08515f7c9db
(14) eap: Previous EAP request found for state 0x1dfcd08515f7c9db, released
from the list
(14) eap: Peer sent packet with method EAP PEAP (25)
(14) eap: Calling submodule eap_peap to process data
(14) eap_peap: (TLS) EAP Done initial handshake
(14) eap_peap: Session established.  Decoding tunneled attributes
(14) eap_peap: PEAP state send tlv success
(14) eap_peap: Received EAP-TLV response
(14) eap_peap: Success
(14) eap: Sending EAP Success (code 3) ID 11 length 4
(14) eap: Freeing handler
(14)     [eap] = ok
(14)   } # authenticate = ok
(14) # Executing section post-auth from file /etc/freeradius/3.0/sites-
enabled/default
(14)   post-auth {
(14)     if (session-state:User-Name && reply:User-Name && request:User-Name
&& (reply:User-Name == request:User-Name)) {
(14)     if (session-state:User-Name && reply:User-Name && request:User-Name
&& (reply:User-Name == request:User-Name))  -> FALSE
(14)     update {
(14)       &reply::Framed-MTU += &session-state:Framed-MTU[*] -> 994
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) recv TLS 1.3 Handshake, ClientHello'
```

```
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 Handshake, ServerHello'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 Handshake, Certificate'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 Handshake, ServerKeyExchange'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 Handshake, ServerHelloDone'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) recv TLS 1.2 Handshake, ClientKeyExchange'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) recv TLS 1.2 Handshake, Finished'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 ChangeCipherSpec'
(14)       &reply::TLS-Session-Information += &session-state:TLS-Session-
Information[*] -> '(TLS) send TLS 1.2 Handshake, Finished'
(14)       &reply::TLS-Session-Cipher-Suite += &session-state:TLS-Session-
Cipher-Suite[*] -> 'ECDHE-RSA-AES256-GCM-SHA384'
(14)       &reply::TLS-Session-Version += &session-state:TLS-Session-
Version[*] -> 'TLS 1.2'
(14)     } # update = noop
(14)     [exec] = noop
(14)     policy remove_reply_message_if_eap {
(14)       if (&reply:EAP-Message && &reply:Reply-Message) {
(14)       if (&reply:EAP-Message && &reply:Reply-Message)  -> FALSE
(14)       else {
(14)         [noop] = noop
(14)       } # else = noop
(14)     } # policy remove_reply_message_if_eap = noop
(14)     if (EAP-Key-Name && &reply:EAP-Session-Id) {
(14)     if (EAP-Key-Name && &reply:EAP-Session-Id)  -> FALSE
(14)   } # post-auth = noop
(14) Sent Access-Accept Id 21 from 10.0.1.254:1812 to 10.0.1.3:1645 length
175
(14)   MS-MPPE-Recv-Key =
0x171c4112125f9828825826210a235d897df09241b7a5ea85135ff5a7c53c48d3
(14)   MS-MPPE-Send-Key =
0xc28dc6f60be98571c8a439836c2ca480ab700efdd78ef2952ed6276ba53a9b14
(14)   EAP-Message = 0x030b0004
(14)   Message-Authenticator = 0x00000000000000000000000000000000
(14)   User-Name = "testing"
(14)   Framed-MTU += 994
(14) Finished request
Waking up in 4.9 seconds.
(10) Cleaning up request packet ID 17 with timestamp +73 due to cleanup_delay
was reached
(11) Cleaning up request packet ID 18 with timestamp +73 due to cleanup_delay
was reached
(12) Cleaning up request packet ID 19 with timestamp +74 due to cleanup_delay
was reached
(13) Cleaning up request packet ID 20 with timestamp +74 due to cleanup_delay
was reached
(14) Cleaning up request packet ID 21 with timestamp +74 due to cleanup_delay
was reached
Ready to process requests
```

IPCONFIG:

```
C:\Users\Lab_user>ipconfig

Windows IP Configuration


Ethernet adapter Ethernet:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Ethernet adapter vEthernet (Default Switch):

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::9d3c:f356:9171:90c8%45
   IPv4 Address. . . . . . . . . . . : 172.27.144.1
   Subnet Mask . . . . . . . . . . . : 255.255.240.0
   Default Gateway . . . . . . . . . :

Ethernet adapter Ethernet 2:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::e526:ac31:b011:c4af%8
   IPv4 Address. . . . . . . . . . . : 192.168.56.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :

Wireless LAN adapter Local Area Connection* 1:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Local Area Connection* 2:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::f62b:f747:72db:ca85%12
   IPv4 Address. . . . . . . . . . . : 10.0.20.4
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 10.0.20.1
```

Tracert to AP:

```
C:\Users\Lab_user>tracert 10.0.1.3

Tracing route to 10.0.1.3 over a maximum of 30 hops

  1     1 ms     1 ms     1 ms  10.0.20.1
  2     2 ms     1 ms     1 ms  10.0.1.3

Trace complete.
```

Tracert to Switch:

```
C:\Users\Lab_user>tracert 10.0.1.2

Tracing route to 10.0.1.2 over a maximum of 30 hops

  1     1 ms     1 ms     1 ms  10.0.20.1
  2     3 ms     3 ms     2 ms  10.0.1.2

Trace complete.
```

Tracert to Router (InterVLAN):

```
C:\Users\Lab_user>tracert 10.0.1.1

Tracing route to 10.0.1.1 over a maximum of 30 hops

  1     1 ms     1 ms     1 ms  10.0.1.1

Trace complete.
```

Tracert to Internet:

```
C:\Users\Lab_user>tracert 1.1.1.1

Tracing route to one.one.one.one [1.1.1.1]
over a maximum of 30 hops:

  1     1 ms     1 ms     1 ms  10.0.20.1
  2     2 ms     1 ms     1 ms  192.168.40.1
  3     2 ms     1 ms     1 ms  172.28.128.1
  4     2 ms     2 ms     2 ms  192.168.15.1
  5    13 ms     9 ms    14 ms  10.61.242.194
  6    14 ms    17 ms    14 ms  po-316-315-
rur401.bellevue.wa.seattle.comcast.net [24.153.84.161]
  7    13 ms    13 ms    14 ms  po-2-rur402.bellevue.wa.seattle.comcast.net
[96.216.61.78]
  8    13 ms    18 ms    15 ms  po-400-xar02.bellevue.wa.seattle.comcast.net
[96.216.61.61]
  9    22 ms    22 ms    18 ms  be-300-arsc1.seattle.wa.seattle.comcast.net
[24.124.128.89]
 10     *       98 ms    17 ms  be-36131-cs03.seattle.wa.ibone.comcast.net
[68.86.93.9]
 11    14 ms    20 ms    17 ms  be-2313-pe13.seattle.wa.ibone.comcast.net
[96.110.44.90]
 12    12 ms     *       17 ms  66.208.232.210
 13    42 ms    89 ms    14 ms  172.71.148.5
 14    19 ms    17 ms    16 ms  one.one.one.one [1.1.1.1]

Trace complete.
```

Routing Table:

DHCP:

```
S1#show ip dhcp binding
Bindings from all pools not associated with VRF:
IP address          Client-ID/              Lease expiration        Type
                    Hardware address/
                    User name
10.0.10.4           01ac.ed5c.3e57.6a       Mar 02 1993 02:29 AM    Automatic
10.0.20.4           0114.abc5.3c08.07       Mar 02 1993 02:20 AM    Automatic
```

NAT:

```
R1#show ip nat translations
Pro  Inside global         Inside local          Outside local
Outside global
tcp  192.168.40.115:4520   10.0.20.4:51161       13.69.116.107:443
13.69.116.107:443
tcp  192.168.40.115:4515   10.0.20.4:51158       52.112.127.50:443
52.112.127.50:443
udp  192.168.40.115:512    10.0.20.4:137         192.168.15.1:137
192.168.15.1:137
udp  192.168.40.115:512    10.0.20.4:137         10.61.242.194:137
10.61.242.194:137
tcp  192.168.40.115:4531   10.0.20.4:51151       13.89.179.8:443
13.89.179.8:443
udp  192.168.40.115:512    10.0.20.4:137         172.28.128.1:137
172.28.128.1:137
tcp  192.168.40.115:4517   10.0.20.4:51058       40.83.240.146:443
40.83.240.146:443
tcp  192.168.40.115:4504   10.0.20.4:51154       13.107.136.10:443
13.107.136.10:443
tcp  192.168.40.115:4525   10.0.20.4:51150       192.168.40.76:7680
192.168.40.76:7680
tcp  192.168.40.115:4505   10.0.20.4:51155       52.104.79.25:443
52.104.79.25:443
tcp  192.168.40.115:4508   10.0.20.4:51049       40.83.240.146:443
40.83.240.146:443
tcp  192.168.40.115:4522   10.0.20.4:51163       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4506   10.0.20.4:51156       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4512   10.0.20.4:51145       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4516   10.0.20.4:51159       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4503   10.0.20.4:56084       52.112.87.139:443
52.112.87.139:443
tcp  192.168.40.115:4519   10.0.20.4:51160       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4501   10.0.20.4:51153       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4502   10.0.20.4:51148       104.18.12.46:80
104.18.12.46:80
udp  192.168.40.115:512    10.0.20.4:137         66.208.232.210:137
66.208.232.210:137
udp  192.168.40.115:4518   10.0.20.4:58947       8.8.4.4:443
8.8.4.4:443
udp  192.168.40.115:4514   10.0.20.4:53615       8.8.4.4:443
8.8.4.4:443
```

```
tcp  192.168.40.115:4518   10.0.20.4:51059       52.112.107.138:443
52.112.107.138:443
tcp  192.168.40.115:4527   10.0.20.4:51146       52.184.216.174:443
52.184.216.174:443
tcp  192.168.40.115:4513   10.0.20.4:51149       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4532   10.0.20.4:51152       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4529   10.0.20.4:51147       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4511   10.0.20.4:51052       162.159.134.234:443
162.159.134.234:443
udp  192.168.40.115:4512   10.0.20.4:58794       8.8.8.8:53
8.8.8.8:53
tcp  192.168.40.115:4521   10.0.20.4:51162       104.18.12.46:80
104.18.12.46:80
tcp  192.168.40.115:4514   10.0.20.4:51157       104.18.12.46:80
104.18.12.46:80
udp  192.168.40.115:4516   10.0.20.4:62045       8.8.8.8:53
8.8.8.8:53
udp  192.168.40.115:512    10.0.20.4:137         192.168.40.1:137
192.168.40.1:137
udp  192.168.40.115:512    10.0.20.4:137         172.71.148.5:137
172.71.148.5:137
udp  192.168.40.115:4517   10.0.20.4:57236       8.8.8.8:53
8.8.8.8:53
icmp 192.168.40.115:1      10.0.20.4:1           1.1.1.1:1
1.1.1.1:1
tcp  192.168.40.115:4530   10.0.20.4:51092       40.83.247.108:443
40.83.247.108:443
Total number of translations: 37
```

Problems:

1) Access Point Nonfunctional

   The bootloader on the first access point we received was corrupted and after several attempts to enter recovery mode, continued to be unresponsive. The access point continued to boot loop, not even reaching OS load. We then exchanged this access point for another one, which worked.

2) Access Point Corrupted

   After loading the appropriate OS and setting up basic interfaces, our access point suddenly corrupted the next day, rendering our previous work unusable. We flashed the OS again and continued working.

3) Rogue DHCP server

   Due to sharing conflicts on a single rack with other groups running the same lab, we realized that address conflicts arose. A DHCP server from another group was configured incorrectly, causing it to use our same subnet.

4) DHCP -> PAT -> DHCP

Initially we did not realize that the upstream DHCP server provided by our class ran on the 192.168.x.x subnets. Since our topology was based on the 10.0.1.x subnet, we needed to use PAT in order to convert the outside 192.168.x.x addresses into our network. After doing that, we were able to confirm that it was functional by connecting our PC to the switch which the interface was connected to. However, we also needed to run PAT back to our own internal DHCP server running on a router. This was necessary in assigning AP clients addresses to get them on the internet.

At first, we tried to run all of these configurations on a Layer 3 switch to reduce topology size and complexity but later realized that the switch was incapable of this. Because of this, we needed to run an interface down to another router, which handled our DHCP and PAT. Then, this interface would run back up to our Layer 3 switch. One interface on the router served as a PAT outside port, and one served as the internal DHCP port.

5) Assigning Clients DNS

After we initially got WPA2 PSK working, we realized we could ping to an address like 8.8.8.8 (Google DNS) but could not access https://google.com on a web browser. After doing an ipconfig, we quickly realized that we had forgotten to assign a default DNS server to the clients on the switch. After assigning a common DNS server such as 1.1.1.1 or 8.8.8.8, we were able to access websites.

6) Port Forwarding in VirtualBox/VMware/WSL

Port forwarding in VM applications did not work as intended, neither did WSL. Initially, we intended to run FreeRadius in a hypervisor setup, but due to conflicts decided it would be better to run it on bare metal with another Ubuntu drive acting as the server.

7) AP Radius Server Issues

Initially we intended to use the Cisco AP's built-in local RADIUS server, but after much configuration and confusion due to absolute lack of documentation, we ditched this idea, opting to use something more standard such as FreeRadius.

8) Switch VLAN Issues

Our configs were not persistent since our racks were shared amongst class members. When loading our switch config, we realized that VLAN interfaces by default were not included in the config. This led us to believe that our switch config was incorrect, but after troubleshooting realized that the VLAN interfaces needed to be manually activated.

9) FreeRadius Configuration Troubles

FreeRadius documentation labelled out of date configuration file locations, leading us to believe that the installation had not fully worked.

FreeRadius refused to accept a shared secret between the AP and the server, however upon changing this key worked as intended.

FreeRadius documentation was scarce and labelled poorly, leading us to configure wrong IP addresses, mixing up the server and the host. However, this did not yield in a useful error prompt, instead telling us that the shared secret was once again incorrect. Upon changing the IP address, the FreeRadius server worked as intended.

Conclusion:

Overall, this lab was a good introduction to AP configuration, as well as a refresher on configuring DHCP and PAT on routers/switches. We needed to design our topology and consider certain restrictions and limitations from the ground up, as we were only given a task. This allowed us to put prior networking knowledge into use, giving us a greater understanding of how these things function in a real topology.

BGP Implementation Documentation

Ryan Chen

CCNP

Purpose:

This lab was primarily used in order to learn basic BGP configuration in conjunction with various routing protocols such as EIGRP, OSPF, and RIP. To do this, we needed to configure both IPv4 and IPv6 versions of BGP. Furthermore, this lab also gave us a refresher on previously learned routing protocols, such as RIP and EIGRP.

Background Information:

BGP is an industry standard protocol used for connecting various different company networks, which may or may not be running on different routing protocols and employ different configuration standards. It is highly important as it allows networks from all around the world to connect to each other, which is the basis for the Internet. Each of these networks that originate from different organizations/companies is referred to as an Autonomous System (AS). BGP allows all these different ASes to share routing information and create a single, interconnected route.

Often times, each AS uses different routing protocols. Industry standards include OSPF, EIGRP, and RIP, however RIP has largely been replaced by more efficient protocols. While these protocols would normally be unable to share routing tables, BGP is a centralized protocol that allows each AS to share and receive routes.

The BGP protocol has a wide variety of configurable attributes that allow it to be highly flexible for both large scale enterprise and also small-scale company level use. The three attributes we focused on are path weight, atomic aggregation, and normal aggregation. In combination, these attributes allowed us to manipulate BGP routes to demonstrate the capabilities of configuration with BGP.

The weight BGP attribute allows us to manually assign a priority to routes distributed by BGP. The number spans from 0 to 65535 and is set on a per route basis. Weight is a local preference, meaning that it isn't distributed to other routers. Each router holds its own locally set route preferences that influence preferred path. Routes with local prefixes (which originate from the router itself) receive a weight of 32768, and the default weight is 0. Changing weight is typically used on a router-by-router basis to prefer a specific route when two routes are present from different AS'es for the same prefix. This allows a network administrator to pick the faster/more desirable path to optimize BGP.

The other two attributes involve subnet aggregation. BGP aggregation combines routes that advertise prefixes which fall under a common subnet/address block. This is used to reduce the number of routes that BGP has to distribute and store, in turn maximizing efficiency and speed. We primarily utilized two types of aggregation: normal and atomic. Normal aggregation simplifies routes that have similar network subnets. For

instance, a 192.168.0.0/25 and a 192.168.0.127/25 will be aggregated into the 192.168.0.0/24 network to reduce the number of routes and packets sent. This reduces network congestion and router resource utilization, which increases BGP speed. On the other hand, atomic aggregation causes all packets with a destination to a previously aggregated network to be sent to the router that initially performed aggregation. If atomic aggregation is configured, it will point towards a router that performs normal aggregation. Thus, any packets that have a destination of an aggregated route will be forwarded to that router that has normal aggregation.

Lab Summary:

In this lab, our objective was to configure a working BGP network that allows multiple different routing protocols to distribute and receive routes. To do so, we first designed a plausible network topology in Packet Tracer. To simplify future configuration, we decided to simulate the three different types of routing protocols using loopback interfaces. Furthermore, each loopback interface was assigned to a larger subnet block, and these subnet blocks would then be distributed across BGP. This allowed for easier troubleshooting, as the subnet blocks would be clearly identifiable in the routing table.

After completing our topology, we started by configuring each routing protocol locally to each router. Upon confirming that all three were working as intended, we moved onto the inter-protocol BGP area. BGP configuration was quite simple as our topology allowed us to easily add neighbors and distribute routes. After setting up BGP, we were able to identify that it was performing as expected by checking each routing table. Each router was populated with neighboring BGP routes, and we were able to confirm that pings across protocols worked using the built-in ping feature on the router.

Afterwards, we chose three attributes and set them up. The weight attribute did not actually influence route selection, as our topology only had one route that could be used, however we were able to configure and confirm that it was working. To demonstrate normal and atomic subnet aggregation, we split our EIGRP and RIP networks into two /25 subnets and configured aggregation to combine them back into a /24. We were able to verify this by viewing routing tables and checking for the aggregation flag.

Lab Commands:

router bgp [PROCESS-ID]

-Initializes the BGP process

bgp router-id [ROUTER-ID]

-Sets BGP router-id for neighbors

neighbor [IPv4/IPv6-ADDRESS] remote-as [AS-NUMBER] weight [WEIGHT-VALUE]

-Adds a BGP neighbor, with optional BGP weight value attribute

neighbor [IP-ADDRESS] activate

-Establishes BGP adjacency with neighbor

redistribute [ROUTING-PROTOCOL] [AS-NUMBER]

-Redistribute routing protocol routes into BGP (OSPF, RIP, EIGRP)

address-family [IPv4/IPv6]

-Specifies IPv4 or IPv6 configurations for BGP

network [ADDRESS]

-Adds a network under IPv4 or IPv6

aggregate-address [ADDRESS] [SUBNET-MASK] summary-only

-Configures normal subnet aggregation

aggregate-address [ADDRESS] [SUBNET-MASK] as-set summary-only

-Configures atomic subnet aggregation

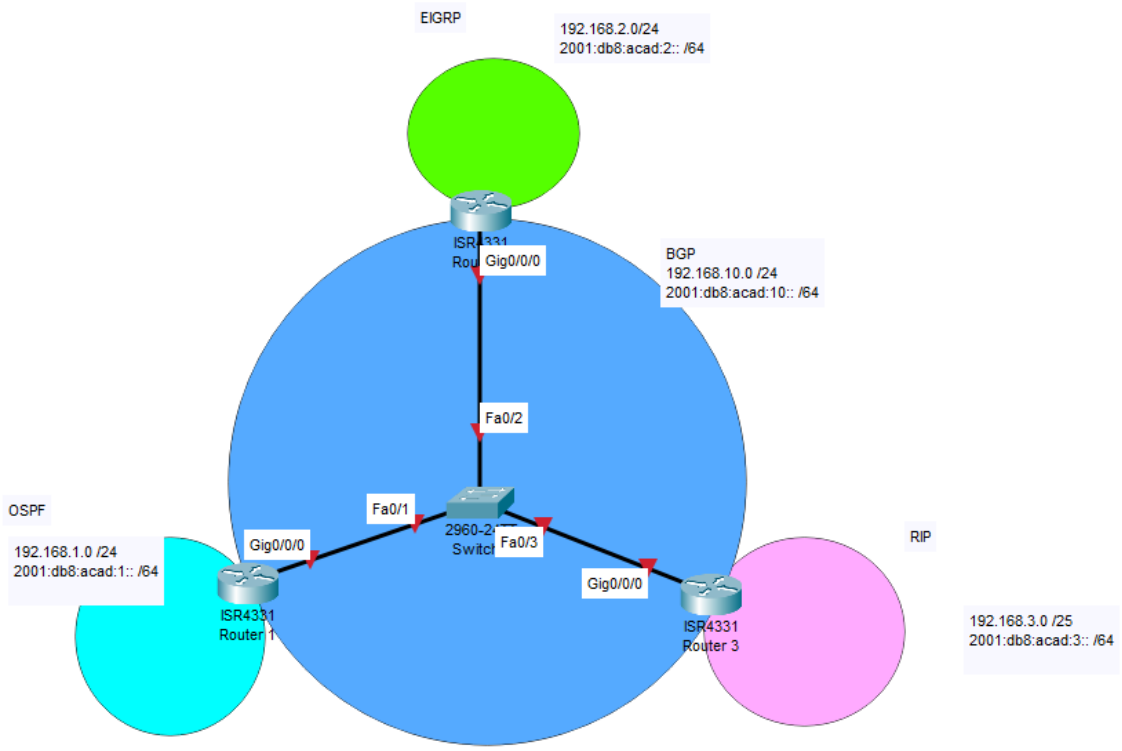
show ip bgp

-Shows all BGP routes

*clear ip bgp **

-Reload the BGP process and delete all stored routes, reestablish neighbors

Network Diagram and IP Table:



	G0/0/0	G0/0/1	Lo0	Lo1
R1	192.168.10.1 255.255.255.0		192.168.1.1 255.255.255.0	
	2001:db8:acad:10::1/64		2001:db8:acad:1::1/64	
R2	192.168.10.2 255.255.255.0		192.168.2.129 255.255.255.128	192.168.2.2 255.255.255.128
	2001:db8:acad:10::2/64		2001:db8:acad:2::2/64	
R3	192.168.10.3 255.255.255.0		192.168.3.3 255.255.255.128	192.168.3.129 255.255.255.128
	2001:db8:acad:10::3/64		2001:db8:acad:3::3/62	

Configurations:

R1

