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Implementing IS-IS Routing and DHCP Services in an IPv4 Network

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Implementing IS-IS Routing and DHCP Services in an IPv4 Network

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Department of Business and Information Technology
Computer Information Systems

Honors Research Project

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Project Proposal

Project Name:

Implementing IS-IS Routing and DHCP Services in an IPv4 Network

Project Components:

Design and configure an IPv4 network running the IS-IS routing protocol, and use a Raspberry Pi as a server to provide DHCP services to the network. OSPF will also be implemented in the network, with redistribution between the 2 routing protocols.

Equipment:

Raspberry Pi B+
4 Cisco 2811 routers
1-2 Cisco 3750 or 2960 Switches

Detailed Objective:

1. Research Topics
 - a. How the IS-IS Routing Protocol works
 - b. How a Raspberry Pi works
 - c. What software to use on the Raspberry Pi
 - d. How to configure the Raspberry Pi as a DHCP server
2. Design Tasks
 - a. Topology of the network
 - i. 4 routers in a hub and spoke topology
 1. 2 of the spoke routers will run IS-IS only
 2. 1 of the spoke routers will run OSPF only
 3. The hub router will be the ASBR between the two domains
 - ii. 1-2 switches will be used for LAN connectivity
 - iii. Raspberry Pi will connect to one of the IS-IS spokes
 - b. IS-IS areas and routing functionality
 - c. OSPF to IS-IS redistribution plan
 - d. Addressing scheme for network devices
 - e. DHCP address pool
3. Implementation
 - a. Cable the devices according to topology designed in phase 2
 - b. Configure the routers with basic configurations and IP addresses
 - c. Configure the IS-IS routing protocol
 - i. IS-IS basic intra-area routing
 - ii. IS-IS areas and Level 2 (inter-area) routing
 - iii. Redistribution between IS-IS and OSPF
 - d. Set-up Raspberry Pi as the DHCP server

4. Testing
 - a. Confirm the configuration of IS-IS
 - i. View routing table
 - b. Use ping/traceroute/etc. to verify optimal routing
 - c. Confirm redistribution between OSPF and IS-IS
 - d. Confirm operation of the Server
 - i. Hosts receive IP addresses via DHCP
 - e. Issue appropriate show commands to verify all configurations

5. Documentation
 - a. Project Plan
 - b. Documentation of research and resources used
 - c. Issue appropriate show commands and capture screenshots to illustrate configuration

Estimated Time to Complete:

	Research	Design	Implementation	Testing	Documentation	Total
Estimate *	30	10	15	5	15	75

*Estimated in hours

Estimated Budget and Associated Costs:

Raspberry Pi	\$35.00
All other equipment	\$0.00 (Used FirstEnergy Lab equipment)

Location of the Work:

The majority of the work will be completed in the lab at FirstEnergy. In order to present this project, I will utilize video recording. Access to the lab will be granted to the professor to view and verify my completion of the project first hand.

Goals of the Project:

- Gain an understanding of the basic functionality of the IS-IS routing protocol
- Understand how to manipulate IS-IS routing, and support its integration with other protocols
- Examine common problems with IS-IS, and learn how to troubleshoot effectively
- Learn about the operation of the Raspberry Pi, and the Raspbian distribution of Linux
- Determine the optimal method for configuration of DHCP services on the network

Final Presentation

The written portion of the project will consist of:

- Weekly status reports
- Show command output exhibiting the configuration of the network devices
- Topology and network design diagrams
- Screen shots and output of Raspberry Pi server configuration
- Step-by-step configuration and troubleshooting guides
- Works cited/reference page

The formal project presentation:

- The formal project presentation will be given in front of my Computer Information Systems Senior Projects class, and will meet the following criteria:
 - PowerPoint presentation
 - Video or live demonstration
 - 15 minutes in length, with additional time granted for questions

Project Analysis

IS-IS Routing and Redistribution

In the early stages of research for this project, the idea of learning and configuring IS-IS seemed like an overwhelming task. IS-IS has many elements that are not configured or used in other IP routing protocols. Despite its intimidating nature, learning the basic operation of this routing protocol was less difficult than expected. Although there are differences in commands, and the underlying routing operations and metric calculation, IS-IS still accomplishes the same tasks as EIGRP, OSPF, and other routing protocols.

Once routing within the IS-IS and OSPF domains was configured and working properly, route redistribution between the two protocols was configured for full connectivity. Like all routing protocols, redistribution into IS-IS is configured within the router IS-IS configuration mode. The OSPF routes, including all subnets, were redistributed into the IS-IS routing domain. This allowed the Intermediate Systems within the IS-IS domain to populate their routing tables with routes to these remote OSPF networks, as IS-IS Level 2 routes. Likewise, route redistribution was also configured into OSPF, allowing the OSPF routers to now have full connectivity to the IS-IS domain via type O E1 redistributed routes.

Although two-way route redistribution can often cause problems such as routing loops within networks, there were no such issues with this project. The main challenges that arose with redistribution dealt with advertisement of specific networks.

Inspecting the intra-domain routes within the routing tables of each router was key to understanding the protocol. However, the inter-domain routes proved to be even more essential to formulating a clear picture of how IS-IS works. This was the central piece of this project, as it not only was the focus of interest and learning, but also created a functioning backbone network upon which the rest of the project plan was implemented.

The main challenges that arose with this aspect of the project dealt with advertisement of specific routes, especially in regards to redistribution.

Raspberry Pi and DHCP/DNS

Implementing DHCP and DNS services into the network through the use of a Raspberry Pi was an inexpensive way to incorporate both Linux, and server configuration into the project. It was also a highly effective way to become all-around more familiar with Linux-based operating systems and commands line.

With a basic knowledge of DHCP and DNS operation, the server implementation was most challenging in terms of syntax. Although the initial project proposal did not include plans for implementation of DNS services on the network, it was added in later to provide more network functionality.

There are occasional intermittent issues with the DHCP service, causing a host to be unsuccessful in acquiring an IP address for the server. This is only resolved by power cycling the Raspberry Pi server, or waiting 2-3 minutes and attempting to release and renew the PC's ip configuration. There is no indication as to the cause of these issues anywhere in the daemon.log

file, which logs all DHCP related traffic entering and leaving the DHCP server. However, these occurrences were very rare and intermittent.

In addition to the items listed on the project proposal, DNS services were also implemented. The service that was used for DHCP is also capable of providing DNS services, so the decision was made to implement some basic DNS functionality into the network as well.

In the initial project proposal, it was stated that the majority of the work would be completed in the FirstEnergy lab. However, personal equipment has since been purchased for this project. Due to the budget changes for the project, an updated cost analysis has been included at the end of this section. Although the expected cost and proposed location of work hasn't been preserved, conformity to the original design has been maintained through the rest of the project.

Overall, these elements combined to serve as an excellent project to meet the requirements of the CIS Senior Projects Class, as well as facilitating interest and learning.

Budget and Associated Costs:

Raspberry Pi	\$35.00
2 – Cisco 2950 Switches	\$95.00
4 – Cisco 2821 Routers	\$360.00
1 – HWIC-1FE Module	\$150.00
Cables, Rack, etc.	Estimated \$40.00
TOTAL	\$680.00

* The figures have been rounded to the nearest dollar amount, and include shipping fees.

Time Analysis:

	Research	Design	Implementation	Testing	Documentation	Total
Estimate	30	10	15	5	15	75
Actual	20	6.5	16	9	19	70.5
Percent of Estimated Hours Worked	66.7%	65%	100.1%	180%	126.7%	94%

* Time values are in hours

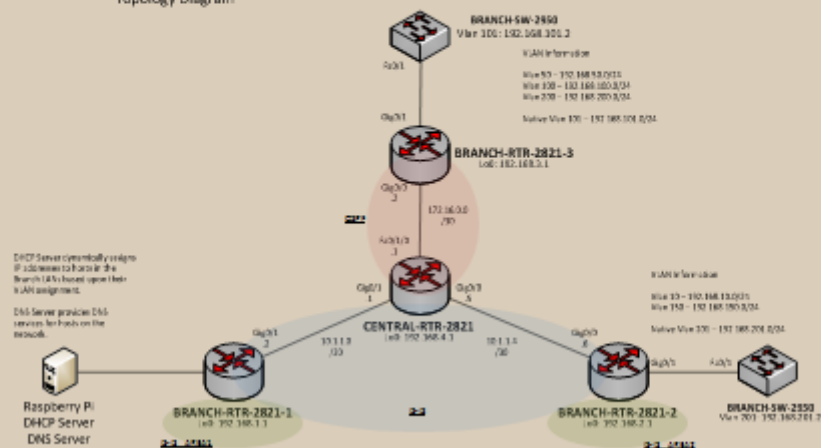
Project Presentation

Implementing IS-IS Routing and DHCP Services in an IPv4 Network

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Topology

Topology Diagram



Overview



Getting Started

- ❑ IOS Version upgrade was performed using PSCP
 - ❑ puTTY Secure Copy
- ❑ IP host configuration for easier remote access
 - ❑ i.e. ip host branch1 192.168.1.1
- ❑ Other basic configurations applied to all devices
- ❑ OSPF domain configured

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\S0720>cd C:\Users\S0720\Documents\putty
C:\Users\S0720\Documents\putty>
C:\Users\S0720\Documents\putty>scp C:\Users\S0720\Documents\putty\c28
000-adip-services37-m-151-4-80-bis cisco012.168.1.1:c28000-adip-services37-m
-151-4-80-bis
The server's host key is not cached in the registry. You
have no guarantee that the server is the computer you
think it is.
The server's rsa2 key fingerprint is:
rsa-rsa 512 7e13a16979b0b1e91161bada7a1411b1ccaa2515f
If you trust this host, enter 'y' to add the key to
PuTTY's cache and carry on connecting.
If you want to carry on connecting just once, without
adding the key to the cache, enter 'n'.
If you do not trust this host, press Return to abandon the
connection.
Store key in cache? (y/n) y
cisco012.168.1.1's password:
c28000-adip-services37-m 1 64616 kb | 193.4 kb/s | ETA: 00:00:00 | 100%
C:\Users\S0720\Documents\putty>
```

What is IS-IS?

- ❑ It is an IGP routing protocol commonly used among service providers
- ❑ It uses the SPF algorithm
- ❑ Originally, it was not designed for IP networks, but rather OSI CLNS (Connectionless Mode Network Service)
 - ❑ Based off of the OSI model, not the TCP/IP model.
- ❑ IS-IS for IP is called integrated IS-IS

IS-IS NET Address

- ❑ IS-IS uses NSAP addresses
- ❑ NSAP has 3 parts:
 - ❑ Area ID
 - ❑ System ID
 - ❑ N-selector (NSEL)
- ❑ NET address (NSAP with NSEL set to 00) was used to form adjacencies
- ❑ Configured under each IS-IS process

IS-IS Routing

- IS-IS level-1 and level-2 routes
 - Multiple subdomains can be configured
 - Level-1 routes are within an area
 - Level-2 routes are between areas
 - Additional areas require tags, new NET addresses, etc,
 - Interfaces are configured for specific areas
 - Designated Intermediate System (DIS)
 - Highest Priority
 - Highest MAC address
 - Psuedonode LSP

IS-IS Routing Example

BRANCH-RTR-2821-2

```
router isis
 net 48.001c.f6b1.c5e1.00
 domain-password cisco
 area-password CISCO
!
router isis AREA2
 net 50.001c.f6b1.c5e1.00
 is-type level-1
 domain-password cisco
 area-password CISCO2

interface Loopback0
 ip address 192.168.2.1 255.255.255.255
 ip router isis AREA2
!
interface GigabitEthernet0/1.10
 encapsulation dot1Q 10
 ip address 192.168.10.1 255.255.255.0
 ip helper-address 10.1.100.1
 ip router isis
```

Redistribution

Two-way redistribution was configured on the ASBR

```
router isis
net 48.1c17.d3ec.96a1.00
domain-password cisco
area-password CISCO
redistribute ospf 1
passive-interface FastEthernet0/1/0
```

```
router ospf 1
area 0 authentication message-digest
redistribute connected subnets
redistribute isis level-1-2 subnets
passive-interface GigabitEthernet0/0
passive-interface GigabitEthernet0/1
network 172.16.0.0 0.0.0.3 area 0
```

Routing Tables

```
Router-SP1-2521-2446 ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       E1 - OSPF NSSA external type 1, E2 - OSPF NSSA external type 2
       E3 - OSPF external type 1, E4 - OSPF external type 2
       I - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       Ia - IS-IS leaky area, * - candidate default, O - ODR, P - pre-cost static route
       s - ODR, P - periodically downloaded static route
Gateway of last resort is not set

