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Course	**:**	ECC 3702 COMPUTER NETWORKS
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Laboratory	**:**	INTELLIGENT SYSTEMS LAB
Duration	**:**	3 HOURS
Experiment Date	**:**	23TH DECEMBER 2022 – 30TH DECEMBER 2022
Submission Date	**:**	20TH JANUARY 2023

LAB 5 [REPORT]

STATIC ROUTING

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1.0 Introduction

The network layer can be decomposed into two interacting parts; the data plane and the control plane [1]. The primary role of the network layer is to move data packets from a sending host to a receiving host. The two main functions of the network layer are forwarding and routing. Forwarding takes place in the data plane of the network layer and is the router-local action of transferring a datagram from an input link interface to the appropriate output link interface and is typically implemented using hardware. Routing takes place in the control plane and is the network-wide process of determining the end-to-end paths taken by the datagrams from source to destination and is typically implemented using software. Figure 1 below shows the distinction between the data plane and the control plane on a single router.

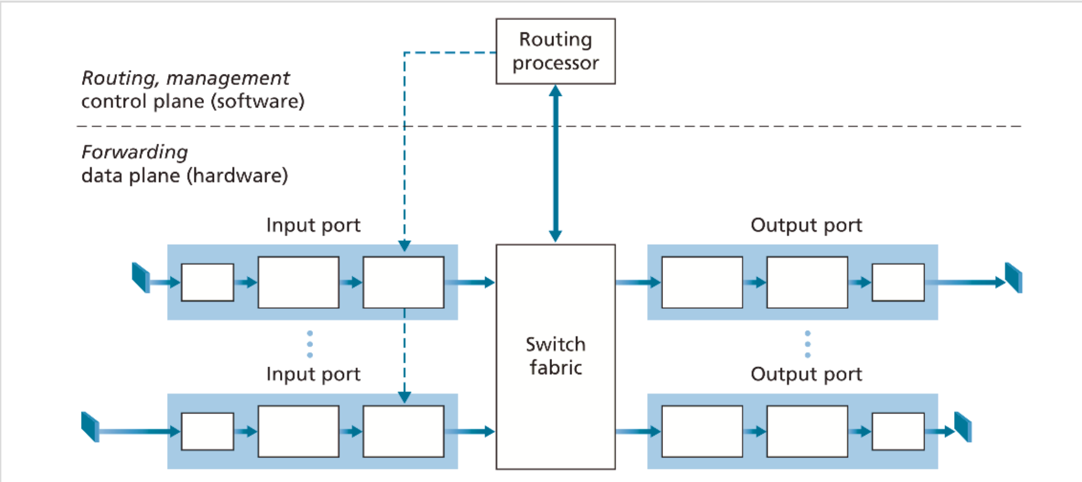


Figure 1: Distinction of data plane and control plane on a single router

A key element in every network router is its forwarding table which is determined by a routing algorithm whose goal is to determine 'good paths' or routes from senders to receivers [1]. One method of classifying routing algorithms is according to whether they are static or dynamic. In static routing algorithms, the routes change very slowly often due to human intervention by manually configuring routing entries. Comparatively, in dynamic routing algorithms, the paths between nodes are changed with respect to any changes in the topology or link cost. Although dynamic routing algorithms are adaptable and respond to changes n the network, they are more susceptible to problems such as routing loops and route oscillation [1].

Static routing uses the static routing algorithm and connects computers or end-devices in different local area networks (LANs) with different gateways using manually configured routing entries instead of information from a dynamic routing system. This method of routing provides a number of advantages and disadvantages as listed below [2]:

- *Advantages of static routing*
    - Static routes are not advertised thus having better security.
    - Use less bandwidth than dynamic routing protocols as routers do not exchange routes
    - No CPU cycles are used to calculate and communicate routes
    - The path used to send data is known in a static route

- *Disadvantages of static routing*
    - Initial configuration and maintenance are time-consuming as it needs to be done on-site.
    - Configuration is prone to human errors, especially in larger networks.
    - Administrator intervention is required to maintain changing route information.
    - With growing networks, maintenance becomes cumbersome due to the scale.
    - Knowledge of the entire network is required for proper implementation.

For this laboratory experiment, the network emulation, and hardware implementation of a star-topology network configuration was carried out. The emulation was done on GNS3 using the Quagga router emulator. For the hardware implementation of the experiment, the LISA NA-810C hardware appliance was used.

2.0 Objectives

- Familiarisation with static routing techniques with multiple gateways.
- Emulation of a static routing configuration with star-topology configuration
- Hardware implementation of a static routing configuration with star-topology configuration

3.0 List of Equipment

No.	Equipment	Quantity
1	GNS3 software	1
2	VirtualBox software	1
3	Wireshark software	1
4	Linux Switch Application (LISA) Image	1
5	Linux Router Appliance [NA-810C - 1U Rackmount Network Appliance Platform]	2
6	Desktop computer	4

4.0 Procedures

1) Emulation of static routing connection on GNS3

i. A star topology configuration was constructed on GNS3 using the Quagga router emulator as shown in Figure 2 below with straight-through cables connecting the VPCS (Virtual PC Simulator) with the router.

