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Implementation of OSPF routing on Campus Network of project-1

Project Report - 2

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Abstract

The main goal of this project is to turn our project 2 from static routing to a dynamic routing using OSPF. Using this protocol has many benefits over VLSM protocol which we will discuss in details in this report. After the project is complete we will make sure that the PC and Routers can communicate with each other without any problem.

Acknowledgements

It has been a very challenging project for us due to its sequential procedure. Without the help of the team mates it'd be very hard for me to complete this project without any hassle. Thanks to Mushfiquis Salehin Afnan, Mahafujul Alam, Md. Abul Bashar and Pritom Saha, my fellow team mates to help me finish the project and to follow my lead – Mahir Shadid (Team Leader).

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1. Introduction:

In the project 1 we were instructed to create a campus network which includes various departments and make all the PCs communicate with each other without any faults. But in project 2 we will further improve the routing and make it dynamic which has many perks over VLSM. To do this we are basically using the same topology with minor tweaks which surprisingly makes the project a lot simpler. We also had to change the routing table a little and use totally different commands and procedure.

2. Background:

The importance of our project pretty significant because by the perfect execution of our project we can make it very easy, simple and secure communication between the devices of different departments of our campus. Moreover we are using a more sufficient and easy protocol which is even better.

The main tool that was used in building the project was a simulation software called GNS3. This mainly used by network developers to emulate their network structures in real time. This a pretty heavy software which requires high end PC if the network system is a major one containing huge amount of devices.

The method to develop the campus network is called OSPF. These are further discussed down below.

3. Literature Review:

3.1. Campus Network:

We have to design a functional campus network where there are different departments that contains PCs and our job is to make the network in such ways so that the PCs can communicate with each other at ease. And we will do all these using the updated OSPF Protocol.

3.2. OSPF:

Open Shortest Path First (OSPF) is a link-state routing protocol that was developed for IP networks and is based on the Shortest Path First (SPF) algorithm. OSPF is an Interior Gateway Protocol (IGP).

In an OSPF network, routers or systems within the same area maintain an identical link-state database that describes the topology of the area. Each router or system in the area generates its link-state database from the link-state advertisements (LSAs) that it receives from all the other routers or systems in the same area and the LSAs that itself generates. An LSA is a packet that contains information about neighbors and path costs. Based on the link-state database, each router or system calculates a shortest-path spanning tree, with itself as the root, using the SPF algorithm.

OSPF has the following key advantages:

- Compared with distance-vector routing protocols such as the Routing Information Protocol (RIP), OSPF is more suitable for serving large, heterogeneous internetworks. OSPF can recalculate the routes in a short amount of time when the network topology changes.
- With OSPF, you can divide an Autonomous System (AS) into areas and keep area topologies separate to decrease the OSPF routing traffic and the size of the link-state database of each area.
- OSPF provides equal-cost multipath routing. You can add duplicate routes to the TCP stack using different next hops.

3.3. GNS3:

The software we used for our project is called GNS3. GNS3 is used by network engineers worldwide to emulate, configure, test and troubleshoot virtual and real networks. GNS3 allows us to run a small topology consisting of only a few devices on your laptop, to those that have many devices hosted on multiple servers or even hosted in the cloud.

3.4. Routing:

Network routing is the process of selecting a path across one or more networks. The principles of routing can apply to any type of network, from telephone networks to public

transportation. In packet-switching networks, such as the Internet, routing selects the paths for Internet Protocol (IP) packets to travel from their origin to their destination. These Internet routing decisions are made by specialized pieces of network hardware called routers.

3.5. Cisco images:

IOS image files contain the system code that your router uses to function, that is, the image contains the IOS itself, plus various feature sets (optional features or router-specific features). However, the features are not configured in any way. In our project, we are using the Cisco 7200 router ISO image as routers in our campus network system. This is downloaded from the official Cisco website / marketplace.

4. Problem Statement:

After doing the subnetting and topology in Project 1, the main works were done basically. Although Project 2 seems simple there was a challenging part. This was configuring the wildcards while doing the routings.

5. Designs:

4.1. OSPF: *Open Shortest Path First* (OSPF) is a link-state routing protocol that was developed for IP networks and is based on the Shortest Path First (SPF) algorithm. OSPF is an Interior Gateway Protocol (IGP).

In an OSPF network, routers or systems within the same area maintain an identical link-state database that describes the topology of the area. Each router or system in the area generates its link-state database from the link-state advertisements (LSAs) that it receives from all the other routers or systems in the same area and the LSAs that itself generates. An LSA is a packet that contains information about neighbors and path costs. Based on the link-state database, each router or system calculates a shortest-path spanning tree, with itself as the root, using the SPF algorithm.

Subnet Mask: Every device on a network has an IP address. A subnet mask splits this IP address into the host and network addresses. This helps define which part of the IP address belongs to the network, and which part belongs to the device. The subnet mask is a 32-bit number, where all the host bits are set to 0, and the network bits are set to 1. So, the subnet mask consists of a sequence of 1s followed by a block of 0s, where the 1s represent the network prefix and the 0s mark the host identifier.

- Subnetting: In subnetting, a large network is logically or physically divided into multiple small networks or "subnets." The reason for subnetting a large network is to address network congestion and its negative impact on speed and productivity. Subnetting also improves efficiency due to the way an address space is utilized in a small network. Finally, the divisions between subnets allow organizations to enforce access control, which improves network security, and helps contain security incidents.
- Wildcards: A wildcard mask is similar to a subnet mask in that it uses the ANDing process to identify which bits in an IPv4 address to match. However, a wildcard mask and a subnet mask differ in the way they match binary 1s and 0s. Unlike with a subnet mask, in which binary 1 is equal to a match, and binary 0 is not a match, with a wildcard mask, the reverse is true.

4.2. Calculations: The available IP address block is 169.110.224.0/21, and the requirement is to create subnets for six departments:

CSE: 225 hosts

EEE: 100 hosts

BBA: 70 hosts

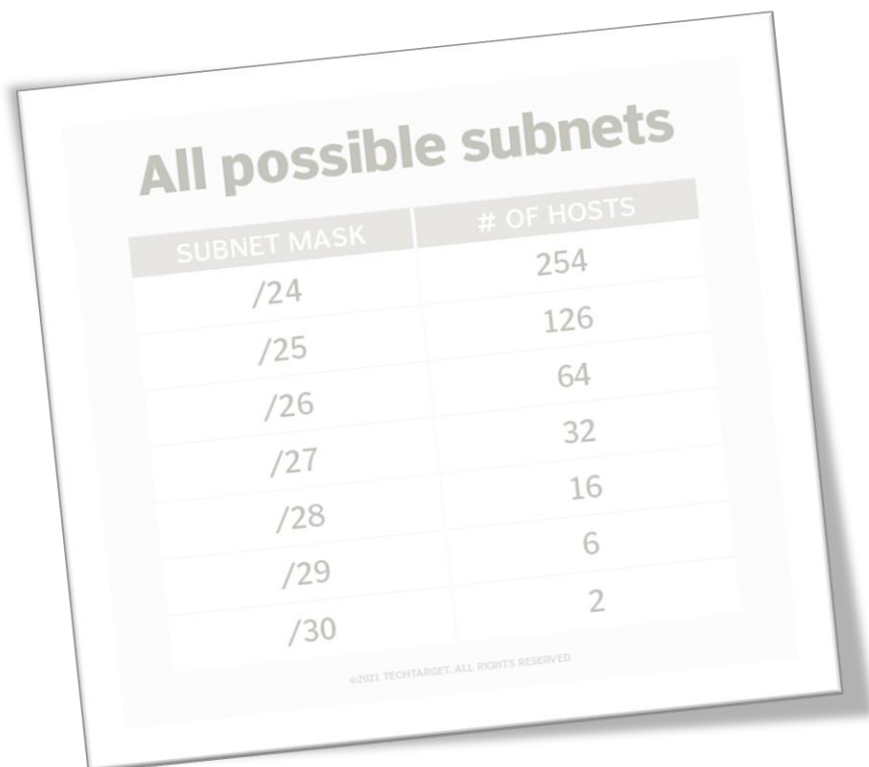
Administrative: 50 hosts

ELL: 40 hosts

Civil: 28 hosts

Here are the steps to allocate the IPs for departments using VLSM:

1. Select the block size for each segment. This must be greater than or at least equal to the sum of the host addresses, broadcast addresses and network addresses.
2. List all possible subnets:



SUBNET MASK	# OF HOSTS
/24	254
/25	126
/26	64
/27	32
/28	16
/29	6
/30	2

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Figure-1

3. Keeping the block size in mind, arrange all the segments in descending order, i.e. list the highest first, then the second highest, and so on, all the way down to the subnet with the lowest requirement. For this example, the order would be:

CSE: 225 hosts

EEE: 100 hosts

BBA: 70 hosts

Administrative: 50 hosts

ELL: 40 hosts

Civil: 28 hosts

4. Assign the appropriate subnet mask to each subnet. Identify the highest IP available and allocate it to the highest requirement. So, here, 169.110.224.0/24 has 256 valid IP addresses that can be assigned to the 225 hosts required by CSE.
5. For the next segment, an IP is required that can handle 100 hosts. The IP subnet mask /25 is the next highest in the list. It can accommodate 128 hosts, so it should be assigned to the 100-host requirement of EEE.

6. Similarly, other departments requirements are also fulfilled withing $2^{11}=2048$ hosts.
7. Area segment is made to use among routers to exchange packets.
8. Wildcard is calculated using (255 - Last Byte of Subnet mask).