```
hostname R1
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
address-family ipv4
```

```
exit-address-family
address-family ipv6
exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO21491LXV
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
mode none
vlan internal allocation policy ascending
interface Loopback0
ip address 192.168.1.1 255.255.255.0
ipv6 address 2001:DB8:ACAD:1::1/64
ipv6 ospf 1 area 0
interface GigabitEthernet0/0/0
ip address 192.168.10.1 255.255.255.0
negotiation auto
ipv6 address 2001:DB8:ACAD:10::1/64
interface GigabitEthernet0/0/1
no ip address
shutdown
negotiation auto

interface Serial0/1/0
no ip address
shutdown
interface Serial0/1/1
no ip address
shutdown
interface GigabitEthernet0
vrf forwarding Mgmt-intf
no ip address
shutdown
negotiation auto
interface Vlan1
no ip address
shutdown
router ospf 1
router-id 1.1.1.1
network 192.168.1.0 0.0.0.255 area 0
router bgp 1
bgp router-id 1.1.1.1
bgp log-neighbor-changes
neighbor 2001:DB8:ACAD:10::2 remote-as 2
neighbor 2001:DB8:ACAD:10::3 remote-as 3
neighbor 192.168.10.2 remote-as 2
neighbor 192.168.10.3 remote-as 3
address-family ipv4
network 192.168.1.0
network 192.168.10.0
redistribute ospf 1
no neighbor 2001:DB8:ACAD:10::2 activate
no neighbor 2001:DB8:ACAD:10::3 activate
```

```
neighbor 192.168.10.2 activate
neighbor 192.168.10.2 weight 1337
neighbor 192.168.10.3 activate
exit-address-family
address-family ipv6
redistribute ospf 1
network 2001:DB8:ACAD:1::/64
network 2001:DB8:ACAD:10::/64
neighbor 2001:DB8:ACAD:10::2 activate
neighbor 2001:DB8:ACAD:10::3 activate
exit-address-family
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router ospf 1
router-id 1.1.1.1
control-plane
line con 0
stopbits 1
line aux 0
stopbits 1
line vty 0 4
login

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, Loopback0
L        192.168.1.1/32 is directly connected, Loopback0
B     192.168.2.0/24 [20/0] via 192.168.10.2, 00:32:12
B     192.168.3.0/24 [20/0] via 192.168.10.3, 00:31:59
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0/0
L        192.168.10.1/32 is directly connected, GigabitEthernet0/0/0
```

R2

```
hostname R2
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
address-family ipv4
exit-address-family
address-family ipv6
exit-address-family
no aaa new-model
```

```
ipv6 unicast-routing
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420QQ
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
mode none
vlan internal allocation policy ascending
interface Loopback0
ip address 192.168.2.129 255.255.255.128
ipv6 address 2001:DB8:ACAD:2::2/64
ipv6 eigrp 2

interface Loopback1
ip address 192.168.2.2 255.255.255.128

interface GigabitEthernet0/0/0
ip address 192.168.10.2 255.255.255.0
negotiation auto
ipv6 address 2001:DB8:ACAD:10::2/64
ipv6 eigrp 2

interface GigabitEthernet0/0/1
no ip address
shutdown
negotiation auto

interface Serial0/1/0
no ip address
shutdown

interface Serial0/1/1
no ip address
shutdown

interface GigabitEthernet0
vrf forwarding Mgmt-intf
no ip address
shutdown
negotiation auto

interface Vlan1
no ip address
shutdown


router eigrp 2
network 192.168.2.0 0.0.0.127
network 192.168.2.128 0.0.0.127
eigrp router-id 2.2.2.2

router bgp 2
bgp router-id 2.2.2.2
bgp log-neighbor-changes
neighbor 2001:DB8:ACAD:10::1 remote-as 1
```

```
neighbor 2001:DB8:ACAD:10::3 remote-as 3
neighbor 192.168.10.1 remote-as 1
neighbor 192.168.10.3 remote-as 3

address-family ipv4
network 192.168.2.0 mask 255.255.255.128
network 192.168.2.128 mask 255.255.255.128
network 192.168.10.0
aggregate-address 192.168.2.0 255.255.255.0 summary-only
redistribute eigrp 2
no neighbor 2001:DB8:ACAD:10::1 activate
no neighbor 2001:DB8:ACAD:10::3 activate
neighbor 192.168.10.1 activate
neighbor 192.168.10.3 activate
exit-address-family

address-family ipv6
redistribute eigrp 2
network 2001:DB8:ACAD:2::/64
network 2001:DB8:ACAD:10::/64
neighbor 2001:DB8:ACAD:10::1 activate
neighbor 2001:DB8:ACAD:10::3 activate
exit-address-family
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router eigrp 1
eigrp router-id 2.2.2.2
control-plane
line con 0
stopbits 1
line aux 0
stopbits 1
line vty 0 4
login

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

B     192.168.1.0/24 [20/0] via 192.168.10.1, 00:34:18
      192.168.2.0/24 is variably subnetted, 5 subnets, 3 masks
B        192.168.2.0/24 [200/0], 00:34:36, Null0
C        192.168.2.0/25 is directly connected, Loopback1
L        192.168.2.2/32 is directly connected, Loopback1
C        192.168.2.128/25 is directly connected, Loopback0
L        192.168.2.129/32 is directly connected, Loopback0
```

```
B     192.168.3.0/24 [20/0] via 192.168.10.3, 00:34:25
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0/0
L        192.168.10.2/32 is directly connected, GigabitEthernet0/0/0
```

R3

```
hostname R3
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
address-family ipv4
exit-address-family
address-family ipv6
exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420HY
license boot level securityk9
spanning-tree extend system-id
redundancy
mode none
vlan internal allocation policy ascending
vlan 10,20
interface Loopback0
ip address 192.168.3.3 255.255.255.128
ipv6 address 2001:DB8:ACAD:3::3/64
ipv6 rip 1 enable
interface Loopback1
ip address 192.168.3.129 255.255.255.128
interface GigabitEthernet0/0/0
ip address 192.168.10.3 255.255.255.0
negotiation auto
ipv6 address 2001:DB8:ACAD:10::3/64
interface GigabitEthernet0/0/1
no ip address
negotiation auto
interface Serial0/1/0
no ip address
interface Serial0/1/1
no ip address
interface GigabitEthernet0
vrf forwarding Mgmt-intf
no ip address
negotiation auto
interface Vlan1
no ip address
router rip
network 192.168.3.0
router bgp 3
bgp router-id 3.3.3.3
bgp log-neighbor-changes
neighbor 2001:DB8:ACAD:10::1 remote-as 1
```

```
neighbor 2001:DB8:ACAD:10::2 remote-as 2
neighbor 192.168.10.1 remote-as 1
neighbor 192.168.10.2 remote-as 2

address-family ipv4
network 192.168.10.0
aggregate-address 192.168.3.0 255.255.255.0 as-set summary-only
redistribute rip
no neighbor 2001:DB8:ACAD:10::1 activate
no neighbor 2001:DB8:ACAD:10::2 activate
neighbor 192.168.10.1 activate
neighbor 192.168.10.2 activate
neighbor 192.168.10.2 weight 1337
exit-address-family

address-family ipv6
redistribute rip 1
network 2001:DB8:ACAD:3::/64
network 2001:DB8:ACAD:10::/64
neighbor 2001:DB8:ACAD:10::1 activate
neighbor 2001:DB8:ACAD:10::2 activate
exit-address-family

ip forward-protocol nd
no ip http server
no ip http secure-server
ipv6 router rip 1
control-plane
line con 0
stopbits 1
line aux 0
stopbits 1
line vty 0 4
login
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

B     192.168.1.0/24 [20/0] via 192.168.10.1, 00:34:58
B     192.168.2.0/24 [20/0] via 192.168.10.2, 00:35:17
      192.168.3.0/24 is variably subnetted, 5 subnets, 3 masks
B        192.168.3.0/24 [200/0], 00:35:17, Null0
C        192.168.3.0/25 is directly connected, Loopback0
L        192.168.3.3/32 is directly connected, Loopback0
C        192.168.3.128/25 is directly connected, Loopback1
L        192.168.3.129/32 is directly connected, Loopback1
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
```

```
C        192.168.10.0/24 is directly connected, GigabitEthernet0/0/0
L        192.168.10.3/32 is directly connected, GigabitEthernet0/0/0
```

BGP Attributes:

Weight (1337)

```
R1#show ip bgp
BGP table version is 7, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  192.168.1.0      0.0.0.0                  0         32768 i
 *>  192.168.2.0      192.168.10.2             0          1337 2 i
 *                    192.168.10.2                           0 3 2 i
 *>  192.168.3.0      192.168.10.3                        1337 2 3 ?
 *                    192.168.10.3             0             0 3 ?
 *   192.168.10.0     192.168.10.2             0          1337 2 i
 *                    192.168.10.3             0             0 3 i
 *>                   0.0.0.0                  0         32768 i
R1#
```

Atomic and Normal Aggregation (Suppressed / Atomic)

```
R3#show ip bgp
BGP table version is 10, local router ID is 3.3.3.3
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  192.168.1.0      192.168.10.1                        1337 2 1 i
 *                    192.168.10.1             0             0 1 i
 *   192.168.2.0      192.168.10.2                           0 1 2 i
 *>                   192.168.10.2             0          1337 2 i
 s>  192.168.3.0/25   0.0.0.0                  0         32768 ?
 *>  192.168.3.0      0.0.0.0                            100  32768 ?
 s>  192.168.3.128/25 0.0.0.0                  0         32768 ?
 *   192.168.10.0     192.168.10.1             0             0 1 i
 *                    192.168.10.2             0          1337 2 i
 *>                   0.0.0.0                  0         32768 i
```

```
R3#show ip bgp 192.168.2.0
BGP routing table entry for 192.168.2.0/24, version 3
Paths: (2 available, best #2, table default)
  Advertised to update-groups:
     1
  Refresh Epoch 1
  1 2, (aggregated by 2 2.2.2.2)
    192.168.10.2 from 192.168.10.1 (1.1.1.1)
      Origin IGP, localpref 100, valid, external, atomic-aggregate
      rx pathid: 0, tx pathid: 0
  Refresh Epoch 1
  2, (aggregated by 2 2.2.2.2)
    192.168.10.2 from 192.168.10.2 (2.2.2.2)
      Origin IGP, metric 0, localpref 100, weight 1337, valid, external, atomic-aggregate, best
      rx pathid: 0, tx pathid: 0x0
```

Pings:

Note: Traceroutes are omitted because our network is small and hardly includes any address hops

```
R1#ping 192.168.10.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 192.168.2.129
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.129, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 192.168.2.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 192.168.10.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 192.168.3.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 192.168.3.129
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.129, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R1#ping 2001:db8:acad:10::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 2001:db8:acad:2::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:2::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 2001:db8:acad:10::3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 2001:db8:acad:3::3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R2#ping 192.168.10.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 192.168.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 192.168.10.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 192.168.3.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 192.168.3.129
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.3.129, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R2#ping 2001:db8:acad:10::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 2001:db8:acad:1::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:1::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 2001:db8:acad:10::3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R2#ping 2001:db8:acad:3::3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:3::3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R3#ping 192.168.10.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 192.168.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 192.168.10.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.10.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 192.168.2.129
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.129, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 2001:db8:acad:10::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 2001:db8:acad:1::1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:1::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 2001:db8:acad:10::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:10::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R3#ping 2001:db8:acad:2::2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:ACAD:2::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

Problems:

1) Atomic vs Normal aggregation
   When trying to configure this attribute, we had trouble understand the differences between the two types and which commands we needed to use for which. We initially thought as-set was normal aggregation, but later realized that it was atomic and that no as-set was normal. Furthermore, we also did not know how to setup the attribute correctly, which we later figured out that we had to split our Loopback network into two subnets and then aggregate them again.

2) Viewing BGP info
   When trying to configure attributes, we struggled to verify whether or not they were functioning correctly, since we didn't know the basic BGP view commands. Later on, we learned that "show ip bgp" allows us to view weights, and that "show ip bgp [ADDRESS]" allows us to view normal/atomic subnet aggregation.
3) Router-Specific Issues
   Some of the routers that we loaded our configs into (on days that we didn't have access to our normal rack) did not function as we expected. A few of the routers had some different type of command/functionality which affected our configs and rendered them useless. This meant that we were only able to use our configs on the routers that we usually worked with, slowing our progress down quite significantly.

Conclusion:

BGP is an industry standard routing protocol that allows different routing protocols such as OSPF, EIGRP, and RIP to communicate and distribute routes amongst themselves. Without BGP, these different protocols would not be able to share routing tables. Furthermore, BGP attributes allow BGP to be highly flexible to adapt to individual needs. Attributes such as subnet aggregation allow for faster operation and lower resource usage, whereas weight allows route selection to be optimized. Overall, knowing BGP configuration is a crucial part of networking, as it is used in much of the modern Internet to provide connectivity.

IBGP Implementation Documentation

Ryan Chen

CCNP

Purpose:

The primary purpose of this lab is to introduce the uses and configuration of iBGP, while at the same time implementing previously learned protocols such as eBGP and OSPF. It also acted as a review of previously learned concepts such as setting up different AS's and linking them via BGP.

Background Information:

One of the most important protocols that connects the internet is BGP (Border Gateway Protocol), which we previously covered. This protocol is primarily used to connect various different company networks in the real world, which are often running different network protocols each carrying their own attributes and varied information. In order for them to mesh into a single cohesive network, BGP is required as an intermediary routing protocol. Primarily, each of these organizations is referred to as an Autonomous System (AS) and are thus interconnected using BGP.

Previously, the version of BGP that waws implemented was eBGP, which acts as a protocol that connects different networks (AS's) together. However, there exists another form of BGP that runs strictly within a single internal network and brings numerous different benefits with it. This variant is called iBGP and utilizes a fully meshed network design.

There are numerous reasons why iBGP is used in combination with BGP, but primarily iBGP acts as a "transit AS". In between two eBGP links, prefixes and data must be sent through the network. Although this is possible by redistributing BGP information into an IGP protocol such as EIGRP or OSPF, it is heavily discouraged for two reasons. First, BGP attribute information is dropped when it crosses an IGP, meaning that crucial information would be lost in transit. Secondly, the actual internet routing prefix table is extremely large, consisting of nearly 500k prefixes. Redistributing such a large amount of routing information to an IGP would almost certainly cause network downtime or slowness.

iBGP is fully meshed, which differs from traditional IGPs. Routers do not have to be directly connected to be peered, and all routers are aware of each other in a topology. This allows for greater efficiency in selecting routing paths and sending packets, increasing overall performance. Furthermore, iBGP preserves attribute information, which fixes issues that IGP's face.

Typically, iBGP must be implemented in conjunction with an IGP. In order to achieve a fully meshed topology, each router must be able to reach one another. This is only possible by utilizing a protocol like OSPF, which distributes prefix information within the

network in order for the routers to be able to reach each other to distribute iBGP information.

Lab Summary:

In this lab, we created three different autonomous systems, with two being the endpoints and one being a transit. The primary goal is to achieve connectivity between the two endpoints by configuring iBGP in the transit AS.

To begin, we outlined this topology within Packet Tracer, where we were able to highlight the different AS's and their respective regions. This allowed us to visualize the role that iBGP has as an intermediary protocol. eBGP connects the iBGP network to each external AS.

After this, we first implemented our transit AS by establishing OSPF adjacencies along the three routers. This was the prerequisite for configuring iBGP, as it requires a fully meshed network, meaning all routers must be able to ping each other. Then, we configured each of the two external AS's. In order to simplify our topology, we added loopback interfaces on each of the routers and put them inside their own network. This essentially emulated a different network that would allow us to test if our lab worked. Finally, we configured eBGP to connect the link between the transit AS and our two external networks.

iBGP was configured by adding a loopback interface to each existing router inside the transit AS. These prefixes were then propagated using OSPF, and iBGP utilized them as their connection link. Then, iBGP was configured the same way as BGP would, with a few additional commands.