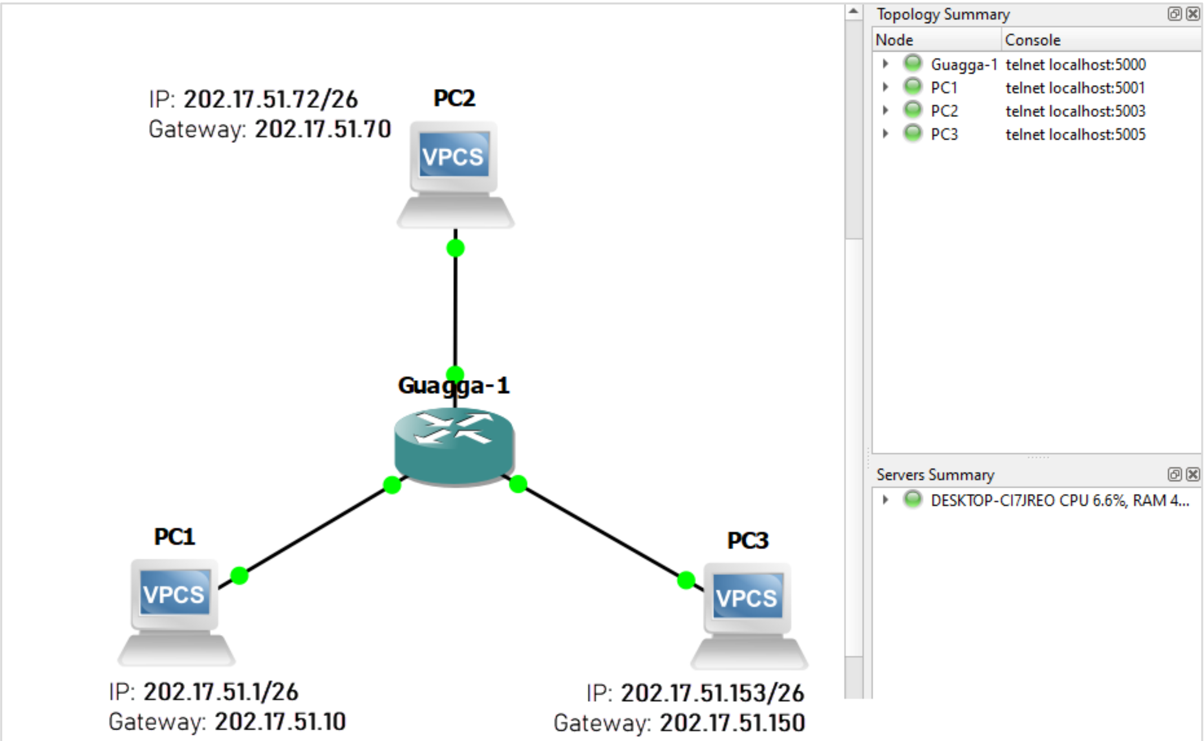


Figure 2: Star-topology configuration using Quagga router emulator on GNS3 for static routing emulation

ii. The emulation was run and the console was opened. The Quagga router emulator was configured to have a different LAN at each interface as shown in Figure 3 below. The gateway of the VPCS should be set as the respective port IP addresses of the router.

iii. The IP addresses for each of the VPCS were set on the console window as well.

iv. The network configuration was tested using the *'traceroute'* command and recorded.

v. The *'ping'* command was also carried out between the VPCS.

Figure 3: Configuration of Quagga router emulator on GNS3 for static routing emulation

2) *Hardware implementation of static routing connection on GNS3*

i. Before setting up the NA-810C hardware appliance, the PCs in use were all disconnected from any Internet connections and the firewall was turned off to allow all ingoing and outgoing connections.

ii. A monitor was connected to the Linux router appliance along with a mouse and keyboard to allow configuration of the appliance. Straight-through cables were used to connect the PCs to the appliance.

iii. For each PC that was used, the following steps were carried out to change the IPV4 addresses of each PC: Control Panel > Network and Sharing Center > Change adapter settings > Ethernet (Select Linux router appliance connection) > Properties > Double click Internet Protocol Version 4 > Change IP addresses. Figure 4 below shows the process of changing the IP address of a PC.

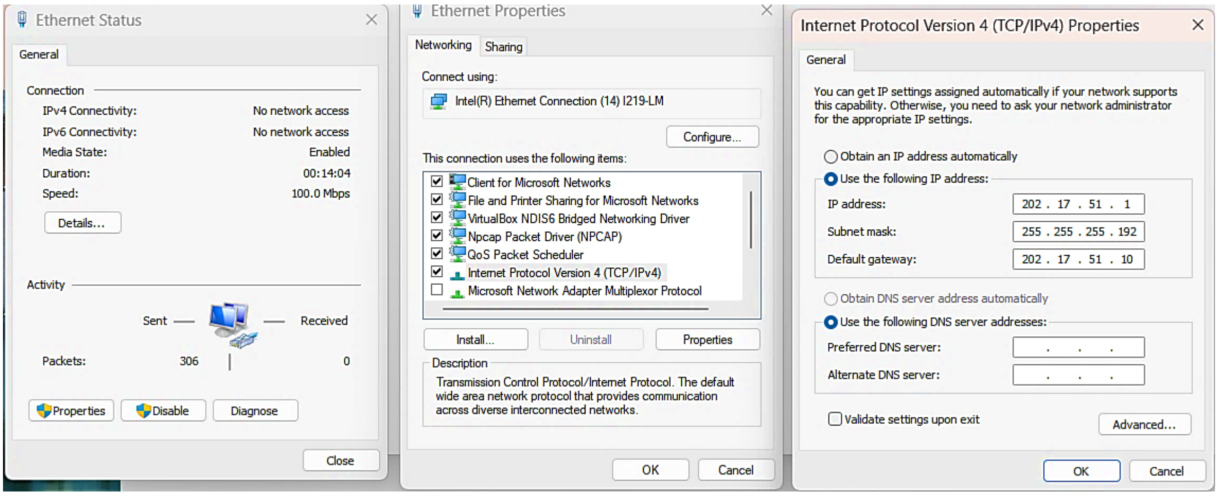


Figure 4: Process of changing IP address of the PCs (showing for PC1)

iv. After all the IP addresses were set for each PC, the Linux routing appliance was configured using the Terminal using the lines shown in Figure 5 below. The '*show interface*' command was used to check if the port connections were configured correctly.

v. The command prompt was opened on all PCs and the '*traceroute*' command was carried out between the PCs.

```
 1
 2 [router12@Router12 ~]$ tc
 3 Usage: tc [ OPTIONS ] OBJECT { COMMAND | help }
 4        tc [-force] -batch filename
 5 where  OBJECT := { qdisc | class | filter | action | monitor }
 6        OPTIONS := { -s[tatistics] | -d[etails] | -r[aw] | -p[retty] | -b[atch] [filename] }
 7 [router12@Router12 ~]$ su
 8 Password:
 9 [root@Router12 router12]# vtysh
10
11 Hello, this is Quagga (version 0.99.15).
12 Copyright 1996-2005 Kunihiro Ishiguro, et al.
13
```