4.3. IP Table:

Building	NET ID	FIRST ADD.	LAST ADD.	BROAD. ADD.	NET MASK
CSE	169.110.224.0	169.110.224.1	169.110.224.254	169.110.224.255	255.255.255.0
EEE	169.110.225.0	169.110.225.1	169.110.225.126	169.110.225.127	255.255.255.128
BBA	169.110.225.128	169.110.225.129	169.110.225.254	169.110.225.255	255.255.255.128
ADMINISTRATIVE	169.110.226.0	169.110.226.1	169.110.226.62	169.110.226.63	255.255.255.192
ELL	169.110.226.64	169.110.226.65	169.110.226.126	169.110.226.127	255.255.255.192
CIVIL	169.110.226.128	169.110.226.129	169.110.226.158	169.110.226.159	255.255.255.224
AREA-SEG	169.110.226.160	169.110.226.161	169.110.226.190	169.110.226.191	255.255.255.224

4.4. Software and hardware:

The software used is GNS3. GNS3 is used by hundreds of thousands of network engineers worldwide to emulate, configure, test and troubleshoot virtual and real networks. GNS3 allows you to run a small topology consisting of only a few devices on your laptop, to those that have many devices hosted on multiple servers or even hosted in the cloud. GNS3 is open source, free software that you can download from <http://gns3.com>. It is actively developed and supported and has a growing community of over 800,000 members. GNS3 has allowed network engineers to virtualize real hardware devices for over 10 years. Originally only emulating Cisco devices using software called Dynamips, GNS3 has now evolved and supports many devices from multiple network vendors including Cisco virtual switches, Cisco ASAs, Brocade vRouters, Cumulus Linux switches, Docker instances, HPE VSRs, multiple Linux appliances and many others.

The hardware used is above average Computer or Laptop that provides efficient emulation of the routers as the routers requires virtual RAM and they have high CPU usage. Shortly, More threads, more performance.

4.5. Topology:

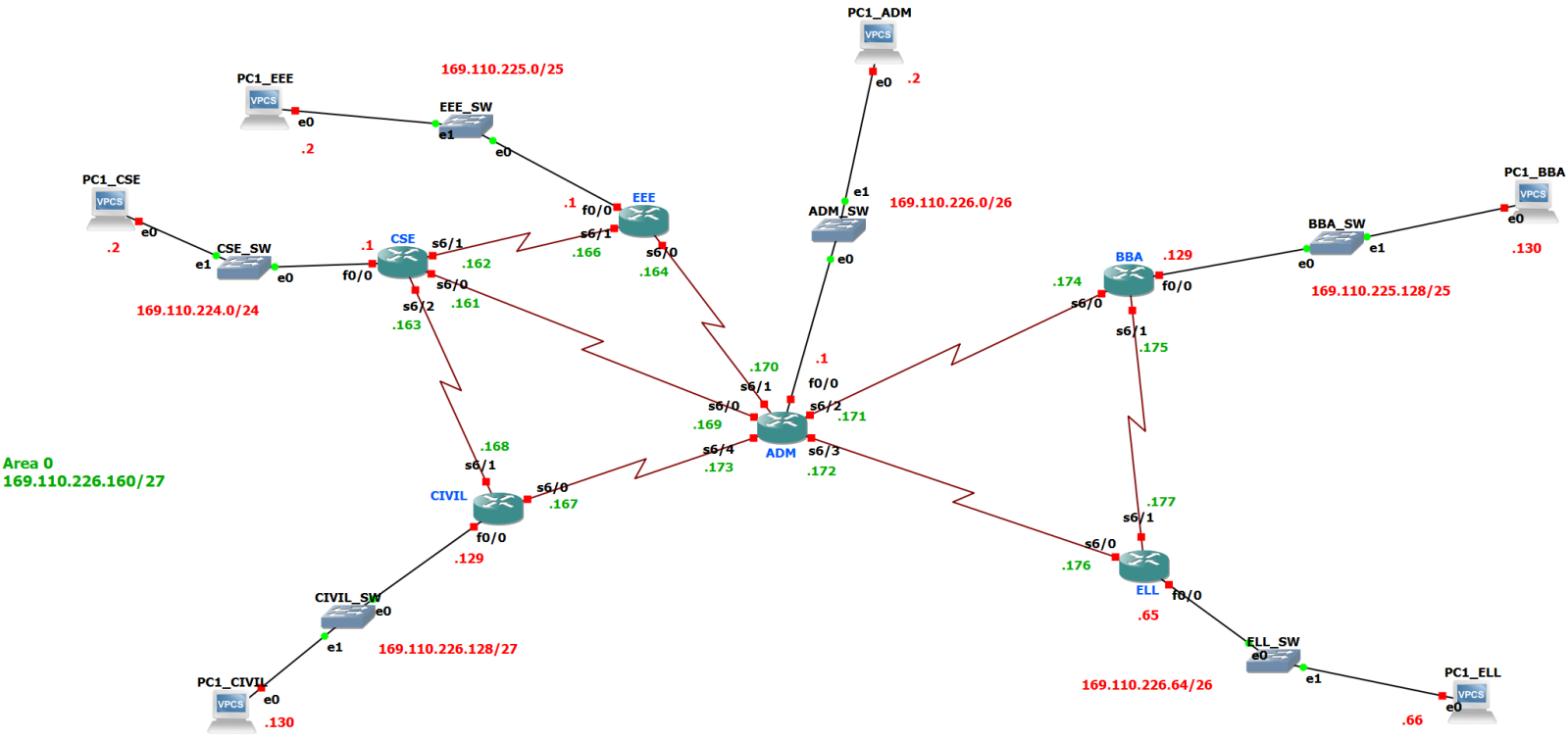


Figure-2

6. Implementation:

5.1. Install GNS3: Download GNS3 from the official website. And then follow the instructions that are given in their website to successfully install GNS3 in windows operating system. The link is: <https://docs.gns3.com/docs/getting-started/installation/windows/>

5.2. Importing Routers: The router we used to build the campus network is Cisco 7200. To import the router in GNS3 we have to get the ISO file of this router from the official marketplace of Cisco. Then we have follow the instruction that are given in the following link: <https://www.cybrary.it/blog/0p3n/installing-cisco-ios-router-gns3-vm/#:~:text=STEP%201%3A%20Open%20the%20GNS3,by%20clicking%20on%20%E2%80%9CBrowse%E2%80%9D.>

5.3. Configuration:

- First thing was to create the topology
- Then assigning the IPs to the respected Hosts and Routers
- Routers then connected by OSPF method
- Testing was done using Debug method of OSPF

7. Experimental and Theoretical Results:

6.1. Tools:

Ping Tool: After designing the network we use the ping tool to configure the PC and routers. To do this we use various syntaxes. They are given below:

For routers:

```
R1#config t
R1(config)#int f1/0
R1(config-if)#ip add 169.110.226.161 255.255.255.252
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#
```

For PCs:

```
PC1> ping 169.110.225.1
```

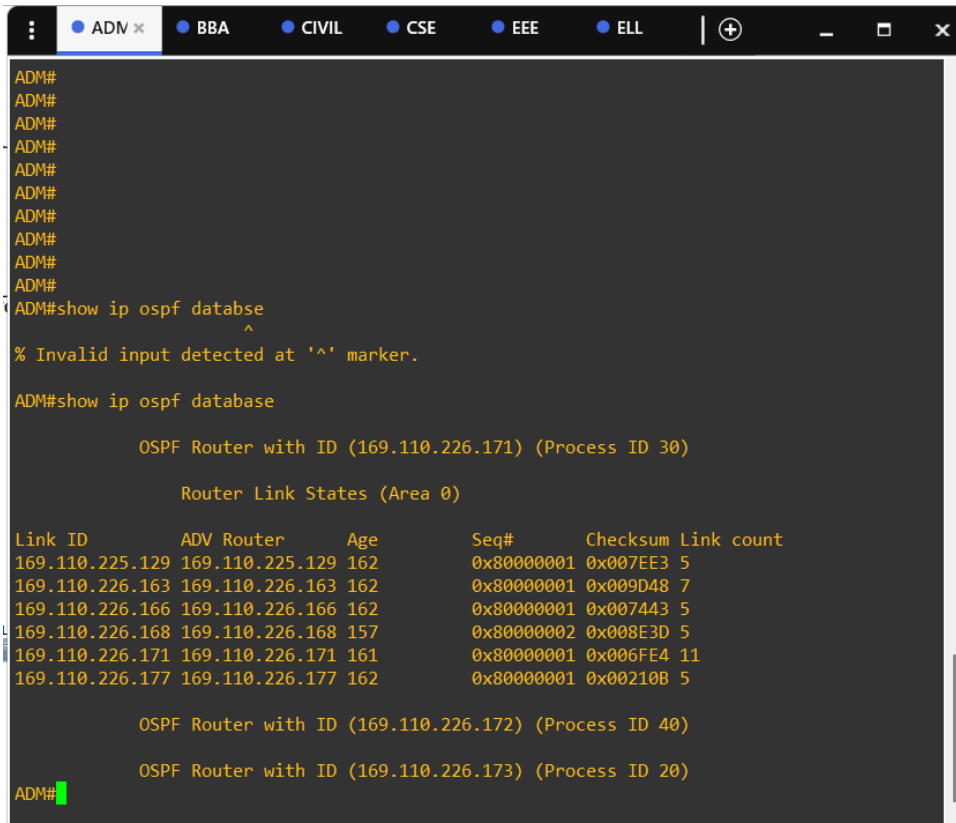
OSPF tool: OSPF has many types of tools to use. Some of them that we used are,

```
R1#config t
R1(config)#int f0/0
R1(config-if)#ip add 169.110.226.161 255.255.255.252
R1(config-if)#no shut
R1(config-if)#exit
R1(config)#router ospf 10
R1(router-config)#network 169.110.226.160 0.0.0.3 area 0
R1(router-config)#end
```

Here, 0.0.0.3 is called a Wildcard address.