0/0 192.168.100.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
0/0 192.168.10.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
172.16.0.0/20 is subnetted, 1 subnets
C 172.16.0.0 is directly connected, GigabitEthernet0/0
0 192.168.200.0/24 is directly connected, GigabitEthernet0/1.200
192.168.0.0/24 is subnetted, 1 subnets
0/0 192.168.0.0 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
0/0 192.168.201.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
10.0.0.0/30 is subnetted, 3 subnets
0/0 10.0.0.0 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
0/0 10.0.0.4 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
0/0 10.0.0.8 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
0/0 192.168.10.0/24 is directly connected, GigabitEthernet0/1.50
192.168.1.0/24 is subnetted, 1 subnets
0/0 192.168.1.1 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
192.168.2.0/24 is subnetted, 1 subnets
0/0 192.168.2.1 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
192.168.100.0/24 is directly connected, GigabitEthernet0/1.100
192.168.0.0/30 is subnetted, 1 subnets
C 192.168.0.0 is directly connected, GigabitEthernet0/0
0 192.168.101.0/24 is directly connected, GigabitEthernet0/1.101
Router-SP1-2521-2446

Router-SP2-2521-2446 ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       E1 - OSPF NSSA external type 1, E2 - OSPF NSSA external type 2
       E3 - OSPF external type 1, E4 - OSPF external type 2
       I - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       Ia - IS-IS leaky area, * - candidate default, O - ODR, P - pre-cost static route
       s - ODR, P - periodically downloaded static route
Gateway of last resort is not set

0/0 192.168.100.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
0/0 192.168.10.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
172.16.0.0/20 is subnetted, 1 subnets
C 172.16.0.0 is directly connected, GigabitEthernet0/1
0/0 192.168.200.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
192.168.0.0/24 is subnetted, 1 subnets
0/0 192.168.0.0 [110/20] via 10.0.0.1, GigabitEthernet0/1
0/0 192.168.201.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
10.0.0.0/30 is subnetted, 3 subnets
C 10.0.0.0 is directly connected, GigabitEthernet0/1
0/0 10.0.0.4 [110/20] via 10.0.0.1, GigabitEthernet0/1
0/0 10.0.0.8 is directly connected, GigabitEthernet0/1
0/0 192.168.10.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
192.168.1.0/24 is subnetted, 1 subnets
C 192.168.1.1 is directly connected, Loopback0
192.168.2.0/24 is subnetted, 1 subnets
0/0 192.168.2.1 [110/20] via 10.0.0.1, GigabitEthernet0/1
0/0 192.168.100.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
192.168.0.0/30 is subnetted, 1 subnets
0/0 192.168.0.0 [110/20] via 10.0.0.1, GigabitEthernet0/1
0/0 192.168.101.0/24 [110/20] via 10.0.0.1, GigabitEthernet0/1
Router-SP2-2521-2446
```

Routing Tables

[illegible]

Raspberry Pi DHCP Server

- ❑ Dnsmasq was used on the Raspberry Pi for DHCP and DNS services
- ❑ The dnsmasq.conf file was used for most of the DHCP configuration
- ❑ Contains configuration of:
 - ❑ Address range, mask, and domain
 - ❑ Lease time
 - ❑ Additional DHCP options

Raspberry Pi DNS Server

- DNS configurations are stored in two files
 - Dnsmasq.conf
 - Contains domain information and DHCP options pointing to the DNS server
 - Hosts
 - Contains the IP Address to hostname mappings
- Daemon.log
 - Server information is logged to the daemon.log file

Server Configuration

```
root@raspberrypi:/etc# cat dnsmasq.conf
interface=eth0
dhcp-range=vlan10,192.168.10.10,192.168.10.254,255.255.255.0,24h
dhcp-range=vlan50,192.168.50.10,192.168.50.254,255.255.255.0,24h
dhcp-range=vlan100,192.168.100.10,192.168.100.254,255.255.255.0,24h
dhcp-range=vlan150,192.168.150.10,192.168.150.254,255.255.255.0,24h
dhcp-range=vlan200,192.168.200.10,192.168.200.254,255.255.255.0,24h
log-dhcp

domain=Thompson.test
expand-hosts
local=/Thompson.test/

interface=eth0
dhcp-option=vlan10,6,10.1.100.1
dhcp-option=vlan50,6,10.1.100.1
dhcp-option=vlan100,6,10.1.100.1
dhcp-option=vlan150,6,10.1.100.1
dhcp-option=vlan200,6,10.1.100.1
root@raspberrypi:/etc#
```

Server Configuration

```
root@raspberrypi:/etc# cat hosts
127.0.0.1      localhost
::1          localhost ip6-localhost ip6-loopback
fe00::0       ip6-localnet
ff00::0       ip6-mcastprefix
ff02::1       ip6-allnodes
ff02::2       ip6-allrouters

127.0.1.1      raspberrypi

192.168.1.1     branch-rtr-2021-1
192.168.2.1     branch-rtr-2021-2
192.168.3.1     branch-rtr-2021-3
192.168.4.1     central-rtr-2021
192.168.101.2   branch-sw-2050-1
192.168.201.2   branch-sw-2050-2

172.16.0.2      branch-rtr-2021-3-gig0-0
172.16.0.1      central-rtr-2021-fa0-1-0

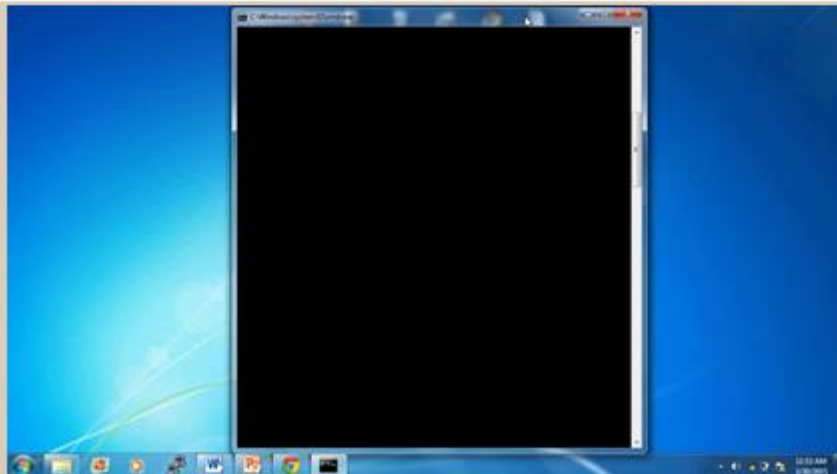
10.1.1.1       central-rtr-2021-gig0-1
10.1.1.2       branch-rtr-2021-1-gig0-1

10.1.1.5       central-rtr-2021-gig0-0
10.1.1.6       branch-rtr-2021-gig0-0

192.168.10.1    branch-rtr-2021-2-subif-10
192.168.150.1   branch-rtr-2021-2-subif-150
192.168.201.1   branch-rtr-2021-2-subif-201

192.168.50.1    branch-rtr-2021-3-subif-50
192.168.100.1   branch-rtr-2021-3-subif-100
192.168.200.1   branch-rtr-2021-3-subif-200
192.168.101.1   branch-rtr-2021-3-subif-101
```

Demonstration Video



Questions and Comments

Thank You

Project Description

1.1 IP Addressing Scheme and Topology

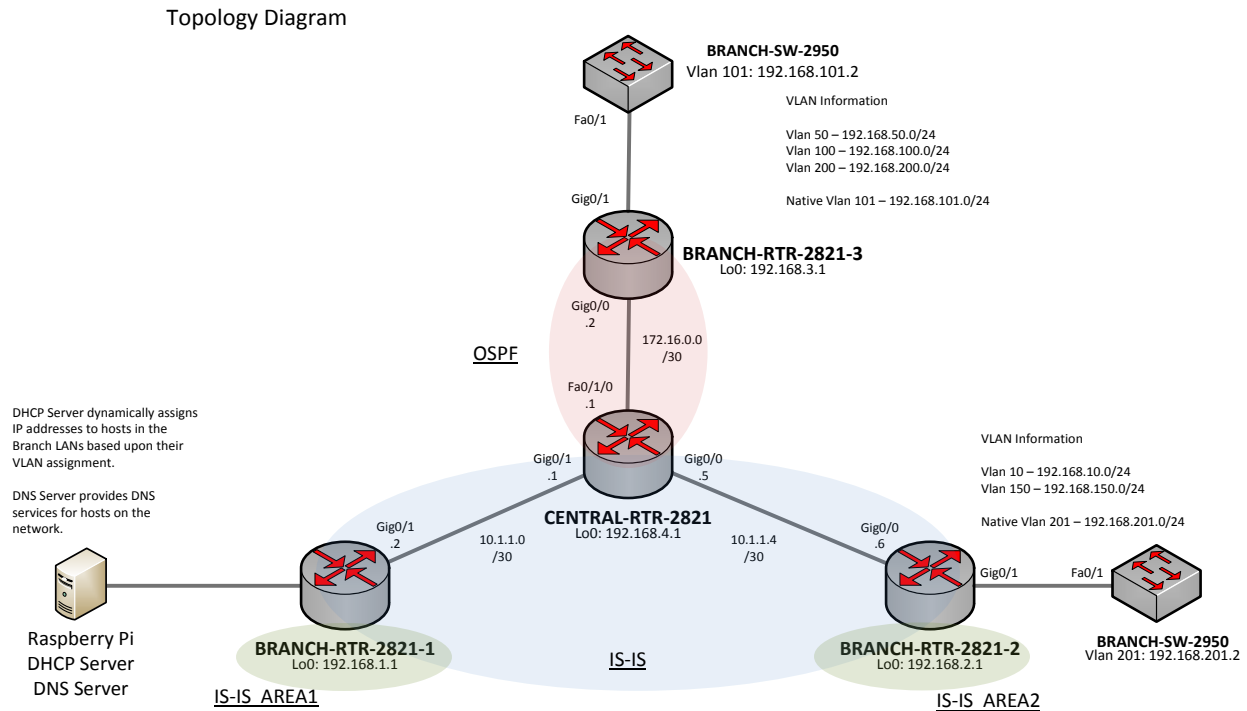
<u>Subnet</u>	<u>Device 1</u>	<u>Interface</u>	<u>IP</u>	<u>Device 2</u>	<u>Interface</u>	<u>IP</u>
Rtr Interconnects						
10.1.1.0/30	CENTRAL-RTR-2821	Gig0/1	10.1.1.1	BRANCH-RTR-2821-1	Gig0/1	10.1.1.2
10.1.1.4/30	CENTRAL-RTR-2821	Gig0/0	10.1.1.5	BRANCH-RTR-2821-2	Gig0/0	10.1.1.6
172.16.0.0/30	CENTRAL-RTR-2821	Fa0/1/0	172.16.0.1	BRANCH-RTR-2821-3	Gig0/0	172.16.0.2
Branch1 to Server						
10.1.100.0/30	BRANCH-RTR-2821-1	Gig0/0	10.1.100.2	RaspberryPi	Eth0	10.1.100.1
Switch1 VLANS						
192.168.50.0/24	BRANCH-RTR-2821-3	Gig0/1.50	192.168.50.1	BRANCH-SW-2950-1	Fa0/1	trunk
192.168.100.0/24	BRANCH-RTR-2821-3	Gig0/1.100	192.168.100.1	BRANCH-SW-2950-1	Fa0/1	trunk
192.168.200.0/24	BRANCH-RTR-2821-3	Gig0/1.200	192.168.200.1	BRANCH-SW-2950-1	Fa0/1	trunk
Switch2 VLANS						
192.168.10.0/24	BRANCH-RTR-2821-2	Gig0/1.10	192.168.10.1	BRANCH-SW-2950-2	Fa0/1	trunk
192.168.150.0/24	BRANCH-RTR-2821-2	Gig0/1.150	192.168.150.1	BRANCH-SW-2950-2	Fa0/1	trunk
Loopbacks						
192.168.1.1	BRANCH-RTR-2821-1	Lo0				
192.168.2.1	BRANCH-RTR-2821-2	Lo0				
192.168.3.1	BRANCH-RTR-2821-3	Lo0				
192.168.4.1	CENTRAL-RTR-2821	Lo0				
192.168.101.2	BRANCH-SW-2950-1	Native Vlan 101				
192.168.201.2	BRANCH-SW-2950-2	Native Vlan 201				

The table above shows the overall IP Addressing scheme that was used for this project.

All point to point links were given a /30 address. The loopback addresses assigned to the routers were /32 addresses, and all of the LANs stemming from the switch were given a /24 address space. Individual static addresses were assigned according to the table above.

The Topology and cabling design varied slightly throughout the project. Initially, the work was to be performed at FirstEnergy lab, however the purchase of personal equipment allowed for the set-up of a home lab for this project. Because of this, the router and switch models changed with this new development, and slight changes were made to the initial topology design. None of these changes have had any effect on the functionality of the project, or the overall structural design.

The final design and cabling structure of the network is as seen in the figure below.



The CENTRAL-RTR-2821 serves as the ASBR router, providing routing services for both the OSPF and IS-IS domains. As seen in the figure, BRANCH-RTR-2821-1 and BRANCH-RTR-2821-2 are both members of the IS-IS routing domain, and each is also a member of additional IS-IS areas. This is known as multi-area IS-IS, and it was configured and studied to understand the differences between Level 1 and Level 2 routes. This will be explained further in later sections.

Router BRANCH-RTR-2821-3 is not a member of the IS-IS domain, but rather the OSPF routing domain. Both BRANCH-RTR-2821-2 and BRANCH-RTR-2821-3 have attached switches which contain several user vlans. BRANCH-RTR-2821-3 connects to BRANCH-SW-2950-1, which has 3 user vlans. They are vlan 50, vlan 100, and vlan 200. BRANCH-SW-2950-1 also has a native vlan, vlan 101. BRANCH-SW-2950-2 is connected to the network via BRANCH-RTR-2821-2, and it has 2 user vlans. These are vlans 10 and 150. The native vlan for this switch is vlan 201.

By connecting to the ports of these switches, hosts are able to acquire an IP address on the correct vlan from the Raspberry Pi DHCP server. In order to contact the server, hosts on vlans 50, 100, and 200 must traverse both the OSPF and IS-IS routing domains. In order to implement this, two-way redistribution was configured to allow full connectivity between these two domains. Hosts on the vlans 10 and 150 must also traverse the IS-IS routing domain in order to contact the server.

In addition to DHCP services, the Raspberry Pi was also configured for additional functionality. It is also a fully functioning DNS server, which can perform lookups, and reverse lookups for hosts on the network.

1.2 Router Code Upgrades

Code or IOS version upgrades were performed on all of the Cisco Routers. The IOS version was chosen based upon the following factors:

1. Newest/Latest Supported IOS version
2. Memory/System requirements of the devices

For the Cisco 2821 Routers, 2 different IOS versions were chosen:

15.1.4M9 is the latest recommended IOS version, and was chosen for CENTRAL.

12.4.8 was chosen for the 3 remaining 2821 routers, as it is the latest IOS version suitable for their memory.

The IOS versions were downloaded directly from Cisco's website. In order to transfer the IOS onto the routers, PSCP was used from the command prompt of a management PC. PSCP (the puTTY Secure Copy Client) was used not only for the file transfer to the receiving router, but also to pull the old IOS version from the routers. This was done to ensure that there was a usable IOS version available for the routers in the event of upgrade issues.

The following were configured/enabled on the device prior to the initiation of transfer:

- 1) Hostname
- 2) Reachable IP address
- 3) Username and password
- 4) SSH and local authentication
- 5) SCP services (ip scp server enable)

6) Enable secret password

These configurations are necessary to allow the PSCP transfer. Once these requirements had been satisfied, the necessary files were copied to/from a computer on the same network.

The following screenshots display:

- 1) the syntax for a PSCP transfer to a device
- 2) the syntax for pulling a file from a device using PSCP.