Checking port connections
[Test 1]

```
14 Router12# show interface
15 Interface eth0 is up, line protocol is down
```

Port interface had no connection
[Connection was changed after]

```
16   Description: link to PC1
17   index 2 metric 1 mtu 1500
18   flags: <UP,BROADCAST,MULTICAST>
19   HWaddr: 00:60:e0:50:62:7c
20 Interface eth1 is up, line protocol is up
21   Description: link to PC2
22   index 3 metric 1 mtu 1500
23   flags: <UP,BROADCAST,RUNNING,MULTICAST>
24   HWaddr: 00:60:e0:50:62:7b
25   inet6 fe80::260:e0ff:fe50:627b/64
26 Interface eth2 is up, line protocol is up
27   Description: link to PC3
28   index 4 metric 1 mtu 1500
29   flags: <UP,BROADCAST,RUNNING,MULTICAST>
30   HWaddr: 00:60:e0:50:62:7a
31   inet6 fe80::260:e0ff:fe50:627a/64
32 Interface eth3 is up, line protocol is up
33   index 5 metric 1 mtu 1500
34   flags: <UP,BROADCAST,RUNNING,MULTICAST>
35   HWaddr: 00:60:e0:50:62:79
36   inet6 fe80::260:e0ff:fe50:6279/64
37 Interface li is down
38   pseudo interface
39
40 ...skipping one line
41   index 1 metric 1 mtu 16436
42   flags: <UP,LOOPBACK,RUNNING>
43   inet 10.200.1.2/32
44   inet 127.0.0.1/8
45   inet6 ::1/128
```

Checking port connections
[Test 2]

```
46 Router12# show interface
47 Interface eth0 is up, line protocol is up
48   Description: link to PC1
49   index 2 metric 1 mtu 1500
50   flags: <UP,BROADCAST,RUNNING,MULTICAST>
51   HWaddr: 00:60:e0:50:62:7c
52   inet6 fe80::260:e0ff:fe50:627c/64
53 Interface eth1 is up, line protocol is up
54   Description: link to PC2
55   index 3 metric 1 mtu 1500
56   flags: <UP,BROADCAST,RUNNING,MULTICAST>
57   HWaddr: 00:60:e0:50:62:7b
58   inet6 fe80::260:e0ff:fe50:627b/64
59 Interface eth2 is up, line protocol is up
60   Description: link to PC3
61   index 4 metric 1 mtu 1500
62   flags: <UP,BROADCAST,RUNNING,MULTICAST>
63   HWaddr: 00:60:e0:50:62:7a
64   inet6 fe80::260:e0ff:fe50:627a/64
65 Interface eth3 is up, line protocol is down
66   index 5 metric 1 mtu 1500
67   flags: <UP,BROADCAST,MULTICAST>
68   HWaddr: 00:60:e0:50:62:79
69   inet6 fe80::260:e0ff:fe50:6279/64
70
```

Desired connections made
[eth0, eth1 and eth2]

Figure 5(a): Configuration of the Linux routing appliance on the Terminal for star-topology for static routing (Lines 1 to 70)

```
71  ...skipping 23 lines
72  Router12# conf t
73  Router12(config)# interface eth0
74  \Router12(config-if)# ip a 202.17.51.10/26
75  Router12(config-if)# interface eth1
76  Router12(config-if)# ip a 202.17.51.110/26
77  Router12(config-if)# interface eth2
78  Router12(config-if)# ip a 202.17.51.190/26
79  Router12(config-if)# end
80  Router12# show ip route
81  Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
82         I - ISIS, B - BGP, > - selected route, * - FIB route
83
84  O   10.200.1.2/32 [110/10] is directly connected, lo, 00:06:23
85  C>* 10.200.1.2/32 is directly connected, lo
86  C>* 127.0.0.0/8 is directly connected, lo
87  C>* 202.17.51.0/26 is directly connected, eth0
88  C>* 202.17.51.64/26 is directly connected, eth1
89  C>* 202.17.51.128/26 is directly connected, eth2
```

Port eth0 set with PC1 gateway

Port eth1 set with PC2 gateway

Port eth2 set with PC3 gateway

Summary of port configuration

Figure 5(b): Configuration of the Linux routing appliance on the Terminal for star-topology for static routing (Lines 71 to 89)

5.0 Results and Observations

1) Emulation of static routing connection on GNS3

Figure 6, Figure 7, and Figure 8 below show the console windows for PC1, PC2 and PC3 respectively. For each PC, the IP address was configured, the ping command was carried out between the PCs and lastly, the ‘trace’ command was carried out between the PCs to trace for the routes. Table 1 below shows a summary of the PC IP address configurations.

