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Course	:	ECC 3702 COMPUTER NETWORKS
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Submission Date	:	29TH DECEMBER 2022

LAB 4 [REPORT]

VLAN SWITCHING

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1.0 Introduction

A switching network uses a switching hierarchy as shown in Figure 1 below whereby different departments in an institution are connected by link-layer switches that forward frames and thus do not recognise network-layer addresses or use routing algorithms [2]. Although the shown configuration is fully functional in the ideal scenario, three practical drawbacks were identified:

- *Lack of traffic isolation* – Although the hierarchy localises group traffic within a single switch, the broadcast traffic must still traverse the whole of the institutional network. Limiting the scope of the broadcast traffic would not only improve the LAN performance but also allow for more security and privacy within the network [2].
- *Inefficient use of switches* - Assuming for the shown network, instead of three groups, there were more groups. Assuming N groups, then N first-level switches would be required however these switches could be replaced by a single multi-port switch that could accommodate N groups which would not provide traffic isolation [2].
- *Managing users* – If a user from one group were to move from one group to another, the user would have to physically change the cabling to the changed group [2].

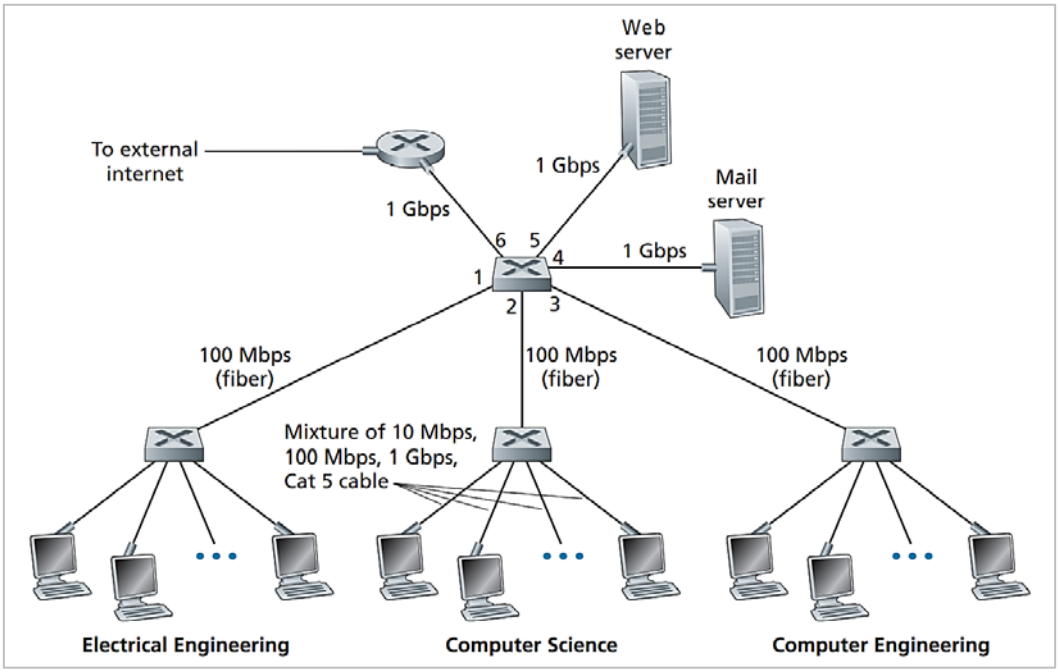


Figure 1: Institutional network connected together by four switches [2]

Due to all the prior drawbacks mentioned, virtual local area network (VLAN) switching is used to virtually isolate and connect computers in the same local area network (LAN) and at the same time limit collision domain for packet frame transmission. A switch that allows VLANs allows multiple virtual local area networks to be defined over a single switch over a single physical local area network infrastructure or in other words a single switched network is partitioned into a set of overlaid virtual networks [1][2]. Hosts within a VLAN are able to communicate with each other but not the hosts of another VLAN connected to the same switch [2].

Just like LAN, VLANs operate at Layer 2 of the network and meet different functional and security requirements. The partitioning of a single LAN avoids the need to have multiple distinct

physical networks for different uses [1]. There are two main types of VLAN; port-based or static VLAN and use-based or dynamic VLAN. In port-based VLAN, the ports on the switch or interfaces, are divided into groups by a network manager or engineer [1][2] Each group constitutes a VLAN, with the ports in each VLAN forming a broadcast domain [2]. In use-based VLAN, traffic is assigned to VLANs dynamically, based on the type of traffic or the device creating the traffic. A port may be assigned to a VLAN based on the identity of the device attached [1]. A single port can be associated with multiple dynamic VLANs.