Lab Commands:

router bgp [PROCESS-ID]

-Initializes the BGP process

bgp router-id [ROUTER-ID]

-Sets BGP router-id for neighbors

neighbor [IPv4/IPv6-ADDRESS] remote-as [AS-NUMBER]

-Adds a BGP neighbor, with optional BGP weight value attribute

neighbor [IP-ADDRESS] activate

-Establishes BGP adjacency with neighbor

neighbor [ADDRESS] update-source [LOOPBACK]

-Core command for iBGP which establishes full mesh, must be applied to all routers in the iBGP network

redistribute [ROUTING-PROTOCOL] [AS-NUMBER]

-Redistribute routing protocol routes into BGP (OSPF, RIP, EIGRP)

address-family [IPv4/IPv6]

-Specifies IPv4 or IPv6 configurations for BGP

network [ADDRESS]

-Adds a network under IPv4 or IPv6

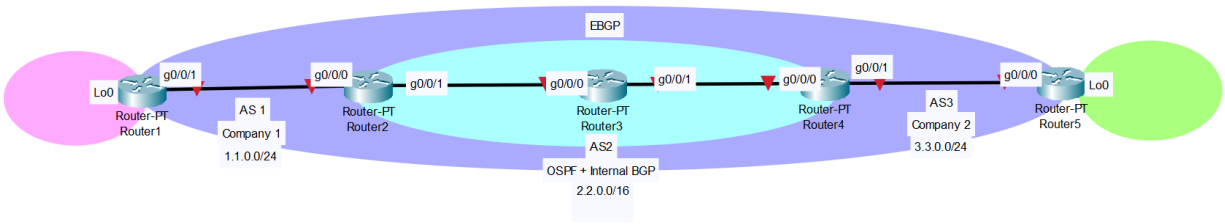
show ip bgp

-Shows all BGP routes

*clear ip bgp **

-Reload the BGP process and delete all stored routes, reestablish neighbors

Network Diagram and IP Table:



Device	Port	IPv4
Router 1	G0/0/0	
	G0/0/1	2.2.1.1/24
	Lo0	1.1.0.254
Router 2	G0/0/0	2.2.1.2/24
	G0/0/1	2.2.2.2/24
	Lo0	2.2.128.254/24
Router 3	G0/0/0	2.2.2.3/24
	G0/0/1	2.2.3.3/24
	Lo0	2.2.129.254/24
Router 4	G0/0/0	2.2.3.4/24
	G0/0/1	2.2.4.4/24
	Lo0	2.2.130.254/24
Router 5	G0/0/0	2.2.4.5/24
	G0/0/1	
	Lo0	3.3.0.254

Configurations:

R1:

```
hostname R1


boot-start-marker

boot-end-marker
```

```
vrf definition Mgmt-intf

 address-family ipv4
 exit-address-family

 address-family ipv6
 exit-address-family

no aaa new-model

subscriber templating

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO21491LXV
license accept end user agreement
license boot level securityk9

spanning-tree extend system-id

redundancy
 mode none

vlan internal allocation policy ascending

interface Loopback0
 ip address 1.1.0.254 255.255.255.0

interface GigabitEthernet0/0/0
 no ip address
 shutdown
```

```
 negotiation auto

interface GigabitEthernet0/0/1
 ip address 2.2.1.1 255.255.255.0
 negotiation auto

interface Serial0/1/0

interface Serial0/1/1

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto

interface Vlan1
 no ip address
 shutdown

router bgp 1
 bgp router-id 1.1.1.1
 bgp log-neighbor-changes
 network 1.1.0.0 mask 255.255.255.0
 neighbor 2.2.1.2 remote-as 2

ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0

control-plane
```

```
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

end
```

Pings and Traceroute:

```
R1#ping 2.2.128.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.128.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 2.2.129.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.129.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R1#ping 2.2.130.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.130.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms
R1#ping 3.3.0.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 3.3.0.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R1#traceroute 3.3.0.254
Type escape sequence to abort.
Tracing the route to 3.3.0.254
VRF info: (vrf in name/id, vrf out name/id)
  1 2.2.1.2 [AS 2] 1 msec 1 msec 0 msec
  2 2.2.2.3 [AS 2] 1 msec 1 msec 0 msec
  3 2.2.3.4 [AS 2] 1 msec 1 msec 0 msec
  4 2.2.4.5 [AS 2] 2 msec 1 msec *
```

Routing Table:

```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      1.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        1.1.0.0/24 is directly connected, Loopback0
L        1.1.0.254/32 is directly connected, Loopback0
      2.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
C        2.2.1.0/24 is directly connected, GigabitEthernet0/0/1
L        2.2.1.1/32 is directly connected, GigabitEthernet0/0/1
B        2.2.2.0/24 [20/0] via 2.2.1.2, 00:44:43
B        2.2.3.0/24 [20/2] via 2.2.1.2, 00:44:43
B        2.2.4.0/24 [20/3] via 2.2.1.2, 00:19:03
B        2.2.128.0/24 [20/0] via 2.2.1.2, 00:44:43
B        2.2.128.254/32 [20/0] via 2.2.1.2, 00:42:00
B        2.2.129.0/24 [20/0] via 2.2.1.2, 00:44:11
B        2.2.129.254/32 [20/2] via 2.2.1.2, 00:44:43
B        2.2.130.0/24 [20/0] via 2.2.1.2, 00:42:00
B        2.2.130.254/32 [20/3] via 2.2.1.2, 00:44:43
      3.0.0.0/24 is subnetted, 1 subnets
B        3.3.0.0 [20/0] via 2.2.1.2, 00:08:24
```

BGP Info:

```
R1#show ip bgp
BGP table version is 26, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  1.1.0.0/24       0.0.0.0                  0         32768 i
 r>  2.2.1.0/24       2.2.1.2                  0             0 2 ?
 *>  2.2.2.0/24       2.2.1.2                  0             0 2 ?
 *>  2.2.3.0/24       2.2.1.2                  2             0 2 ?
 *>  2.2.4.0/24       2.2.1.2                  3             0 2 ?
 *>  2.2.128.0/24     2.2.1.2                  0             0 2 ?
 *>  2.2.128.254/32   2.2.1.2                                 0 2 ?
 *>  2.2.129.0/24     2.2.1.2                                 0 2 ?
 *>  2.2.129.254/32   2.2.1.2                  2             0 2 ?
 *>  2.2.130.0/24     2.2.1.2                                 0 2 ?
 *>  2.2.130.254/32   2.2.1.2                  3             0 2 ?
 *>  3.3.0.0/24       2.2.1.2                                 0 2 3 i
```

```
R1#show ip bgp summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 26, main routing table version 26
12 network entries using 2976 bytes of memory
12 path entries using 1440 bytes of memory
6/6 BGP path/bestpath attribute entries using 1488 bytes of memory
2 BGP AS-PATH entries using 64 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 5968 total bytes of memory
BGP activity 18/6 prefixes, 18/6 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.1.2         4            2      64      60       26    0    0 00:49:43        11
```

R2:

```
hostname R2


boot-start-marker
boot-end-marker


vrf definition Mgmt-intf

 address-family ipv4
 exit-address-family

 address-family ipv6
 exit-address-family


no aaa new-model


subscriber templating


multilink bundle-name authenticated


license udi pid ISR4321/K9 sn FDO214420QQ
license accept end user agreement
license boot level securityk9
```

```
spanning-tree extend system-id

redundancy
 mode none

vlan internal allocation policy ascending

interface Loopback0
 ip address 2.2.128.254 255.255.255.0

interface GigabitEthernet0/0/0
 ip address 2.2.1.2 255.255.255.0
 negotiation auto

interface GigabitEthernet0/0/1
 ip address 2.2.2.2 255.255.255.0
 negotiation auto

interface Serial0/1/0
 no ip address
 shutdown

interface Serial0/1/1
 no ip address
 shutdown

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
```

```
interface Vlan1
 no ip address
 shutdown

router ospf 1
 router-id 2.2.2.2
 redistribute bgp 2 subnets
 network 2.2.1.0 0.0.0.255 area 0
 network 2.2.2.0 0.0.0.255 area 0
 network 2.2.128.0 0.0.0.255 area 0

router bgp 2
 bgp router-id 2.2.2.2
 bgp log-neighbor-changes
 neighbor 2.2.1.1 remote-as 1
 neighbor 2.2.2.3 remote-as 2
 neighbor 2.2.2.3 update-source Loopback0
 neighbor 2.2.3.4 remote-as 2
 neighbor 2.2.3.4 update-source Loopback0

 address-family ipv4
  network 2.2.1.0
  network 2.2.2.0
  network 2.2.128.0
  redistribute ospf 1
  neighbor 2.2.1.1 activate
  neighbor 2.2.2.3 activate
  neighbor 2.2.3.4 activate
 exit-address-family

ip forward-protocol nd
no ip http server
```

```
no ip http secure-server
ip tftp source-interface GigabitEthernet0

control-plane

line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

end
```

Routing Table:

```
R2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      1.0.0.0/24 is subnetted, 1 subnets
B        1.1.0.0 [20/0] via 2.2.1.1, 00:37:19
      2.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C        2.2.1.0/24 is directly connected, GigabitEthernet0/0/0
L        2.2.1.2/32 is directly connected, GigabitEthernet0/0/0
C        2.2.2.0/24 is directly connected, GigabitEthernet0/0/1
L        2.2.2.2/32 is directly connected, GigabitEthernet0/0/1
O        2.2.3.0/24 [110/2] via 2.2.2.3, 01:09:07, GigabitEthernet0/0/1
O        2.2.4.0/24 [110/3] via 2.2.2.3, 00:25:14, GigabitEthernet0/0/1
C        2.2.128.0/24 is directly connected, Loopback0
L        2.2.128.254/32 is directly connected, Loopback0
B        2.2.129.0/24 [200/0] via 2.2.2.3, 00:37:19
O        2.2.129.254/32 [110/2] via 2.2.2.3, 01:11:24, GigabitEthernet0/0/1
B        2.2.130.0/24 [200/0] via 2.2.3.4, 00:37:19
O        2.2.130.254/32 [110/3] via 2.2.2.3, 01:07:33, GigabitEthernet0/0/1
      3.0.0.0/24 is subnetted, 1 subnets
O E2     3.3.0.0 [110/1] via 2.2.2.3, 00:14:09, GigabitEthernet0/0/1
```

BGP Info:

```
R2#show ip bgp
BGP table version is 18, local router ID is 2.2.2.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  1.1.0.0/24       2.2.1.1                  0             0 1 i
 * i 2.2.1.0/24       2.2.3.3                  3    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 * i 2.2.2.0/24       2.2.3.3                  2    100      0 ?
 * i                  2.2.2.3                  0    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 * i 2.2.3.0/24       2.2.3.4                  0    100      0 ?
 * i                  2.2.2.3                  0    100      0 ?
 *>                   2.2.2.3                  2         32768 ?
 *>  2.2.4.0/24       2.2.2.3                  3         32768 ?
 * i                  2.2.3.4                  2    100      0 ?
 * i                  2.2.3.4                  0    100      0 ?
 *>  2.2.128.0/24     0.0.0.0                  0         32768 ?
 r>i 2.2.128.254/32   2.2.3.3                  3    100      0 ?
     Network          Next Hop            Metric LocPrf Weight Path
 *>i 2.2.129.0/24     2.2.2.3                  0    100      0 ?
 * i 2.2.129.254/32   2.2.3.3                  2    100      0 ?
 *>                   2.2.2.3                  2         32768 ?
 *>i 2.2.130.0/24     2.2.3.4                  0    100      0 ?
 * i 2.2.130.254/32   2.2.3.4                  2    100      0 ?
 *>                   2.2.2.3                  3         32768 ?
 r>i 3.3.0.0/24       2.2.4.5                  0    100      0 3 i
```

```
R2#show ip bgp summary
BGP router identifier 2.2.2.2, local AS number 2
BGP table version is 18, main routing table version 18
12 network entries using 2976 bytes of memory
21 path entries using 2520 bytes of memory
8/7 BGP path/bestpath attribute entries using 1984 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 7528 total bytes of memory
BGP activity 19/7 prefixes, 28/7 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.1.1         4            1      64      68       18    0    0 00:53:25        1
2.2.2.3         4            2      64      65       18    0    0 00:51:42        5
2.2.3.4         4            2      65      64       18    0    0 00:49:31        8
```

R3:

```
hostname R3
```

```
boot-start-marker
boot-end-marker

vrf definition Mgmt-intf

 address-family ipv4
 exit-address-family

 address-family ipv6
 exit-address-family

no aaa new-model

subscriber templating
vtp domain cisco
vtp mode transparent

multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO214420HY
license boot level securityk9

spanning-tree extend system-id

redundancy
 mode none

vlan internal allocation policy ascending

vlan 10,20

interface Loopback0
```

```
 ip address 2.2.129.254 255.255.255.0

interface GigabitEthernet0/0/0
 ip address 2.2.2.3 255.255.255.0
 negotiation auto

interface GigabitEthernet0/0/1
 ip address 2.2.3.3 255.255.255.0
 negotiation auto

interface Serial0/1/0
 no ip address

interface Serial0/1/1
 no ip address

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 negotiation auto

interface Vlan1
 no ip address

router ospf 1
 router-id 3.3.3.3
 redistribute bgp 2 subnets
 network 2.2.2.0 0.0.0.255 area 0
 network 2.2.3.0 0.0.0.255 area 0
 network 2.2.129.0 0.0.0.255 area 0

router bgp 2
```

```
 bgp router-id 3.3.3.3
 bgp log-neighbor-changes
 neighbor 2.2.2.2 remote-as 2
 neighbor 2.2.3.4 remote-as 2

 address-family ipv4
  network 2.2.2.0
  network 2.2.3.0
  network 2.2.129.0
  redistribute ospf 1
  neighbor 2.2.2.2 activate
  neighbor 2.2.3.4 activate
 exit-address-family

ip forward-protocol nd
no ip http server
no ip http secure-server

control-plane

line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

end
```

Routing Table:

```
R3#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      1.0.0.0/24 is subnetted, 1 subnets
O E2     1.1.0.0 [110/1] via 2.2.2.2, 00:36:04, GigabitEthernet0/0/0
      2.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
O        2.2.1.0/24 [110/2] via 2.2.2.2, 00:30:04, GigabitEthernet0/0/0
C        2.2.2.0/24 is directly connected, GigabitEthernet0/0/0
L        2.2.2.3/32 is directly connected, GigabitEthernet0/0/0
C        2.2.3.0/24 is directly connected, GigabitEthernet0/0/1
L        2.2.3.3/32 is directly connected, GigabitEthernet0/0/1
O        2.2.4.0/24 [110/2] via 2.2.3.4, 00:27:55, GigabitEthernet0/0/1
B        2.2.128.0/24 [200/0] via 2.2.2.2, 00:52:38
O        2.2.128.254/32 [110/2] via 2.2.2.2, 01:14:17, GigabitEthernet0/0/0
C        2.2.129.0/24 is directly connected, Loopback0
L        2.2.129.254/32 is directly connected, Loopback0
B        2.2.130.0/24 [200/0] via 2.2.3.4, 00:51:34
O        2.2.130.254/32 [110/2] via 2.2.3.4, 01:10:14, GigabitEthernet0/0/1
      3.0.0.0/24 is subnetted, 1 subnets
O E2     3.3.0.0 [110/1] via 2.2.3.4, 00:16:50, GigabitEthernet0/0/1
```

BGP Info:

```
R3#show ip bgp
BGP table version is 19, local router ID is 3.3.3.3
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 r>i 1.1.0.0/24       2.2.1.1                  0    100      0 1 i
 *>  2.2.1.0/24       2.2.2.2                  2         32768 ?
 * i                  2.2.2.2                  0    100      0 ?
 * i 2.2.2.0/24       2.2.2.2                  0    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 * i 2.2.3.0/24       2.2.3.4                  0    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 *>  2.2.4.0/24       2.2.3.4                  2         32768 ?
 * i                  2.2.3.4                  0    100      0 ?
 *>i 2.2.128.0/24     2.2.2.2                  0    100      0 ?
 *>  2.2.128.254/32   2.2.2.2                  2         32768 ?
 *>  2.2.129.0/24     0.0.0.0                  0         32768 ?
 *>i 2.2.130.0/24     2.2.3.4                  0    100      0 ?
 *>  2.2.130.254/32   2.2.3.4                  2         32768 ?
     Network          Next Hop            Metric LocPrf Weight Path
 r>i 3.3.0.0/24       2.2.4.5                  0    100      0 3 i
```

```
R3#show ip bgp summary
BGP router identifier 3.3.3.3, local AS number 2
BGP table version is 19, main routing table version 19
11 network entries using 2728 bytes of memory
15 path entries using 1800 bytes of memory
5/5 BGP path/bestpath attribute entries using 1240 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 5816 total bytes of memory
BGP activity 16/5 prefixes, 20/5 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.2.2         4            2      67      66       19    0    0 00:53:22        4
2.2.3.4         4            2      66      67       19    0    0 00:52:19        4
```

R4:

```
hostname R4


boot-start-marker
boot-end-marker


vrf definition Mgmt-intf


 address-family ipv4
 exit-address-family


 address-family ipv6
 exit-address-family


no aaa new-model


subscriber templating
vtp domain cisco
vtp mode transparent


multilink bundle-name authenticated


license udi pid ISR4321/K9 sn FDO214333H6
```

```
license boot level securityk9

spanning-tree extend system-id

redundancy
 mode none

vlan internal allocation policy ascending

vlan 10,20

interface Loopback0
 ip address 2.2.130.254 255.255.255.0

interface GigabitEthernet0/0/0
 ip address 2.2.3.4 255.255.255.0
 negotiation auto

interface GigabitEthernet0/0/1
 ip address 2.2.4.4 255.255.255.0
 negotiation auto

interface Serial0/1/0
 no ip address
 shutdown

interface Serial0/1/1
 no ip address
 shutdown

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
```

```
 no ip address
 shutdown
 negotiation auto

interface Vlan1
 no ip address
 shutdown

router ospf 1
 router-id 4.4.4.4
 redistribute bgp 2 subnets
 network 2.2.3.0 0.0.0.255 area 0
 network 2.2.4.0 0.0.0.255 area 0
 network 2.2.130.0 0.0.0.255 area 0

router ospf 2

router bgp 2
 bgp router-id 4.4.4.4
 bgp log-neighbor-changes
 network 2.2.3.0
 network 2.2.4.0
 network 2.2.130.0
 redistribute ospf 1
 neighbor 2.2.2.2 remote-as 2
 neighbor 2.2.2.2 update-source Loopback0
 neighbor 2.2.3.3 remote-as 2
 neighbor 2.2.3.3 update-source Loopback0
 neighbor 2.2.4.5 remote-as 3

ip forward-protocol nd
no ip http server
```

```
no ip http secure-server
ip tftp source-interface GigabitEthernet0

control-plane

line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

end
```

Routing Table:

```
R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      1.0.0.0/24 is subnetted, 1 subnets
O E2     1.1.0.0 [110/1] via 2.2.3.3, 00:33:54, GigabitEthernet0/0/0
      2.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
O        2.2.1.0/24 [110/3] via 2.2.3.3, 00:27:54, GigabitEthernet0/0/0
O        2.2.2.0/24 [110/2] via 2.2.3.3, 01:08:02, GigabitEthernet0/0/0
C        2.2.3.0/24 is directly connected, GigabitEthernet0/0/0
L        2.2.3.4/32 is directly connected, GigabitEthernet0/0/0
C        2.2.4.0/24 is directly connected, GigabitEthernet0/0/1
L        2.2.4.4/32 is directly connected, GigabitEthernet0/0/1
B        2.2.128.0/24 [200/0] via 2.2.2.2, 00:48:16
O        2.2.128.254/32 [110/3] via 2.2.3.3, 01:08:02, GigabitEthernet0/0/0
B        2.2.129.0/24 [200/0] via 2.2.3.3, 00:49:24
O        2.2.129.254/32 [110/2] via 2.2.3.3, 01:08:02, GigabitEthernet0/0/0
C        2.2.130.0/24 is directly connected, Loopback0
L        2.2.130.254/32 is directly connected, Loopback0
      3.0.0.0/24 is subnetted, 1 subnets
B        3.3.0.0 [20/0] via 2.2.4.5, 00:14:40
```

BGP Info:

```
R4#show ip bgp
BGP table version is 17, local router ID is 4.4.4.4
Status codes: s suppressed, d damped, h history, * valid, > best, i - intern
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filte
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 r>i 1.1.0.0/24       2.2.1.1                  0    100      0 1 i
 *>  2.2.1.0/24       2.2.3.3                  3         32768 ?
 * i                  2.2.2.2                  2    100      0 ?
 * i                  2.2.2.2                  0    100      0 ?
 * i 2.2.2.0/24       2.2.2.2                  0    100      0 ?
 * i                  2.2.3.3                  0    100      0 ?
 *>                   2.2.3.3                  2         32768 ?
 * i 2.2.3.0/24       2.2.2.3                  2    100      0 ?
 * i                  2.2.3.3                  0    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 * i 2.2.4.0/24       2.2.2.3                  3    100      0 ?
 *>                   0.0.0.0                  0         32768 ?
 *>i 2.2.128.0/24     2.2.2.2                  0    100      0 ?
 * i 2.2.128.254/32   2.2.2.2                  2    100      0 ?
     Network          Next Hop            Metric LocPrf Weight Path
 *>                   2.2.3.3                  3         32768 ?
 *>i 2.2.129.0/24     2.2.3.3                  0    100      0 ?
 * i 2.2.129.254/32   2.2.2.3                  2    100      0 ?
 *>                   2.2.3.3                  2         32768 ?
 *>  2.2.130.0/24     0.0.0.0                  0         32768 ?
 r>i 2.2.130.254/32   2.2.2.3                  3    100      0 ?
 *>  3.3.0.0/24       2.2.4.5                  0             0 3 i
```

```
R2#show ip bgp summary
BGP router identifier 2.2.2.2, local AS number 2
BGP table version is 18, main routing table version 18
12 network entries using 2976 bytes of memory
21 path entries using 2520 bytes of memory
8/7 BGP path/bestpath attribute entries using 1984 bytes of memory
2 BGP AS-PATH entries using 48 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 7528 total bytes of memory
BGP activity 19/7 prefixes, 28/7 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.1.1         4            1      64      68       18    0    0 00:53:25        1
2.2.2.3         4            2      64      65       18    0    0 00:51:42        5
2.2.3.4         4            2      65      64       18    0    0 00:49:31        8
```