```
C:\Users\50720\Documents\puTTY>pscp.exe -scp C:\Users\50720\Documents\puTTY\c2800nm-advipservicesk9-mz.151-4.M9.bin cisco@192.168.1.1:c2800nm-advipservicesk9-mz.151-4.M9.bin
The server's host key is not cached in the registry. You
have no guarantee that the server is the computer you
think it is.
The server's rsa2 key fingerprint is:
ssh-rsa 512 7e:3a:69:78:0b:e9:16:6a:da:7a:41:1b:cc:ae:25:5f
If you trust this host, enter "y" to add the key to
PuTTY's cache and carry on connecting.
If you want to carry on connecting just once, without
adding the key to the cache, enter "n".
If you do not trust this host, press Return to abandon the
connection.
Store key in cache? (y/n) y
cisco@192.168.1.1's password:
c2800nm-advipservicesk9-m 64416 kB | 193.4 kB/s | ETA: 00:00:00 | 100%
```

```
C:\Users\50720\Documents\puTTY>
C:\Users\50720\Documents\puTTY>pscp.exe -scp cisco@192.168.1.1:c2800nm-advipserv
icesk9-mz.151-4.M9.bin c2800nm-advipservicesk9-mz.151-4.M9.bin
cisco@192.168.1.1's password:
c2800nm-advipservicesk9-m 14080 kB | 251.4 kB/s | ETA: 00:03:20 | 21%
```


The IOS image file was then verified on each router, to ensure that the code was not corrupted in the file transfer process. The following screenshots demonstrate the image verification command syntax and output.

```
R2#verify /md5 flash:c2800nm-advipservicesk9-mz.124-8.bin
```

```
.....Done!  
verify /md5 (flash:c2800nm-advipservicesk9-mz.124-8.bin) = dcce913c6ce518cdca045ec381b7735e
```

The value that is output after the verification is complete can be checked against Cisco's website to ensure that the IOS image is not corrupt. This was performed after each file transfer. None of the transfers had any issues with corrupt code, however it is still a good practice to verify the image. After successful verification, the code was upgraded on each router using the following command syntax:

boot system flash:*filename.bin*

The routers were then reloaded to apply the changes. Neither BRANCH-SW-2950-1 or BRANCH-SW-2950-2 was upgraded, as they were both already running the recommended code.

1.3 Basic Device Configuration

The configurations described in this section apply to all of the Cisco Routers and Switches used in this project. For configurations specific to Switches see Section 1.4, and for configurations specific to Routers, see section 1.5.

Basic Configuration

Basic configurations including hostname, usernames and passwords, console and vty line configurations, and no ip domain-lookup were applied to each device. The following banner was configured as well.

Notice! Unauthorized use of this system is strictly forbidden!

Laura Thompson - CIS Senior Project 2015

IP Host Configuration

In order to easily and quickly remote to each device, some basic ip host configurations were applied to each terminal server. These configuration allow the user to establish remote login sessions to the specified device by entering the ip host name for that device from privileged exec mode. The ip host name configured for each device is different from that devices actual hostname, for simplicity in typing. The configurations are shown below.

```
ip host branch3 192.168.3.1
```

```
ip host branch2 192.168.2.1
```

```
ip host central 192.168.4.1
```

```
ip host sw2 192.168.201.2
```

```
ip host sw1 192.168.101.2
```

```
ip host branch1 192.168.1.1
```

When entering the given ip host name for a device from privileged exec mode, the configured banner is displayed, and the user is then prompted for that devices username and password. Upon successful authentication, the user is now actively connected to the device as shown below.

```
central-rtr-2821#branch2
Trying branch2 (192.168.2.1)... Open

Notice! Unauthorized use of this system is strictly forbidden!

Laura Thompson - CIS Senior Project 2015

User Access Verification

Username: Laura
Password:
branch-rtr-2821-2#
```

1.4 Basic Switch Configuration

Access Port Configuration

The following configurations have been applied to each Access port on BRANCH-SW-2950-1 AND BRANCH-SW-2950-2.

1. Vlan access
2. Spanning-tree portfast
3. BPDUGuard
4. Interface Descriptions

The overall configuration for each access port is as follows. The interface and vlan numbers vary, and the exact configuration below is only an example.

```
interface FastEthernet0/20
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
```

The images below show the vlans and port assignments on each switch

BRANCH-SW-2950-1

```
branch-sw-2950-1(config)#do sh vlan
```

VLAN	Name	Status	Ports
1	default	active	Gi0/2
50	test50	active	Fa0/1, Fa0/2, Fa0/3, Fa0/4 Fa0/5, Fa0/6, Fa0/7, Fa0/8 Fa0/9, Fa0/10, Fa0/11, Fa0/12 Fa0/13, Fa0/14, Fa0/15, Fa0/16
100	test100	active	Fa0/17, Fa0/18, Fa0/19, Fa0/20 Fa0/21, Fa0/22, Fa0/23, Fa0/24 Fa0/25, Fa0/26, Fa0/27, Fa0/28 Fa0/29, Fa0/30, Fa0/31, Fa0/32
101	native	active	
200	test200	active	Fa0/33, Fa0/34, Fa0/35, Fa0/36 Fa0/37, Fa0/38, Fa0/39, Fa0/40 Fa0/41, Fa0/42, Fa0/43, Fa0/44 Fa0/45, Fa0/46, Fa0/47, Fa0/48

BRANCH-SW-2950-2

```
branch-sw-2950-2(config)#do sh vlan
```

VLAN	Name	Status	Ports
1	default	active	
10	test10	active	Fa0/2, Fa0/3, Fa0/4, Fa0/5 Fa0/6, Fa0/7, Fa0/8, Fa0/9 Fa0/10, Fa0/11, Fa0/12
150	test150	active	Fa0/13, Fa0/14, Fa0/15, Fa0/16 Fa0/17, Fa0/18, Fa0/19, Fa0/20 Fa0/21, Fa0/22, Fa0/23, Fa0/24
201	NATIVE	active	

Switch Trunk Port Configuration

The following configurations have been applied to the trunk links on BRANCH-SW-2950-1 AND BRANCH-SW-2950-2

1. Trunking for all vlans
2. Native vlan
3. Interface Descriptions

The configurations for each trunk port are as follows. The router subinterface configurations used to establish router-on-a-stick connectivity can be viewed in the Basic Router Configurations Section.

BRANCH-SW-2950-1

```
interface GigabitEthernet0/1
description uplink to branch-rtr-2821-3
switchport trunk native vlan 101
switchport mode trunk
```

BRANCH-SW-2950-2

```
interface FastEthernet0/1
description uplink to branch-rtr-2821-2
switchport trunk native vlan 201
switchport mode trunk
```

1.5 Basic Router Configuration

Router Interfaces

The Router interfaces were assigned IP addresses according to the IP addressing scheme table that can be found in section 1.1. In addition, each router interface was given an interface description matching the following format:

interface description *to connected_device_name*

Router Subinterfaces

The Router subinterfaces were assigned IP addresses in the same fashion as the physical parent and loopback interfaces. They were also configured with the encapsulation dot1q command to allow full router-on-a-stick connectivity.

BRANCH-SW-2950-1 and BRANCH-SW-2950-2 both have multiple vlans, on which hosts need to acquire IP addresses from the Raspberry Pi DHCP server. In order to allow these DHCP requests to be forwarded to the DHCP server with the correct vlan tag, the ip helper address command was applied to each user vlan subinterface. The command syntax is as follows, with 10.1.100.1 being the IP address of the server:

ip helper-address 10.1.100.1

Applying this command to all router subinterfaces allowed the hosts to reach and communicate with the DHCP server on a different subnet.

1.6 IS-IS Configuration

IS-IS NSAP Address

The IS-IS Routing protocol uses what is referred to as a NSAP (Network Service Access Point) addresses to form and establish neighbor adjacencies. An NSAP address is composed of three different fields merged together to form one long address. The first field is the Area Address. This field identifies the IS-IS area that the address belongs to, and must be identical for all routers in a common area. It is important to note that addresses starting with 48, 49, 50, or 51 are private address spaces. This is a similar concept to IPv4 private addresses.

The second part of an NSAP address is the System ID. The system ID is simply an identifier for the device. Since the system ID is linked to a particular device, the system ID must be unique in an area. The system ID configured for each router was the MAC address of one of its interfaces, as this is a common practice for coming up with System IDs.

The final component of an NSAP address is the N-Selector byte (NSEL). This is used to identify a process. It is important to note that this isn't actually used in routing decisions, but merely as a way to identify a specific process on the device. The NSEL is commonly set to 00, in which case the entire NSAP address is referred to more simply as the NET (Network Entity Title) address. NET was used for this project.

Three different Area Addresses were specified in IS-IS in order to simulate routing between multiple areas. Inter-area routing and Inter-domain routing in IS-IS is commonly called Level 2 routing, while intra-area routing is called Level 1 routing. These types of routes show up in the routing table as L2 and L1 routes, respectively.

For the IS-IS backbone, 48 was used for the Area address. Therefore all three IS-IS routers were configured with a routing process for the main IS-IS domain, and were given a NET address beginning with 48.

For the IS-IS Area containing the Loopback0 of router BRANCH-RTR-2821-1, the Area address 49 was used. This area was also given the name AREA1, which was specified in the router isis command.

Finally, for the IS-IS Area containing the Loopback0 of router BRANCH-RTR-2821-2, the Area address 50 was used. This area was given the name AREA2.

IS-IS Authentication

Similar to many other protocols, IS-IS supports authentication. There are two ways to implement this authentication, and both were used in this project. First, a domain password can be configured. The domain password is used for authentication between all neighbors in the entire IS-IS routing domain. If one of the routers tries to join the domain, and does not have a correct password configured, no adjacencies will be formed. Area specific passwords can also be implemented. These password must match among all routers in the specified area, but do not have to match routers in other areas within the domain. All passwords are case sensitive and must be a single text string.

The examples below show the configurations of BRANCH-RTR-2821-1, BRANCH-RTR-2821-2, and CENTRAL-RTR-2821, respectively. As noted above, the System ID portion of the NET address was derived from the MAC address of one of the router's interfaces. Although these must be unique within an area, they may be duplicated within other areas. Therefore, the same System ID was used in both areas for easier identification. Additionally, router CENTRAL-RTR-2821 has redistribution commands, which will be explained in more detail in section 1.8 Redistribution.

BRANCH-RTR-2821-1