6.2. IP OSPF Database:

Admin:



The screenshot shows a terminal window with a dark background and yellow text. The window has a title bar with tabs for 'ADM', 'BBA', 'CIVIL', 'CSE', 'EEE', and 'ELL'. The terminal output shows the user 'ADM#' entering the command 'show ip ospf database'. The output displays OSPF Router information for ID (169.110.226.171) and ID (169.110.226.173), followed by a table of Router Link States for Area 0. The table has columns for Link ID, ADV Router, Age, Seq#, Checksum, and Link count. The output also shows a message: '% Invalid input detected at '^' marker.' when the user entered an invalid command.

```
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#
ADM#show ip ospf database
^
% Invalid input detected at '^' marker.
ADM#show ip ospf database

      OSPF Router with ID (169.110.226.171) (Process ID 30)

      Router Link States (Area 0)

Link ID        ADV Router    Age      Seq#          Checksum Link count
169.110.225.129 169.110.225.129 162      0x80000001    0x007EE3  5
169.110.226.163 169.110.226.163 162      0x80000001    0x009D48  7
169.110.226.166 169.110.226.166 162      0x80000001    0x007443  5
169.110.226.168 169.110.226.168 157      0x80000002    0x008E3D  5
169.110.226.171 169.110.226.171 161      0x80000001    0x006FE4  11
169.110.226.177 169.110.226.177 162      0x80000001    0x00210B  5

      OSPF Router with ID (169.110.226.172) (Process ID 40)

      OSPF Router with ID (169.110.226.173) (Process ID 20)
ADM#
```

Figure-3

BBA:

```

et3/0, changed state to down
*May 22 18:13:02.847: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/2,
changed state to down
*May 22 18:13:02.967: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/3,
changed state to down
*May 22 18:13:02.983: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/4,
changed state to down
*May 22 18:13:02.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5,
changed state to down
*May 22 18:13:02.999: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6,
changed state to down
*May 22 18:13:03.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7,
changed state to down
BBA#
BBA#show ip ospf database

        OSPF Router with ID (169.110.225.129) (Process ID 30)

                Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 184          0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 186          0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 186          0x80000001 0x007443 5
169.110.226.168 169.110.226.168 182          0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 185          0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 185          0x80000001 0x00210B 5

        OSPF Router with ID (169.110.226.174) (Process ID 40)

        OSPF Router with ID (169.110.226.175) (Process ID 20)
BBA#

```

Figure-4

CIVIL:

```

*May 22 18:13:02.143: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state
to administratively down
*May 22 18:13:02.155: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state
to administratively down
*May 22 18:13:02.171: %LINK-5-CHANGED: Interface FastEthernet5/0, changed state
to administratively down
*May 22 18:13:02.187: %LINK-5-CHANGED: Interface FastEthernet5/1, changed state
to administratively down
*May 22 18:13:02.407: %LINK-5-CHANGED: Interface Serial6/2, changed state to adm
inistratively down
*May 22 18:13:02.439: %LINK-5-CHANGED: Interface Serial6/3, changed state to adm
inistratively down
*May 22 18:13:02.455: %LINK-5-CHANGED: Interface Serial6/4, changed state to adm
inistratively down
CIVIL#
CIVIL#show ip ospf database

        OSPF Router with ID (169.110.226.168) (Process ID 30)

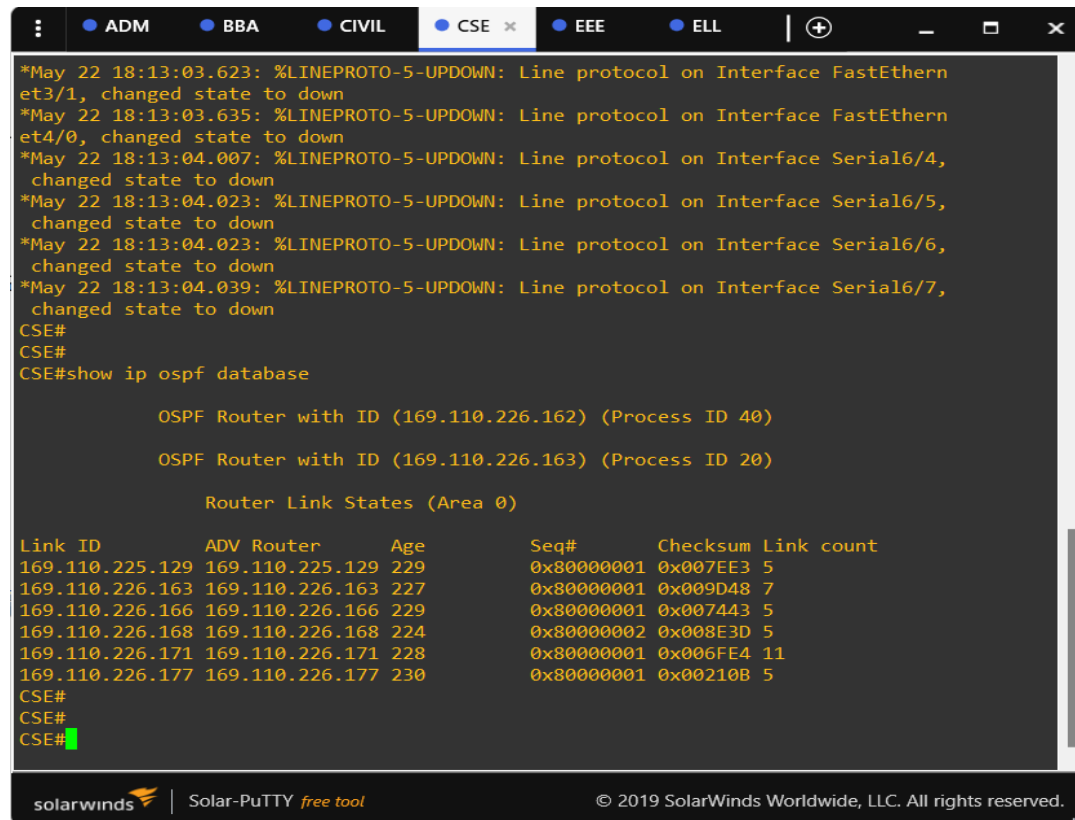
                Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 212          0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 211          0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 212          0x80000001 0x007443 5
169.110.226.168 169.110.226.168 206          0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 211          0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 212          0x80000001 0x00210B 5
CIVIL#
CIVIL#
CIVIL#
CIVIL#

```

Figure-5

CSE:

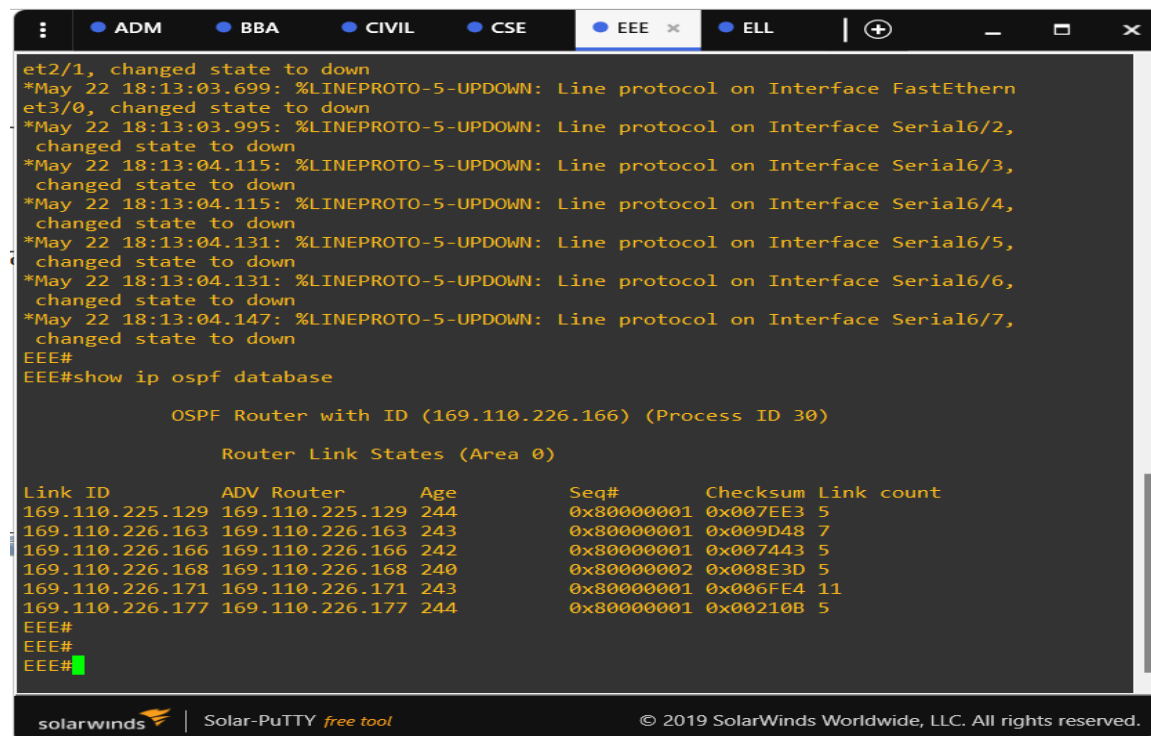


The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'CSE' tab selected. The terminal displays a series of log messages indicating that line protocols on various interfaces (FastEthernet et3/1, et4/0, Serial6/4, Serial6/5, Serial6/6, Serial6/7) have changed state to down. Following these messages, the user enters the command 'show ip ospf database'. The output shows the OSPF Router with ID (169.110.226.162) (Process ID 40) and another OSPF Router with ID (169.110.226.163) (Process ID 20). Below this, the 'Router Link States (Area 0)' are listed in a table format.