R5:

```
hostname R5
```

```
boot-start-marker
boot-end-marker

vrf definition Mgmt-intf

 address-family ipv4
 exit-address-family

 address-family ipv6
 exit-address-family

no aaa new-model

subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated

license udi pid ISR4321/K9 sn FDO21482HYV

spanning-tree extend system-id

redundancy
 mode none

vlan internal allocation policy ascending

vlan 2,10,20

vlan 996
 name CUSTOMER_NATIVE
```

```
interface Loopback0
 ip address 3.3.0.254 255.255.255.0

interface GigabitEthernet0/0/0
 ip address 2.2.4.5 255.255.255.0
 negotiation auto

interface GigabitEthernet0/0/1
 no ip address
 shutdown
 negotiation auto

interface Serial0/1/0
 no ip address
 shutdown

interface Serial0/1/1
 no ip address
 shutdown

interface GigabitEthernet0/2/0
 no ip address
 shutdown
 negotiation auto

interface GigabitEthernet0/2/1
 no ip address
 shutdown
 negotiation auto

interface GigabitEthernet0
 vrf forwarding Mgmt-intf
```

```
 no ip address
 shutdown
 negotiation auto

interface Vlan1
 no ip address
 shutdown

router bgp 3
 bgp router-id 5.5.5.5
 bgp log-neighbor-changes
 network 3.3.0.0 mask 255.255.255.0
 neighbor 2.2.4.4 remote-as 2

ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0

control-plane

line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

end
```

Pings and Traceroute:

```
R5#ping 1.1.0.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 1.1.0.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R5#ping 2.2.128.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.128.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R5#ping 2.2.129.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.129.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
R5#ping 2.2.130.254
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.130.254, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

```
R5#traceroute 1.1.0.254
Type escape sequence to abort.
Tracing the route to 1.1.0.254
VRF info: (vrf in name/id, vrf out name/id)
  1 2.2.4.4 [AS 2] 1 msec 1 msec 0 msec
  2 2.2.3.3 [AS 2] 1 msec 1 msec 1 msec
  3 2.2.2.2 [AS 2] 1 msec 1 msec 1 msec
  4 2.2.1.1 [AS 2] 1 msec 2 msec *
```

Routing Table:

```
R5#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      1.0.0.0/24 is subnetted, 1 subnets
B        1.1.0.0 [20/0] via 2.2.4.4, 00:14:48
      2.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
B        2.2.1.0/24 [20/3] via 2.2.4.4, 00:14:48
B        2.2.2.0/24 [20/2] via 2.2.4.4, 00:14:48
B        2.2.3.0/24 [20/0] via 2.2.4.4, 00:14:48
C        2.2.4.0/24 is directly connected, GigabitEthernet0/0/0
L        2.2.4.5/32 is directly connected, GigabitEthernet0/0/0
B        2.2.128.0/24 [20/0] via 2.2.4.4, 00:14:48
B        2.2.128.254/32 [20/3] via 2.2.4.4, 00:14:48
B        2.2.129.0/24 [20/0] via 2.2.4.4, 00:14:48
B        2.2.129.254/32 [20/2] via 2.2.4.4, 00:14:48
B        2.2.130.0/24 [20/0] via 2.2.4.4, 00:14:48
B        2.2.130.254/32 [20/0] via 2.2.4.4, 00:14:48
      3.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        3.3.0.0/24 is directly connected, Loopback0
L        3.3.0.254/32 is directly connected, Loopback0
```

BGP Info:

```
R5#show ip bgp
BGP table version is 13, local router ID is 5.5.5.5
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  1.1.0.0/24       2.2.4.4                                0 2 1 i
 *>  2.2.1.0/24       2.2.4.4                  3             0 2 ?
 *>  2.2.2.0/24       2.2.4.4                  2             0 2 ?
 *>  2.2.3.0/24       2.2.4.4                  0             0 2 ?
 r>  2.2.4.0/24       2.2.4.4                  0             0 2 ?
 *>  2.2.128.0/24     2.2.4.4                                0 2 ?
 *>  2.2.128.254/32   2.2.4.4                  3             0 2 ?
 *>  2.2.129.0/24     2.2.4.4                                0 2 ?
 *>  2.2.129.254/32   2.2.4.4                  2             0 2 ?
 *>  2.2.130.0/24     2.2.4.4                  0             0 2 ?
 *>  2.2.130.254/32   2.2.4.4                                0 2 ?
 *>  3.3.0.0/24       0.0.0.0                  0         32768 i
```

```
R5#show ip bgp summary
BGP router identifier 5.5.5.5, local AS number 3
BGP table version is 13, main routing table version 13
12 network entries using 2976 bytes of memory
12 path entries using 1440 bytes of memory
6/6 BGP path/bestpath attribute entries using 1488 bytes of memory
2 BGP AS-PATH entries using 64 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 5968 total bytes of memory
BGP activity 12/0 prefixes, 12/0 paths, scan interval 60 secs

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.4.4         4            2      30      26       13    0    0 00:19:00        11
```

Problems:

1) Fully meshed network
   eBGP does not require that all routers in a network have to be fully meshed, meaning each router only needs an adjacency with its directly connected neighbor. However, iBGP requires this, and we originally forgot to set this. Later on, we realized that pings were unable to go through and after adding neighbors with all routers in the network, we were able to fix it.
2) OSPF network setup
   Originally, we forgot to distribute some of the OSPF networks in our topology, meaning that they were also not distributed into BGP. As a result, we were unable to ping across our topology. After adding these network statements into OSPF, it was fixed.
3) OSPF routes taking priority over BGP

Due to incorrect configurations with network statements and redistributing routes, our OSPF routes initially had more precedence over BGP, meaning that we were unable to demonstrate that iBGP had an effect.

4) Redid our entire lab
   Since there were many miscellaneous problems in our config, we redid our lab and realized that we forgot to redistribute our iBGP into OSPF. After fixing this, our entire worked easily.

Conclusion:

Overall, this lab served as a useful introduction to the configuration and uses of iBGP, which we were able to combine with eBGP in order to create a fully functioning network. Furthermore, we were able to review previous concepts such as network subnetting and IGP protocol configuration using OSPF.

5 Router Multiarea OSPF

Ryan Chen

CCNP

Purpose:

The primary purpose of this lab is to tie together previously learned CCNA concepts such as IPv4 subnetting, IPv6 subnetting, and core OSPF concepts (single and multi-area) in one lab to provide a thorough refresher. Technologies such as OSPFv2 and OSPFv3 will be used to connect devices in different areas. Furthermore, this lab serves as an introduction to setting up lab environments without any given outlines, to test skills of designing and creating networks independently, a skill that is needed in order to become a good network engineer.

Background Information:

Within every network, a device identifies itself to other devices using an IP address. IP addresses are similar to how names function for humans – they are unique, individual identifiers for computer devices. However, in larger industry networks with tens of hundreds of devices, it becomes hard to manually connect all the devices together so that they are aware of each other's presence and can communicate with each other. Thus, this is where the use of OSPF comes into play.

Before we can use OSPF however, we must first determine our IP addressing scheme, aka the way that our IP's are set. To do this, we must subnet the IP addresses, which is the process of splitting an entire range of IPs into smaller groups to segment them. In more common terms, each subnet can be thought of a different neighborhood, with each house in the neighborhood representing a single IP address.

OSPF is a network routing protocol that allows the various routers in a large network to easily exchange information amongst each other. OSPF is primarily used to distribute the shortest route that it takes to get to each router in a network. Routes can be thought of as physical directions to another router. Analogous to how a person would use a map to navigate to a destination, routers use distributed OSPF route information to know where to send their information based on a destination. More specifically, OSPF uses the SPF (Shortest Path First/Dijkstra) algorithm to calculate these routes, which are then distributed amongst every router in the network. Before all these routes can be distributed however, each router on the network must run an OSPF process. Upon initializing the process, routers must also establish neighbors – which are routers in a shared network running OSPF – before they can begin to distribute routing information. Each router subsequently distributes all their known routes to their neighbors, allowing the entire network to be connected.

OSPF is highly important in large enterprise networks as it allows routes to be distributed automatically when the OSPF process is activated. Traditionally, network engineers would need to manually add a multitude of routes to a new router in order to connect it to the rest of the network, but with OSPF these routes are populated as soon as the new router forms an adjacency with other neighboring OSPF routers in the network.

Lab Summary:

In our finished version of the lab, we were able to successfully get OSPF running on a multiarea network in both IPv4 and IPv6. This allowed two end PC users in different networks/areas to communicate with each other without the need to configure static routes. Furthermore, this OSPF multiarea network used a backbone area to facilitate the connection between the two different areas.

First off, we created our topology on paper, then assigned each of the subnets and IPs for every router. After finding out that our topology was poorly made, we restarted with a better topology. With the 5 routers that we had, we initialized OSPF on each router, assigned IPs, and finally configured OSPF. This resulted in a working network where end routers could ping each other. Our last step was to assign IPv4 and IPv6 end device addresses and ping, which eventually worked.

Lab Commands:

network

-Advertise OSPF networks and activate OSPF interfaces within a network

ip ospf [PROCESS_ID] area [AREA_ID]

-Alternate way to activate OSPF per interface basis

ipv6 unicast-routing

-Enables IPv6 on router, necessary for the IPv6 OSPF part of this lab

router ospf [PROCESS_ID]

-Enables the OSPF process to allow for route propagation

clear ip ospf process

-Restarts the IPv4 OSPF process

clear ipv6 ospf process

-Restarts the IPv6 OSPF process

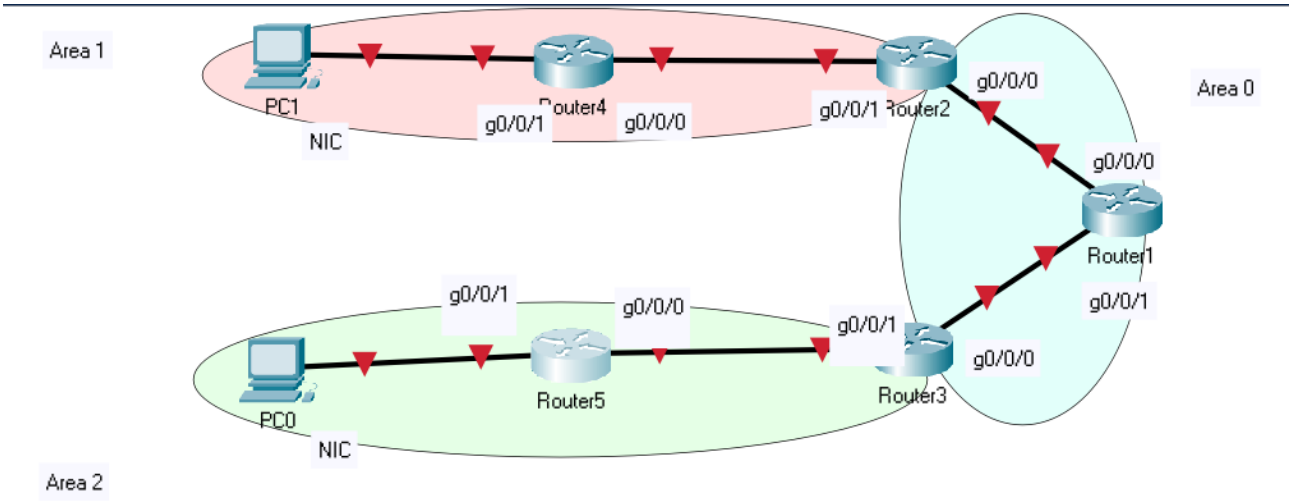
show ip route

-Shows all IPv4 routes

show ipv6 route

-Shows all IPv6 routes

Network Diagram and IP Table:



	G0/0/0	G0/0/1
Router 1	10.0.0.1 255.255.255.0	10.0.1.1 255.255.255.0
	2001:db8:acad::1 /80	2001:db8:acad:1::1 /80
Router 2	10.0.0.2 255.255.255.0	10.1.0.2 255.255.255.0
	2001:db8:acad::2 /80	2001:db8:acad:1::2 /80
Router 3	10.0.1.3 255.255.255.0	10.2.0.3 255.255.255.0
	2001:db8:acad:0:1::3 /80	2001:db8:acad:2::3 /80
Router 4	10.1.0.4 255.255.255.0	10.1.1.4 255.255.255.0
	2001:db8:acad:1::4 /80	2001:db8:acad:1:1::4 /80
Router 5	10.2.0.5 255.255.255.0	10.2.1.4 255.255.255.0
	2001:db8:acad:2::5 /80	2001:db8:acad:2:1::5 /80
	Fast Ethernet	
PC 1	10.1.1.6	
	2001:db8:acad:1:1::6 /80	
PC 2	10.2.1.6	
	2001:db8:acad:2:1::6 /80	

Configurations:

R1:

```
hostname R1

boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO21491LXV
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
vlan internal allocation policy ascending

interface GigabitEthernet0/0/0
 ip address 10.0.0.1 255.255.255.0
 ip ospf 1 area 0
 negotiation auto
 ipv6 address 2001:DB8:ACAD::1/80
 ipv6 ospf 1 area 0
interface GigabitEthernet0/0/1
 ip address 10.0.1.1 255.255.255.0
 ip ospf 1 area 0
 negotiation auto
 ipv6 address 2001:DB8:ACAD:0:1::1/80
```

```
 ipv6 ospf 1 area 0
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown

router ospf 1
 router-id 1.1.1.1
 network 10.0.0.0 0.0.255.255 area 0

ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router ospf 1
 router-id 1.1.1.1
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
```

```
 login
end

R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
C        10.0.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.0.1/32 is directly connected, GigabitEthernet0/0/0
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0/1
L        10.0.1.1/32 is directly connected, GigabitEthernet0/0/1
O IA     10.1.0.0/24 [110/2] via 10.0.0.2, 00:01:05, GigabitEthernet0/0/0
O IA     10.1.1.0/24 [110/3] via 10.0.0.2, 00:01:05, GigabitEthernet0/0/0
O IA     10.2.0.0/24 [110/2] via 10.0.1.3, 00:33:23, GigabitEthernet0/0/1
O IA     10.2.1.0/24 [110/12] via 10.0.1.3, 00:04:55, GigabitEthernet0/0/1

R1#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
```

```
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE -
Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       a - Application
C   2001:DB8:ACAD::/80 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD::1/128 [0/0]
     via GigabitEthernet0/0/0, receive
C   2001:DB8:ACAD:0:1::/80 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   2001:DB8:ACAD:0:1::1/128 [0/0]
     via GigabitEthernet0/0/1, receive
OI  2001:DB8:ACAD:1::/80 [110/2]
     via FE80::B6A8:B9FF:FE47:92C0, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:1:1::/80 [110/3]
     via FE80::B6A8:B9FF:FE47:92C0, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:2::/80 [110/2]
     via FE80::B6A8:B9FF:FE01:AE50, GigabitEthernet0/0/1
OI  2001:DB8:ACAD:2:1::/80 [110/12]
     via FE80::B6A8:B9FF:FE01:AE50, GigabitEthernet0/0/1
L   FF00::/8 [0/0]
     via Null0, receive
```

R2:

```
hostname R2


boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
```

```
 exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420QQ
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none



vlan internal allocation policy ascending

interface GigabitEthernet0/0/0
 ip address 10.0.0.2 255.255.255.0
 ip ospf 1 area 0
 negotiation auto
 ipv6 address 2001:DB8:ACAD::2/80
 ipv6 ospf 1 area 0
interface GigabitEthernet0/0/1
 ip address 10.1.0.2 255.255.255.0
 ip ospf 1 area 1
 negotiation auto
 ipv6 address 2001:DB8:ACAD:1::2/80
 ipv6 ospf 1 area 1
interface Serial0/1/0
 no ip address
 shutdown
```

```
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown

router ospf 1
 router-id 2.2.2.2
 network 10.0.0.0 0.0.255.255 area 0
 network 10.1.0.0 0.0.255.255 area 1

ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router ospf 1
 router-id 2.2.2.2
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
End
```

```
R2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
C        10.0.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.0.2/32 is directly connected, GigabitEthernet0/0/0
O        10.0.1.0/24 [110/2] via 10.0.0.1, 00:07:13, GigabitEthernet0/0/0
C        10.1.0.0/24 is directly connected, GigabitEthernet0/0/1
L        10.1.0.2/32 is directly connected, GigabitEthernet0/0/1
O        10.1.1.0/24 [110/2] via 10.1.0.4, 00:06:13, GigabitEthernet0/0/1
O IA     10.2.0.0/24 [110/3] via 10.0.0.1, 00:07:13, GigabitEthernet0/0/0
O IA     10.2.1.0/24 [110/13] via 10.0.0.1, 00:07:13, GigabitEthernet0/0/0

R2#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE -
Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
```

```
       a - Application

C   2001:DB8:ACAD::/80 [0/0]

     via GigabitEthernet0/0/0, directly connected

L   2001:DB8:ACAD::2/128 [0/0]

     via GigabitEthernet0/0/0, receive

O   2001:DB8:ACAD:0:1::/80 [110/2]

     via FE80::521C:B0FF:FE2D:7100, GigabitEthernet0/0/0

C   2001:DB8:ACAD:1::/80 [0/0]

     via GigabitEthernet0/0/1, directly connected

L   2001:DB8:ACAD:1::2/128 [0/0]

     via GigabitEthernet0/0/1, receive

O   2001:DB8:ACAD:1:1::/80 [110/2]

     via FE80::227:90FF:FEC7:8DB0, GigabitEthernet0/0/1

OI  2001:DB8:ACAD:2::/80 [110/3]

     via FE80::521C:B0FF:FE2D:7100, GigabitEthernet0/0/0

OI  2001:DB8:ACAD:2:1::/80 [110/13]

     via FE80::521C:B0FF:FE2D:7100, GigabitEthernet0/0/0

L   FF00::/8 [0/0]

     via Null0, receive
```

R3:

```
hostname R3
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420HY
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
```

```
vlan internal allocation policy ascending
vlan 10,20

interface GigabitEthernet0/0/0
 ip address 10.0.1.3 255.255.255.0
 ip ospf 1 area 0
 negotiation auto
 ipv6 address 2001:DB8:ACAD:0:1::3/80
 ipv6 ospf 1 area 0
interface GigabitEthernet0/0/1
 ip address 10.2.0.3 255.255.255.0
 ip ospf 1 area 2
 negotiation auto
 ipv6 address 2001:DB8:ACAD:2::3/80
 ipv6 ospf 1 area 2
interface Serial0/1/0
 no ip address
interface Serial0/1/1
 no ip address
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 negotiation auto
interface Vlan1
 no ip address

router ospf 1
 router-id 3.3.3.3
 network 10.0.0.0 0.0.255.255 area 0
 network 10.2.0.0 0.0.255.255 area 2

ip forward-protocol nd
no ip http server
no ip http secure-server
ipv6 router ospf 1
 router-id 3.3.3.3
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
End

R3#show ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP

       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2

       E1 - OSPF external type 1, E2 - OSPF external type 2

       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
```

```
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
O        10.0.0.0/24 [110/2] via 10.0.1.1, 00:25:11, GigabitEthernet0/0/0
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.1.3/32 is directly connected, GigabitEthernet0/0/0
O IA     10.1.0.0/24 [110/3] via 10.0.1.1, 00:05:07, GigabitEthernet0/0/0
O IA     10.1.1.0/24 [110/4] via 10.0.1.1, 00:05:07, GigabitEthernet0/0/0
C        10.2.0.0/24 is directly connected, GigabitEthernet0/0/1
L        10.2.0.3/32 is directly connected, GigabitEthernet0/0/1
            10.2.1.0/24 [110/11] via 10.2.0.5, 00:08:58, GigabitEthernet0/0/1