```
router isis
net 48.0019.e869.6539.00
domain-password cisco
area-password CISCO
!
router isis AREA1
net 49.0019.e869.6539.00
is-type level-1
domain-password cisco
area-password CISCO1
```

BRANCH-RTR-2821-2

```
router isis
net 48.001c.f6b1.c5e1.00
domain-password cisco
area-password CISCO
!
router isis AREA2
net 50.001c.f6b1.c5e1.00
is-type level-1
domain-password cisco
area-password CISCO2
```

CENTRAL-RTR-2821

```
router isis
net 48.1c17.d3ec.96a1.00
domain-password cisco
area-password CISCO
redistribute ospf 1
passive-interface FastEthernet0/1/0
```

Advertising Networks

In addition to creating the IS-IS areas, the networks that need to be advertised must also be specified. This is done in interface configuration mode, rather than router configuration mode. Just as in other routing protocols, a network must be advertised in order for it to appear in the routing tables of other routers within the domain.

The configuration of each interface follows, in order to depict which interfaces are being advertised under which area.

BRANCH-RTR-2821-1

```
interface Loopback0
ip address 192.168.1.1 255.255.255.255
ip router isis AREA1
!
interface GigabitEthernet0/0
description to DHCP server
ip address 10.1.100.2 255.255.255.252
ip router isis
duplex auto
speed auto
!
interface GigabitEthernet0/1
description to central-rtr-2821
ip address 10.1.1.2 255.255.255.252
ip router isis
duplex auto
speed auto
```

BRANCH-RTR-2821-2

```
interface Loopback0
ip address 192.168.2.1 255.255.255.255
ip router isis AREA2
!
interface GigabitEthernet0/0
description to central-rtr-2821
ip address 10.1.1.6 255.255.255.252
ip router isis
duplex auto
speed auto
!
interface GigabitEthernet0/1
no ip address
duplex auto
speed auto
!

interface GigabitEthernet0/1.10
encapsulation dot1Q 10
ip address 192.168.10.1 255.255.255.0
ip helper-address 10.1.100.1
ip router isis
!
interface GigabitEthernet0/1.150
encapsulation dot1Q 150
ip address 192.168.150.1 255.255.255.0
ip helper-address 10.1.100.1
ip router isis
!
interface GigabitEthernet0/1.201
encapsulation dot1Q 201 native
ip address 192.168.201.1 255.255.255.0
ip router isis
```

CENTRAL-RTR-2821

```
interface Loopback0
ip address 192.168.4.1 255.255.255.255
ip router isis
!
interface GigabitEthernet0/0
description to branch-rtr-2821-2
ip address 10.1.1.5 255.255.255.252
ip router isis
duplex auto
speed auto
isis priority 100
!
interface GigabitEthernet0/1
description to branch-rtr-2821-1
ip address 10.1.1.1 255.255.255.252
ip router isis
duplex auto
speed auto
isis priority 100
```

IS-IS Priority

IS-IS elects a router known as the DIS, or Designated Intermediate System. This router is responsible for flooding Link State Packets, as well as creating the Pseudonode LSP. This type of LSP is used to describe the overall LAN topology.

The DIS is elected based upon highest priority. If the priorities are the same, the highest MAC address is used instead. As seen in the interface configuration above for router CENTRAL-RTR-2821, an IS-IS interface priority was configured. Since the default priority is 64, giving each interface a priority of 100 ensures that router CENTRAL-RTR-2821 will be the DIS. The screenshots below show the interface priority configurations for each router, as well as other IS-IS information.

CENTRAL-RTR-2821

```
central-rtr-2821#show clns interface gig0/1
GigabitEthernet0/1 is up, line protocol is up
  Checksums enabled, MTU 1497, Encapsulation SAP
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching enabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 47 seconds
  Routing Protocol: IS-IS
    Circuit Type: level-1-2
    Interface number 0x2, local circuit ID 0x2
    Level-1 Metric: 10, Priority: 100, Circuit ID: central-rtr-28.02
    DR ID: central-rtr-28.02
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 1
    Level-2 Metric: 10, Priority: 100, Circuit ID: central-rtr-28.02
    DR ID: central-rtr-28.02
    Level-2 IPv6 Metric: 10
    Number of active level-2 adjacencies: 1
    Next IS-IS LAN Level-1 Hello in 2 seconds
    Next IS-IS LAN Level-2 Hello in 2 seconds
```

```
central-rtr-2821#show clns interface gig0/0
GigabitEthernet0/0 is up, line protocol is up
  Checksums enabled, MTU 1497, Encapsulation SAP
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching enabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 47 seconds
  Routing Protocol: IS-IS
    Circuit Type: level-1-2
    Interface number 0x1, local circuit ID 0x1
    Level-1 Metric: 10, Priority: 100, Circuit ID: central-rtr-28.01
    DR ID: central-rtr-28.01
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 1
    Level-2 Metric: 10, Priority: 100, Circuit ID: central-rtr-28.01
    DR ID: central-rtr-28.01
    Level-2 IPv6 Metric: 10
    Number of active level-2 adjacencies: 1
    Next IS-IS LAN Level-1 Hello in 288 milliseconds
    Next IS-IS LAN Level-2 Hello in 726 milliseconds
```

BRANCH-RTR-2821-1

```
branch-rtr-2821-1# show clns interface gig0/1
GigabitEthernet0/1 is up, line protocol is up
  Checksums enabled, MTU 1497, Encapsulation SAP
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching enabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 24 seconds
  Routing Protocol: IS-IS
    Circuit Type: level-1-2
    Interface number 0x1, local circuit ID 0x2
    Level-1 Metric: 10, Priority: 64, Circuit ID: central-rtr-28.02
    DR ID: central-rtr-28.02
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 1
    Level-2 Metric: 10, Priority: 64, Circuit ID: central-rtr-28.02
    DR ID: central-rtr-28.02
    Level-2 IPv6 Metric: 10
    Number of active level-2 adjacencies: 1
    Next IS-IS LAN Level-1 Hello in 1 seconds
    Next IS-IS LAN Level-2 Hello in 4 seconds
```

BRANCH-RTR-2821-2

```
branch-rtr-2821-2#sh clns interface gig0/0
GigabitEthernet0/0 is up, line protocol is up
  Checksums enabled, MTU 1497, Encapsulation SAP
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching enabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 28 seconds
  Routing Protocol: IS-IS
    Circuit Type: level-1-2
    Interface number 0x0, local circuit ID 0x1
    Level-1 Metric: 10, Priority: 64, Circuit ID: central-rtr-28.01
    DR ID: central-rtr-28.01
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 1
    Level-2 Metric: 10, Priority: 64, Circuit ID: central-rtr-28.01
    DR ID: central-rtr-28.01
    Level-2 IPv6 Metric: 10
    Number of active level-2 adjacencies: 1
    Next IS-IS LAN Level-1 Hello in 5 seconds
    Next IS-IS LAN Level-2 Hello in 186 milliseconds
```

As seen in the screenshots above, the IS-IS interface priority was changed to 100 for both interfaces on the router CENTRAL-RTR-2821. Just below the priority, the DR ID can be viewed (although this router is generally referred to as the DIS or Designated Intermediate System in IS-IS, the output of this command uses the terminology DR instead).

The DR ID that is shown in output of each of these show commands is central-rtr-28.01 or central-rtr-28.02. The .01 and .02 fields are indicative of the Circuit ID, which is automatically assigned to each circuit in IS-IS.

Due to the interface priority configurations previously applied, the router CENTRAL-RTR-2821 is now the designated intermediate system for the backbone IS-IS routing area.

For IS-IS AREA1 and AREA2, each respective router containing the area was used in the name of the Circuit ID. As each of these areas was simulated using a loopback interface with no physically connected routers, the DIS ID is set to 0000.0000.0000.00. This can be determined by examining the same information from the screenshots that follow.

BRANCH-RTR-2821-1 Loopback 0 in AREA1

```
branch-rtr-2821-1#show clns interface lo0
Loopback0 is up, line protocol is up
  Checksums enabled, MTU 1514, Encapsulation LOOPBACK
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching disabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 49 seconds
  Routing Protocol: IS-IS (AREA1)
    Circuit Type: level-1-2
    Interface number 0x0, local circuit ID 0x1
    Level-1 Metric: 10, Priority: 64, Circuit ID: branch-rtr-282.01
    DR ID: 0000.0000.0000.00
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 0
    Next IS-IS LAN Level-1 Hello in 8 seconds
```

BRANCH-RTR-2821-2 Loopback 0 in AREA2

```
branch-rtr-2821-2#show clns interface lo0
Loopback0 is up, line protocol is up
  Checksums enabled, MTU 1514, Encapsulation LOOPBACK
  ERPDUs enabled, min. interval 10 msec.
  CLNS fast switching disabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 4 seconds
  Routing Protocol: IS-IS (AREA2)
    Circuit Type: level-1-2
    Interface number 0x0, local circuit ID 0x1
    Level-1 Metric: 10, Priority: 64, Circuit ID: branch-rtr-282.01
    DR ID: 0000.0000.0000.00
    Level-1 IPv6 Metric: 10
    Number of active level-1 adjacencies: 0
    Next IS-IS LAN Level-1 Hello in 2 seconds
```

The IS-IS configurations explained in this section allowed both BRANCH-RTR-2821-1 and BRANCH-RTR-2821-2 to form neighbor adjacencies with the Designated Intermediate System, CENTRAL-RTR-2821. The IS-IS neighbor adjacency information is displayed below.

CENTRAL-RTR-2821

```
central-rtr-2821#show isis neighbors
```

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
branch-rtr-2821L1		Gi0/0	10.1.1.6	UP	27	central-rtr-28.01
branch-rtr-2821L2		Gi0/0	10.1.1.6	UP	25	central-rtr-28.01
branch-rtr-2821L1		Gi0/1	10.1.1.2	UP	21	central-rtr-28.02
branch-rtr-2821L2		Gi0/1	10.1.1.2	UP	24	central-rtr-28.02

BRANCH-RTR-2821-1

```
branch-rtr-2821-1#show isis neigh
```

Area null:

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
central-rtr-282L1		Gi0/1	10.1.1.1	UP	9	central-rtr-28.02
central-rtr-282L2		Gi0/1	10.1.1.1	UP	8	central-rtr-28.02

Area AREA1:

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
-----------	------	-----------	------------	-------	----------	------------

BRANCH-RTR-2821-2

```
branch-rtr-2821-2#show isis neigh
```

Area null:

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
central-rtr-282L1		Gi0/0	10.1.1.5	UP	9	central-rtr-28.01
central-rtr-282L2		Gi0/0	10.1.1.5	UP	8	central-rtr-28.01

Area AREA2:

System Id	Type	Interface	IP Address	State	Holdtime	Circuit Id
-----------	------	-----------	------------	-------	----------	------------

The routers maintain separate adjacencies for Level 1 and Level 2 neighbor relationships, even for the same physical neighbor. Each router also separates the adjacencies according to the Area, listing the unnamed backbone area as Area null. Had this area been given a name, it would appear here in place of null.

1.7 OSPF Configuration

OSPF Configuration

The OSPF configurations on both BRANCH-RTR-2821-3 and CENTRAL-RTR-2821 were kept relatively simple. Only Area 0 was implemented due to the small size of the network. The link between the two routers was advertised in the OSPF process on each router. BRANCH-RTR-2821-3 also advertised its loopback address, as well as the attached vlan networks. These configurations combined with redistribution allow these remote networks to be accessible from the IS-IS routing domain.

The OSPF process configuration on each router is shown below. The redistribution configurations will be discussed in the next section, 1.8 Redistribution.

BRANCH-RTR-2821-3

```
router ospf 1
log-adjacency-changes
area 0 authentication message-digest
network 172.16.0.0 0.0.0.3 area 0
network 192.168.3.1 0.0.0.0 area 0
network 192.168.0.0 0.0.255.255 area 0
```

CENTRAL-RTR-2821

```
router ospf 1
area 0 authentication message-digest
redistribute connected subnets
redistribute isis level-1-2 subnets
passive-interface GigabitEthernet0/0
passive-interface GigabitEthernet0/1
network 172.16.0.0 0.0.0.3 area 0
```

MD5 Authentication for the OSPF routers was also configured by setting the key string on the interfaces, and enabling MD5 authentication under the OSPF process. The interface configurations are shown below.

CENTRAL-RTR-2821

```
interface FastEthernet0/1/0
description to branch-rtr-2821-3
ip address 172.16.0.1 255.255.255.252
ip ospf message-digest-key 1 md5 7 14141B180F0B
duplex auto
speed auto
```

BRANCH-RTR-2821-3

```
interface GigabitEthernet0/0
description to central-rtr-2821
ip address 172.16.0.2 255.255.255.252
ip ospf message-digest-key 1 md5 7 110A1016141D
duplex auto
speed auto
```

After configuring the OSPF process on CENTRAL-RTR-2821 and BRANCH-RTR-2821-3, an OSPF adjacency was formed. In the output of the show ip ospf neighbors command below, it can be viewed that CENTRAL-RTR-2821 is the Designated Router (DR), and BRANCH-RTR-2821-3 is the Backup Designated Router (BDR).