A VLAN is identified on a network switch via a VLAN ID whereby each port on a switch may have one or more VLAN IDs assigned to it and it will select a default VLAN if no other VLAN is assigned. Each VLAN provides a data link layer access to all hosts that are connected to the ports configured with its VLAN ID. This VLAN ID is then translated into a VLAN tag which is a 12-bit field in the header data of the frames. Since 12 bits are used, there are a maximum of 4096 VLANs that can be defined per LAN. The VLAN tagging is defined by the IEEE using the 802.1Q standard [1][2]. A VLAN tag is not attached to an Ethernet frame when it is received from a host. The tag is added by the switch, which then forwards these tagged frames toward their destination MAC addresses by forwarding to the ports with which the particular VLAN is associated.

Although VLAN has advantages; helping to control broadcast traffic, tightening security and performance improvement, there are some disadvantages. They are as follows; limit to 4096 VLANs per switching domain, difficulty in the management of spanning tree structure used to prevent traffic loops, and the identification of VLANs that a wall jack or AP has access to.

For this laboratory experiment, the network simulation, emulation, and hardware implementation of a single-switch VLAN star-topology network configuration and a two-switch configuration with link aggregation were carried out. The simulation and emulation stages of the laboratory experiment were done on GNS3 using the GNS3 Ethernet switch and LISA emulator respectively. For the hardware implementation of the experiment, the LISA NA-810C hardware appliance was used.

2.0 Objectives

- Simulation and emulation of VLAN switching on a single switch star topology configuration
- Simulation and emulation of VLAN switching on a configuration with two switches with link aggregation
- Hardware implementation of VLAN switching on a single switch star topology configuration
- Hardware implementation of VLAN switching on a configuration with two switches with link aggregation

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 Switch Hardware Appliance [NA-810C - 1U Rackmount Network Appliance Platform]	2
6	Desktop computer	6

4.0 Procedures

1) Simulation of VLAN switching on a single switch star topology configuration on GNS3

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

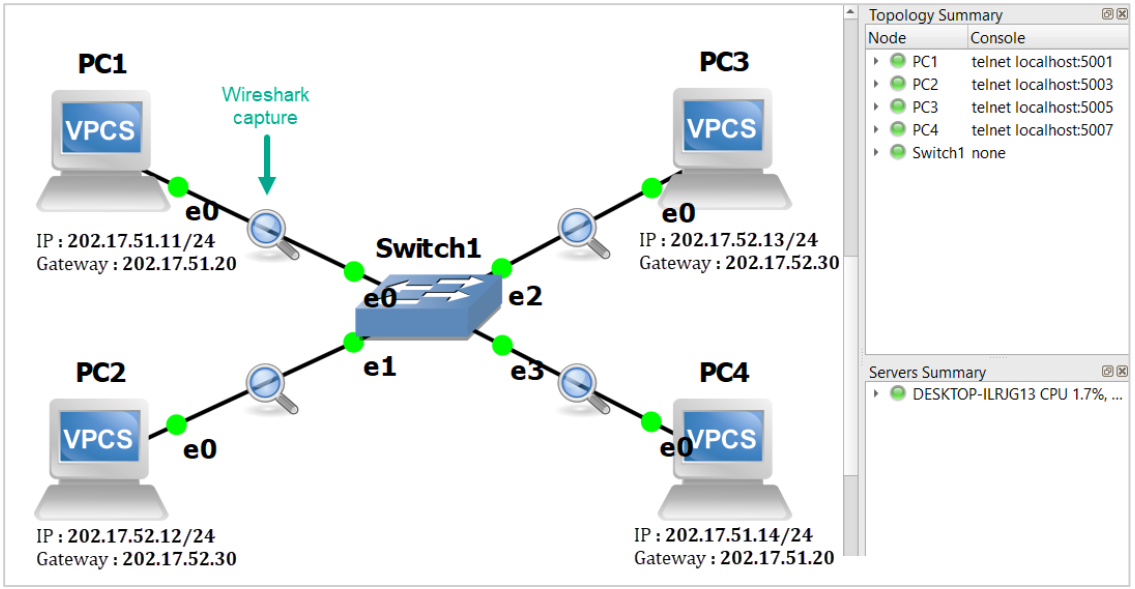


Figure 2: Single switch star-topology configuration using GNS3 Ethernet switch for VLAN switching simulation

ii. The GNS3 Ethernet switch shown in Figure 1 above was configured such that the ports e0 and e3 were connected to PC1 and PC4 respectively in a VLAN while the ports e1 and e2 were connected to PC2 and PC3 respectively in another VLAN. Figure 2 below shows the configuration that was carried out.