R3#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE -
Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       a - Application
O   2001:DB8:ACAD::/80 [110/2]
     via FE80::521C:B0FF:FE2D:7101, GigabitEthernet0/0/0
C   2001:DB8:ACAD:0:1::/80 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:0:1::3/128 [0/0]
```

```
     via GigabitEthernet0/0/0, receive
OI  2001:DB8:ACAD:1::/80 [110/3]
     via FE80::521C:B0FF:FE2D:7101, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:1:1::/80 [110/4]
     via FE80::521C:B0FF:FE2D:7101, GigabitEthernet0/0/0
C   2001:DB8:ACAD:2::/80 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   2001:DB8:ACAD:2::3/128 [0/0]
     via GigabitEthernet0/0/1, receive
O   2001:DB8:ACAD:2:1::/80 [110/11]
     via FE80::521C:B0FF:FE2C:4C80, GigabitEthernet0/0/1
L   FF00::/8 [0/0]
     via Null0, receive
```

R4:

```
hostname R4
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214333H6
license boot level securityk9
spanning-tree extend system-id
redundancy
```

```
 mode none

vlan internal allocation policy ascending
vlan 10,20

interface Tunnel0
 no ip address
interface GigabitEthernet0/0/0
 ip address 10.1.0.4 255.255.255.0
 ip ospf 1 area 1
 negotiation auto
 ipv6 address 2001:DB8:ACAD:1::4/80
 ipv6 ospf 1 area 1
interface GigabitEthernet0/0/1
 ip address 10.1.1.4 255.255.255.0
 ip ospf 1 area 1
 negotiation auto
 ipv6 address 2001:DB8:ACAD:1:1::4/80
 ipv6 ospf 1 area 1
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
```

```
 shutdown

router ospf 1
 router-id 4.4.4.4
 network 10.1.0.0 0.0.255.255 area 1

ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router ospf 1
 router-id 4.4.4.4
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login

R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set
```

```
      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
O IA     10.0.0.0/24 [110/2] via 10.1.0.2, 00:04:44, GigabitEthernet0/0/0
O IA     10.0.1.0/24 [110/3] via 10.1.0.2, 00:04:44, GigabitEthernet0/0/0
C        10.1.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.1.0.4/32 is directly connected, GigabitEthernet0/0/0
C        10.1.1.0/24 is directly connected, GigabitEthernet0/0/1
L        10.1.1.4/32 is directly connected, GigabitEthernet0/0/1
O IA     10.2.0.0/24 [110/4] via 10.1.0.2, 00:04:44, GigabitEthernet0/0/0
O IA     10.2.1.0/24 [110/14] via 10.1.0.2, 00:00:02, GigabitEthernet0/0/0
End


R4#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE -
Destination
       NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
       OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       a - Application
OI  2001:DB8:ACAD::/80 [110/2]
     via FE80::B6A8:B9FF:FE47:92C1, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:0:1::/80 [110/3]
     via FE80::B6A8:B9FF:FE47:92C1, GigabitEthernet0/0/0
C   2001:DB8:ACAD:1::/80 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:1::4/128 [0/0]
     via GigabitEthernet0/0/0, receive
C   2001:DB8:ACAD:1:1::/80 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   2001:DB8:ACAD:1:1::4/128 [0/0]
```

```
     via GigabitEthernet0/0/1, receive
OI  2001:DB8:ACAD:2::/80 [110/4]
     via FE80::B6A8:B9FF:FE47:92C1, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:2:1::/80 [110/14]
     via FE80::B6A8:B9FF:FE47:92C1, GigabitEthernet0/0/0
L   FF00::/8 [0/0]
     via Null0, receive
```

R5:

```
hostname R5
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
ipv6 unicast-routing
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO21482HYV
spanning-tree extend system-id


redundancy
 mode none

vlan internal allocation policy ascending
vlan 2,10,20
vlan 996
 name CUSTOMER_NATIVE

interface GigabitEthernet0/0/0
 ip address 10.2.0.5 255.255.255.0
 ip ospf 1 area 2
 negotiation auto
 ipv6 address 2001:DB8:ACAD:2::5/80
 ipv6 ospf 1 area 2
interface GigabitEthernet0/0/1
 ip address 10.2.1.5 255.255.255.0
 ip ospf 1 area 2
 negotiation auto
 ipv6 address 2001:DB8:ACAD:2:1::5/80
 ipv6 ospf 1 area 2
interface Serial0/1/0
interface Serial0/1/1
interface GigabitEthernet0/2/0
 negotiation auto
```

```
interface GigabitEthernet0/2/1
 negotiation auto
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router ospf 1
 router-id 5.5.5.5
 network 10.2.0.0 0.0.255.255 area 2
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
ipv6 router ospf 1
 router-id 5.5.5.5
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
End

R5(config)#do show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 8 subnets, 2 masks
O IA     10.0.0.0/24 [110/3] via 10.2.0.3, 00:18:56, GigabitEthernet0/0/0
O IA     10.0.1.0/24 [110/2] via 10.2.0.3, 00:31:06, GigabitEthernet0/0/0
O IA     10.1.0.0/24 [110/4] via 10.2.0.3, 00:06:31, GigabitEthernet0/0/0
O IA     10.1.1.0/24 [110/5] via 10.2.0.3, 00:04:58, GigabitEthernet0/0/0
C        10.2.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.2.0.5/32 is directly connected, GigabitEthernet0/0/0
C        10.2.1.0/24 is directly connected, GigabitEthernet0/0/1
L        10.2.1.5/32 is directly connected, GigabitEthernet0/0/1

R5#show ipv6 route
IPv6 Routing Table - default - 9 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
       IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external
```

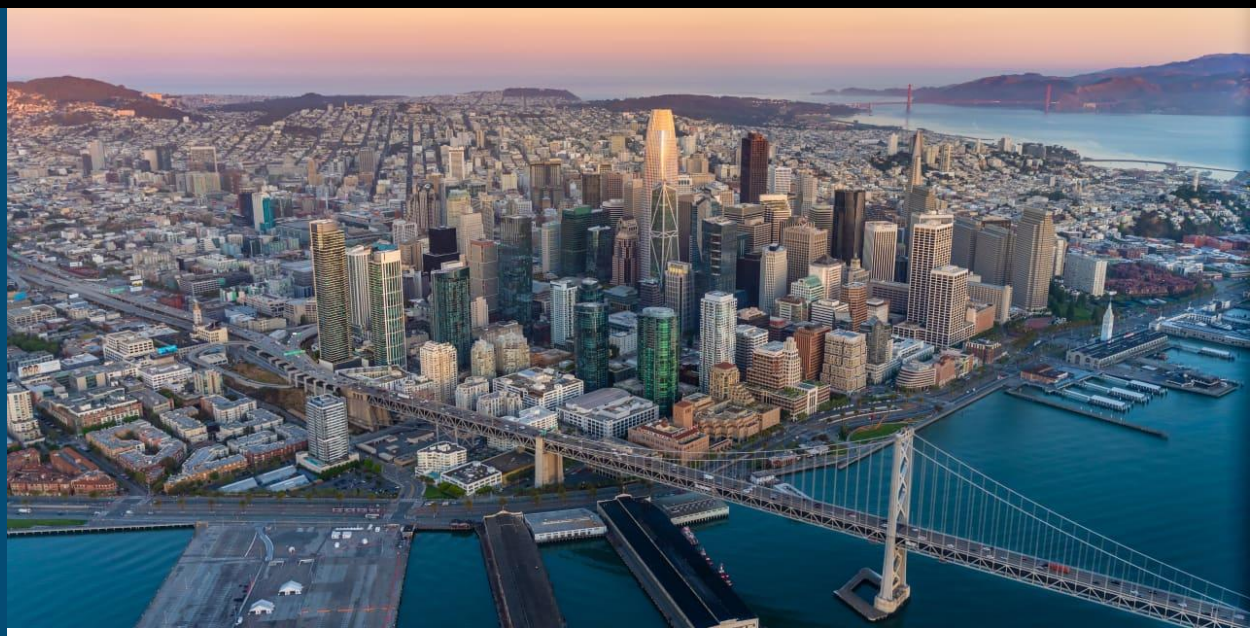
```
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2, a - Application
OI  2001:DB8:ACAD::/80 [110/3]
     via FE80::B6A8:B9FF:FE01:AE51, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:0:1::/80 [110/2]
     via FE80::B6A8:B9FF:FE01:AE51, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:1::/80 [110/4]
     via FE80::B6A8:B9FF:FE01:AE51, GigabitEthernet0/0/0
OI  2001:DB8:ACAD:1:1::/80 [110/5]
     via FE80::B6A8:B9FF:FE01:AE51, GigabitEthernet0/0/0
C   2001:DB8:ACAD:2::/80 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:2::5/128 [0/0]
     via GigabitEthernet0/0/0, receive
C   2001:DB8:ACAD:2:1::/80 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   2001:DB8:ACAD:2:1::5/128 [0/0]
     via GigabitEthernet0/0/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

Problems:

1) Poor topology planning for number of routers in each area
   -At first we tried to use a design that incorporated only 2 routers in the backbone, and the other two areas having 1 and 2 routers each, respectively. This turned out to be much more complicated than necessary, and only made for unnecessary configuration. Eventually, we decided the easiest (and most logical) approach to separating the areas would be having the backbone area the largest, and the other two end-device areas one router each. This simplified our configuration a lot, and also demonstrated a more consistent topology which could be easily expanded.
2) Incorrect subnetting
   -For a day or two, we encountered a constant issue of overlapping IP's when setting interfaces, and eventually realized that the subnets within each area were overlapping, causing our interface IP's to have issues. Initially, we used 192.168.x.x IP's, but we decided to scrap this design and move to the larger private class of 10.x.x.x. Using this IP range, we were able to separate each area into its own subnet, subsequently removing any overlapping IP issues.

Conclusion:

This lab was a thorough review of old concepts and basic router configurations, as well as independent planning and troubleshooting. The biggest thing this lab taught us was the importance of planning your topology, IP's, and subnets BEFORE starting your project. Creating a strong foundation for your project minimizes the chance of error when configuring in the future.



OSPF Area Types Lab Documentation

Ryan Chen

CCNP

Purpose:

The primary purpose of this lab was to learn and distinguish the differences between the various OSPF area types, namely normal area, stub area, totally stubby area, and not-so-stubby area. To do so, we needed to research and identify the different OSPF LSA types in order to compare the differences between area types.

Background Information:

OSPF is a network routing protocol that allows the various routers in a large network to easily exchange information amongst each other. OSPF is primarily used to distribute the shortest route that it takes to get to each router in a network. Routes can be thought of as physical directions to another router. Analogous to how a person would use a map to navigate to a destination, routers use distributed OSPF route information to know where to send their information based on a destination. All routers using OSPF must initialize the process, upon which the network must be initialized before routes can be sent. Each router subsequently distributes all their known routes to their neighbors, allowing the entire network to be connected.

OSPF areas are used in order to separate a large OSPF network into multiple subdomains. Their primary purpose is to organize and manage the various subnetworks for routing in a larger scale network. Each type of area accepts different OSPF Link State Advertisement (LSA) packets, which are necessary for OSPF to function. LSA packets are used in order to fill the database of each OSPF router with routing information about the network. Type 1-3 of OSPF LSA's are primarily used for backbone/standard OSPF routing, and they provide basic information about routes and network topology. Type 4 LSA's are used in networks that have a connection to a non OSPF network. They are broadcasted by each Area Border Router (ABR, connected between OSPF areas) with information about where to find the Autonomous System Border Router (ASBR, connected to non OSPF). Type 5 LSA's include the non OSPF network information, allowing OSPF networks to connect to routing protocols such as RIP, EIGRP, and ISIS. Finally, Type 7 LSA's are used exclusively in NSSA areas, which will be introduced later.

Basic OSPF runs in the backbone area, or otherwise known as Area 0. This is what smaller networks utilize for their routing. In larger multiarea networks, all areas must be connected to this backbone network in order to guarantee connectivity. Aside from the backbone area, different standard OSPF areas can be created which function like the backbone.

In our lab, we utilized stub areas, which do not accept any external routes in the network. However, stub areas still allow internal area routes, meaning routers in the same stub area can communicate with each other. In order to communicate with any external areas, stub areas use a default route to a single ABR which then handles interarea routing. Stub areas block all Type 5 and Type 7 LSA's, which reduces CPU/RAM usage and database size, allowing for faster performance on large networks.

A variant of the stub areas is the totally stubby area, which likewise blocks any external routes but also removes the propagation of any internal routes. In a totally stubby area, all routers rely on an injected default route that points traffic to their ABR, which then handles routing. Totally stubby areas block Type 5, 7, and 3 LSA's, which improves performance even further.

Finally, not-so-stubby areas are stub areas that include an ASBR which allows for non-OSPF connected routers and routes to be advertised into the area. The area does this by converting special external Type 7 LSA's into Type 5 LSA's to be advertised into the network. This allows completely external networks to be connected to an OSPF network.

Lab Summary:

In this lab, our objective was to setup the various OSPF area types, analyze how they work, and understand when/why to use them. To begin, we handwrote out topology with the various OSPF area types, adding interfaces and subnetting the network. After this, we transferred our diagram to Packet Tracer and began to build our network.

The process of building the topology with the different area types was quite simple, as OSPF stub configuration only requires a few additional commands. Our topology consisted of a central backbone area that all other areas connected to. At first, we wanted to connect all three backbone routers together, but quickly realized that the limitation of only having two gigabit ports per router meant we needed a switch in order to connect all three. Inside our lab, we used the 10.x.x.x subnet, incrementing for each area. Routers were given IPs based on their number.

For stub and totally stubby areas, we had a single ABR and a router which simulated the area. However, for our NSSA, we decided to configure our ASBR using a Loopback interface that was configured with EIGRP, allowing us to simulate a fully external network without using another router.

summAfter successfully configuring all the area types, we moved onto analyzing how each area worked. To do so, we needed to intercept traffic between each OSPF router, which was achieved by connected a switch and enabling session monitoring. Session monitoring the switch allowed us to forward all the traffic through our port. Using Wireshark, we could analyze all OSPF LSA types to understand the functions of each area type.

Lab Commands:

area [area-id] stub

-Configures an OSPF area into stub

area [area-id] stub no-summary

-Configures an OSPF area into totally stubby on the ABR

area [area-id] nssa

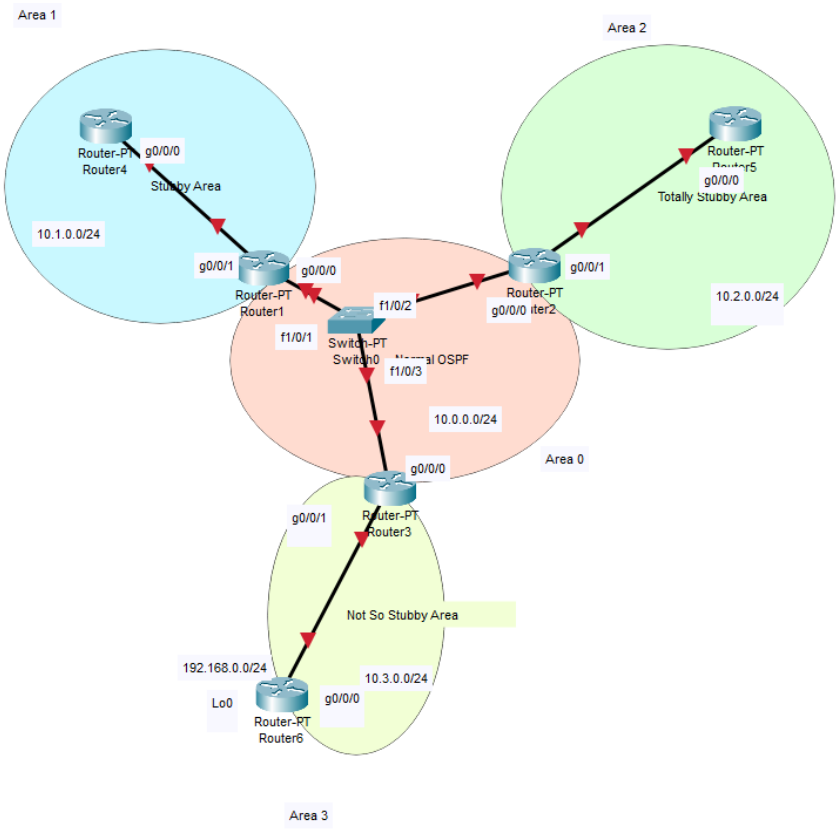
-Configures an OSPF area into NSSA

monitor session [session #] source interface [source interface]

monitor session [session #] destination interface [destination interface]

-Used to forward all traffic to an interface for Wireshark capture

Network Diagram and IP Table:



	G0/0/0	G0/0/01
Router 1	10.0.0.1	10.1.0.1
Router 2	10.0.0.2	10.1.0.2
Router 3	10.0.0.3	10.1.0.3
Router 4	10.1.0.4	10.1.1.4
Router 5	10.2.0.5	10.2.1.5
Router 6	10.3.0.6	10.3.1.6
Router 7	10.3.1.7	N/A

Configurations and Routes:

R1

```
hostname R1
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO21491LXV
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
interface GigabitEthernet0/0/0
 ip address 10.0.0.1 255.255.255.0
 ip ospf 1 area 0
 no shutdown
 negotiation auto
interface GigabitEthernet0/0/1
 ip address 10.1.0.1 255.255.255.0
 ip ospf 1 area 1
 no shutdown
```

```
 negotiation auto
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router ospf 1
 router-id 1.1.1.1
 area 1 stub
 network 10.0.0.0 0.0.255.255 area 0
 network 10.1.0.0 0.0.255.255 area 1
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end

R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.0.1/32 is directly connected, GigabitEthernet0/0/0
C        10.1.0.0/24 is directly connected, GigabitEthernet0/0/1
L        10.1.0.1/32 is directly connected, GigabitEthernet0/0/1
O IA     10.2.0.0/24 [110/2] via 10.0.0.2, 00:09:26, GigabitEthernet0/0/0
O IA     10.3.0.0/24 [110/2] via 10.0.0.3, 00:19:40, GigabitEthernet0/0/0
O E2  192.168.0.0/24 [110/20] via 10.0.0.3, 00:18:35, GigabitEthernet0/0/0
```

R2

```
hostname R2
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
subscriber templating
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420QQ
license accept end user agreement
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
interface GigabitEthernet0/0/0
 ip address 10.0.0.2 255.255.255.0
 ip ospf 1 area 0
 no shutdown
 negotiation auto
interface GigabitEthernet0/0/1
 ip address 10.2.0.2 255.255.255.0
 ip ospf 1 area 2
 no shutdown
 negotiation auto
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router ospf 1
 router-id 2.2.2.2
 network 10.0.0.0 0.0.255.255 area 0
 network 10.2.0.0 0.0.255.255 area 2
 area 2 stub no-summary
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
```

```
end

R2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.0.2/32 is directly connected, GigabitEthernet0/0/0
O IA     10.1.0.0/24 [110/2] via 10.0.0.1, 00:01:54, GigabitEthernet0/0/0
C        10.2.0.0/24 is directly connected, GigabitEthernet0/0/1
L        10.2.0.2/32 is directly connected, GigabitEthernet0/0/1
O IA     10.3.0.0/24 [110/2] via 10.0.0.3, 00:01:54, GigabitEthernet0/0/0
O E2  192.168.0.0/24 [110/20] via 10.0.0.3, 00:01:54, GigabitEthernet0/0/0
```

R3

```
hostname R3
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214420HY
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
interface GigabitEthernet0/0/0
 ip address 10.0.0.3 255.255.255.0
 ip ospf 1 area 0
 no shutdown
 negotiation auto
interface GigabitEthernet0/0/1
 ip address 10.3.0.3 255.255.255.0
 ip ospf 1 area 3
 no shutdown
 negotiation auto
interface Serial0/1/0
 no ip address
```

```
interface Serial0/1/1
 no ip address
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 negotiation auto
interface Vlan1
 no ip address
router ospf 1
 router-id 3.3.3.3
 network 10.0.0.0 0.0.255.255 area 0
 network 10.3.0.0 0.0.255.255 area 3
 area 3 nssa
ip forward-protocol nd
no ip http server
no ip http secure-server
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end

R3#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.0.0.3/32 is directly connected, GigabitEthernet0/0/0
O IA     10.1.0.0/24 [110/2] via 10.0.0.1, 00:20:38, GigabitEthernet0/0/0
O IA     10.2.0.0/24 [110/2] via 10.0.0.2, 00:10:14, GigabitEthernet0/0/0
C        10.3.0.0/24 is directly connected, GigabitEthernet0/0/1
L        10.3.0.3/32 is directly connected, GigabitEthernet0/0/1
O N2  192.168.0.0/24 [110/20] via 10.3.0.6, 00:19:24, GigabitEthernet0/0/1
```