```
central-rtr-2821#show ip ospf neigh
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.3.1	1	FULL/BDR	00:00:32	172.16.0.2	FastEthernet0/1/0

```
branch-rtr-2821-3#show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.4.1	1	FULL/DR	00:00:31	172.16.0.1	GigabitEthernet0/0

1.8 Redistribution

IS-IS Redistribution

IS-IS Redistribution was configured within the OSPF routing process of the redistributing router. In order to allow full connectivity within the network and between the routing domains, several pieces of configuration were required.

First, redistribution of IS-IS level 1 and level 2 routes was configured using the following command:

```
redistribute isis level-1-2 subnets
```

The level-1-2 keyword declares that both level 1 and level 2 routes should be redistributed. Since the AREA1 and AREA2 subdomains appear as level 2 routes to CENTRAL-RTR-2821, and the main IS-IS domain appears as level 1 routes, this keyword is necessary for full redistribution. Without it, only level 1 routes would be redistributed and devices in the OSPF domain would no longer have connectivity to AREA1 or AREA2. The subnets keyword is necessary in order for all classless subnets to be redistributed into the OSPF domain.

After applying this redistribution command, there were still a few remote networks that were unreachable from the OSPF domain. After verifying that these networks were being advertised in IS-IS, the routing table was used for further troubleshooting. It was discovered that these networks were not being redistributed because they appeared in the routing table of the ASBR as connected routes.

In order to solve this issue, an additional redistribution command was used to ensure that full connectivity would be achieved. The following command allowed the remaining connected routes to be redistributed into OSPF.

redistribute connected subnets

After applying this command, the connected routes could then be seen in the routing table of router BRANCH-RTR-2821-3.

OSPF Redistribution

After having redistributed the IS-IS routes, two way redistribution was configured for full connectivity both ways. Basic redistribution of OSPF routes into IS-IS was configured. The routing tables of each router are shown below with brief explanations of the types of routes that are seen.

CENTRAL-RTR-2821

```
central-rtr-2821#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
       + - replicated route, % - next hop override

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C       10.1.1.0/30 is directly connected, GigabitEthernet0/1
L       10.1.1.1/32 is directly connected, GigabitEthernet0/1
C       10.1.1.4/30 is directly connected, GigabitEthernet0/0
L       10.1.1.5/32 is directly connected, GigabitEthernet0/0
i L1    10.1.100.0/30 [115/20] via 10.1.1.2, 00:04:56, GigabitEthernet0/1
172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, FastEthernet0/1/0
L       172.16.0.1/32 is directly connected, FastEthernet0/1/0
192.168.1.0/32 is subnetted, 1 subnets
i L2    192.168.1.1 [115/20] via 10.1.1.2, 03:59:41, GigabitEthernet0/1
192.168.2.0/32 is subnetted, 1 subnets
i L2    192.168.2.1 [115/20] via 10.1.1.6, 00:04:17, GigabitEthernet0/0
192.168.3.0/32 is subnetted, 1 subnets
O       192.168.3.1 [110/2] via 172.16.0.2, 03:59:02, FastEthernet0/1/0
192.168.4.0/32 is subnetted, 1 subnets
C       192.168.4.1 is directly connected, Loopback0
i L1    192.168.10.0/24 [115/20] via 10.1.1.6, 00:04:17, GigabitEthernet0/0
O       192.168.50.0/24 [110/2] via 172.16.0.2, 00:04:22, FastEthernet0/1/0
O       192.168.100.0/24 [110/2] via 172.16.0.2, 00:04:22, FastEthernet0/1/0
O       192.168.101.0/24 [110/2] via 172.16.0.2, 00:04:22, FastEthernet0/1/0
i L1    192.168.150.0/24 [115/20] via 10.1.1.6, 00:04:17, GigabitEthernet0/0
O       192.168.200.0/24 [110/2] via 172.16.0.2, 00:04:22, FastEthernet0/1/0
i L1    192.168.201.0/24 [115/20] via 10.1.1.6, 00:04:17, GigabitEthernet0/0
central-rtr-2821#
```

In router CENTRAL-RTR-2821's routing table, all of the IS-IS routes appear with the code "i". The additional codes, L1 and L2 represent Level 1 and Level 2 routes respectively. The routes to 192.168.1.1 and 192.168.1.1 both appear as L2 routes, because these networks are part of IS-IS AREA1 and AREA2.

BRANCH-RTR-2821-1

```
branch-rtr-2821-1#sh ip route
Codes: 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

Gateway of last resort is not set

i L1 192.168.150.0/24 [115/30] via 10.1.1.1, GigabitEthernet0/1
i L1 192.168.10.0/24 [115/30] via 10.1.1.1, GigabitEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
i L1    172.16.0.0 [115/10] via 10.1.1.1, GigabitEthernet0/1
i L2 192.168.200.0/24 [115/10] via 10.1.1.1, GigabitEthernet0/1
    192.168.4.0/32 is subnetted, 1 subnets
i L1    192.168.4.1 [115/20] via 10.1.1.1, GigabitEthernet0/1
i L1 192.168.201.0/24 [115/30] via 10.1.1.1, GigabitEthernet0/1
    10.0.0.0/30 is subnetted, 3 subnets
C      10.1.1.0 is directly connected, GigabitEthernet0/1
i L1    10.1.1.4 [115/20] via 10.1.1.1, GigabitEthernet0/1
C      10.1.100.0 is directly connected, GigabitEthernet0/0
i L2 192.168.50.0/24 [115/10] via 10.1.1.1, GigabitEthernet0/1
    192.168.1.0/32 is subnetted, 1 subnets
C      192.168.1.1 is directly connected, Loopback0
    192.168.2.0/32 is subnetted, 1 subnets
i L2    192.168.2.1 [115/30] via 10.1.1.1, GigabitEthernet0/1
i L2 192.168.100.0/24 [115/10] via 10.1.1.1, GigabitEthernet0/1
    192.168.3.0/32 is subnetted, 1 subnets
i L2    192.168.3.1 [115/10] via 10.1.1.1, GigabitEthernet0/1
i L2 192.168.101.0/24 [115/10] via 10.1.1.1, GigabitEthernet0/1
```

In the routing table of BRANCH-RTR-2821-1, some IS-IS routes also appear as L2 routes. These are the routes that are being redistributed into IS-IS from OSPF. Since these routes are not a part of the IS-IS domain, they will also appear as L2 routes in the routing table.

BRANCH-RTR-2821-2

```
branch-rtr-2821-2#sh ip route
Codes: 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

Gateway of last resort is not set

C      192.168.150.0/24 is directly connected, GigabitEthernet0/1.150
C      192.168.10.0/24 is directly connected, GigabitEthernet0/1.10
      172.16.0.0/30 is subnetted, 1 subnets
i L1    172.16.0.0 [115/10] via 10.1.1.5, GigabitEthernet0/0
i L2 192.168.200.0/24 [115/10] via 10.1.1.5, GigabitEthernet0/0
      192.168.4.0/32 is subnetted, 1 subnets
i L1    192.168.4.1 [115/20] via 10.1.1.5, GigabitEthernet0/0
C      192.168.201.0/24 is directly connected, GigabitEthernet0/1.201
      10.0.0.0/30 is subnetted, 3 subnets
i L1    10.1.1.0 [115/20] via 10.1.1.5, GigabitEthernet0/0
C      10.1.1.4 is directly connected, GigabitEthernet0/0
i L1    10.1.100.0 [115/30] via 10.1.1.5, GigabitEthernet0/0
i L2 192.168.50.0/24 [115/10] via 10.1.1.5, GigabitEthernet0/0
      192.168.1.0/32 is subnetted, 1 subnets
i L2    192.168.1.1 [115/30] via 10.1.1.5, GigabitEthernet0/0
      192.168.2.0/32 is subnetted, 1 subnets
C      192.168.2.1 is directly connected, Loopback0
i L2 192.168.100.0/24 [115/10] via 10.1.1.5, GigabitEthernet0/0
      192.168.3.0/32 is subnetted, 1 subnets
i L2    192.168.3.1 [115/10] via 10.1.1.5, GigabitEthernet0/0
i L2 192.168.101.0/24 [115/10] via 10.1.1.5, GigabitEthernet0/0
branch-rtr-2821-2#
```

The L2 routes to the OSPF networks appear in router BRANCH-RTR-2821's routing table as well. As pictured above, the administrative distance for all IS-IS routes is 115.

BRANCH-RTR-2821-3

```
branch-rtr-2821-3#sh ip route
Codes: 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

Gateway of last resort is not set

O E2 192.168.150.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
O E2 192.168.10.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
    172.16.0.0/30 is subnetted, 1 subnets
C     172.16.0.0 is directly connected, GigabitEthernet0/0
C     192.168.200.0/24 is directly connected, GigabitEthernet0/1.200
    192.168.4.0/32 is subnetted, 1 subnets
O E2   192.168.4.1 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
O E2 192.168.201.0/24 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
    10.0.0.0/30 is subnetted, 3 subnets
O E2   10.1.1.0 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
O E2   10.1.1.4 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
O E2   10.1.100.0 [110/20] via 172.16.0.1, 00:10:42, GigabitEthernet0/0
C     192.168.50.0/24 is directly connected, GigabitEthernet0/1.50
    192.168.1.0/32 is subnetted, 1 subnets
O E2   192.168.1.1 [110/20] via 172.16.0.1, 00:10:43, GigabitEthernet0/0
    192.168.2.0/32 is subnetted, 1 subnets
O E2   192.168.2.1 [110/20] via 172.16.0.1, 00:10:43, GigabitEthernet0/0
C     192.168.100.0/24 is directly connected, GigabitEthernet0/1.100
    192.168.3.0/32 is subnetted, 1 subnets
C     192.168.3.1 is directly connected, Loopback0
C     192.168.101.0/24 is directly connected, GigabitEthernet0/1.101
branch-rtr-2821-3#
```

In the routing table of BRANCH-RTR-2821-3, the redistributed IS-IS routes are coded as O E2 routes. All of these routes were redistributed into OSPF from IS-IS.

1.9 Complete Device Configuration

This section includes the complete configuration of all devices. For explanations regarding specific pieces of configuration, see the previous sections.

CENTRAL-RTR-2821