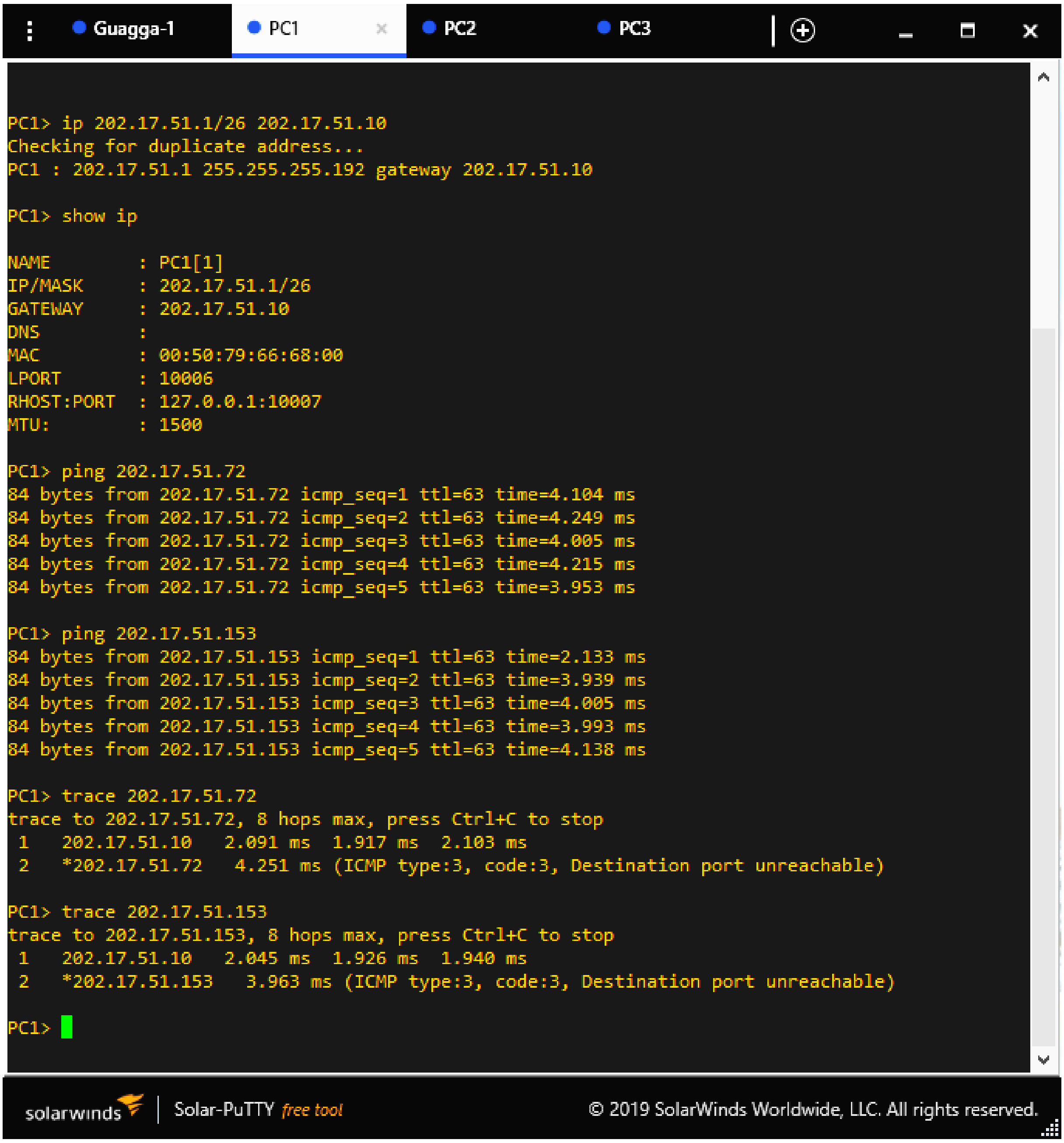


Figure 6: Setting up the IP address for PC1 and execution of ping and trace commands GNS3 static routing emulation

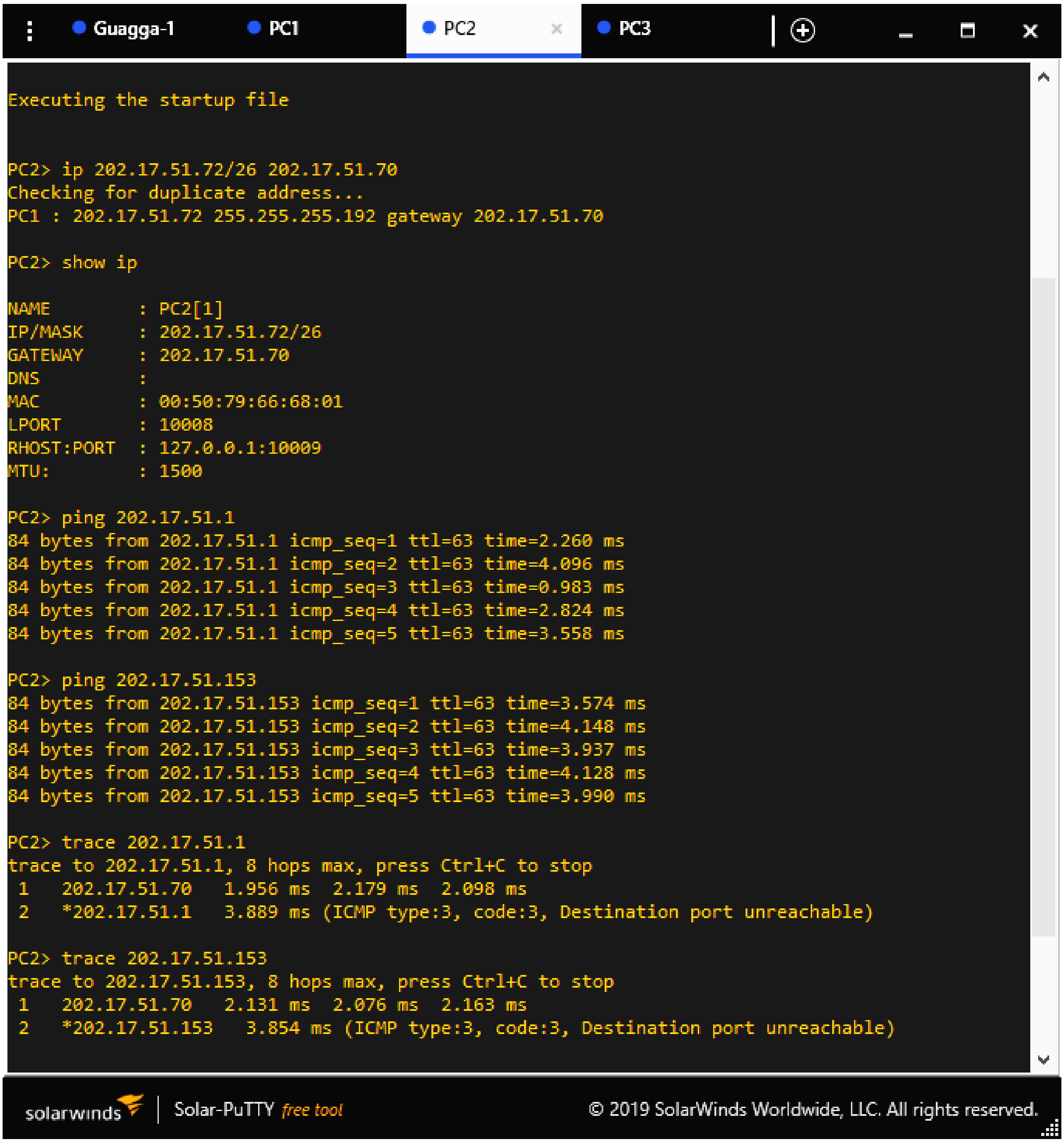


Figure 7: Setting up the IP address for PC2 and execution of ping and trace commands GNS3 static routing emulation