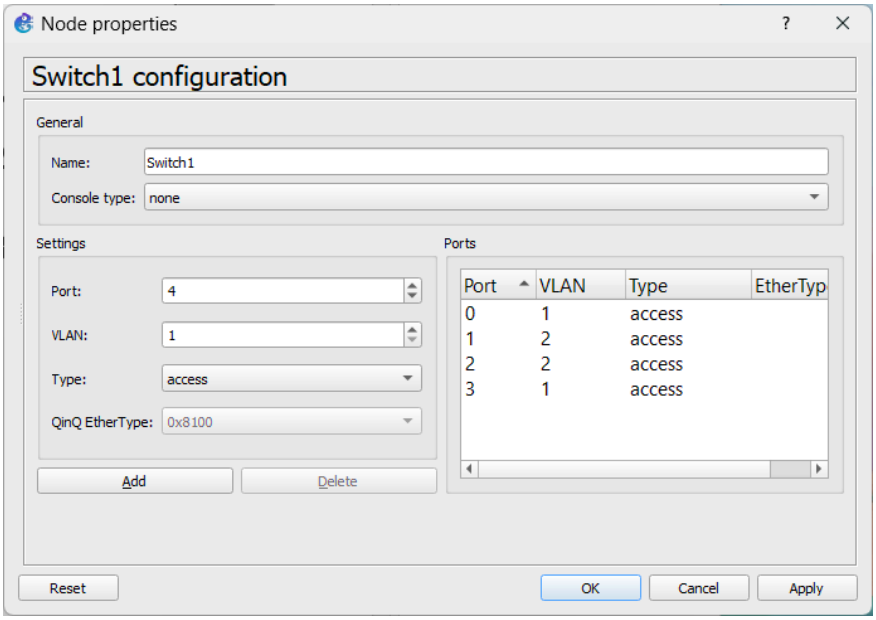


Figure 3: VLAN configuration of Ethernet switch on GNS3 for simulation of single switch star-topology configuration

iii. The simulation was then run and the console was opened. Each connection was also made to capture the packet transfer using Wireshark.

iv. The ping command was carried out between the PCs with each other to observe the behaviour of the VLAN connections.

2) Emulation of VLAN switching on a single switch star topology configuration on GNS3 using LISA

i. A star topology configuration was constructed on GNS3 using the LISA emulator switch as shown in Figure 4 below with straight-through cables connecting the VPCS (Virtual PC Simulator) with the switch.

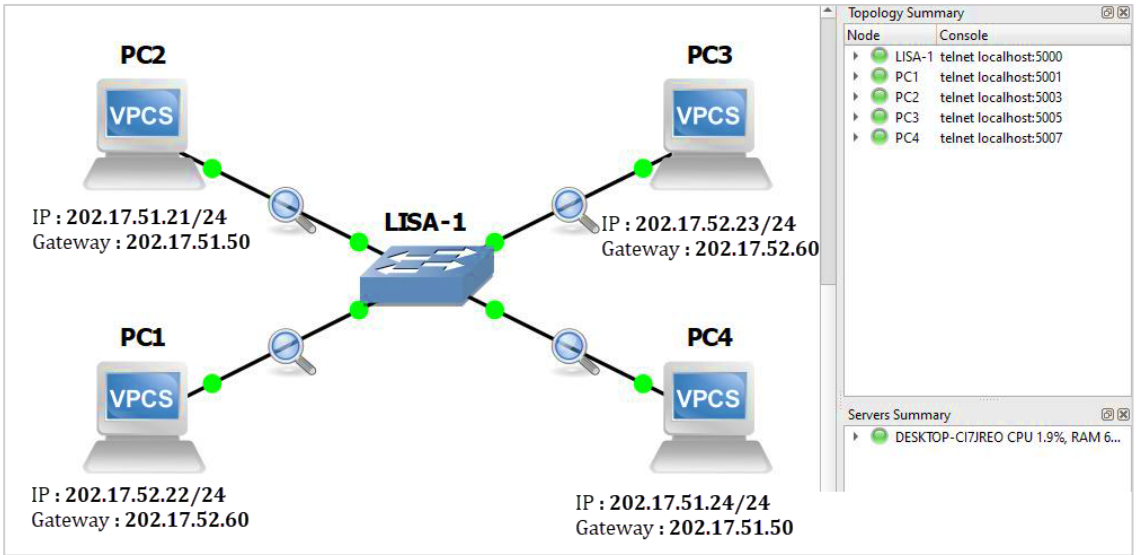


Figure 4: Single switch star-topology configuration using LISA switch emulator for VLAN switching simulation

ii. The simulation was run and the console was opened. The LISA switch emulator was configured to have two different VLANs comprising of PC1 and PC4 in one and PC2 and PC3 in another. Figure 5 below shows the configuration that was carried out.

s

Figure 5: Configuration of LISA switch on console with VLAN setup

v. Each connection was made to capture the packet transfer on Wireshark.

vi. The ping command was carried out between the PCs with each other to observe the behaviour of the VLAN connections.