```
central-rtr-2821#show run
```

```
Building configuration...
```

```
Current configuration : 2065 bytes
```

```
!
```

```
version 15.1
```

```
service timestamps debug datetime msec
```

```
service timestamps log datetime msec
```

```
service password-encryption
```

```
!
```

```
hostname central-rtr-2821
```

```
!
```

```
boot-start-marker
```

```
boot-end-marker
```

```
!
```

```
!
```

```
!
```

```
no aaa new-model
```

```
!
```

```
!
```

```
dot11 syslog
```

```
ip source-route
```

```
!
```

```
!
```

```
ip cef
```

```
!
```

```
!
```

```
!
```

```
no ip domain lookup
```

```
ip domain name Thompson.test
```

```
ip host branch1 192.168.1.1
```

```
ip host branch2 192.168.2.1
```

```
ip host branch3 192.168.3.1
```

```
ip host sw2 192.168.201.2
```

```
ip host sw1 192.168.101.2
```

```
no ipv6 cef
```

```

!
multilink bundle-name authenticated
!
!
voice-card 0
!
crypto pki token default removal timeout 0
!
!
license udi pid CISCO2821 sn FTX1425A0YA
username Laura privilege 15 secret 5 $1$kEP8$5O2T9IYee0VLCWC12jE3u0
!
redundancy
!
!
!
interface Loopback0
ip address 192.168.4.1 255.255.255.255
ip router isis
!
interface GigabitEthernet0/0
description to branch-rtr-2821-2
ip address 10.1.1.5 255.255.255.252
ip router isis
duplex auto
speed auto
!
interface GigabitEthernet0/1
description to branch-rtr-2821-1
ip address 10.1.1.1 255.255.255.252
ip router isis
duplex auto
speed auto
!
interface FastEthernet0/1/0
description to branch-rtr-2821-3
ip address 172.16.0.1 255.255.255.252
ip ospf message-digest-key 1 md5 7 14141B180F0B
duplex auto
speed auto
!
router ospf 1
area 0 authentication message-digest
redistribute connected subnets
redistribute isis level-1-2 subnets
passive-interface GigabitEthernet0/0

```

```

passive-interface GigabitEthernet0/1
network 172.16.0.0 0.0.0.3 area 0
!
router isis
net 48.1c17.d3ec.96a1.00
domain-password cisco
area-password CISCO
redistribute ospf 1
passive-interface FastEthernet0/1/0
!
ip forward-protocol nd
no ip http server
no ip http secure-server
!
!
!
logging source-interface Loopback0
!
!
control-plane
!
!
mgcp profile default
!
!
banner motd ^C
Notice! Unauthorized use of this system is strictly forbidden!

```

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```

^C
!
line con 0
line aux 0
line vty 0 4
exec-timeout 50 0
login local
transport input telnet ssh
!
scheduler allocate 20000 1000
end

```

BRANCH-RTR-2821-1

branch-rtr-2821-1#show run

Building configuration...

Current configuration : 1514 bytes

!

version 12.4

service timestamps debug datetime msec

service timestamps log datetime msec

service password-encryption

!

hostname branch-rtr-2821-1

!

boot-start-marker

boot-end-marker

!

no aaa new-model

ip subnet-zero

!

!

ip cef

!

!

no ip domain lookup

ip domain name Thompson.test

ip host branch1 192.168.1.1

ip host branch2 192.168.2.1

ip host branch3 192.168.3.1

ip host sw2 192.168.201.2

ip host sw1 192.168.101.2

ip host central 192.168.4.1

no ftp-server write-enable

!

!

username Laura privilege 15 secret 5 \$1\$QMKo\$oS1jfuVLMMeUPRQJZ84Vcd/

!

!

interface Loopback0

ip address 192.168.1.1 255.255.255.255

ip router isis AREA1

!

interface GigabitEthernet0/0

description to DHCP server

ip address 10.1.100.2 255.255.255.252

```

ip router isis
duplex auto
speed auto
!
interface GigabitEthernet0/1
description to central-rtr-2821
ip address 10.1.1.2 255.255.255.252
ip router isis
duplex auto
speed auto
!
router isis
net 48.0019.e869.6539.00
domain-password cisco
area-password CISCO
!
router isis AREA1
net 49.0019.e869.6539.00
is-type level-1
domain-password cisco
area-password CISCO1
!
ip classless
!
ip http server
no ip http secure-server
!
control-plane
!
banner motd ^C
Notice! Unauthorized use of this system is strictly forbidden!

```

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```

^C
!
line con 0
logging synchronous
line aux 0
line vty 0 4
exec-timeout 50 0
login local
transport input telnet ssh
!
scheduler allocate 20000 1000
!
end

```


BRANCH-RTR-2821-2

branch-rtr-2821-2#show run

Building configuration...

Current configuration : 1816 bytes

!

version 12.4

service timestamps debug datetime msec

service timestamps log datetime msec

service password-encryption

!

hostname branch-rtr-2821-2

!

boot-start-marker

boot-end-marker

!

!

no aaa new-model

!

resource policy

!

!

!

ip cef

!

!

no ip domain lookup

ip domain name Thompson.test

ip host branch1 192.168.1.1

ip host branch3 192.168.3.1

ip host sw2 192.168.201.2

ip host sw1 192.168.101.2

ip host central 192.168.4.1

!

!

voice-card 0

no dspfarm

!

!

username Laura privilege 15 secret 5 \$1\$YieH\$gEUsf5T4MgzttezbheDB1

!

!

interface Loopback0

ip address 192.168.2.1 255.255.255.255

ip router isis AREA2

```

!
interface GigabitEthernet0/0
description to central-rtr-2821
ip address 10.1.1.6 255.255.255.252
ip router isis
duplex auto
speed auto
!
interface GigabitEthernet0/1
no ip address
duplex auto
speed auto
!
interface GigabitEthernet0/1.10
encapsulation dot1Q 10
ip address 192.168.10.1 255.255.255.0
ip helper-address 10.1.100.1
ip router isis
!
interface GigabitEthernet0/1.150
encapsulation dot1Q 150
ip address 192.168.150.1 255.255.255.0
ip helper-address 10.1.100.1
ip router isis
!
interface GigabitEthernet0/1.201
encapsulation dot1Q 201 native
ip address 192.168.201.1 255.255.255.0
ip router isis
!
router isis
net 48.001c.f6b1.c5e1.00
domain-password cisco
area-password CISCO
!
router isis AREA2
net 50.001c.f6b1.c5e1.00
is-type level-1
domain-password cisco
area-password CISCO2
!
!
!
ip http server
no ip http secure-server
!

```

```
!  
!  
control-plane  
!  
!  
banner motd ^C  
Notice! Unauthorized use of this system is strictly forbidden!
```

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```
^C  
!  
line con 0  
  logging synchronous  
line aux 0  
line vty 0 4  
  exec-timeout 50 0  
  login local  
  transport input telnet ssh  
!  
scheduler allocate 20000 1000  
!  
end
```

BRANCH-RTR-2821-3

branch-rtr-2821-3#sho run

Building configuration...

Current configuration : 1982 bytes

!

version 12.4

service timestamps debug datetime msec

service timestamps log datetime msec

service password-encryption

!

hostname branch-rtr-2821-3

!

boot-start-marker

boot-end-marker

!

!

no aaa new-model

!

resource policy

!

!

ip cef

!

!

no ip domain lookup

ip domain name Thompson.test

ip host branch1 192.168.1.1

ip host sw2 192.168.201.2

ip host sw1 192.168.101.2

ip host central 192.168.4.1

ip host branch2 192.168.2.1

!

!

voice-card 0

no dspfarm

!

!

username Laura privilege 15 secret 5 \$1\$9VXY\$OeOvKlOwgJi29kmgH19D.1

!

!

interface Loopback0

ip address 192.168.3.1 255.255.255.255

!

```

!
interface GigabitEthernet0/0
description to central-rtr-2821
ip address 172.16.0.2 255.255.255.252
ip ospf message-digest-key 1 md5 7 110A1016141D
duplex auto
speed auto
!
interface GigabitEthernet0/1
description to branch-sw-2950
no ip address
ip helper-address 10.1.100.1
duplex auto
speed auto
!
interface GigabitEthernet0/1.50
encapsulation dot1Q 50
ip address 192.168.50.1 255.255.255.0
ip helper-address 10.1.100.1
!
interface GigabitEthernet0/1.100
encapsulation dot1Q 100
ip address 192.168.100.1 255.255.255.0
ip helper-address 10.1.100.1
!
interface GigabitEthernet0/1.101
encapsulation dot1Q 101 native
ip address 192.168.101.1 255.255.255.0
!
interface GigabitEthernet0/1.200
encapsulation dot1Q 200
ip address 192.168.200.1 255.255.255.0
ip helper-address 10.1.100.1
!
router ospf 1
log-adjacency-changes
area 0 authentication message-digest
network 172.16.0.0 0.0.0.3 area 0
network 192.168.3.1 0.0.0.0 area 0
network 192.168.0.0 0.0.255.255 area 0
!
!
!
ip http server
no ip http secure-server
!

```

```
!  
control-plane  
!  
!  
!  
banner motd ^C  
Notice! Unauthorized use of this system is strictly forbidden!
```

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```
^C  
!  
line con 0  
  logging synchronous  
line aux 0  
line vty 0 4  
  exec-timeout 50 0  
  login local  
  transport input telnet ssh  
!  
scheduler allocate 20000 1000  
!  
end
```

BRANCH-SW-2950-1

branch-sw-2950-1#show run

Building configuration...

Current configuration : 9068 bytes

!

version 12.1

no service pad

service timestamps debug uptime

service timestamps log uptime

service password-encryption

!

hostname branch-sw-2950-1

!

!

username Laura privilege 15 secret 5 \$1\$4OA4\$2lgf/WP64FXXX2a/g6mz51

ip subnet-zero

ip dhcp relay information option

ip dhcp relay forward spanning-tree

!

ip host branch3 192.168.3.1

ip host branch2 192.168.2.1

ip host central 192.168.4.1

ip host sw2 192.168.201.2

ip host branch1 192.168.1.1

!

spanning-tree mode pvst

no spanning-tree optimize bpdu transmission

spanning-tree extend system-id

!

!

!

!

interface FastEthernet0/1

description vlan 50 ports

switchport access vlan 50

switchport mode access

spanning-tree portfast

spanning-tree bpduguard enable

!

interface FastEthernet0/2

description vlan 50 ports

switchport access vlan 50

switchport mode access

```

spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/3
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/4
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/5
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/6
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/7
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/8
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/9

```



```

description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/10
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/11
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/12
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/13
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/14
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/15
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast

```

```

spanning-tree bpduguard enable
!
interface FastEthernet0/16
description vlan 50 ports
switchport access vlan 50
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/17
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/18
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/19
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/20
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/21
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/22
description vlan 100 ports

```

```

switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/23
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/24
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/25
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/26
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/27
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/28
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable

```

```

!
interface FastEthernet0/29
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/30
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/31
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/32
description vlan 100 ports
switchport access vlan 100
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/33
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/34
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/35
description vlan 200 ports
switchport access vlan 200

```

```

switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/36
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/37
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/38
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/39
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/40
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/41
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!

```

```

interface FastEthernet0/42
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/43
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/44
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/45
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/46
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/47
description vlan 200 ports
switchport access vlan 200
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/48
description vlan 200 ports
switchport access vlan 200
switchport mode access

```

```
spanning-tree portfast
spanning-tree bpduguard enable
!
interface GigabitEthernet0/1
description uplink to branch-rtr-2821-3
switchport trunk native vlan 101
switchport mode trunk
!
interface GigabitEthernet0/2
description interface not in use
shutdown
!
interface Vlan1
no ip address
no ip route-cache
shutdown
!
interface Vlan101
ip address 192.168.101.2 255.255.255.0
no ip route-cache
!
ip default-gateway 192.168.101.1
no ip http server
banner motd ^C
Notice! Unauthorized use of this system is strictly forbidden!
```

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```
^C
!
line con 0
logging synchronous
line vty 0 4
login local
transport input telnet
line vty 5 15
login
!
!
end
```

BRANCH-SW-2950-2

branch-sw-2950-2#show run

Building configuration...

Current configuration : 4809 bytes

!

version 12.1

no service pad

service timestamps debug uptime

service timestamps log uptime

service password-encryption

!

hostname branch-sw-2950-2

!

!

username Laura privilege 15 secret 5 \$1\$G58H\$/GyEAs366OTsrUheil0Z0

ip subnet-zero

!

ip host branch1 192.168.1.1

ip host branch3 192.168.3.1

ip host branch2 192.168.2.1

ip host central 192.168.4.1

ip host sw1 192.168.101.2

ip domain-name Thompson.test

!

spanning-tree mode pvst

no spanning-tree optimize bpdu transmission

spanning-tree extend system-id

!

!

!

!

interface FastEthernet0/1

description uplink to branch-rtr-2821-2

switchport trunk native vlan 201

switchport mode trunk

!

interface FastEthernet0/2

description vlan 10 ports

switchport access vlan 10

switchport mode access

spanning-tree portfast

spanning-tree bpduguard enable

!


```

interface FastEthernet0/3
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/4
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/5
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/6
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/7
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/8
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/9
description vlan 10 ports
switchport access vlan 10
switchport mode access

```

```
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/10
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/11
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/12
description vlan 10 ports
switchport access vlan 10
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/13
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/14
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/15
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/16
```

```

description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/17
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/18
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/19
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/20
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/21
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/22
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast

```

```

spanning-tree bpduguard enable
!
interface FastEthernet0/23
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface FastEthernet0/24
description vlan 150 ports
switchport access vlan 150
switchport mode access
spanning-tree portfast
spanning-tree bpduguard enable
!
interface Vlan1
no ip address
no ip route-cache
shutdown
!
interface Vlan201
ip address 192.168.201.2 255.255.255.0
no ip route-cache
!
ip default-gateway 192.168.201.1
ip http server
banner motd ^C
Notice! Unauthorized use of this system is strictly forbidden!