Link ID	ADV Router	Age	Seq#	Checksum	Link count
169.110.225.129	169.110.225.129	229	0x80000001	0x007EE3	5
169.110.226.163	169.110.226.163	227	0x80000001	0x009D48	7
169.110.226.166	169.110.226.166	229	0x80000001	0x007443	5
169.110.226.168	169.110.226.168	224	0x80000002	0x008E3D	5
169.110.226.171	169.110.226.171	228	0x80000001	0x006FE4	11
169.110.226.177	169.110.226.177	230	0x80000001	0x00210B	5

Figure-6

EEE:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'EEE' tab selected. The terminal displays a series of log messages indicating that line protocols on various interfaces (FastEthernet et2/1, et3/0, Serial6/2, Serial6/3, Serial6/4, Serial6/5, Serial6/6, Serial6/7) have changed state to down. Following these messages, the user enters the command 'show ip ospf database'. The output shows the OSPF Router with ID (169.110.226.166) (Process ID 30) and the 'Router Link States (Area 0)' are listed in a table format.

Link ID	ADV Router	Age	Seq#	Checksum	Link count
169.110.225.129	169.110.225.129	244	0x80000001	0x007EE3	5
169.110.226.163	169.110.226.163	243	0x80000001	0x009D48	7
169.110.226.166	169.110.226.166	242	0x80000001	0x007443	5
169.110.226.168	169.110.226.168	240	0x80000002	0x008E3D	5
169.110.226.171	169.110.226.171	243	0x80000001	0x006FE4	11
169.110.226.177	169.110.226.177	244	0x80000001	0x00210B	5

Figure-7

ELL:

The screenshot shows a SolarWinds Solar-PuTTY terminal window with multiple tabs (ADM, BBA, CIVIL, CSE, EEE, ELL). The active tab is ELL. The terminal displays a series of log messages indicating interface state changes for various FastEthernet and Serial interfaces. Below the logs, the user enters the command 'show ip ospf database', which outputs the OSPF Router Link States for Area 0, listing link IDs, adjacent routers, ages, sequence numbers, checksums, and link counts.

```
*May 22 18:13:02.279: %LINK-5-CHANGED: Interface FastEthernet3/1, changed state to administratively down
*May 22 18:13:02.295: %LINK-5-CHANGED: Interface FastEthernet4/0, changed state to administratively down
*May 22 18:13:02.311: %LINK-5-CHANGED: Interface FastEthernet4/1, changed state to administratively down
*May 22 18:13:02.327: %LINK-5-CHANGED: Interface FastEthernet5/0, changed state to administratively down
*May 22 18:13:02.327: %LINK-5-CHANGED: Interface FastEthernet5/1, changed state to administratively down
*May 22 18:13:02.547: %LINK-5-CHANGED: Interface Serial6/2, changed state to administratively down
*May 22 18:13:02.579: %LINK-5-CHANGED: Interface Serial6/3, changed state to administratively down
ELL#
ELL#
ELL#show ip ospf database

        OSPF Router with ID (169.110.226.177) (Process ID 30)

        Router Link States (Area 0)

Link ID      ADV Router    Age      Seq#          Checksum Link count
169.110.225.129 169.110.225.129 266      0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 267      0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 267      0x80000001 0x007443 5
169.110.226.168 169.110.226.168 262      0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 266      0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 265      0x80000001 0x00210B 5
ELL#
ELL#
ELL#
```

Figure-8

6.3. IP OSPF Neighbors:

Admin:

The screenshot shows a SolarWinds Solar-PuTTY terminal window with the ADM tab active. The user enters the command 'show ip ospf database', which results in an error message: '% Invalid input detected at '^' marker.' The user then enters 'show ip ospf database' again, which outputs the OSPF Router Link States for Area 0 for three different routers. Finally, the user enters 'show ip ospf neighbor', which outputs a table showing the status of OSPF neighbors, including their IDs, priorities, states, dead times, addresses, and interfaces.

```
ADM#show ip ospf database
^
% Invalid input detected at '^' marker.
ADM#show ip ospf database

        OSPF Router with ID (169.110.226.171) (Process ID 30)

        Router Link States (Area 0)

Link ID      ADV Router    Age      Seq#          Checksum Link count
169.110.225.129 169.110.225.129 162      0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 162      0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 162      0x80000001 0x007443 5
169.110.226.168 169.110.226.168 157      0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 161      0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 162      0x80000001 0x00210B 5

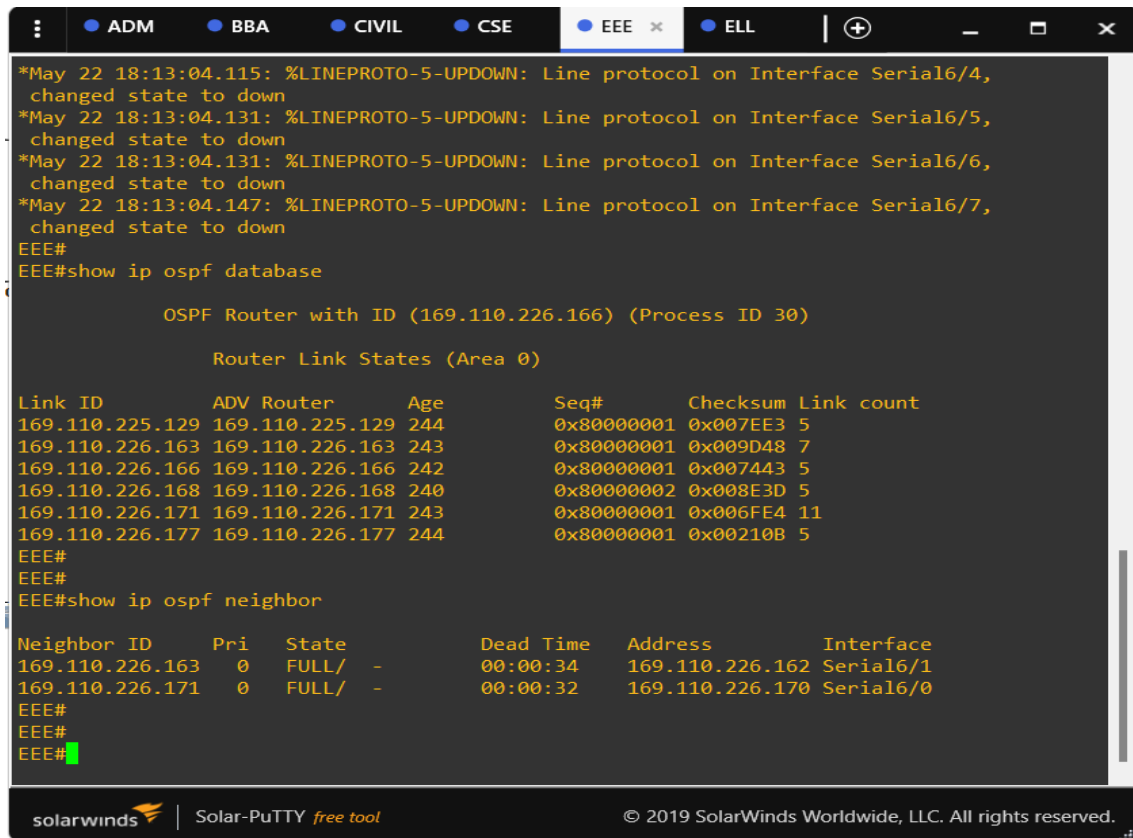
        OSPF Router with ID (169.110.226.172) (Process ID 40)

        OSPF Router with ID (169.110.226.173) (Process ID 20)
ADM#
ADM#show ip ospf neighbor

Neighbor ID  Pri  State           Dead Time   Address         Interface
169.110.226.168 0    FULL/-         00:00:36   169.110.226.167 Serial6/4
169.110.226.177 0    FULL/-         00:00:34   169.110.226.176 Serial6/3
169.110.225.129 0    FULL/-         00:00:32   169.110.226.174 Serial6/2
169.110.226.166 0    FULL/-         00:00:37   169.110.226.164 Serial6/1
169.110.226.163 0    FULL/-         00:00:36   169.110.226.161 Serial6/0
ADM#
ADM#
```