R4

```
hostname R4
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
```

```
 exit-address-family
no aaa new-model
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214333H6
license boot level securityk9
spanning-tree extend system-id
redundancy
 mode none
interface GigabitEthernet0/0/0
 ip address 10.1.0.4 255.255.255.0
 ip ospf 1 area 1
 negotiation auto
 no shutdown
interface GigabitEthernet0/0/1
 no ip address
 shutdown
 negotiation auto
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router ospf 1
 router-id 4.4.4.4
 area 1 stub
 network 10.1.0.0 0.0.0.255 area 1
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end

R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
```

```
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is 10.1.0.1 to network 0.0.0.0

O*IA  0.0.0.0/0 [110/2] via 10.1.0.1, 00:32:40, GigabitEthernet0/0/0
      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O IA     10.0.0.0/24 [110/2] via 10.1.0.1, 00:32:40, GigabitEthernet0/0/0
C        10.1.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.1.0.4/32 is directly connected, GigabitEthernet0/0/0
O IA     10.2.0.0/24 [110/3] via 10.1.0.1, 00:11:25, GigabitEthernet0/0/0
O IA     10.3.0.0/24 [110/3] via 10.1.0.1, 00:21:39, GigabitEthernet0/0/0
```

R5

```
hostname R5
boot-start-marker
boot-end-marker
vrf definition Mgmt-intf
 address-family ipv4
 exit-address-family
 address-family ipv6
 exit-address-family
no aaa new-model
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO21482HYV
spanning-tree extend system-id
redundancy
 mode none
interface GigabitEthernet0/0/0
 ip address 10.2.0.5 255.255.255.0
 negotiation auto
 no shutdown
interface GigabitEthernet0/0/1
 no ip address
 shutdown
 negotiation auto
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0/2/0
 no ip address
 shutdown
 negotiation auto
interface GigabitEthernet0/2/1
 no ip address
 shutdown
 negotiation auto
```

```
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router ospf 1
 router-id 5.5.5.5
 area 2 stub
 network 10.2.0.0 0.0.0.255 area 2
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end

R5#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is 10.2.0.2 to network 0.0.0.0

O*IA  0.0.0.0/0 [110/2] via 10.2.0.2, 00:02:24, GigabitEthernet0/0/0
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        10.2.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.2.0.5/32 is directly connected, GigabitEthernet0/0/0
```

R6

```
hostname R6

boot-start-marker

boot-end-marker

vrf definition Mgmt-intf

 address-family ipv4

 exit-address-family
```

```
 address-family ipv6
 exit-address-family
no aaa new-model
subscriber templating
vtp domain cisco
vtp mode transparent
multilink bundle-name authenticated
license udi pid ISR4321/K9 sn FDO214913GF
spanning-tree extend system-id
redundancy
 mode none
vlan internal allocation policy ascending
interface Loopback0
 ip address 192.168.0.1 255.255.255.0
interface GigabitEthernet0/0/0
 ip address 10.3.0.6 255.255.255.0
 negotiation auto
interface GigabitEthernet0/0/1
 ip address 10.3.1.6 255.255.255.0
 negotiation auto
interface Serial0/1/0
 no ip address
 shutdown
interface Serial0/1/1
 no ip address
 shutdown
interface GigabitEthernet0/2/0
 no ip address
 shutdown
 negotiation auto
interface GigabitEthernet0/2/1
 no ip address
```

```
 shutdown
 negotiation auto
interface GigabitEthernet0
 vrf forwarding Mgmt-intf
 no ip address
 shutdown
 negotiation auto
interface Vlan1
 no ip address
 shutdown
router eigrp 1
 network 192.168.0.0
 redistribute connected
router ospf 1
 router-id 6.6.6.6
 area 3 nssa
 redistribute connected subnets
 network 10.3.0.0 0.0.255.255 area 3
ip forward-protocol nd
no ip http server
no ip http secure-server
ip tftp source-interface GigabitEthernet0
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end

R6#show ip route
```

```
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O IA     10.0.0.0/24 [110/2] via 10.3.0.3, 00:19:47, GigabitEthernet0/0/0
O IA     10.1.0.0/24 [110/3] via 10.3.0.3, 00:19:47, GigabitEthernet0/0/0
O IA     10.2.0.0/24 [110/3] via 10.3.0.3, 00:10:37, GigabitEthernet0/0/0
C        10.3.0.0/24 is directly connected, GigabitEthernet0/0/0
L        10.3.0.6/32 is directly connected, GigabitEthernet0/0/0
      192.168.0.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.0.0/24 is directly connected, Loopback0
L        192.168.0.1/32 is directly connected, Loopback0
```

LSA Types:

Type 1:

```
LSA-type 1 (Router-LSA), len 36
    .000 1110 0001 0000 = LS Age (seconds): 3600
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x22, (DC) Demand Circuits, (E) External Routing
    LS Type: Router-LSA (1)
    Link State ID: 1.1.1.1
    Advertising Router: 1.1.1.1
    Sequence Number: 0x80000005
    Checksum: 0x67a8
    Length: 36
  > Flags: 0x01, (B) Area border router
    Number of Links: 1
  > Type: Transit  ID: 10.0.0.1        Data: 10.0.0.1        Metric: 1
```

Type 2:

```
LSA-type 2 (Network-LSA), len 36
    .000 1110 0001 0000 = LS Age (seconds): 3600
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x22, (DC) Demand Circuits, (E) External Routing
    LS Type: Network-LSA (2)
    Link State ID: 10.0.0.1
    Advertising Router: 1.1.1.1
    Sequence Number: 0x80000002
    Checksum: 0x48c5
    Length: 36
    Netmask: 255.255.255.0
    Attached Router: 1.1.1.1
    Attached Router: 2.2.2.2
    Attached Router: 3.3.3.3
```

Type 3:

```
LSA-type 3 (Summary-LSA (IP network)), len 28
    .000 1110 0001 0000 = LS Age (seconds): 3600
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x22, (DC) Demand Circuits, (E) External Routing
    LS Type: Summary-LSA (IP network) (3)
    Link State ID: 10.1.0.0
    Advertising Router: 1.1.1.1
    Sequence Number: 0x80000001
    Checksum: 0xe646
    Length: 28
    Netmask: 255.255.255.0
    TOS: 0
    Metric: 1
```

Type 4:

c

```
LSA-type 4 (Summary-LSA (ASBR)), len 28
    .000 0000 0000 0010 = LS Age (seconds): 2
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x22, (DC) Demand Circuits, (E) External Routing
    LS Type: Summary-LSA (ASBR) (4)
    Link State ID: 3.3.3.3
    Advertising Router: 1.1.1.1
    Sequence Number: 0x80000001
    Checksum: 0xdc4e
    Length: 28
    Netmask: 0.0.0.0
    TOS: 0
    Metric: 1
```

Type 5:

```
LSA-type 5 (AS-External-LSA (ASBR)), len 36
    .000 1110 0001 0000 = LS Age (seconds): 3600
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x20, (DC) Demand Circuits
    LS Type: AS-External-LSA (ASBR) (5)
    Link State ID: 192.168.0.0
    Advertising Router: 3.3.3.3
    Sequence Number: 0x80000002
    Checksum: 0xf733
    Length: 36
    Netmask: 255.255.255.0
    1... .... = External Type: Type 2 (metric is larger than any other link state path)
    .000 0000 = TOS: 0
    Metric: 16777215
    Forwarding Address: 10.3.0.6
    External Route Tag: 0
```

Type 7:

```
LSA-type 7 (NSSA AS-External-LSA), len 36
    .000 0000 0000 0001 = LS Age (seconds): 1
    0... .... .... .... = Do Not Age Flag: 0
  > Options: 0x28, (DC) Demand Circuits, (P) Propagate
    LS Type: NSSA AS-External-LSA (7)
    Link State ID: 192.168.0.0
    Advertising Router: 6.6.6.6
    Sequence Number: 0x80000001
    Checksum: 0xd32e
    Length: 36
    Netmask: 255.255.255.0
    1... .... = External Type: Type 2 (metric is larger than any other link state path)
    .000 0000 = TOS: 0
    Metric: 20
    Forwarding Address: 10.3.0.6
    External Route Tag: 0
```

Problems:

-When we were making our topology, we initially planned to directly connect all three routers in our backbone area, but quickly realized that it would not be possible because each router only had two gigabit ports

-To fix this, we connected all the routers in the backbone to a Type 2 switch

-Upon configuring NSSA, we initially wanted to use a seventh router, but external route propagation didn't work

-To fix this, we decided to eliminate the seventh router and instead configure EIGRP on the loopback to simplify the topology

-When monitoring packets at first, we kept getting OSPF area mismatch errors but pings worked

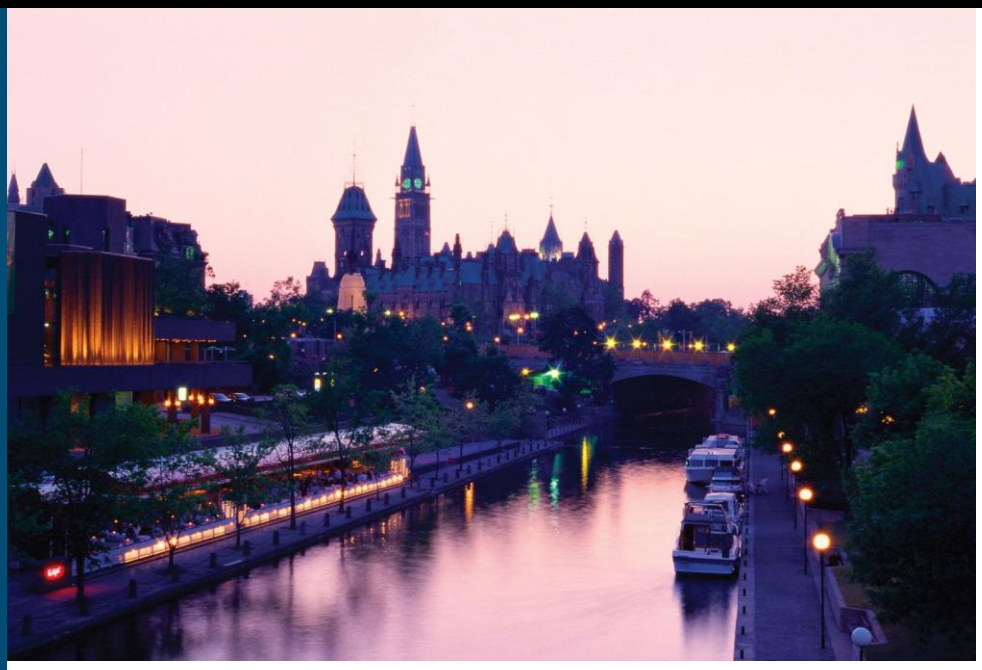
-Later realized that the switch was connected to another device that was sending packets, causing OSPF to not recognize it, so we fixed it by disconnected the device

-We weren't able to get all the OSPF updates, especially type 4 and type 7 packets even after connected switch as an intermediary device

-To fix this, we had to use session monitoring to forward all traffic sent through the switch, which showed us the complete LSA types

Conclusion:

This lab taught us the importance of troubleshooting skills alongside what the different OSPF area types are and how to configure them. When we were making the topology, we realized the switch issue, and later on had the annoying problem of mismatching area IDs. To troubleshoot these, we made sure to go through all possible issues and eventually was able to fix it. As for OSPF area types, stubby and totally stubby provide a more efficient OSPF alternate. Wireshark can be used for packet analysis and was a crucial part in this lab as well.



VRF Implementation Documentation

Ryan Chen

CCNP

Purpose:

The primary purpose of this lab is to familiarize ourselves with VRF routing concepts as well as implementation. To do so, we utilized the GNS3 network virtualization software, which provides enterprise-level software for companies to create fully virtualized simulations or infrastructure. Along the way, we learned commands on how to implement VRF on Cisco devices, as well as VRF configuration of other protocols such as OSPF. This lab was also a basic refresher on fundamental concepts such as subnetting, OSPF setup, and other.

Background Information:

Virtual Route Forwarding, or VRF for short is a type of networking technology that utilizes virtualization in order to optimize network efficiency by reducing the number of network devices needed. In a traditional network topology, multiple routers must exist for an overlapping IP address scheme to be used. Due to the nature of routing tables, overlapping IP addresses would resulting in unresolvable errors. Since routers assume that their tables are completely non-overlapping, having an overlapping range would result in incorrect packets being forwarded, or more likely no packets being forwarded at all.

VRF fixes this by logically segmenting the router into multiple different “virtual” routers. Each of these routers has an independent routing table, allowing multiple overlapping subnets to exist on the same router, bypassing traditional limitations. There exist numerous use cases for this technology, as it brings benefits such as security, efficiency, and ease of configuration.

For one, VRF introduces greater network isolation. Segmenting the router into numerous, separate virtual routers allows hypothetical customers to be fully separate from each other. This means malicious activity/traffic on one virtual router would not have a significant effect on other customers. Using the example of an ISP company, configuring VRF’s brings near full isolation between customers. Customers can use the same subnet ranges internally, however, still function as if they were running on completely different routers.

Continuing the example of an ISP company, configuring VRF’s simplifies network topology and efficiency. Combining the traditional task of numerous routers into one router allows ISP companies to scale more easily, as well as making debugging and physical network topology simpler. Having less network devices reduces the need for troubleshooting if an issue occurs.

Despite this, there are also tradeoffs that must be considered before implementing VRF. Having multiple virtual routers exist on a single router leads to a more concentrated

single point of failure. If the single router fails, multiple customers may be immediately affected. This would be mitigated in a traditional topology, where one customer usually corresponds to one router. However, this can be alleviated by introducing standby routers or other failover technologies.

There are two primary types of VRF: normal VRF and VRF-lite. In this lab, we utilized VRF-lite. The only significant difference between the two types is that normal VRF requires configuration of MPBGP and MPLS, making it more complicated and used for a different purpose. Normal VRF is more typically used in production or business environments, as it allows for more scalability. On the other hand, VRF-lite is used by individuals or businesses for test environments.

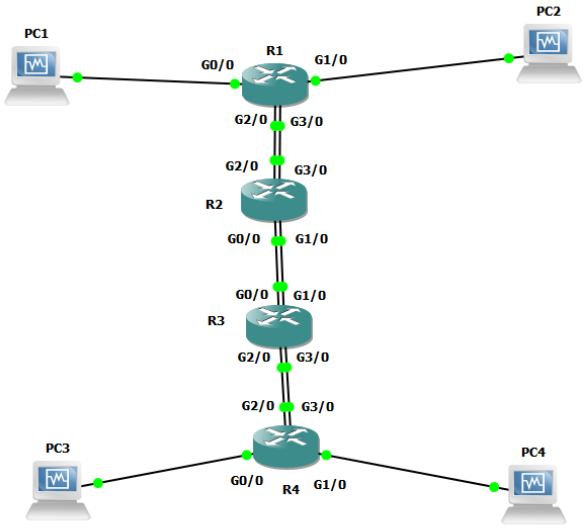
Lab Summary:

Within this lab, we utilized GNS3 combined with VirtualBox in order to simulate a real routing topology. We segmented our topology into two different VRF's, with left and right sharing the same subnet but different logical routing. This means that PC1 and PC3 can ping each other, but not to P2 or P4, despite them being on the same subnet.

GNS3 was the primary network virtualization software that allowed us to simulate real C7200 Cisco routers. With compatibility between GNS3 and common desktop virtualization software, we were able to create four virtual machines (simulating customers) and then import them into GNS3.

Generally, the topology reflects a hypothetical situation where an ISP might use VRF's in order to logically segment two customers while reducing topology complexity. Each side of the network is separate, and functions on its own with minimal disruption.

Network Diagram and IP Table:

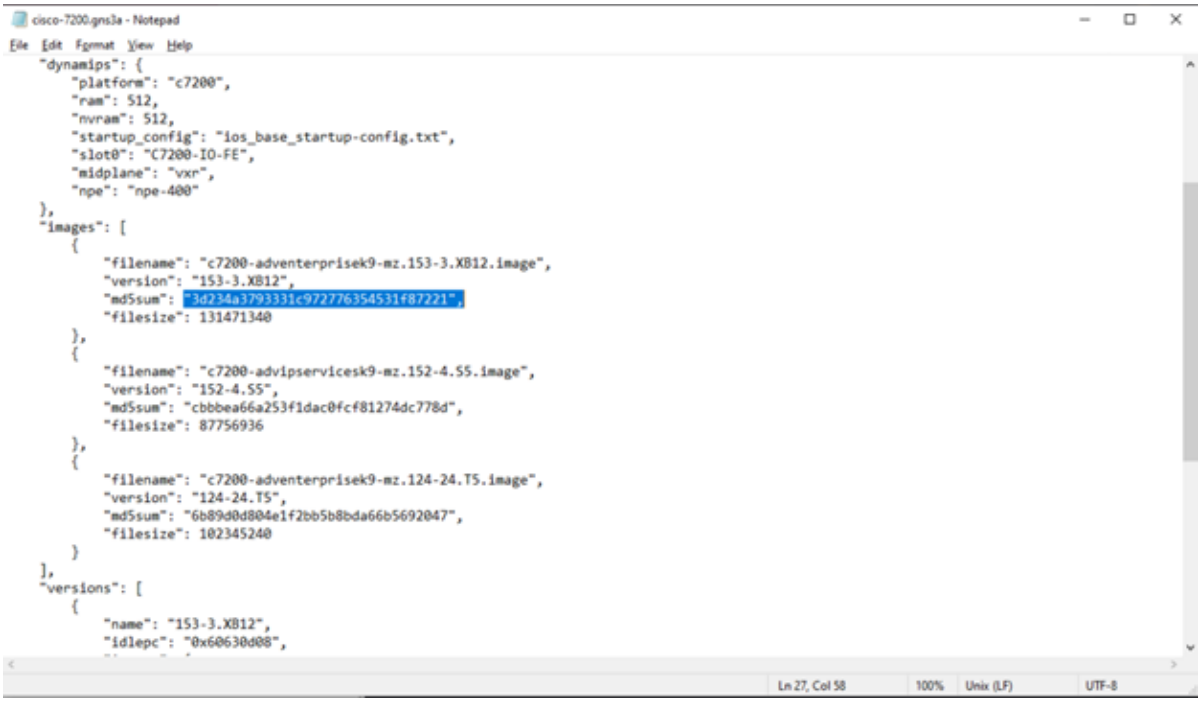


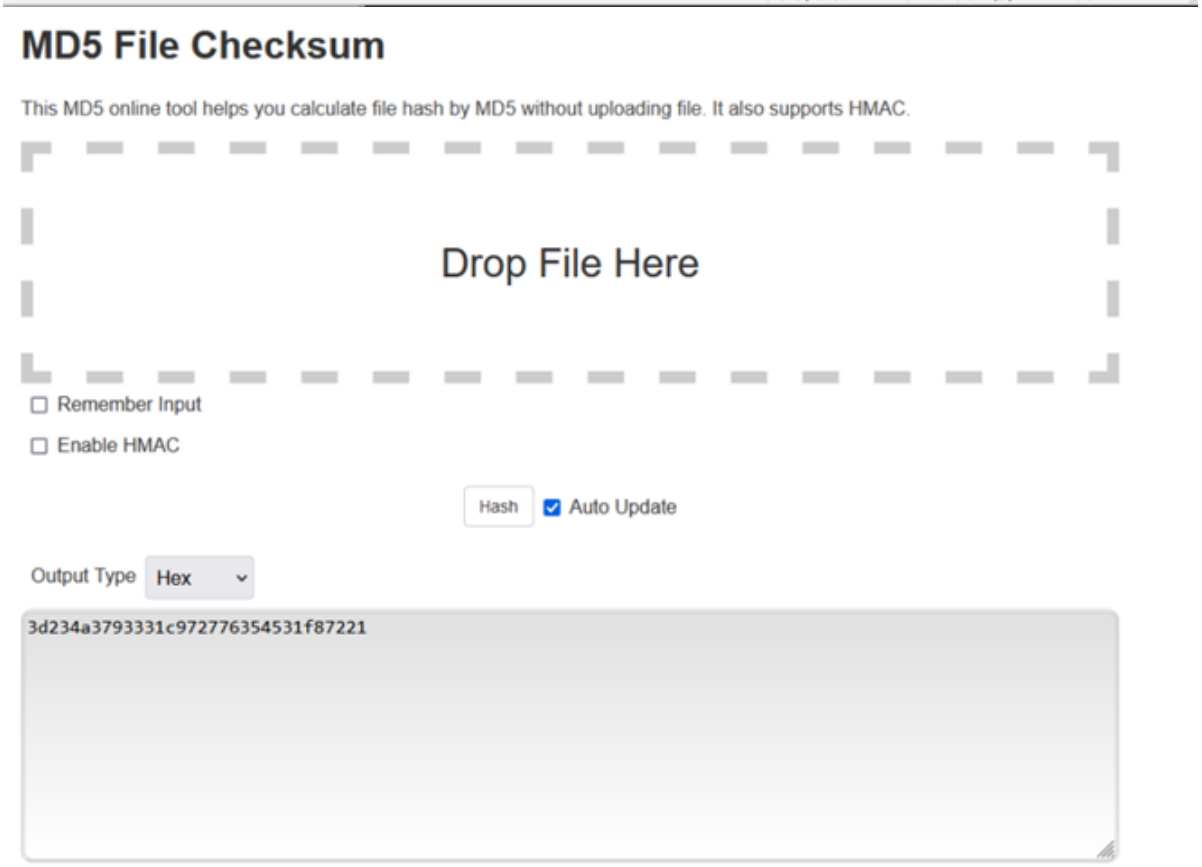
Device	Port	VRF Left	VRF Right	Mask
R1	g0/0	10.0.1.1		255.255.255.0
	g1/0		10.0.1.1	255.255.255.0
	g2/0	10.0.2.1		255.255.255.0
	g3/0		10.0.2.1	255.255.255.0
R2	g0/0	10.0.3.2		255.255.255.0
	g1/0		10.0.3.2	255.255.255.0
	g2/0	10.0.2.2		255.255.255.0
	g3/0		10.0.2.2	255.255.255.0
R3	g0/0	10.0.3.3		255.255.255.0
	g1/0		10.0.3.3	255.255.255.0
	g2/0	10.0.4.3		255.255.255.0
	g3/0		10.0.4.3	255.255.255.0
R4	g0/0	10.0.5.4		255.255.255.0
	g1/0		10.0.5.4	255.255.255.0
	g2/0	10.0.4.4		255.255.255.0
	g3/0		10.0.4.4	255.255.255.0
PC1		10.0.1.254		255.255.255.0
PC2			10.0.1.254	255.255.255.0
PC3		10.0.5.254		255.255.255.0
PC4			10.0.5.254	255.255.255.0

Configurations:

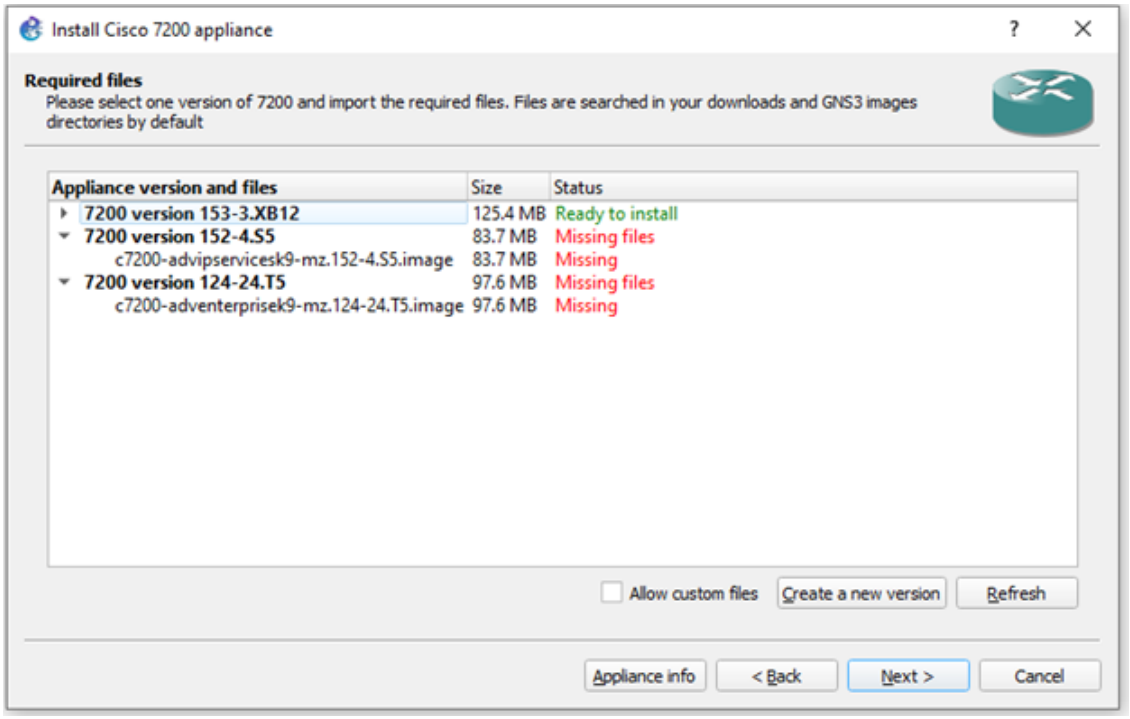
GNS3 C7200 Setup:

1) Navigate to the following link and download an appropriate version of the Cisco C7200 router: https://github.com/hegdepavankumar/Cisco-Images-for-GNS3-and-EVE-NG?tab=readme-ov-filehttps://gns3.com/cisco-7200
2) Ensure that the file downloaded matches the known checksum for the file. This is to prevent installing any potential malicious software. You can find the known checksum of the C7200 router in the given GNS3 configuration file. Then, check that the MD5 checksum matches.

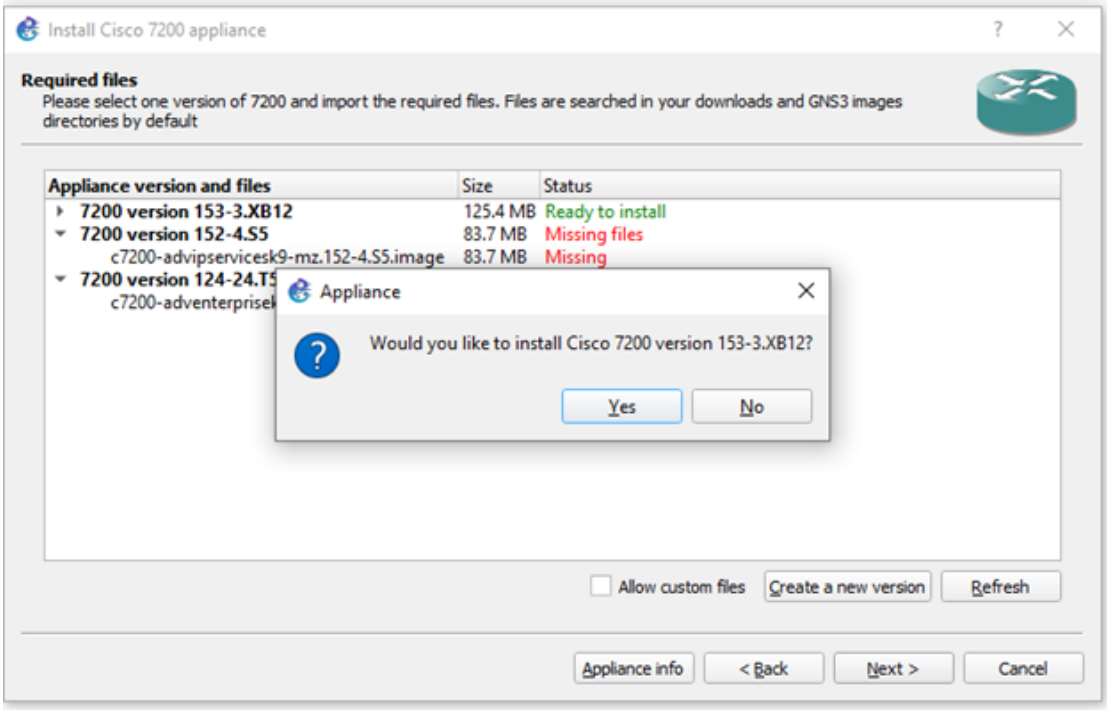




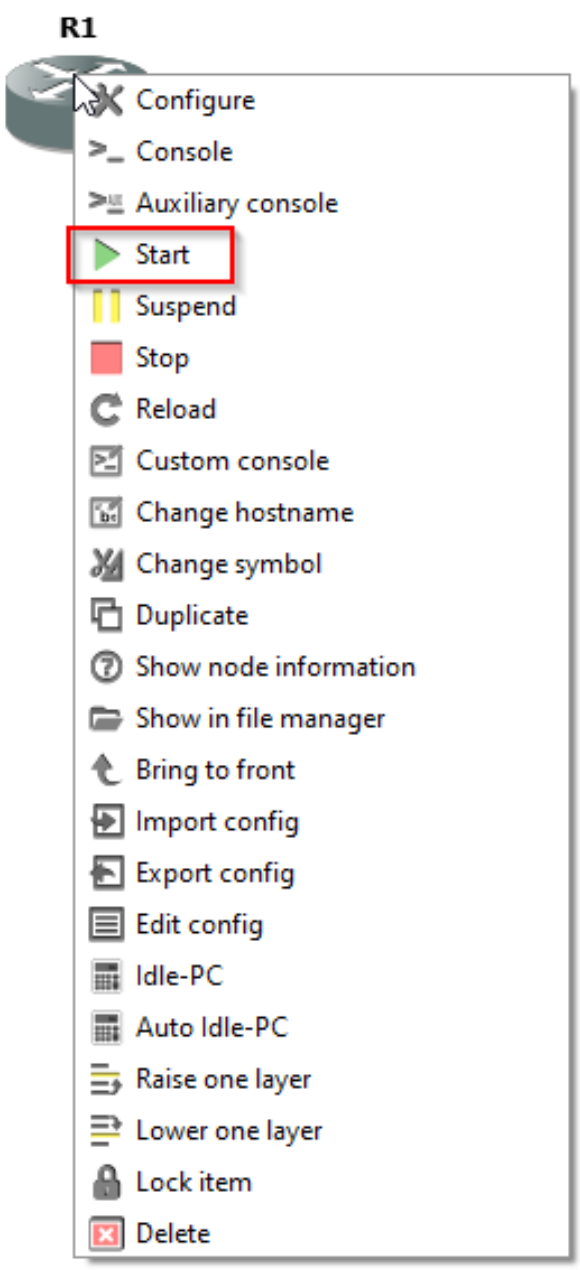
3) If the checksum matches, you can now proceed to installing the router image using GNS3. Select the appropriate version name, and GNS3 will check if the router image is correct. If it is fine, it will display that it is ready to install.

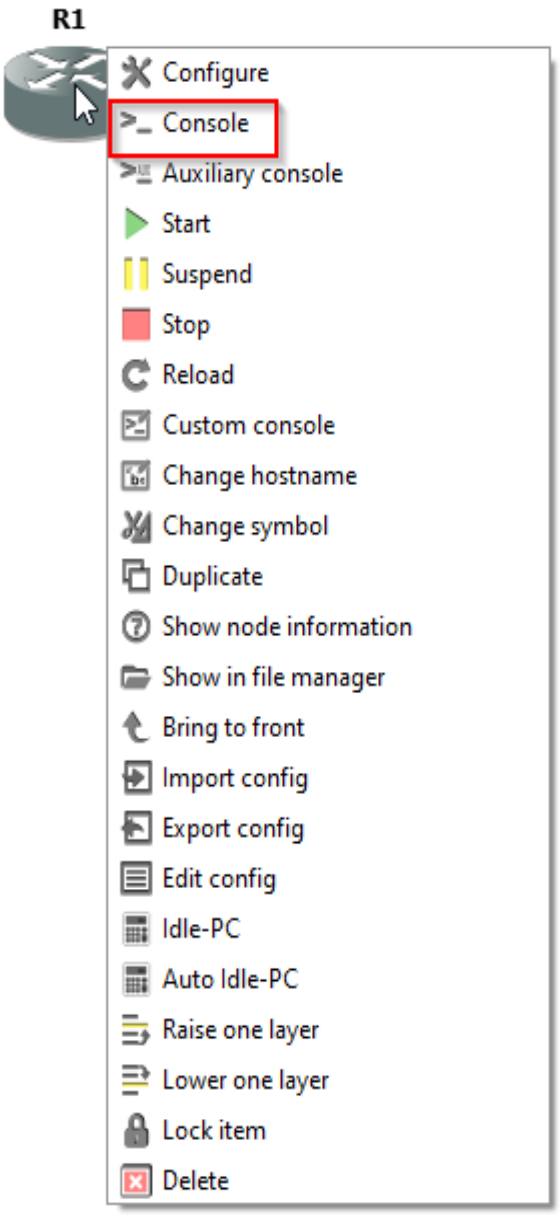


4) Continue to installation, and GNS3 will install the template for the C7200 router. The template will appear in the GNS3 router devices category, and can be dragged into the network topology to be used.



5) Ensure that the router is functioning by starting it. It can be started by right clicking and pressing “Start”. To enter into the virtualized Cisco CLI, press the Console button.





6) Ensure that the device is correctly virtualized by checking the CLI startup log messages.

R1:

```
hostname R1

boot-start-marker
boot-end-marker
aqm-register-fnf
vrf definition left
 address-family ipv4
 exit-address-family
vrf definition right
 address-family ipv4
 exit-address-family
no aaa new-model
no ip icmp rate-limit unreachable
no ip domain lookup
ip cef
no ipv6 cef
multilink bundle-name authenticated
redundancy
ip tcp synwait-time 5
interface Ethernet0/0
 no ip address
 shutdown
 duplex auto
interface GigabitEthernet0/0
 no shutdown
 vrf forwarding left
 ip address 10.0.1.1 255.255.255.0
 duplex full
 speed 1000
 media-type gbic
 negotiation auto
interface GigabitEthernet1/0
 no shutdown
 vrf forwarding right
 ip address 10.0.1.1 255.255.255.0
```

```
 negotiation auto
interface GigabitEthernet2/0
 no shutdown
 vrf forwarding left
 ip address 10.0.2.1 255.255.255.0
 negotiation auto
interface GigabitEthernet3/0
 no shutdown
 vrf forwarding right
 ip address 10.0.2.1 255.255.255.0
 negotiation auto
router ospf 1 vrf left
 router-id 1.1.1.1
 network 10.0.1.0 0.0.0.255 area 0
 network 10.0.2.0 0.0.0.255 area 0
router ospf 10 vrf right
 router-id 1.1.1.0
 network 10.0.1.0 0.0.0.255 area 0
 network 10.0.2.0 0.0.0.255 area 0
ip forward-protocol nd
no ip http server
no ip http secure-server
no cdp log mismatch duplex
control-plane
mgcp behavior rsip-range tgcp-only
mgcp behavior comedia-role none
mgcp behavior comedia-check-media-src disable
mgcp behavior comedia-sdp-force disable
mgcp profile default
gatekeeper
 shutdown
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line vty 0 4
 login
 transport input all
end
```

R2:

```
hostname R2

boot-start-marker
boot-end-marker
aqm-register-fnf
vrf definition left
 address-family ipv4
 exit-address-family
vrf definition right
```

```
 address-family ipv4
 exit-address-family
no aaa new-model
no ip icmp rate-limit unreachable
no ip domain lookup
ip cef
no ipv6 cef
multilink bundle-name authenticated
redundancy
ip tcp synwait-time 5
interface Ethernet0/0
 no ip address
 shutdown
 duplex auto
interface GigabitEthernet0/0
 vrf forwarding left
 ip address 10.0.3.2 255.255.255.0
 duplex full
 speed 1000
 media-type gbic
 negotiation auto
interface GigabitEthernet1/0
 vrf forwarding right
 ip address 10.0.3.2 255.255.255.0
 negotiation auto
interface GigabitEthernet2/0
 vrf forwarding left
 ip address 10.0.2.2 255.255.255.0
 negotiation auto
interface GigabitEthernet3/0
 vrf forwarding right
 ip address 10.0.2.2 255.255.255.0
 negotiation auto
router ospf 1 vrf left
 router-id 2.2.2.2
 network 10.0.2.0 0.0.0.255 area 0
 network 10.0.3.0 0.0.0.255 area 0
router ospf 10 vrf right
 router-id 2.2.2.0
 network 10.0.2.0 0.0.0.255 area 0
 network 10.0.3.0 0.0.0.255 area 0
ip forward-protocol nd
no ip http server
no ip http secure-server
no cdp log mismatch duplex
control-plane
mgcp behavior rsip-range tgcp-only
mgcp behavior comedia-role none
mgcp behavior comedia-check-media-src disable
mgcp behavior comedia-sdp-force disable
mgcp profile default
gatekeeper
 shutdown
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
```

```
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line vty 0 4
 login
 transport input all
end
```

R3:

```
hostname R3

boot-start-marker
boot-end-marker
aqm-register-fnf
vrf definition left
 address-family ipv4
 exit-address-family
vrf definition right
 address-family ipv4
 exit-address-family
no aaa new-model
no ip icmp rate-limit unreachable
no ip domain lookup
ip cef
no ipv6 cef
multilink bundle-name authenticated
redundancy
ip tcp synwait-time 5
interface Ethernet0/0
 no ip address
 shutdown
 duplex auto
interface GigabitEthernet0/0
 no shutdown
 vrf forwarding left
 ip address 10.0.3.3 255.255.255.0
 duplex full
 speed 1000
 media-type gbic
 negotiation auto
interface GigabitEthernet1/0
 no shutdown
 vrf forwarding right
 ip address 10.0.3.3 255.255.255.0
 negotiation auto
interface GigabitEthernet2/0
 no shutdown
 vrf forwarding left
 ip address 10.0.4.3 255.255.255.0
 negotiation auto
interface GigabitEthernet3/0
 no shutdown
 vrf forwarding right
```

```
 ip address 10.0.4.3 255.255.255.0
 negotiation auto
router ospf 1 vrf left
 router-id 3.3.3.3
 network 10.0.4.0 0.0.0.255 area 0
 network 10.0.3.0 0.0.0.255 area 0
router ospf 10 vrf right
 router-id 3.3.3.0
 network 10.0.4.0 0.0.0.255 area 0
 network 10.0.3.0 0.0.0.255 area 0
ip forward-protocol nd
no ip http server
no ip http secure-server
no cdp log mismatch duplex
control-plane
mgcp behavior rsip-range tgcp-only
mgcp behavior comedia-role none
mgcp behavior comedia-check-media-src disable
mgcp behavior comedia-sdp-force disable
mgcp profile default
gatekeeper
 shutdown
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line vty 0 4
 login
 transport input all
end
```

R4:

```
hostname R4

boot-start-marker
boot-end-marker
aqm-register-fnf
vrf definition left
 address-family ipv4
 exit-address-family
vrf definition right
 address-family ipv4
 exit-address-family
no aaa new-model
no ip icmp rate-limit unreachable
no ip domain lookup
ip cef
no ipv6 cef
multilink bundle-name authenticated
redundancy
```