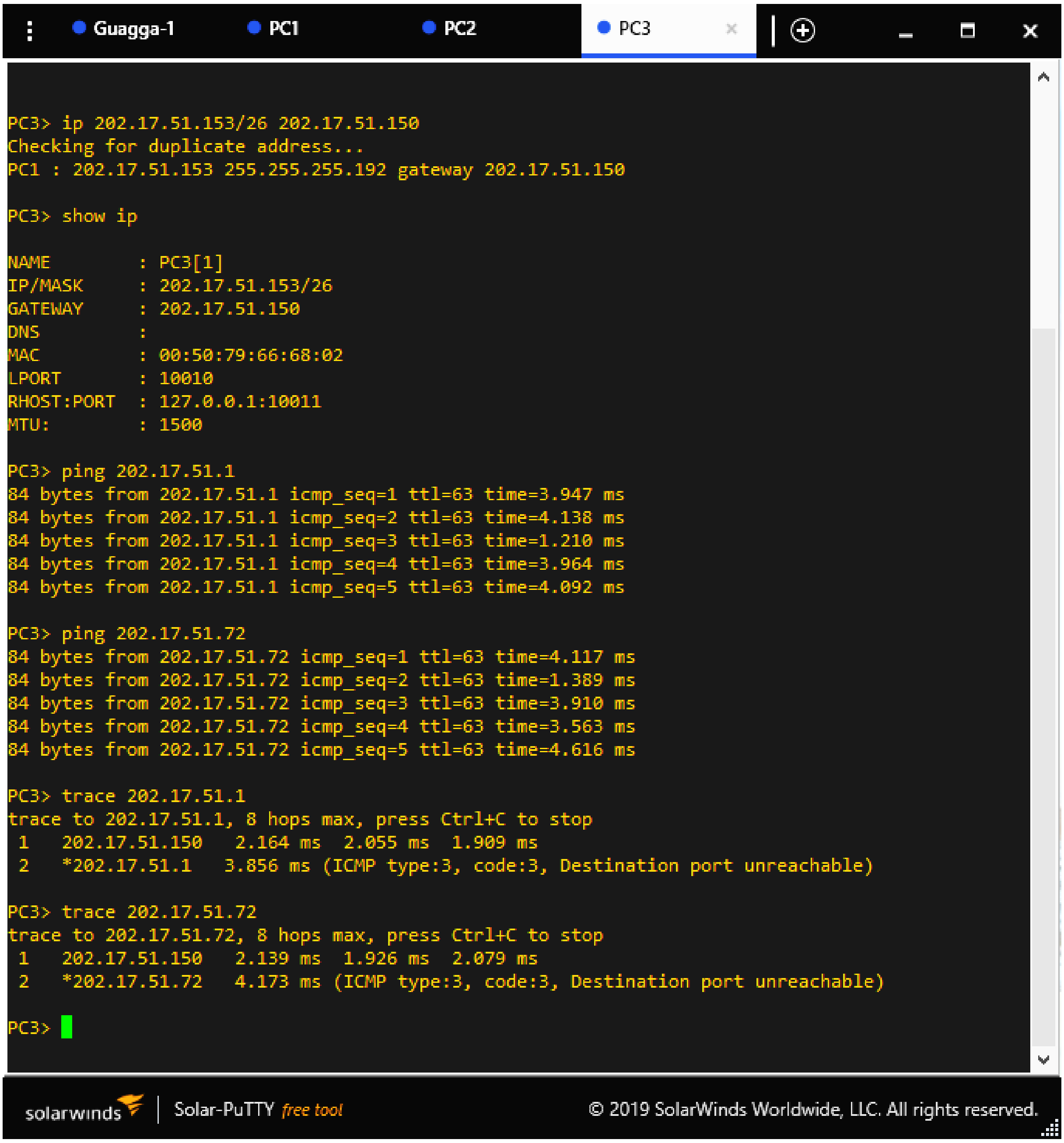


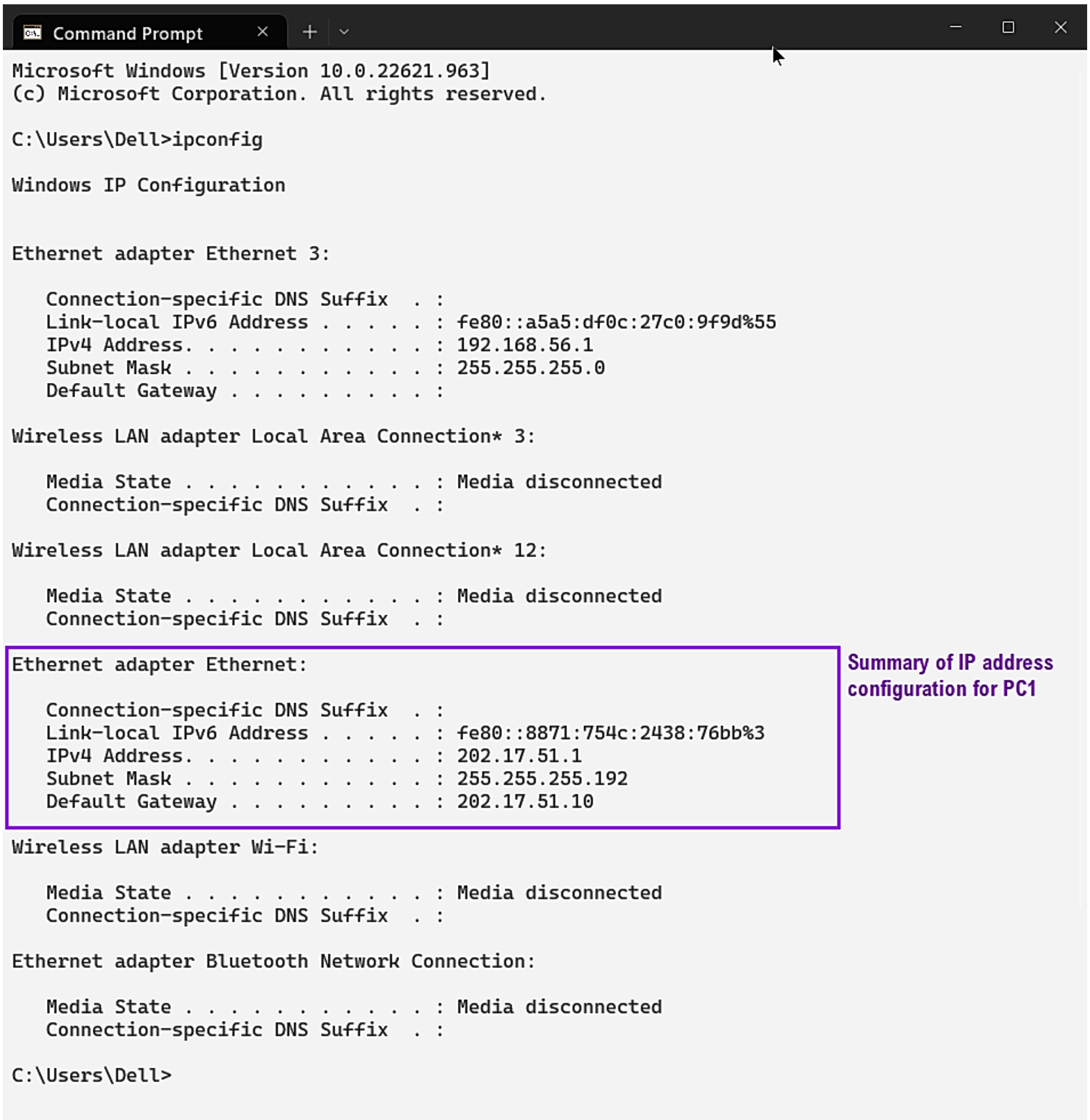
Figure 8: Setting up the IP address for PC3 and execution of ping and trace commands GNS3 static routing emulation