Figure-9

EEE:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'EEE' tab selected. The terminal displays a series of log messages indicating that the line protocol on interfaces Serial6/4, Serial6/5, Serial6/6, and Serial6/7 has changed state to down. The user 'EEE' enters the command 'show ip ospf database'. The output shows the OSPF Router with ID (169.110.226.166) and its Router Link States for Area 0. This is followed by a table of link states. The user then enters 'show ip ospf neighbor', and the output shows two neighbors: 169.110.226.163 and 169.110.226.171, both in a FULL state.

```
*May 22 18:13:04.115: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/4,
changed state to down
*May 22 18:13:04.131: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5,
changed state to down
*May 22 18:13:04.131: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6,
changed state to down
*May 22 18:13:04.147: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7,
changed state to down
EEE#
EEE#show ip ospf database

        OSPF Router with ID (169.110.226.166) (Process ID 30)

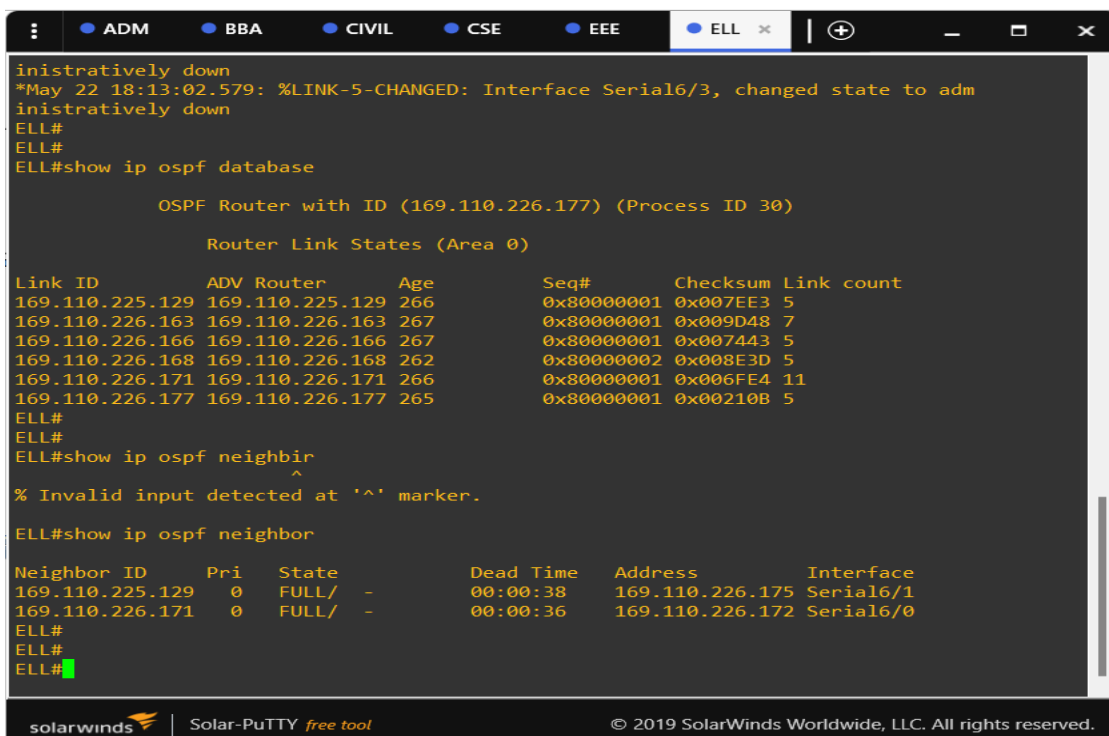
        Router Link States (Area 0)

Link ID      ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 244          0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 243          0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 242          0x80000001 0x007443 5
169.110.226.168 169.110.226.168 240          0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 243          0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 244          0x80000001 0x00210B 5
EEE#
EEE#
EEE#show ip ospf neighbor

Neighbor ID    Pri   State           Dead Time   Address        Interface
169.110.226.163 0     FULL/ -         00:00:34    169.110.226.162 Serial6/1
169.110.226.171 0     FULL/ -         00:00:32    169.110.226.170 Serial6/0
EEE#
EEE#
EEE#
```

Figure-10

ELL:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'ELL' tab selected. The terminal displays a log message indicating that the line protocol on interface Serial6/3 has changed state to administratively down. The user 'ELL' enters the command 'show ip ospf database'. The output shows the OSPF Router with ID (169.110.226.177) and its Router Link States for Area 0. This is followed by a table of link states. The user then enters 'show ip ospf neighbor', but the terminal shows an error message: '% Invalid input detected at '^' marker.' The user then enters 'show ip ospf neighbor' again, and the output shows two neighbors: 169.110.225.129 and 169.110.226.171, both in a FULL state.

```
inistratively down
*May 22 18:13:02.579: %LINK-5-CHANGED: Interface Serial6/3, changed state to adm
inistratively down
ELL#
ELL#
ELL#show ip ospf database

        OSPF Router with ID (169.110.226.177) (Process ID 30)

        Router Link States (Area 0)

Link ID      ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 266          0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 267          0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 267          0x80000001 0x007443 5
169.110.226.168 169.110.226.168 262          0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 266          0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 265          0x80000001 0x00210B 5
ELL#
ELL#
ELL#show ip ospf neighbor
^
% Invalid input detected at '^' marker.
ELL#show ip ospf neighbor

Neighbor ID    Pri   State           Dead Time   Address        Interface
169.110.225.129 0     FULL/ -         00:00:38    169.110.226.175 Serial6/1
169.110.226.171 0     FULL/ -         00:00:36    169.110.226.172 Serial6/0
ELL#
ELL#
ELL#
```

Figure-11

CSE:

The screenshot shows a Solar-PuTTY terminal window with the 'CSE' tab selected. The terminal displays the following commands and output:

```
changed state to down
*May 22 18:13:04.023: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6,
changed state to down
*May 22 18:13:04.039: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7,
changed state to down
CSE#
CSE#
CSE#show ip ospf database

      OSPF Router with ID (169.110.226.162) (Process ID 40)

      OSPF Router with ID (169.110.226.163) (Process ID 20)

      Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 229          0x80000001  0x007EE3  5
169.110.226.163 169.110.226.163 227          0x80000001  0x009D48  7
169.110.226.166 169.110.226.166 229          0x80000001  0x007443  5
169.110.226.168 169.110.226.168 224          0x80000002  0x008E3D  5
169.110.226.171 169.110.226.171 228          0x80000001  0x006FE4  11
169.110.226.177 169.110.226.177 230          0x80000001  0x00210B  5
CSE#
CSE#
CSE#show ip ospf neighbor

Neighbor ID    Pri  State           Dead Time   Address        Interface
169.110.226.168 0    FULL/ -         00:00:37   169.110.226.168 Serial6/2
169.110.226.166 0    FULL/ -         00:00:38   169.110.226.166 Serial6/1
169.110.226.171 0    FULL/ -         00:00:38   169.110.226.169 Serial6/0
CSE#
CSE#
```

The bottom of the window shows the SolarWinds logo, 'Solar-PuTTY free tool', and the copyright notice: '© 2019 SolarWinds Worldwide, LLC. All rights reserved.'

Figure-12

BBA:

The screenshot shows a Solar-PuTTY terminal window with the 'BBA' tab selected. The terminal displays the following commands and output:

```
*May 22 18:13:02.987: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/5,
changed state to down
*May 22 18:13:02.999: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/6,
changed state to down
*May 22 18:13:03.003: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/7,
changed state to down
BBA#
BBA#show ip ospf database

      OSPF Router with ID (169.110.225.129) (Process ID 30)

      Router Link States (Area 0)

Link ID        ADV Router    Age          Seq#          Checksum Link count
169.110.225.129 169.110.225.129 184          0x80000001  0x007EE3  5
169.110.226.163 169.110.226.163 186          0x80000001  0x009D48  7
169.110.226.166 169.110.226.166 186          0x80000001  0x007443  5
169.110.226.168 169.110.226.168 182          0x80000002  0x008E3D  5
169.110.226.171 169.110.226.171 185          0x80000001  0x006FE4  11
169.110.226.177 169.110.226.177 185          0x80000001  0x00210B  5

      OSPF Router with ID (169.110.226.174) (Process ID 40)

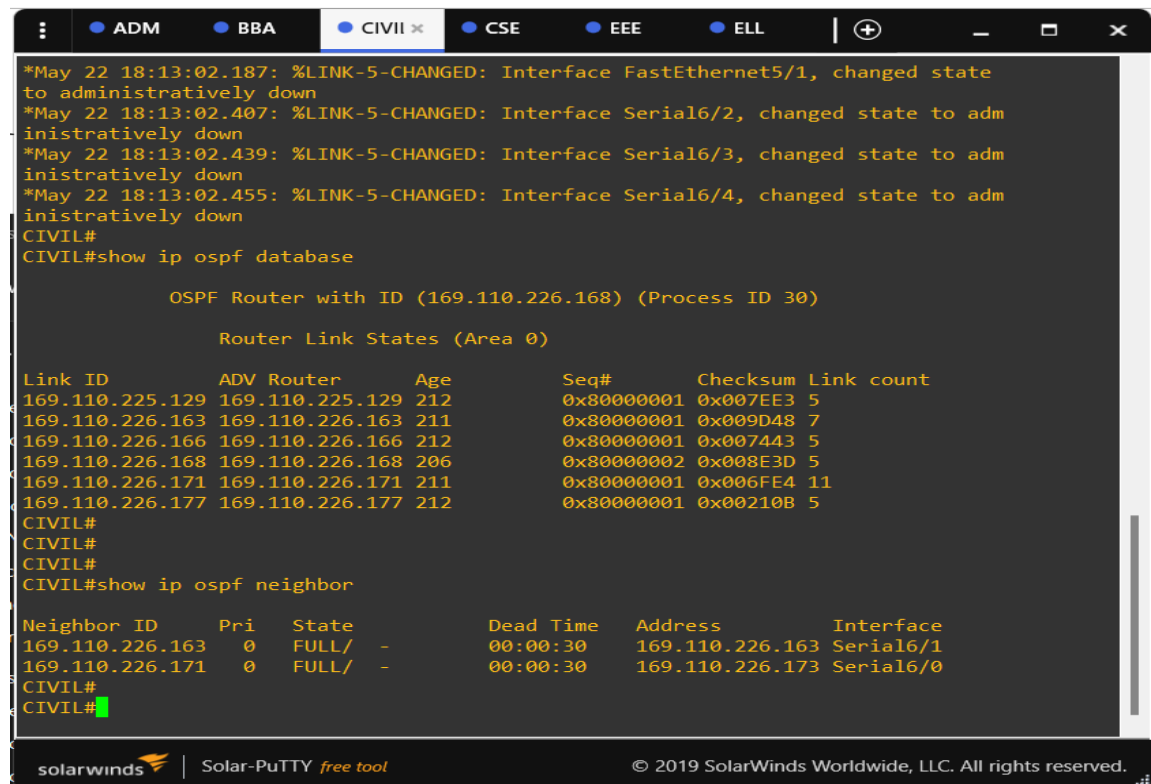
      OSPF Router with ID (169.110.226.175) (Process ID 20)
BBA#
BBA#show ip ospf neighbor

Neighbor ID    Pri  State           Dead Time   Address        Interface
169.110.226.177 0    FULL/ -         00:00:38   169.110.226.177 Serial6/1
169.110.226.171 0    FULL/ -         00:00:38   169.110.226.171 Serial6/0
BBA#
BBA#
```

The bottom of the window shows the SolarWinds logo, 'Solar-PuTTY free tool', and the copyright notice: '© 2019 SolarWinds Worldwide, LLC. All rights reserved.'