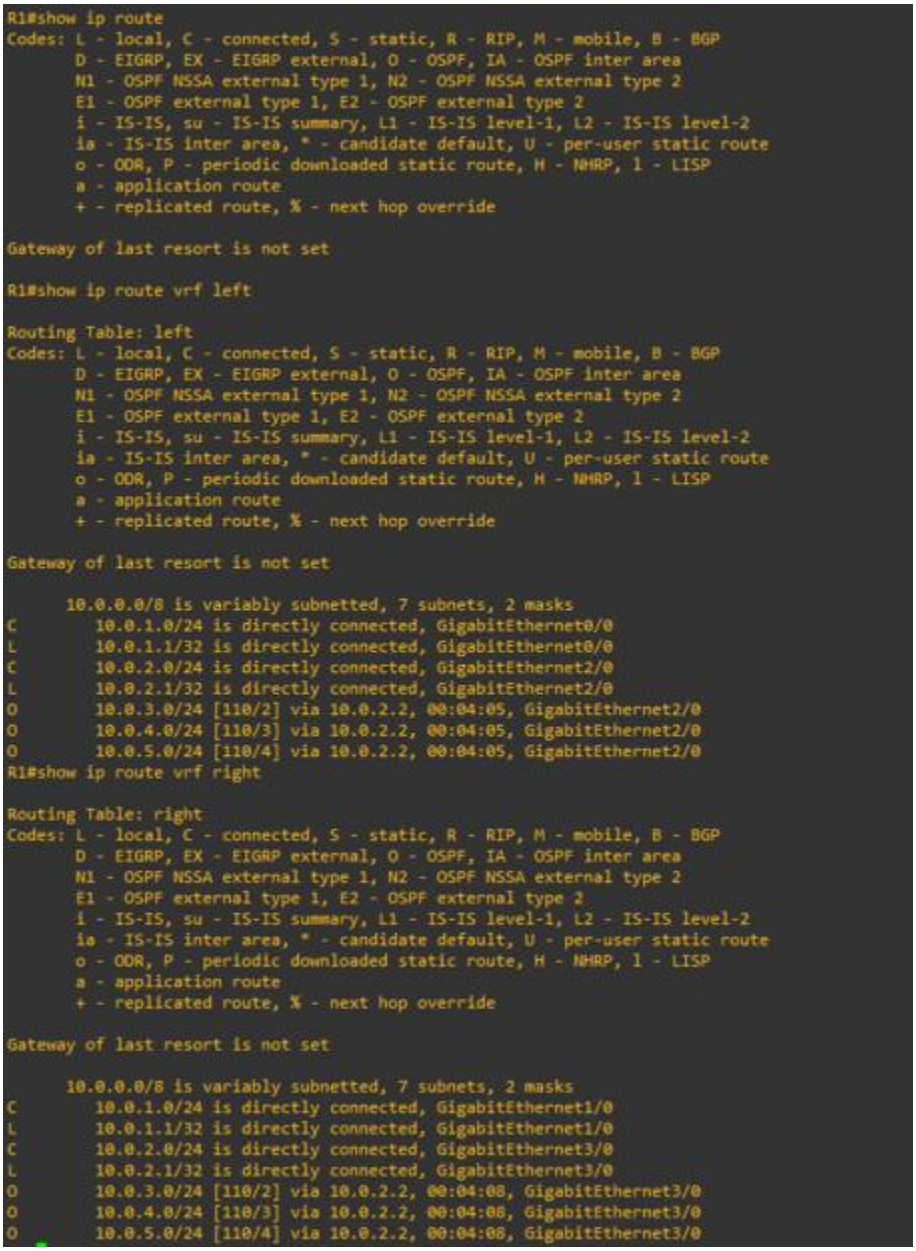
```
ip tcp synwait-time 5
interface Ethernet0/0
 no ip address
 shutdown
 duplex auto
interface GigabitEthernet0/0
 no shutdown
 vrf forwarding left
 ip address 10.0.5.4 255.255.255.0
 duplex full
 speed 1000
 media-type gbic
 negotiation auto
interface GigabitEthernet1/0
 no shutdown
 vrf forwarding right
 ip address 10.0.5.4 255.255.255.0
 negotiation auto
interface GigabitEthernet2/0
 no shutdown
 vrf forwarding left
 ip address 10.0.4.4 255.255.255.0
 negotiation auto
interface GigabitEthernet3/0
 no shutdown
 vrf forwarding right
 ip address 10.0.4.4 255.255.255.0
 negotiation auto
router ospf 1 vrf left
 router-id 4.4.4.4
 network 10.0.4.0 0.0.0.255 area 0
 network 10.0.5.0 0.0.0.255 area 0
router ospf 10 vrf right
 router-id 4.4.4.0
 network 10.0.4.0 0.0.0.255 area 0
 network 10.0.5.0 0.0.0.255 area 0
ip forward-protocol nd
no ip http server
no ip http secure-server
no cdp log mismatch duplex
control-plane
mgcp behavior rsip-range tgcp-only
mgcp behavior comedia-role none
mgcp behavior comedia-check-media-src disable
mgcp behavior comedia-sdp-force disable
mgcp profile default
gatekeeper
 shutdown
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
 stopbits 1
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
```

```
 stopbits 1
line vty 0 4
 login
 transport input all
end
```

Traceroute and Routing Tables:

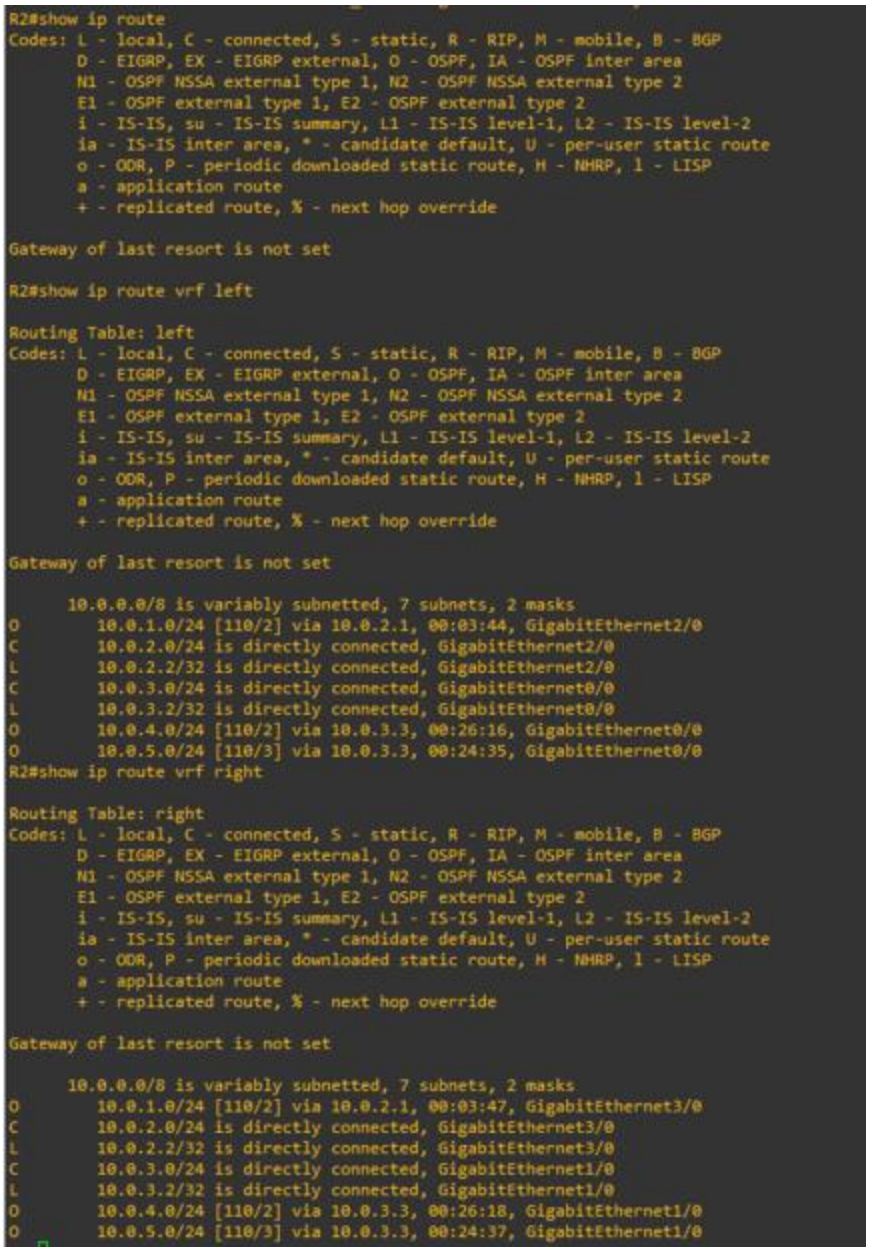
Routing Tables:

PC1:



```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

R1#show ip route vrf left

Routing Table: left
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        10.0.1.0/24 is directly connected, GigabitEthernet0/0
L        10.0.1.1/32 is directly connected, GigabitEthernet0/0
C        10.0.2.0/24 is directly connected, GigabitEthernet2/0
L        10.0.2.1/32 is directly connected, GigabitEthernet2/0
O        10.0.3.0/24 [110/2] via 10.0.2.2, 00:04:05, GigabitEthernet2/0
O        10.0.4.0/24 [110/3] via 10.0.2.2, 00:04:05, GigabitEthernet2/0
O        10.0.5.0/24 [110/4] via 10.0.2.2, 00:04:05, GigabitEthernet2/0
R1#show ip route vrf right

Routing Table: right
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        10.0.1.0/24 is directly connected, GigabitEthernet1/0
L        10.0.1.1/32 is directly connected, GigabitEthernet1/0
C        10.0.2.0/24 is directly connected, GigabitEthernet3/0
L        10.0.2.1/32 is directly connected, GigabitEthernet3/0
O        10.0.3.0/24 [110/2] via 10.0.2.2, 00:04:08, GigabitEthernet3/0
O        10.0.4.0/24 [110/3] via 10.0.2.2, 00:04:08, GigabitEthernet3/0
O        10.0.5.0/24 [110/4] via 10.0.2.2, 00:04:08, GigabitEthernet3/0
```

PC2:


R2#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
a - application route
+ - replicated route, % - next hop override
Gateway of last resort is not set
R2#show ip route vrf left
Routing Table: left
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
a - application route
+ - replicated route, % - next hop override
Gateway of last resort is not set
10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O 10.0.1.0/24 [110/2] via 10.0.2.1, 00:03:44, GigabitEthernet2/0
C 10.0.2.0/24 is directly connected, GigabitEthernet2/0
L 10.0.2.2/32 is directly connected, GigabitEthernet2/0
C 10.0.3.0/24 is directly connected, GigabitEthernet0/0
L 10.0.3.2/32 is directly connected, GigabitEthernet0/0
O 10.0.4.0/24 [110/2] via 10.0.3.3, 00:26:16, GigabitEthernet0/0
O 10.0.5.0/24 [110/3] via 10.0.3.3, 00:24:35, GigabitEthernet0/0
R2#show ip route vrf right
Routing Table: right
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
a - application route
+ - replicated route, % - next hop override
Gateway of last resort is not set
10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O 10.0.1.0/24 [110/2] via 10.0.2.1, 00:03:47, GigabitEthernet3/0
C 10.0.2.0/24 is directly connected, GigabitEthernet3/0
L 10.0.2.2/32 is directly connected, GigabitEthernet3/0
C 10.0.3.0/24 is directly connected, GigabitEthernet1/0
L 10.0.3.2/32 is directly connected, GigabitEthernet1/0
O 10.0.4.0/24 [110/2] via 10.0.3.3, 00:26:18, GigabitEthernet1/0
O 10.0.5.0/24 [110/3] via 10.0.3.3, 00:24:37, GigabitEthernet1/0

PC3:

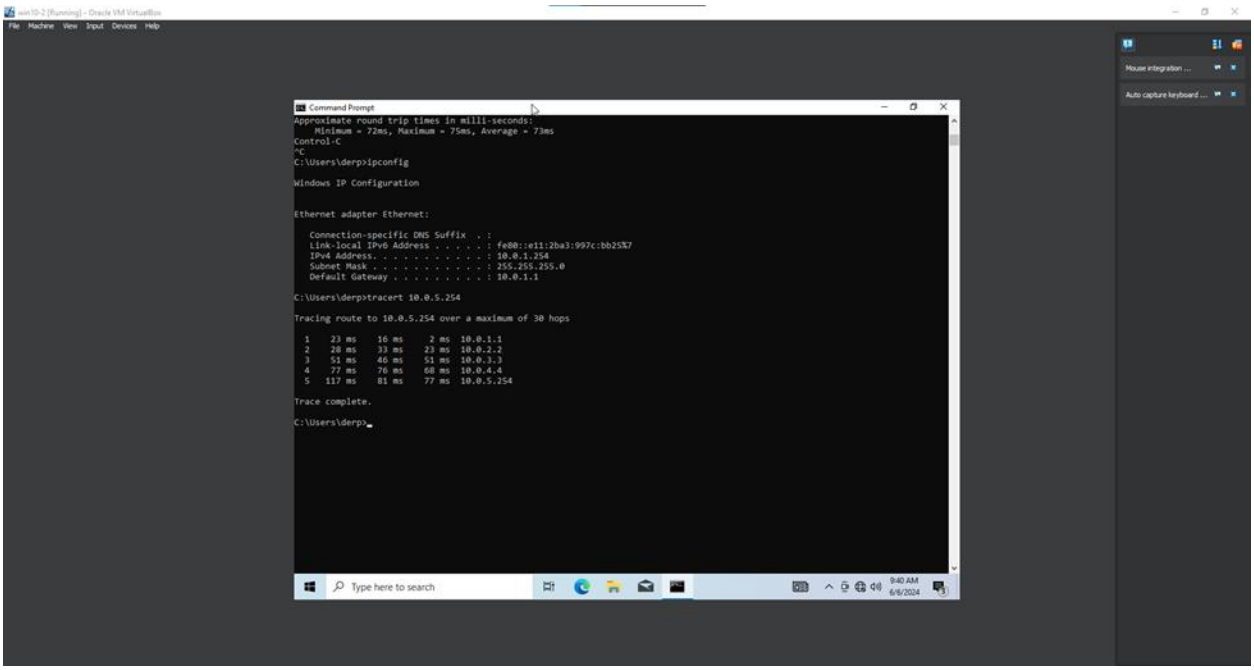
```
R3#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

R3#show ip route vrf left

Routing Table: left
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O        10.0.1.0/24 [110/3] via 10.0.3.2, 00:05:13, GigabitEthernet0/0
O        10.0.2.0/24 [110/2] via 10.0.3.2, 00:06:16, GigabitEthernet0/0
C        10.0.3.0/24 is directly connected, GigabitEthernet0/0
L        10.0.3.3/32 is directly connected, GigabitEthernet0/0
C        10.0.4.0/24 is directly connected, GigabitEthernet2/0
L        10.0.4.3/32 is directly connected, GigabitEthernet2/0
O        10.0.5.0/24 [110/2] via 10.0.4.4, 00:26:04, GigabitEthernet2/0
R3#show ip route vrf right

Routing Table: right
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O        10.0.1.0/24 [110/3] via 10.0.3.2, 00:05:16, GigabitEthernet1/0
O        10.0.2.0/24 [110/2] via 10.0.3.2, 00:06:19, GigabitEthernet1/0
C        10.0.3.0/24 is directly connected, GigabitEthernet1/0
L        10.0.3.3/32 is directly connected, GigabitEthernet1/0
C        10.0.4.0/24 is directly connected, GigabitEthernet3/0
L        10.0.4.3/32 is directly connected, GigabitEthernet3/0
O        10.0.5.0/24 [110/2] via 10.0.4.4, 00:26:06, GigabitEthernet3/0
```

PC4:

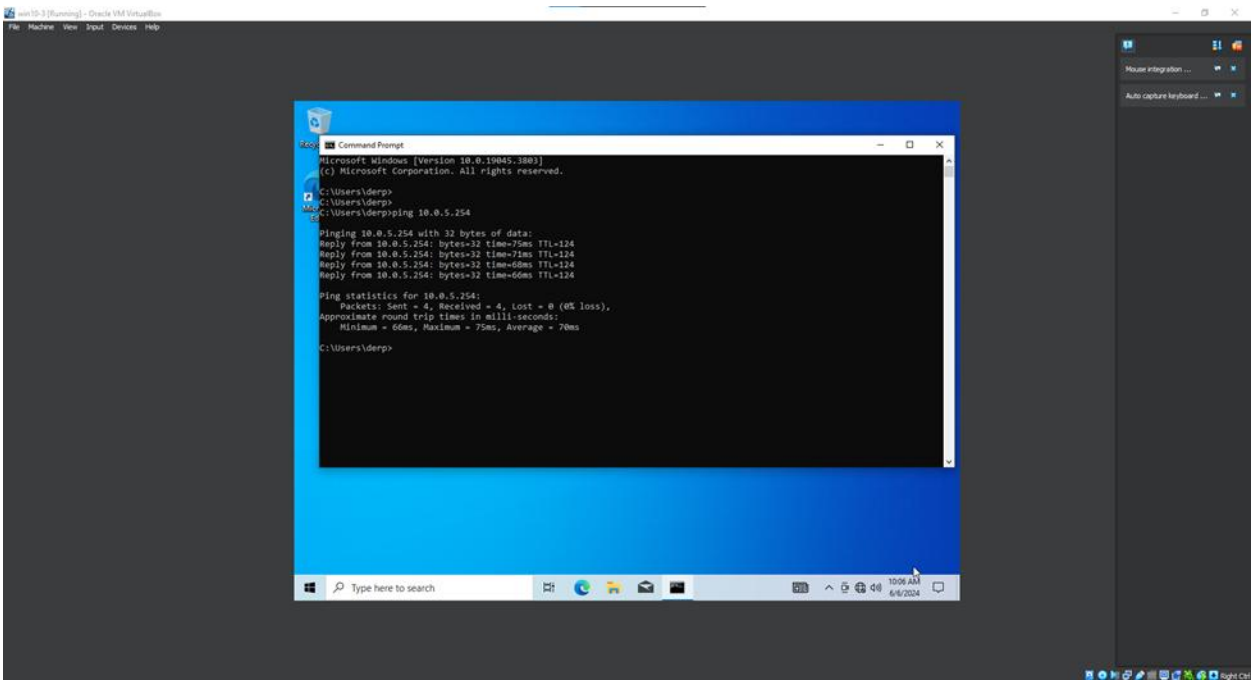
```
R4#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

R4#show ip route vrf left

Routing Table: left
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O        10.0.1.0/24 [110/4] via 10.0.4.3, 00:05:37, GigabitEthernet2/0
O        10.0.2.0/24 [110/3] via 10.0.4.3, 00:06:40, GigabitEthernet2/0
O        10.0.3.0/24 [110/2] via 10.0.4.3, 00:26:22, GigabitEthernet2/0
C        10.0.4.0/24 is directly connected, GigabitEthernet2/0
L        10.0.4.4/32 is directly connected, GigabitEthernet2/0
C        10.0.5.0/24 is directly connected, GigabitEthernet0/0
L        10.0.5.4/32 is directly connected, GigabitEthernet0/0
R4#show ip route vrf right

Routing Table: right
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O        10.0.1.0/24 [110/4] via 10.0.4.3, 00:05:40, GigabitEthernet3/0
O        10.0.2.0/24 [110/3] via 10.0.4.3, 00:06:44, GigabitEthernet3/0
O        10.0.3.0/24 [110/2] via 10.0.4.3, 00:26:24, GigabitEthernet3/0
C        10.0.4.0/24 is directly connected, GigabitEthernet3/0
L        10.0.4.4/32 is directly connected, GigabitEthernet3/0
C        10.0.5.0/24 is directly connected, GigabitEthernet1/0
L        10.0.5.4/32 is directly connected, GigabitEthernet1/0
```

Traceroute:

PC1 to PC3:



PC2 to PC4:



Problems:

10)Didn’t Save GNS3 Configs

Initially, we didn’t realize that GNS3 did not autosave router configs, and after we had finished our lab and come back the next day, our entire network topology configuration had been wiped.

11) VMware VMnet interfaces

We started off using GNS3 with VMware, but were unaware that GNS3 configuration of VMware interfaces required us to setup the VMnet settings in VMware. Due to unfamiliarity with this software, we decided instead to use VirtualBox in order to virtualize our Windows machines.

Conclusion:

Overall, this lab served as a thorough introduction to what VRF is and how to configure it. Furthermore, we learned how to use network virtualization software as well, utilizing GNS3 to create a virtual network. We were also able to review some network design and implementation basics, such as subnetting and topology configuration.