```

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```

^C
!
line con 0
line vty 0 4
login local
transport input telnet
line vty 5 15
login
!
!
end

```

2.1 Raspberry Pi Setup and dnsmasq Install

Operating System Install

The initial task involved with the Raspberry Pi was the Operating System install. After researching different OS versions available for the Raspberry Pi, Raspbian was chosen. Raspbian is a Debian distribution available for the Pi, and it was downloaded from the Raspberry Pi website and installed.

System Updates

Once the Pi had been connected to the internet, it was necessary to check for and download any available updates, using the following command syntax:

```
root@raspberrypi:~# sudo apt-get update
Hit http://mirrordirector.raspbian.org wheezy Release.gpg
Hit http://raspberrypi.collabora.com wheezy Release.gpg
Hit http://archive.raspberrypi.org wheezy Release.gpg
Hit http://mirrordirector.raspbian.org wheezy Release
Hit http://raspberrypi.collabora.com wheezy Release
Hit http://archive.raspberrypi.org wheezy Release
Hit http://mirrordirector.raspbian.org wheezy/main armhf Packages
Hit http://raspberrypi.collabora.com wheezy/rpi armhf Packages
Hit http://mirrordirector.raspbian.org wheezy/contrib armhf Packages
Hit http://archive.raspberrypi.org wheezy/main armhf Packages
Hit http://mirrordirector.raspbian.org wheezy/non-free armhf Packages
Hit http://mirrordirector.raspbian.org wheezy/rpi armhf Packages
Ign http://raspberrypi.collabora.com wheezy/rpi Translation-en_GB
Ign http://raspberrypi.collabora.com wheezy/rpi Translation-en
Ign http://archive.raspberrypi.org wheezy/main Translation-en_GB
Ign http://archive.raspberrypi.org wheezy/main Translation-en
Ign http://mirrordirector.raspbian.org wheezy/contrib Translation-en_GB
Ign http://mirrordirector.raspbian.org wheezy/contrib Translation-en
Ign http://mirrordirector.raspbian.org wheezy/main Translation-en_GB
Ign http://mirrordirector.raspbian.org wheezy/main Translation-en
Ign http://mirrordirector.raspbian.org wheezy/non-free Translation-en_GB
Ign http://mirrordirector.raspbian.org wheezy/non-free Translation-en
Ign http://mirrordirector.raspbian.org wheezy/rpi Translation-en_GB
Ign http://mirrordirector.raspbian.org wheezy/rpi Translation-en
Reading package lists... Done
root@raspberrypi:~#
```

Dnsmasq Installation

Some initial research led to several different DHCP Server programs available for the Raspberry Pi. Dnsmasq is a very lightweight service that consumes low resources and is therefore very efficient. Not only is it equipped with the functionality and capability to provide DHCP services for small home networks, but it can also provide DNS services as well.

Because of its efficiency, ease of use and configuration, and overall usefulness, dnsmasq was chosen to provide DHCP services for this network. The following command syntax was used to install dnsmasq:

```
root@raspberrypi:~# sudo apt-get install dnsmasq
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  dnsmasq-base libnetfilter-conntrack3
Suggested packages:
  resolvconf
The following NEW packages will be installed:
  dnsmasq dnsmasq-base libnetfilter-conntrack3
0 upgraded, 3 newly installed, 0 to remove and 8 not upgraded.
Need to get 405 kB of archives.
After this operation, 984 kB of additional disk space will be used.
Do you want to continue [Y/n]? y
Get:1 http://mirrordirector.raspbian.org/raspbian/ wheezy/main libnetfilter-conntrack3 armhf 1.0.1-1 [32.2 kB]
Get:2 http://mirrordirector.raspbian.org/raspbian/ wheezy/main dnsmasq-base armhf 2.62-3+deb7u1 [356 kB]
Get:3 http://mirrordirector.raspbian.org/raspbian/ wheezy/main dnsmasq all 2.62-3+deb7u1 [16.4 kB]
Fetched 405 kB in 1s (344 kB/s)
Selecting previously unselected package libnetfilter-conntrack3:armhf.
(Reading database ... 76926 files and directories currently installed.)
Unpacking libnetfilter-conntrack3:armhf (from ../libnetfilter-conntrack3_1.0.1-1_armhf.deb) ...
Selecting previously unselected package dnsmasq-base.
Unpacking dnsmasq-base (from ../dnsmasq-base_2.62-3+deb7u1_armhf.deb) ...
Selecting previously unselected package dnsmasq.
Unpacking dnsmasq (from ../dnsmasq_2.62-3+deb7u1_all.deb) ...
Processing triggers for man-db ...
Setting up libnetfilter-conntrack3:armhf (1.0.1-1) ...
Setting up dnsmasq-base (2.62-3+deb7u1) ...
Setting up dnsmasq (2.62-3+deb7u1) ...
[ ok ] Starting DNS forwarder and DHCP server: dnsmasq.
root@raspberrypi:~#
```

Dnsmasq.conf File

The configuration of DHCP and DNS services is done within the dnsmasq.conf file. By default, this file can be located in the etc directory of root.

```
root@raspberrypi:~# cd /
root@raspberrypi:/# ls
bin  boot  dev  etc  home  lib  lost+found  media  mnt  opt  proc  root  run  sbin  screenshots  selinux  srv  sys
root@raspberrypi:/# cd etc
root@raspberrypi:/etc# ls
adduser.conf      default      gnome        iproute2      magic.mime    pam.d         rcS.d
alternatives      deluser.conf groff         issue         mailcap       papersize     request
apm               dhcp         group        issue.net     mailcap.order passwd        resolv
apparmor.d        dhcp3        group-       issue.net.orig manpath.config passwd-       resolv.
apt               dictionaries-common gshadow      issue.orig    menu          perl          rmt
avahi             dillo        gshadow-     kbd           menu-methods  plymouth      rpc
bash.bashrc       dnsmasq.conf gssapi_mech.conf kernel         mime.types    pm            rpi-iss
bash_completion   dnsmasq.d    gtk-2.0      ldap          mke2fs.conf  polkit-1      rsyslog
```

For simplicity, the file was kept in this location for the duration of the project.

Network Configuration

After the necessary downloads had completed, the Raspberry Pi was disconnected from the Internet and given a static IP address according to the topology and IP addressing scheme previously designed.

```
root@raspberrypi:~# ifconfig
eth0      Link encap:Ethernet  HWaddr b8:27:eb:04:92:f8
          inet addr:10.1.100.1  Bcast:10.1.100.3  Mask:255.255.255.252
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:273  errors:0  dropped:0  overruns:0  frame:0
          TX packets:191  errors:0  dropped:0  overruns:0  carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:22930 (22.3 KiB)  TX bytes:24036 (23.4 KiB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:2  errors:0  dropped:0  overruns:0  frame:0
          TX packets:2  errors:0  dropped:0  overruns:0  carrier:0
          collisions:0 txqueuelen:0
          RX bytes:190 (190.0 B)  TX bytes:190 (190.0 B)

root@raspberrypi:~# █
```

A default route was also added to the Raspberry Pi to allow it to have full connectivity and network reachability. The screenshots below display the syntax that was used as well as the ip routing table.

```
root@raspberrypi:~# route add default gw 10.1.100.2 eth0
```

```
root@raspberrypi:~# route
Kernel IP routing table
Destination Gateway Genmask Flags Metric Ref Use Iface
default 10.1.100.2 0.0.0.0 UG 0 0 0 eth0
10.1.100.0 * 255.255.255.252 U 0 0 0 eth0
root@raspberrypi:~#
```

The first entry seen in the routing table appears as a result of the route command previously entered. As pictured, the route is specified as a default route, and the gateway is the next hop address of 10.1.100.2.

2.2 DHCP and DNS Configuration

DHCP Configuration

Similar to many other DHCP services, dnsmasq works by first specifying a range or ranges of addresses that may be dynamically assigned to hosts. Although some variations in the syntax can still possibly produce working results, the most reliable and correct syntax is as follows:

if=interface_name

dhcp-range=tag,starting_ip,ending_ip,subnet,_mask,lease_time

For this network, the DHCP server needed to be able to assign addresses for five different subnets, therefore five different ranges needed to be specified. The ranges were created according to the following rules:

1. Create a range for each vlan on the remote switches.
2. Exclude the first 10 addresses for network use.

The following displays the configuration for each of the DHCP ranges for this network:

```
root@raspberrypi:/etc# cat dnsmasq.conf
interface=eth0
dhcp-range=vlan10,192.168.10.10,192.168.10.254,255.255.255.0,24h
dhcp-range=vlan50,192.168.50.10,192.168.50.254,255.255.255.0,24h
dhcp-range=vlan100,192.168.100.10,192.168.100.254,255.255.255.0,24h
dhcp-range=vlan150,192.168.150.10,192.168.150.254,255.255.255.0,24h
dhcp-range=vlan200,192.168.200.10,192.168.200.254,255.255.255.0,24h
log-dhcp

domain=Thompson.test
expand-hosts
local=/Thompson.test/

interface=eth0
dhcp-option=vlan10,6,10.1.100.1
dhcp-option=vlan50,6,10.1.100.1
dhcp-option=vlan100,6,10.1.100.1
dhcp-option=vlan150,6,10.1.100.1
dhcp-option=vlan200,6,10.1.100.1
root@raspberrypi:/etc#
```

Each of the ranges was also given a tag. The purpose of the tag was to allow the server to append additional options in the DHCP packets. For this network, option 6 was used. Option 6 is used to specify the Domain Name Server (DNS) for the subnet, using the following syntax:

```
dhcp-option=tag,option#,server_ip
```

As pictured above, the domain name to be communicated to the hosts needed to be specified, as well as the domain that the server itself resides within. This is achieved through the following lines:

```
domain=domain.name
```

```
local=/domain.name/
```

Based upon these configurations, a host requesting an IP address from this server is now able to receive an IP within the correct subnet, domain information, and the IP address of the DNS server. `Daemon.log`, a detailed log file containing all DHCP related messages can be found on the Raspberry Pi in order to troubleshoot problems with the DHCP service. This will be explored further in the “Testing Documentation” tab.

DNS Configuration

The `dnsmasq` service not only provides DHCP services to the network, but it can also provide DNS services as well. Although including a DNS server was not an initial part of the project plan, it was implemented as an additional feature within the network.

The domain information configured in the `dnsmasq.conf` file is used for DNS as well as DHCP. In addition to this, the hostnames and IP addresses that will be resolved by the server must also be specified.

The IP addresses were statically mapped to their corresponding hostname or DNS name within the `hosts` file. This file can be found within the `/etc` directory.

The following screenshot shows the IP addresses and their corresponding DNS names that were entered for this network.

```
root@raspberrypi:/etc# cat hosts
127.0.0.1      localhost
::1           localhost ip6-localhost ip6-loopback
fe00::0       ip6-localnet
ff00::0       ip6-mcastprefix
ff02::1       ip6-allnodes
ff02::2       ip6-allrouters

127.0.1.1     raspberrypi

192.168.1.1    branch-rtr-2821-1
192.168.2.1    branch-rtr-2821-2
192.168.3.1    branch-rtr-2821-3
192.168.4.1    central-rtr-2821
192.168.101.2  branch-sw-2950-1
192.168.201.2  branch-sw-2950-2

172.16.0.2     branch-rtr-2821-3-gig0-0
172.16.0.1     central-rtr-2821-fa0-1-0

10.1.1.1       central-rtr-2821-gig0-1
10.1.1.2       branch-rtr-2821-1-gig0-1

10.1.1.5       central-rtr-2821-gig0-0
10.1.1.6       branch-rtr-2821-gig0-0

192.168.10.1    branch-rtr-2821-2-subif-10
192.168.150.1  branch-rtr-2821-2-subif-150
192.168.201.1  branch-rtr-2821-2-subif-201

192.168.50.1    branch-rtr-2821-3-subif-50
192.168.100.1  branch-rtr-2821-3-subif-100
192.168.200.1  branch-rtr-2821-3-subif-200
192.168.101.1  branch-rtr-2821-3-subif-101
```

Additional screenshots were taken to verify that hosts could acquire IP addresses on all vlans. Nslookup and ping commands were used to verify that DNS hostnames and IP addresses were resolving properly. Testing and verification for the DHCP and DNS services can be found under the Testing Documentation tab.

Project Testing Documentation

The following screenshots demonstrate the ability of the Raspberry Pi DHCP server to assign IP addresses for different subnets. A test PC was patched into a port on each vlan, and received the IP addresses shown below. The PC also successfully received its domain suffix information, subnet mask, and default gateway from the Raspberry Pi DHCP server as well. Although it isn't shown here, the DHCP server also communicated information about the DNS server to the host.