Figure-13

CIVIL:



```
ADM BBA CIVIL x CSE EEE ELL | + - □ x
*May 22 18:13:02.187: %LINK-5-CHANGED: Interface FastEthernet5/1, changed state
to administratively down
*May 22 18:13:02.407: %LINK-5-CHANGED: Interface Serial6/2, changed state to adm
inistratively down
*May 22 18:13:02.439: %LINK-5-CHANGED: Interface Serial6/3, changed state to adm
inistratively down
*May 22 18:13:02.455: %LINK-5-CHANGED: Interface Serial6/4, changed state to adm
inistratively down
CIVIL#
CIVIL#show ip ospf database

        OSPF Router with ID (169.110.226.168) (Process ID 30)

        Router Link States (Area 0)

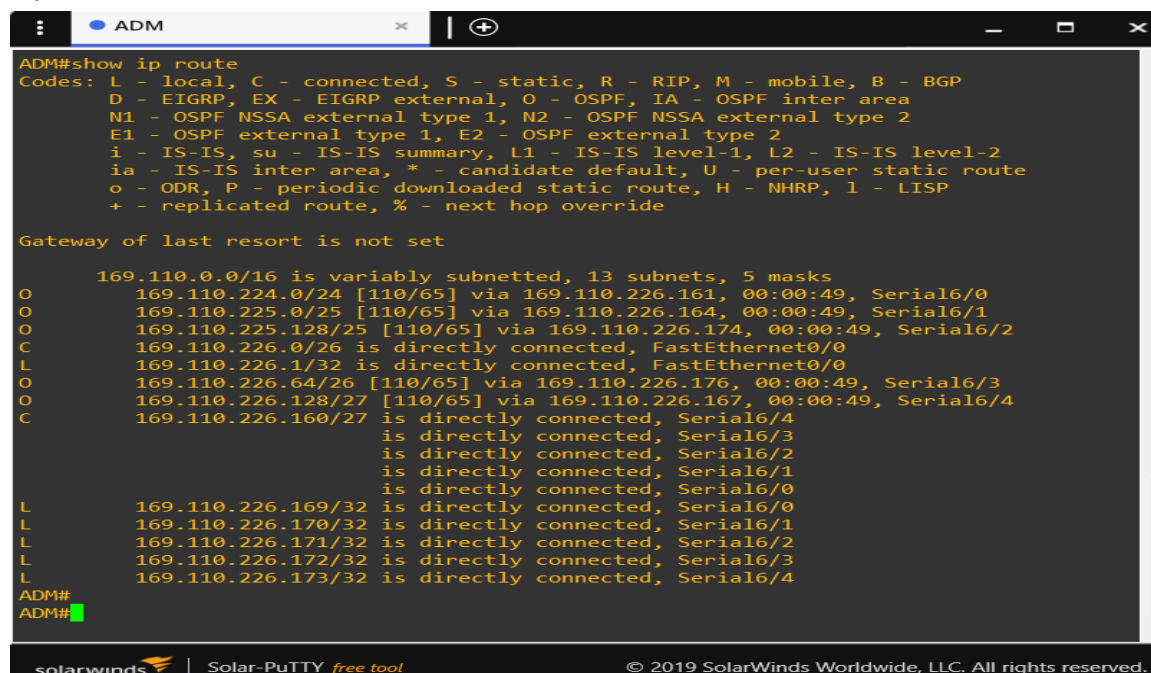
Link ID        ADV Router    Age          Seq#           Checksum Link count
169.110.225.129 169.110.225.129 212          0x80000001 0x007EE3 5
169.110.226.163 169.110.226.163 211          0x80000001 0x009D48 7
169.110.226.166 169.110.226.166 212          0x80000001 0x007443 5
169.110.226.168 169.110.226.168 206          0x80000002 0x008E3D 5
169.110.226.171 169.110.226.171 211          0x80000001 0x006FE4 11
169.110.226.177 169.110.226.177 212          0x80000001 0x00210B 5
CIVIL#
CIVIL#
CIVIL#
CIVIL#show ip ospf neighbor

Neighbor ID    Pri   State           Dead Time   Address        Interface
169.110.226.163 0     FULL/ -         00:00:30    169.110.226.163 Serial6/1
169.110.226.171 0     FULL/ -         00:00:30    169.110.226.173 Serial6/0
CIVIL#
CIVIL#
```

Figure-14

6.4. IP Routes:

Admin:



```
ADM x | + - □ x
ADM#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

169.110.0.0/16 is variably subnetted, 13 subnets, 5 masks
O    169.110.224.0/24 [110/65] via 169.110.226.161, 00:00:49, Serial6/0
O    169.110.225.0/25 [110/65] via 169.110.226.164, 00:00:49, Serial6/1
O    169.110.225.128/25 [110/65] via 169.110.226.174, 00:00:49, Serial6/2
C    169.110.226.0/26 is directly connected, FastEthernet0/0
L    169.110.226.1/32 is directly connected, FastEthernet0/0
O    169.110.226.64/26 [110/65] via 169.110.226.176, 00:00:49, Serial6/3
O    169.110.226.128/27 [110/65] via 169.110.226.167, 00:00:49, Serial6/4
C    169.110.226.160/27
        is directly connected, Serial6/4
        is directly connected, Serial6/3
        is directly connected, Serial6/2
        is directly connected, Serial6/1
        is directly connected, Serial6/0
L    169.110.226.169/32 is directly connected, Serial6/0
L    169.110.226.170/32 is directly connected, Serial6/1
L    169.110.226.171/32 is directly connected, Serial6/2
L    169.110.226.172/32 is directly connected, Serial6/3
L    169.110.226.173/32 is directly connected, Serial6/4
ADM#
ADM#
```

Figure-15

BBA:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'BBA' tab selected. The terminal output shows the user logging in as BBA, then typing 'show ip route'. The output displays a list of routes for the 169.110.0.0/16 network, including directly connected interfaces and routes learned via Serial6/0 and Serial6/1. The terminal window has a title bar with tabs for ADM, EEE, CSE, CIVIL, BBA, and ELL. The bottom status bar shows 'solarwinds | Solar-PuTTY free tool' and '© 2019 SolarWinds Worldwide, LLC. All rights reserved.'

```
/1 from LOADING to FULL, Loading Done
*May 22 16:25:05.335: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.171 on Serial6
/0 from LOADING to FULL, Loading Done
BBA#
BBA#
BBA#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

169.110.0.0/16 is variably subnetted, 10 subnets, 5 masks
O    169.110.224.0/24 [110/129] via 169.110.226.171, 00:03:13, Serial6/0
O    169.110.225.0/25 [110/129] via 169.110.226.171, 00:03:13, Serial6/0
C    169.110.225.128/25 is directly connected, FastEthernet0/0
L    169.110.225.129/32 is directly connected, FastEthernet0/0
O    169.110.226.0/26 [110/65] via 169.110.226.171, 00:03:13, Serial6/0
O    169.110.226.64/26 [110/65] via 169.110.226.177, 00:03:23, Serial6/1
O    169.110.226.128/27 [110/129] via 169.110.226.171, 00:03:13, Serial6/0
C    169.110.226.160/27 is directly connected, Serial6/1
                        is directly connected, Serial6/0
L    169.110.226.174/32 is directly connected, Serial6/0
L    169.110.226.175/32 is directly connected, Serial6/1
BBA#
BBA#
BBA#
```

Figure-16

CSE:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'CSE' tab selected. The terminal output shows the user logging in as CSE, then typing 'show ip route'. The output displays a list of routes for the 169.110.0.0/16 network, including directly connected interfaces and routes learned via Serial6/1 and Serial6/2. The terminal window has a title bar with tabs for ADM, EEE, CSE, CIVIL, BBA, and ELL. The bottom status bar shows 'solarwinds | Solar-PuTTY free tool' and '© 2019 SolarWinds Worldwide, LLC. All rights reserved.'

```
/2 from LOADING to FULL, Loading Done
*May 22 16:25:04.095: %OSPF-5-ADJCHG: Process 20, Nbr 169.110.226.171 on Serial6
/0 from LOADING to FULL, Loading Done
CSE#
CSE#
CSE#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

169.110.0.0/16 is variably subnetted, 11 subnets, 5 masks
C    169.110.224.0/24 is directly connected, FastEthernet0/0
L    169.110.224.1/32 is directly connected, FastEthernet0/0
O    169.110.225.0/25 [110/65] via 169.110.226.166, 00:02:58, Serial6/1
O    169.110.225.128/25 [110/129] via 169.110.226.169, 00:02:48, Serial6/0
O    169.110.226.0/26 [110/65] via 169.110.226.169, 00:02:48, Serial6/0
O    169.110.226.64/26 [110/129] via 169.110.226.169, 00:02:48, Serial6/0
O    169.110.226.128/27 [110/65] via 169.110.226.168, 00:02:58, Serial6/2
C    169.110.226.160/27 is directly connected, Serial6/2
                        is directly connected, Serial6/1
                        is directly connected, Serial6/0
L    169.110.226.161/32 is directly connected, Serial6/0
L    169.110.226.162/32 is directly connected, Serial6/1
L    169.110.226.163/32 is directly connected, Serial6/2
CSE#
```