Table 1: Summary of LAN and PC IP address configuration for static routing emulation

Computer	IP Address	Netmask	Gateway Address
PC1	202.17.51.1	255.255.255.192	202.17.51.10
PC2	202.17.51.72	255.255.255.192	202.17.51.70
PC3	202.17.51.153	255.255.255.192	202.17.51.150

2) *Hardware implementation of static routing connection on GNS3*

Figure 9, Figure 11, and Figure 13 below show the command windows for PC1, PC2, and PC3 respectively after carrying out the 'ipconfig' command to view the newly set IP addresses. Figure 10, Figure 12, and Figure 14 show the 'tracert' command that was carried out between the PCs to trace the routes for PC1, PC2, and PC3 respectively Table 2 below shows a summary of the PC IP address configurations.




```
Microsoft Windows [Version 10.0.22621.963]
(c) Microsoft Corporation. All rights reserved.

C:\Users\Dell>ipconfig

Windows IP Configuration


Ethernet adapter Ethernet 3:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::a5a5:df0c:27c0:9f9d%55
   IPv4 Address. . . . . . . . . . . : 192.168.56.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :

Wireless LAN adapter Local Area Connection* 3:

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

Wireless LAN adapter Local Area Connection* 12:

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

Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::8871:754c:2438:76bb%3
   IPv4 Address. . . . . . . . . . . : 202.17.51.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.192
   Default Gateway . . . . . . . . . : 202.17.51.10

Wireless LAN adapter Wi-Fi:

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

Ethernet adapter Bluetooth Network Connection:

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

C:\Users\Dell>
```

Figure 9: IP configuration summary of PC1 for the hardware implementation of static routing in star-topology configuration

```
C:\Users\Dell>tracert 202.17.51.125

Tracing route to LAPTOP-8LFPTCBV [202.17.51.125]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  202.17.51.10
  2     1 ms    <1 ms    <1 ms  LAPTOP-8LFPTCBV [202.17.51.125]

Trace complete.

C:\Users\Dell>tracert 202.17.51.129

Tracing route to DESKTOP-CI7JREO [202.17.51.129]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  202.17.51.10
  2     1 ms     1 ms     1 ms  DESKTOP-CI7JREO [202.17.51.129]

Trace complete.

C:\Users\Dell>
```

Traceroute to PC2

Traceroute to PC3

Figure 10: 'tracert' command executed from PC1 on the hardware implementation of static routing in star-topology configuration

```
Command Prompt
Microsoft Windows [Version 10.0.22000.1335]
(c) Microsoft Corporation. All rights reserved.

C:\Users\g3>ipconfig

Windows IP Configuration


Ethernet adapter Ethernet 2:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::cea3:764c:e639:2786%12
   IPv4 Address. . . . . . . . . . . : 192.168.56.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :

Wireless LAN adapter Local Area Connection* 3:

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

Wireless LAN adapter Local Area Connection* 12:

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

Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::cb5b:e828:7068:d26f%21
   IPv4 Address. . . . . . . . . . . : 202.17.51.125
   Subnet Mask . . . . . . . . . . . : 255.255.255.192
   Default Gateway . . . . . . . . . : 202.17.51.110

Wireless LAN adapter Wi-Fi:

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

Summary of IP address configuration for PC2

Figure 11: IP configuration summary of PC2 for the hardware implementation of static routing in star-topology configuration

```
C:\Users\g3>tracert 202.17.51.1

Tracing route to DESKTOP-ILRJG13 [202.17.51.1]
over a maximum of 30 hops:

  1     1 ms     1 ms     1 ms  202.17.51.110
  2    <1 ms    <1 ms    <1 ms  DESKTOP-ILRJG13 [202.17.51.1]

Trace complete.