```
Ethernet adapter Local Area Connection:
```

```
Connection-specific DNS Suffix . : Thompson.test
Link-local IPv6 Address . . . . . : fe80::45f3:edbe:3ea6:4595%13
IPv4 Address. . . . . : 192.168.10.64
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.10.1
```

```
Ethernet adapter Local Area Connection:
```

```
Connection-specific DNS Suffix . : Thompson.test
Link-local IPv6 Address . . . . . : fe80::45f3:edbe:3ea6:4595%13
IPv4 Address. . . . . : 192.168.50.64
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.50.1
```

```
Ethernet adapter Local Area Connection:
```

```
Connection-specific DNS Suffix . : Thompson.test
Link-local IPv6 Address . . . . . : fe80::45f3:edbe:3ea6:4595%13
IPv4 Address. . . . . : 192.168.100.64
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.100.1
```

```
Ethernet adapter Local Area Connection:
```

```
Connection-specific DNS Suffix . : Thompson.test
Link-local IPv6 Address . . . . . : fe80::45f3:edbe:3ea6:4595%13
IPv4 Address. . . . . : 192.168.150.64
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.150.1
```

Ethernet adapter Local Area Connection:

```
Connection-specific DNS Suffix . : Thompson.test
Link-local IPv6 Address . . . . . : fe80::45f3:edbe:3ea6:4595%13
IPv4 Address. . . . . : 192.168.200.64
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.200.1
```

After acquiring an IP address, hosts in each vlan were able to perform nslookups and reverse lookups for any of the hostnames or IP addresses configured on the network. The example below shows nslookup commands and pings performed on a test PC. When performing an nslookup with a hostname, the request initially times out, however this issue resolves itself within the same attempt.

```
C:\Users\50720>nslookup 192.168.1.1
DNS request timed out.
    timeout was 2 seconds.
Server: UnKnown
Address: 10.1.100.1

Name:    branch-rtr-2821-1.Thompson.test
Address: 192.168.1.1

C:\Users\50720>nslookup 192.168.5.1
DNS request timed out.
    timeout was 2 seconds.
Server: UnKnown
Address: 10.1.100.1

Name:    branch-sw-2950.Thompson.test
Address: 192.168.5.1
```

```
C:\Users\50720>ping central-rtr-2821.Thompson.test

Pinging central-rtr-2821.Thompson.test [192.168.4.1] with 32 bytes of data:
Reply from 192.168.4.1: bytes=32 time=23ms TTL=254
Reply from 192.168.4.1: bytes=32 time=1ms TTL=254
Reply from 192.168.4.1: bytes=32 time=1ms TTL=254
Reply from 192.168.4.1: bytes=32 time=1ms TTL=254

Ping statistics for 192.168.4.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 23ms, Average = 6ms
```

Contents of the Raspberry Pi's Daemon.log file are shown below. Additional conversation occurred between the client and the server, however it was excluded in order to emphasize the information that follows. Throughout the exchange below, a DHCP discover message is received on interface Ethernet 0 of the Pi from a host on vlan 50, including its name and current domain. The DHCP server then send out an offer message with information such as an IP address, domain name, and DNS server. The host then responds with a DHCP request for an IP on that subnet. When the server receives the request, it responds with a DHCP Acknowledgement message.

All of the DHCP related traffic received on and sent from the Raspberry Pi is logged to this file, so these types of messages are recorded for every DHCP address acquired by any host.

```
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 DHCPDISCOVER(eth0) 2c:41:38:04:77:d0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 tags: vlan50, eth0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 DHCPOFFER(eth0) 192.168.50.151
2c:41:38:04:77:d0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 next server: 10.1.100.1
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 54 server-identifier 10.1.100.1
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 51 lease-time 86400
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 1 netmask 255.255.255.0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 28 broadcast 192.168.50.255
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 3 router 192.168.50.1
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 13 option: 15 domain-name
Thompson.test
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 sent size: 4 option: 6 dns-server 10.1.100.1
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 available DHCP range: 192.168.50.10 --
192.168.50.254
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 client provides name: TAG178809.fenetwork.com
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 DHCPREQUEST(eth0) 192.168.50.151
2c:41:38:04:77:d0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 tags: vlan50, eth0
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: Ignoring domain fenetwork.com for DHCP host name
TAG178809
Feb 15 17:33:46 raspberrypi dnsmasq-dhcp[1983]: 3170466944 DHCPACK(eth0) 192.168.50.151
2c:41:38:04:77:d0 TAG178809
```

Project Weekly Journals

Summary – Week ending: February 1, 2015

Date	Start Time	End Time	Description	Total Hours
1/26/2015	2:00 pm	3:00 pm	Racked and cabled devices	1
1/28/2015	2:00 pm	4:00 pm	Ordered server equipment, downloaded OS	2
1/29/2011	5:00 pm	8:30 pm	Researched IS-IS	3.5
			Total Hours This Week	6.5
			Total Hours to Date	6.5

Journal Details

1/26/2015

- Racked and cabled devices.
 - Routers and switches were racked in the lab to match the topology design.
 - Devices were cabled according to the topology.

1/28/2015

- Ordered server equipment.
 - Raspberry Pi B+ model will be used for DHCP server.
 - Equipment will not arrive until next week.
 - Configuration will begin next week.
- Downloaded Operating System.
 - Researched Operating Systems for the Raspberry Pi.
 - Raspbian, an Operating System designed specifically for the Raspberry Pi will be used for this project.

1/29/2011

- Researched IS-IS.
 - Began researching basic functionality and configuration of IS-IS.
 - Started creating an addressing scheme.
 - Router and switch IPs.
 - Server IP.
 - DHCP Pool.

Summary – Week ending: February 8, 2015

Date	Start Time	End Time	Description	Total Hours
2/3/2015	3:00 pm	5:00 pm	Installed the OS	2
2/5/2015	5:00 pm	8:00 pm	Continued IS-IS research	3
2/6/2015	4:00 pm	5:00 pm	Documentation	1
			Total Hours This Week	6
			Total Hours to Date	12.5

Journal Details

2/3/2015

- Installed the OS.
 - Installed the Raspbian Operating System on the Raspberry Pi.
 - Researched DHCP services for the Raspberry Pi.
 - Experimented to become more familiar with the Command Line and functionality of the Pi.

2/5/2015

- Continued to research IS-IS.
- Began implementing basic configurations for each of the network devices.

2/6/2015

- Documented Addressing.
 - Began creating formal documentation for the network addressing scheme.
- Documented Links.
 - Began creating formal documentation for the links between network devices.

Summary – Week ending: February 15, 2015

Date	Start Time	End Time	Description	Total Hours
2/11/2015	8:00 am	10:00 am	Configured DHCP Server	2
2/12/2015	6:00 pm	8:00 pm	Re-cabled new devices	2
2/13/2015	4:00 pm	6:00 pm	Performed code upgrade	2
			Total Hours This Week	6
			Total Hours to Date	18.5

Journal Details**2/11/2015**

- Configured DHCP Server
 - Configured the Raspberry Pi as the DHCP Server for the network.

2/12/2015

- Re-cabled the devices.
 - Upon the acquisition of my own equipment, I transferred the configurations to these devices and re-cabled the topology. The project devices will no longer be FirstEnergy lab devices.

2/13/2015

- Performed code upgrade.
 - Upgrade the IOS version on the routers using PSCP (SCP for puTTY).

Summary – Week ending: February 22, 2015

Date	Start Time	End Time	Description	Total Hours
2/16/2015	1:00 pm	4:30 pm	Updated Documentation	3.5
2/17/2015	10:00 am	1:00 pm	IS-IS Configuration	3
2/19/2015	6:00 pm	10:00 pm	IS-IS Research and Configuration	4
			Total Hours This Week	10.5
			Total Hours to Date	29

Journal Details2/16/2015

- Updated Documentation

2/17/2015

- IS-IS Configuration
 - Worked on and experimented with basic IS-IS configuration.

2/19/2015

- IS-IS Research and Configuration
 - Continued to research IS-IS.

Summary – Week ending: March 1, 2015

Date	Start Time	End Time	Description	Total Hours
2/27/2015	9:00 am	1:00 pm	IS-IS Configuration	4
2/28/2015	12:30 am	2:00 am	Documentation	1.5
3/1/2015	2:30 pm	7:30 pm	IS-IS Research and Configuration	5
			Total Hours This Week	10.5
			Total Hours to Date	39.5

Journal Details2/27/2015

- IS-IS Configuration
 - Worked on IS-IS routing and areas.

2/28/2015

- Documentation
 - Worked on updating documentation.

3/1/2015

- IS-IS Research and Configuration
 - Researched IS-IS areas, and how to use show commands to verify operation. Also worked on configuration.

Summary – Week ending: March 8, 2015

Date	Start Time	End Time	Description	Total Hours
3/2/2015	4:00 pm	9:00 pm	OSPF and Redistribution Configuration	5
3/3/2015	4:30 pm	6:30 pm	Switch and Router-on-a-Stick Configuration	2
3/4/2015	8:00 pm	11:00 pm	DHCP Configuration per Subnet	3
3/5/2015	6:00 pm	9:00 pm	Researched and Implemented DNS	3
			Total Hours This Week	13
			Total Hours to Date	52.5

Journal Details

3/2/2015

- OSPF and Redistribution Configuration
 - Configured OSPF area 0 and implemented redistribution between the two domains for full connectivity.

3/3/2015

- Switch and Router-on-a-Stick Configuration
 - Configured vlans, sub-interfaces, router-on-a-stick, etc.

3/4/2015

- DHCP Configuration per Subnet
 - Worked with the Raspberry Pi DHCP server to implement DHCP services for different subnets.

3/5/2015

- Researched and Implemented DNS
 - Used dnsmasq to implement DNS services for the network.

Summary – Week ending: March 15, 2015

Date	Start Time	End Time	Description	Total Hours
3/9/2015	2:30 pm	6:00 pm	Updated Documentation	3.5
3/11/2015	4:30 pm	6:30 pm	Updated Documentation	2
			Total Hours This Week	5.5
			Total Hours to Date	58

Journal Details**3/9/2015**

- Updated Documentation
 - Updated documentation on the Raspberry Pi and server configuration process.

3/11/2015

- Updated Documentation
 - Updated documentation of the overall device configuration.

Summary – Week ending: March 22, 2015

Date	Start Time	End Time	Description	Total Hours
3/16/2015	2:00 pm	4:00 pm	Completed Network Testing	2
3/16/2015	8:00 pm	11:00 pm	Updated Documentation	3
3/21/2015	4:00 pm	8:00 pm	Documentation and Presentation	4
			Total Hours This Week	9
			Total Hours to Date	67

Journal Details3/16/2015

- Completed Network Testing
 - Finished network testing and gathering screenshots for final report.

3/16/2015

- Updated Documentation
 - Updated documentation for the Project Description Section

3/21/2015

- Documentation and Presentation
 - Continued updated documentation and worked on Presentation

References

- Configuring IS-IS for IP on Cisco Routers. (2005, August 10). Retrieved February 5, 2015, from <http://www.cisco.com/c/en/us/support/docs/ip/integrated-intermediate-system-to-intermediate-system-is-is/13795-is-is-ip-config.html>
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- Lab 4-1 Configuring Basic Integrated IS-IS. (2006). *CCNP: Building Scalable Internetworks V5.0*, 1-17. Retrieved February 27, 2015, from http://www.cs.rpi.edu/~kotfid/routing/PDF/CCNP1_lab_4_1_en.pdf
- Marty, A. (2002). IS-IS Areas and Routing Hierarchy. In *IS-IS Network Design Solutions* (Networking Technology). Cisco Press. Retrieved February 5, 2015, from <http://www.ciscopress.com/articles/article.asp?p=26850&seqNum=3>
- Raspberry Pi Foundation. (n.d.). Dynamic Host Configuration Protocol (DHCP). Retrieved February 20, 2015, from <http://www.raspberrypi.org/learning/networking-lessons/lesson-3/README.md>

Schroder, C. (2011, November 28). Dnsmasq for Easy LAN Name Services. Retrieved March 2, 2015, from <https%3A%2F%2Fwww.linux.com%2Flearn%2Ftutorials%2F516220-dnsmasq-for-easy-lan-name-services>