Figure-17

CIVIL:

```
ADM  EEE  CSE  CIVI x  BBA  ELL  | + - □ x
/1 from LOADING to FULL, Loading Done
*May 22 16:25:04.939: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.171 on Serial6
/0 from LOADING to FULL, Loading Done
CIVIL#
CIVIL#
CIVIL#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

    169.110.0.0/16 is variably subnetted, 10 subnets, 5 masks
O       169.110.224.0/24 [110/65] via 169.110.226.163, 00:03:10, Serial6/1
O       169.110.225.0/25 [110/129] via 169.110.226.173, 00:03:00, Serial6/0
         [110/129] via 169.110.226.163, 00:03:10, Serial6/1
O       169.110.225.128/25 [110/129] via 169.110.226.173, 00:03:00, Serial6/0
O       169.110.226.0/26 [110/65] via 169.110.226.173, 00:03:00, Serial6/0
O       169.110.226.64/26 [110/129] via 169.110.226.173, 00:03:00, Serial6/0
C       169.110.226.128/27 is directly connected, FastEthernet0/0
L       169.110.226.129/32 is directly connected, FastEthernet0/0
C       169.110.226.160/27 is directly connected, Serial6/1
         is directly connected, Serial6/0
L       169.110.226.167/32 is directly connected, Serial6/0
L       169.110.226.168/32 is directly connected, Serial6/1
CIVIL#
CIVIL#
```

Figure-18

EEE:

```
ADM  EEE x  CSE  CIVIL  BBA  ELL  | + - □ x
changed state to down
*May 22 16:25:02.843: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.163 on Serial6
/1 from LOADING to FULL, Loading Done
*May 22 16:25:04.887: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.171 on Serial6
/0 from LOADING to FULL, Loading Done
EEE#
EEE#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

    169.110.0.0/16 is variably subnetted, 10 subnets, 5 masks
O       169.110.224.0/24 [110/65] via 169.110.226.162, 00:02:39, Serial6/1
C       169.110.225.0/25 is directly connected, FastEthernet0/0
L       169.110.225.1/32 is directly connected, FastEthernet0/0
O       169.110.225.128/25 [110/129] via 169.110.226.170, 00:02:29, Serial6/0
O       169.110.226.0/26 [110/65] via 169.110.226.170, 00:02:29, Serial6/0
O       169.110.226.64/26 [110/129] via 169.110.226.170, 00:02:29, Serial6/0
O       169.110.226.128/27 [110/129] via 169.110.226.170, 00:02:29, Serial6/0
         [110/129] via 169.110.226.162, 00:02:39, Serial6/1
C       169.110.226.160/27 is directly connected, Serial6/1
         is directly connected, Serial6/0
L       169.110.226.164/32 is directly connected, Serial6/0
L       169.110.226.166/32 is directly connected, Serial6/1
EEE#
```

Figure-19

ELL:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'ELL' tab selected. The terminal output shows the configuration of the ELL process and the display of the IP routing table. The configuration includes OSPF-5-ADJCHG settings and a list of codes for route types. The IP routing table shows various routes, including those learned via Serial6/0 and those directly connected.

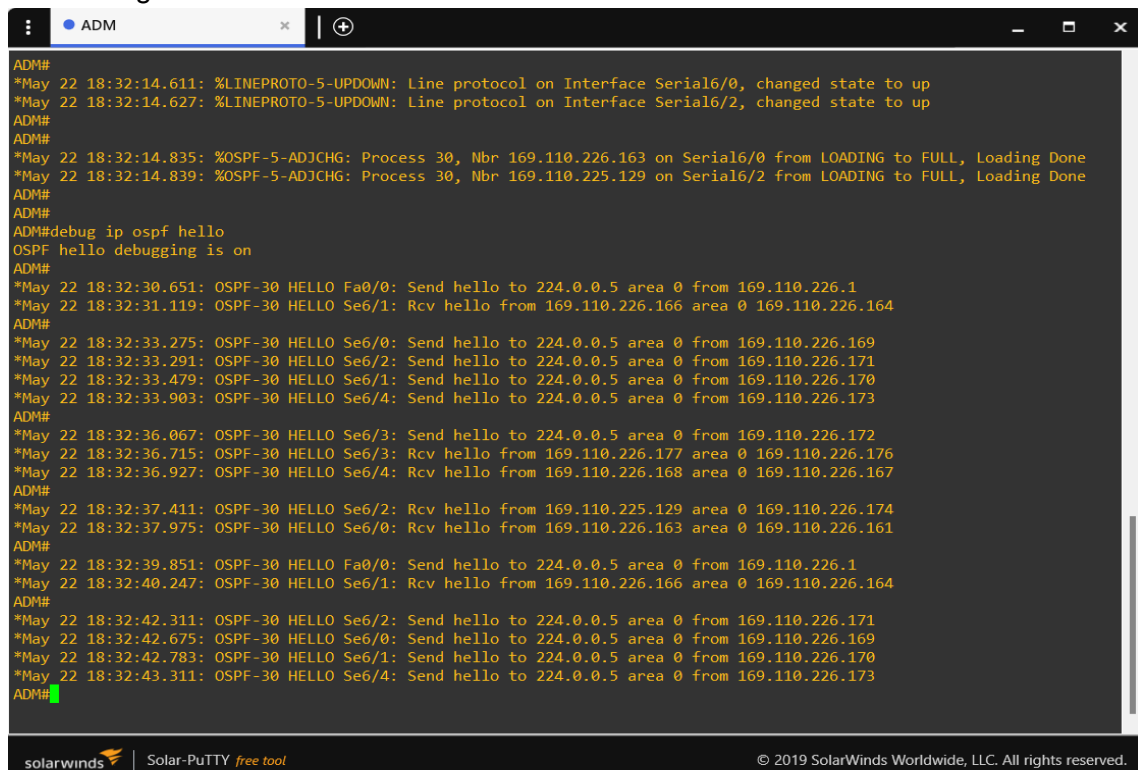
```
*May 22 16:25:04.527: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.171 on Serial6
/0 from LOADING to FULL, Loading Done
ELL#
ELL#
ELL#
ELL#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF 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

    169.110.0.0/16 is variably subnetted, 10 subnets, 5 masks
O       169.110.224.0/24 [110/129] via 169.110.226.172, 00:03:25, Serial6/0
O       169.110.225.0/25 [110/129] via 169.110.226.172, 00:03:25, Serial6/0
O       169.110.225.128/25 [110/65] via 169.110.226.175, 00:03:35, Serial6/1
O       169.110.226.0/26 [110/65] via 169.110.226.172, 00:03:25, Serial6/0
C       169.110.226.64/26 is directly connected, FastEthernet0/0
L       169.110.226.65/32 is directly connected, FastEthernet0/0
O       169.110.226.128/27 [110/129] via 169.110.226.172, 00:03:25, Serial6/0
C       169.110.226.160/27 is directly connected, Serial6/1
               is directly connected, Serial6/0
L       169.110.226.176/32 is directly connected, Serial6/0
L       169.110.226.177/32 is directly connected, Serial6/1
ELL#
ELL#
ELL#
```

Figure-20

6.5. Debug IP OSPF:



The screenshot shows a SolarWinds Solar-PuTTY terminal window with the 'ADM' tab selected. The terminal output shows the configuration of the OSPF process and the display of the OSPF debug output. The debug output shows OSPF hello messages being sent and received on various interfaces.

```
ADM#
*May 22 18:32:14.611: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/0, changed state to up
*May 22 18:32:14.627: %LINEPROTO-5-UPDOWN: Line protocol on Interface Serial6/2, changed state to up
ADM#
ADM#
*May 22 18:32:14.835: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.226.163 on Serial6/0 from LOADING to FULL, Loading Done
*May 22 18:32:14.839: %OSPF-5-ADJCHG: Process 30, Nbr 169.110.225.129 on Serial6/2 from LOADING to FULL, Loading Done
ADM#
ADM#
ADM#debug ip ospf hello
OSPF hello debugging is on
ADM#
*May 22 18:32:30.651: OSPF-30 HELLO Fa0/0: Send hello to 224.0.0.5 area 0 from 169.110.226.1
*May 22 18:32:31.119: OSPF-30 HELLO Se6/1: Rcv hello from 169.110.226.166 area 0 169.110.226.164
ADM#
*May 22 18:32:33.275: OSPF-30 HELLO Se6/0: Send hello to 224.0.0.5 area 0 from 169.110.226.169
*May 22 18:32:33.291: OSPF-30 HELLO Se6/2: Send hello to 224.0.0.5 area 0 from 169.110.226.171
*May 22 18:32:33.479: OSPF-30 HELLO Se6/1: Send hello to 224.0.0.5 area 0 from 169.110.226.170
*May 22 18:32:33.903: OSPF-30 HELLO Se6/4: Send hello to 224.0.0.5 area 0 from 169.110.226.173
ADM#
*May 22 18:32:36.067: OSPF-30 HELLO Se6/3: Send hello to 224.0.0.5 area 0 from 169.110.226.172
*May 22 18:32:36.715: OSPF-30 HELLO Se6/3: Rcv hello from 169.110.226.177 area 0 169.110.226.176
*May 22 18:32:36.927: OSPF-30 HELLO Se6/4: Rcv hello from 169.110.226.168 area 0 169.110.226.167
ADM#
*May 22 18:32:37.411: OSPF-30 HELLO Se6/2: Rcv hello from 169.110.225.129 area 0 169.110.226.174
*May 22 18:32:37.975: OSPF-30 HELLO Se6/0: Rcv hello from 169.110.226.163 area 0 169.110.226.161
ADM#
*May 22 18:32:39.851: OSPF-30 HELLO Fa0/0: Send hello to 224.0.0.5 area 0 from 169.110.226.1
*May 22 18:32:40.247: OSPF-30 HELLO Se6/1: Rcv hello from 169.110.226.166 area 0 169.110.226.164
ADM#
*May 22 18:32:42.311: OSPF-30 HELLO Se6/2: Send hello to 224.0.0.5 area 0 from 169.110.226.171
*May 22 18:32:42.675: OSPF-30 HELLO Se6/0: Send hello to 224.0.0.5 area 0 from 169.110.226.169
*May 22 18:32:42.783: OSPF-30 HELLO Se6/1: Send hello to 224.0.0.5 area 0 from 169.110.226.170
*May 22 18:32:43.311: OSPF-30 HELLO Se6/4: Send hello to 224.0.0.5 area 0 from 169.110.226.173
ADM#
```