C:\Users\g3>tracert 202.17.51.129

Tracing route to DESKTOP-CI7JREO [202.17.51.129]
over a maximum of 30 hops:

  1     1 ms    <1 ms    <1 ms  202.17.51.110
  2    <1 ms     1 ms     1 ms  DESKTOP-CI7JREO [202.17.51.129]

Trace complete.
```

Traceroute to PC1

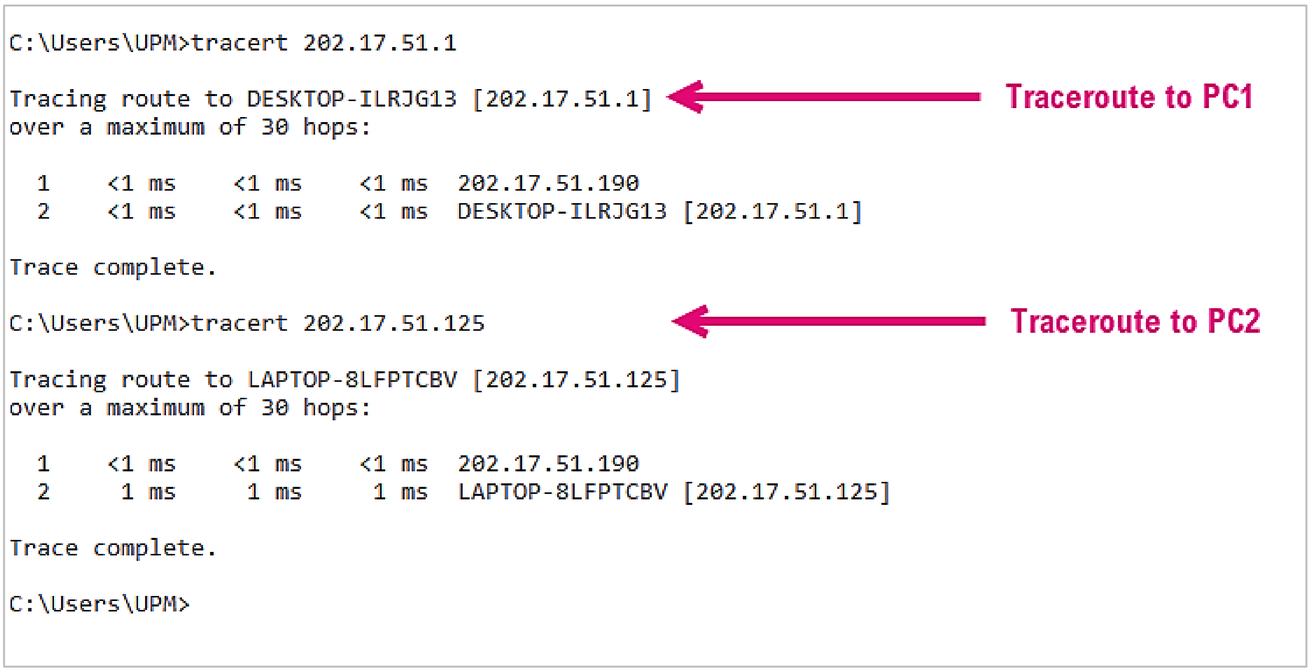
Traceroute to PC3

Figure 12: 'tracert' command executed from PC2 on the hardware implementation of static routing in star-topology configuration

```
Command Prompt
Microsoft Windows [Version 10.0.19044.2364]
(c) Microsoft Corporation. All rights reserved.

C:\Users\UPM>ipconfig

Windows IP Configuration


Ethernet adapter Ethernet 2:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::f34:ec87:7055:bb26%2
   Autoconfiguration IPv4 Address. . : 169.254.107.245
   Subnet Mask . . . . . . . . . . . : 255.255.0.0
   Default Gateway . . . . . . . . . :

Wireless LAN adapter Local Area Connection* 9:

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

Wireless LAN adapter Local Area Connection* 10:

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

Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::c52b:d05f:b0:a9%11
   IPv4 Address. . . . . . . . . . . : 202.17.51.129
   Subnet Mask . . . . . . . . . . . : 255.255.255.192
   Default Gateway . . . . . . . . . : 202.17.51.190

Wireless LAN adapter Wi-Fi:

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

Ethernet adapter Bluetooth Network Connection:

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

Summary of IP address configuration for PC3

Figure 13: IP configuration summary of PC3 for the hardware implementation of static routing in star-topology configuration



```
C:\Users\UPM>tracert 202.17.51.1

Tracing route to DESKTOP-ILRJG13 [202.17.51.1]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  202.17.51.190
  2    <1 ms    <1 ms    <1 ms  DESKTOP-ILRJG13 [202.17.51.1]

Trace complete.

C:\Users\UPM>tracert 202.17.51.125

Tracing route to LAPTOP-8LFPTCBV [202.17.51.125]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  202.17.51.190
  2     1 ms     1 ms     1 ms  LAPTOP-8LFPTCBV [202.17.51.125]

Trace complete.

C:\Users\UPM>
```


Figure 14: 'tracert' command executed from PC3 on the hardware implementation of static routing in star-topology configuration

Table 2: Summary of LAN and PC IP address configuration for static routing emulation

Computer	IP Address	Netmask	Gateway Address
PC1	202.17.51.1	255.255.255.192	202.17.51.10
PC2	202.17.51.125	255.255.255.192	202.17.51.110
PC3	202.17.51.129	255.255.255.192	202.17.51.190

6.0 Discussion

a) What is the purpose of routing?

A computer network comprises many devices called nodes which are connected together by paths or links. Routing is the process by which the best path selection is carried out in a network using predetermined rules [3]. Routing is crucial as it creates efficiency in network communication and also helps to minimise network failure by managing traffic so the network can be used at an optimum capacity without congestion.

b) Discuss static and dynamic routing.

Static routing uses the static routing algorithm and connects computers or end devices in different local area networks (LANs) with different gateways using manually configured routing entries instead of information from a dynamic routing system. In contrast, dynamic routing is the mechanism by which information is exchanged between routers and remote routes are learned automatically to determine the optimal path between network devices [2], [4]. A dynamic routing protocol is utilised to identify and announce the network paths. Table 3 below highlights the differences in static and dynamic routing.

Table 3: Differences between static and dynamic routing [2]

	Static Routing	Dynamic Routing
Configuration Complexity	Increasing complexity with an increase in network size	Independent of network size
Topology Changes	Administrator intervention is required	Adapts automatically
Scaling	Suitable for simple topologies	Suitable for both simple and complex topologies
Security	More secure	Less secure
Resource Usage	No extra resources required	Uses CPU, memory, and link bandwidth
Predictability	Route is always the same	Route is dependent on current topology

c) Does static routing run a routing algorithm? Provide an explanation for your answer.

Static routing is also known as non-adaptive routing meaning that the routing table of a particular router will not change unless being manually modified by the network administrator [5]. Therefore, no complex routing algorithms are used unlike in dynamic routing. The routing tables are changed according to changes in the network topology.

d) ***What is the difference between using Telnet and interactive shell vtysh to configure Quagga routing software?***

Quagga is an open-source routing software that is based on the Zebra router and supports the main standardised routing protocols such as RIP, OSPF or BGP [7]. The daemons can be accessed by telnetting their port number as each has its own configuration file and terminal interface. However, it is not practical to configure the router by telnetting the daemons separately. For this reason, 'vtysh' was introduced to configure everything using a single interface [7]. 'vtysh' is an integrated user interface shell provided by Quagga which connects to each daemon with the UNIX domain socket [6]. It acts as a proxy for user input.

The Quagga daemons are listed below [7]:

- zebra - Interface declaration and static routing
- bgpd – BGP routing protocol
- ospfd – OSPF routing protocol
- ospf6d – OSPF IPv6 routing protocol
- ripd – RIP v2 routing protocol
- ripngd – RIP IPv6 routing protocol

e) ***What is the main configuration file of Quagga routing software and where is it located?***

Configuration files need to be created each time a Quagga daemon is activated [7]. The Quagga daemons and their associated file are listed below:

- zebra - zebra.conf
- bgpd – bgpd.conf
- ospfd – ospfd.conf
- ospf6d – ospf6d.conf
- ripd – ripd.conf
- ripngd – ripngd.conf

The configuration files can be found in the following directory: `/etc/quagga/*.conf` [6].

f) ***How can we enable IP forwarding in Linux for routing?***

Forwarding is disabled on most Linux systems by default [8]. In order to configure Linux as a router, this feature needs to be enabled by changing the corresponding parameter to 1 from 0 which indicates that forwarding is disabled. In order to update the kernel parameters, the `/etc/sysctl.conf` needs to be edited.

g) Why do we need to enable IP forwarding in Linux for routing to work?

IP forwarding is a fundamental role of a router which allows the router to forward traffic from one network interface to another [8]. IP forwarding is the ability of an operating system to accept network packets on one interface, recognise that it is not for the system, then forward the packets accordingly [9]. This allows end devices on one network to reach another end device on another network when configured along with the routing software. If IP forwarding is not enabled, then the connected hosts may be able to communicate with each other however, the network packets would not be able to move from one network to the other.

h) Why do we need to test the connection using Traceroute instead of Ping?

The ping test performs a basic test to determine if a remote host is available whereas the traceroute test checks the complete route which the network packets take from one host to another [10]. This is especially useful to diagnose locations where network slowdowns and congestions occur. Traceroute is a utility that traces packets from the computer to the host and also shows the number of steps or hops required to reach there along with the time taken by each hop [11].

i) Discuss your achievements and problems encountered during the laboratory session.

The objectives of the laboratory session were fulfilled successfully as the desired results were obtained. Static routing of a star-topology network was carried out in two methods; emulation on GNS3 using the Quagga router software and hardware implementation using the NA-810C Linux routing appliance. For both laboratory tasks, the traceroute command was carried out to trace the path taken by the network packets between the hosts. There were no notable issues encountered throughout the experiments and the expected results were obtained.

For both lab experiments, a network of four subnets was designed using the block address 202.17.51.0/24. Since there are three separate LANs required for the given star topology, the closest value of 2^n to accommodate is 4, thus four subnets were created. Figure 15 below shows the calculations made in order to obtain the four subnets.

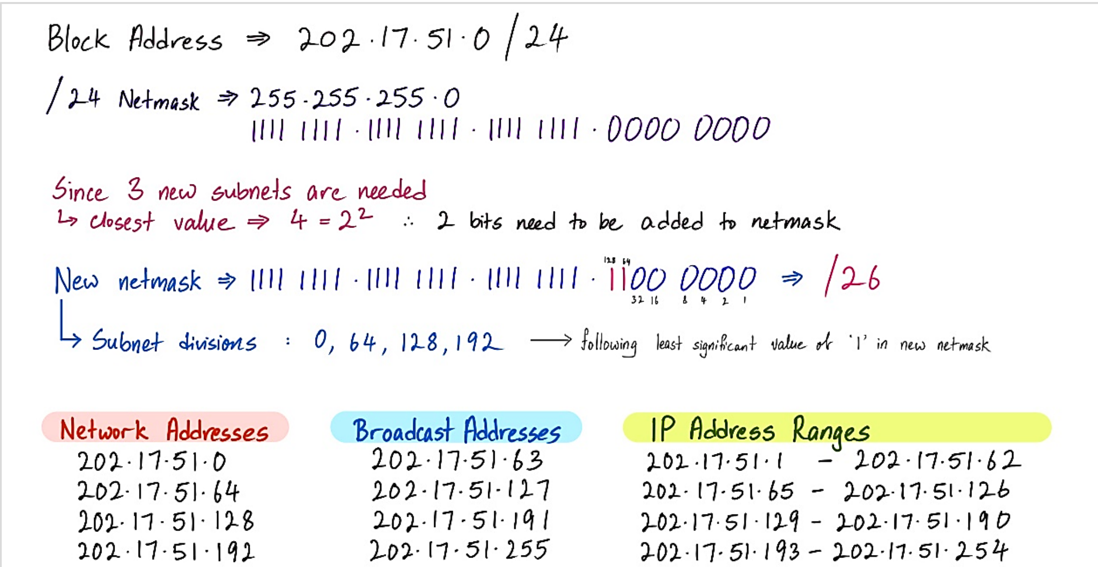


Figure 15: Calculations for creating subnets

7.0 Conclusion

The objectives of the laboratory session were fulfilled successfully as the desired results were obtained. The emulation and hardware implementation of static routing was carried out on a star-topology network configuration. The purpose of static routing was understood and was distinguished from dynamic routing. The functionality of the traceroute command was also observed and the number of hops taken from one PC to another was seen. Since there was only one router between any two devices, two hops were observed in both the emulation and hardware implementation.

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