6.6. Pings:

BBA to CIVIL:

Figure-22

```

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Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 169.110.226.130 255.255.255.224 gateway 169.110.226.129

PC1_CIVIL> ping 169.110.225.2
169.110.225.2 icmp_seq=1 timeout
*169.110.226.129 icmp_seq=2 ttl=255 time=30.369 ms (ICMP type:3, code:1, Destination host unreachable)
*169.110.226.129 icmp_seq=3 ttl=255 time=15.475 ms (ICMP type:3, code:1, Destination host unreachable)
*169.110.226.129 icmp_seq=4 ttl=255 time=15.323 ms (ICMP type:3, code:1, Destination host unreachable)
169.110.225.2 icmp_seq=5 timeout

PC1_CIVIL> ping 169.110.225.2
84 bytes from 169.110.225.2 icmp_seq=1 ttl=61 time=90.209 ms
84 bytes from 169.110.225.2 icmp_seq=2 ttl=61 time=75.234 ms
84 bytes from 169.110.225.2 icmp_seq=3 ttl=61 time=90.539 ms
84 bytes from 169.110.225.2 icmp_seq=4 ttl=61 time=91.117 ms
84 bytes from 169.110.225.2 icmp_seq=5 ttl=61 time=90.158 ms

PC1_CIVIL>

```

Figure-23

CSE to BBA:

```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
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Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 169.110.224.2 255.255.255.0 gateway 169.110.224.1

PC1_CSE> ping 169.110.225.130
84 bytes from 169.110.225.130 icmp_seq=1 ttl=61 time=259.247 ms
84 bytes from 169.110.225.130 icmp_seq=2 ttl=61 time=89.907 ms
84 bytes from 169.110.225.130 icmp_seq=3 ttl=61 time=90.606 ms
84 bytes from 169.110.225.130 icmp_seq=4 ttl=61 time=90.127 ms
84 bytes from 169.110.225.130 icmp_seq=5 ttl=61 time=90.413 ms

PC1_CSE>
  
```

Figure-24

EEE to ADM:

```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
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Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 169.110.225.2 255.255.255.128 gateway 169.110.225.1

PC1_EEE> ping 169.110.226.2
169.110.226.2 icmp_seq=1 timeout
169.110.226.2 icmp_seq=2 timeout
84 bytes from 169.110.226.2 icmp_seq=3 ttl=62 time=59.314 ms
84 bytes from 169.110.226.2 icmp_seq=4 ttl=62 time=60.179 ms
84 bytes from 169.110.226.2 icmp_seq=5 ttl=62 time=45.677 ms

PC1_EEE>
  
```


Figure-25

ELL to ADM:

```

Welcome to Virtual PC Simulator, version 0.6.2
Dedicated to Daling.
Build time: Apr 10 2019 02:42:20
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For more information, please visit wiki.freecode.com.cn.

Press '?' to get help.

Executing the startup file

Checking for duplicate address...
PC1 : 169.110.226.66 255.255.255.192 gateway 169.110.226.65

PC1_ELL> ping 169.110.226.2
84 bytes from 169.110.226.2 icmp_seq=1 ttl=62 time=150.235 ms
84 bytes from 169.110.226.2 icmp_seq=2 ttl=62 time=61.382 ms
84 bytes from 169.110.226.2 icmp_seq=3 ttl=62 time=60.391 ms
84 bytes from 169.110.226.2 icmp_seq=4 ttl=62 time=60.367 ms
84 bytes from 169.110.226.2 icmp_seq=5 ttl=62 time=60.187 ms

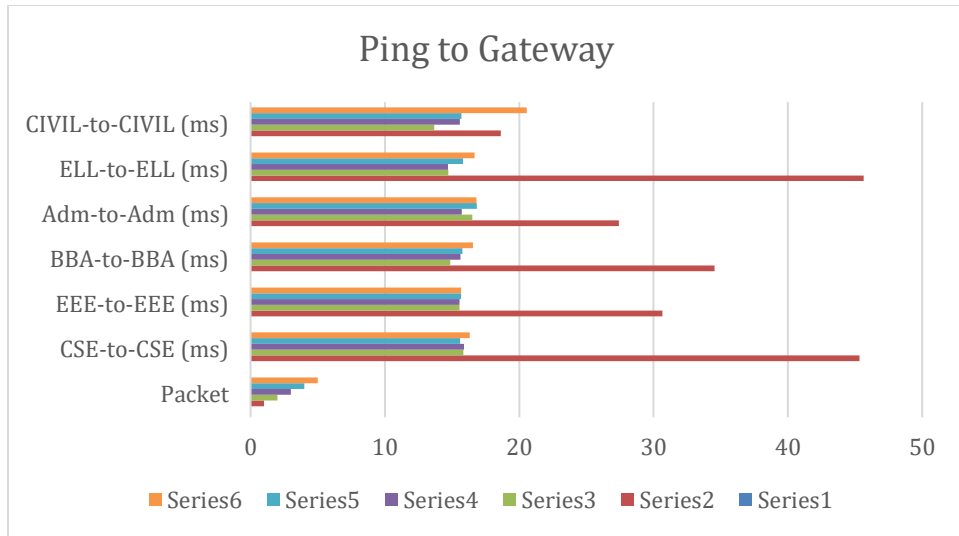
PC1_ELL>
  
```

Figure-26

6.7. Table of ping results:

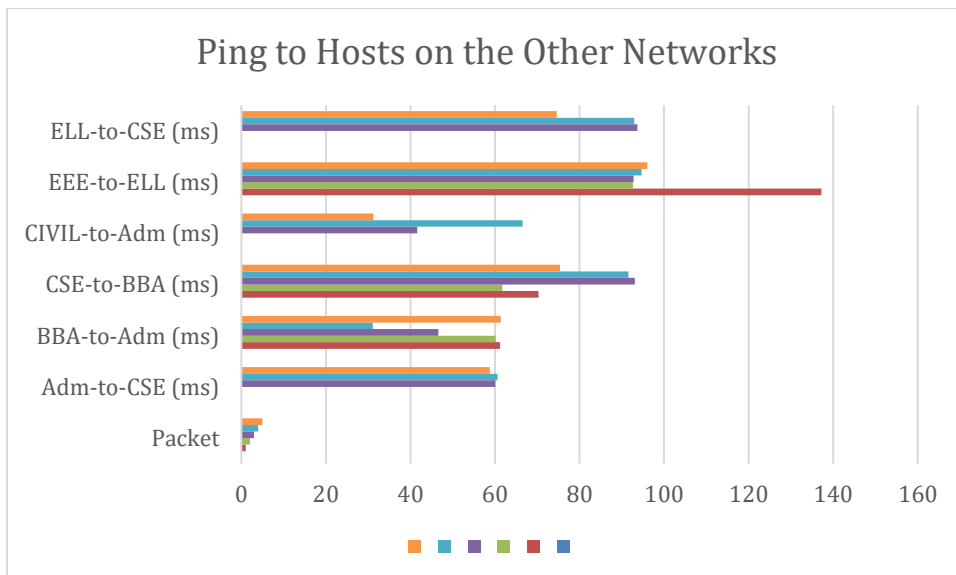
Ping to Gateway:

Packet No.	CSE-to-CSE (ms)	EEE-to-EEE (ms)	BBA-to-BBA (ms)	Adm-to-Adm (ms)	ELL-to-ELL (ms)	CIVIL-to-CIVIL (ms)
1	45.326	30.666	34.549	27.427	45.655	18.627
2	15.846	15.551	14.875	16.517	14.729	13.663
3	15.889	15.559	15.627	15.713	14.707	15.570
4	15.608	15.682	15.780	16.832	15.825	15.708
5	16.310	15.670	16.569	16.819	16.688	20.571



Ping to the Hosts to other networks:

Packet No.	Adm-to-CSE (ms)	BBA-to-Adm (ms)	CSE-to-BBA (ms)	CIVIL-to-Adm (ms)	EEE-to-ELL (ms)	ELL-to-CSE (ms)
1	timeout	61.235	70.329	timeout	137.180	timeout
2	timeout	60.184	61.732	timeout	92.653	timeout
3	60.063	46.594	93.088	41.584	92.776	93.665
4	60.613	31.067	91.534	66.545	94.694	92.953
5	58.821	61.357	75.340	31.265	96.022	74.606



6.8. Discussion on result: After doing all the routing and pinging we can see that all the test results came back positive which means in all the cases the other device pinged back and the debug hello is also working properly. So it is safe to say we did our project perfectly and without fault.

8. Future Work: In future we can further do more to improve project 2 network even more by adding something like cloud pinging, authentication etc.
9. Conclusions: After doing all the designing, subnetting, routing, ip assigning, result analysis we can say that our project is a success. Because by looking at the results we can see that all the devices and routers of all the departments can communicate with each other without any problem and that was our main goal when we started the project. Our OSPF works without any faults which means the routing, wildcard configurations and everything else were done perfectly.

10. References:

- GNS3 doc: <https://docs.gns3.com/docs/>
- Project Format:
https://docs.google.com/document/d/1XYSfDQnW0E2sAnnB1_5auTSHXd9CAIhDbgRZt5EYgY0/edit
- Yaser Rahmati's Exercise on commands: <https://yaserrahmati.gitbook.io/gns3/lab-3-configure-static-route-in-gns3>
- Dr. AK session: <https://www.youtube.com/watch?v=HkizT7oNLtE&feature=youtu.be>
- Documentation of GNS3: <https://gns3.com/community/discussions/gns3-documentation>
- Section IO: <https://www.section.io/engineering-education/understanding-static-dynamic-routing/>
- Sysnet: <https://www.sysnettechsolutions.com/en/configure-ospf-on-cisco-router-in-gns3/>