3) Hardware implementation of VLAN switching on a single switch star topology configuration using hardware LISA appliance

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

ii. A monitor was connected to the LISA appliance along with a mouse and keyboard to allow the configuration of the appliance. Straight-through cables were used to connect the PCs to the LISA switching 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 LISA appliance connection) > Properties > Double click Internet Protocol Version 4 > Change IP addresses. Figure 6 below shows the process of changing the IP addresses of the PCs.

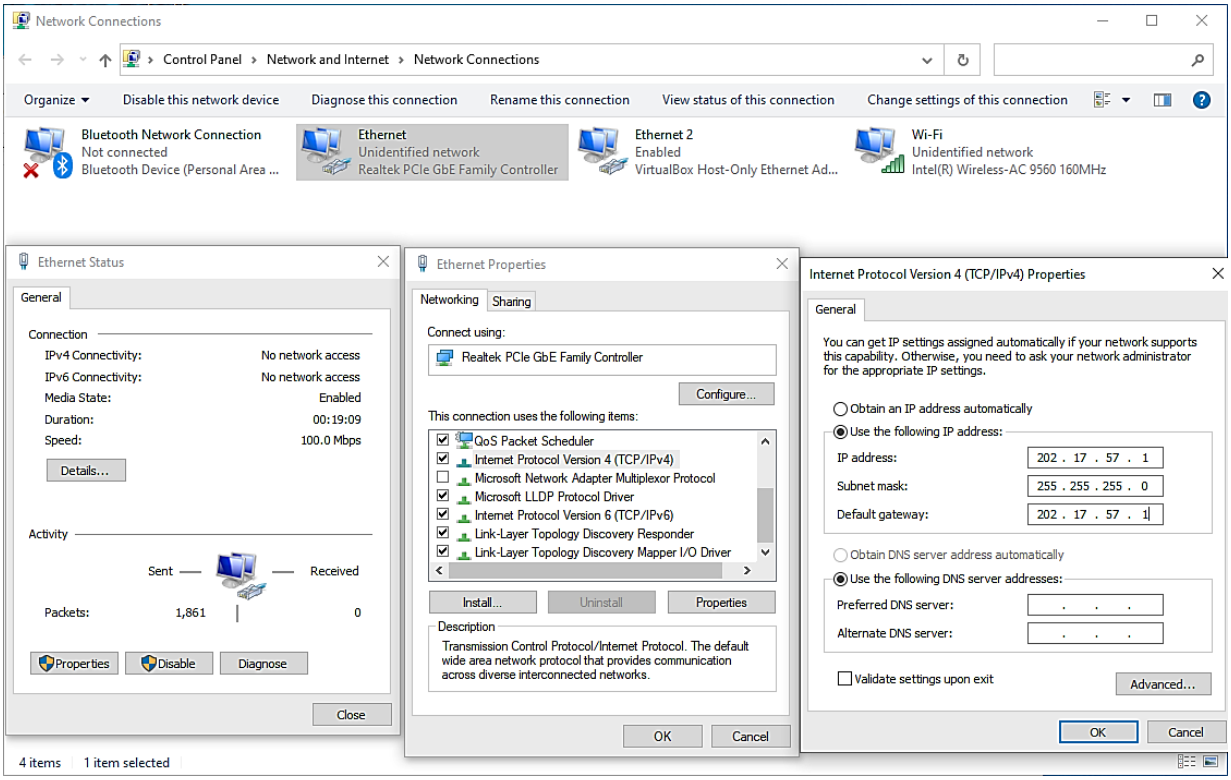


Figure 6: Process of changing the IP address of the PCs (showing for PC1)

iv. After all the IP addresses were set for each PC, the LISA appliance was configured using the Terminal using the following lines shown in Figure 7 below.

v. The command prompt was then opened on all PCs along with Wireshark. The ping command was carried out among all PCs for each individual PC and the packet transfer was observed on Wireshark.

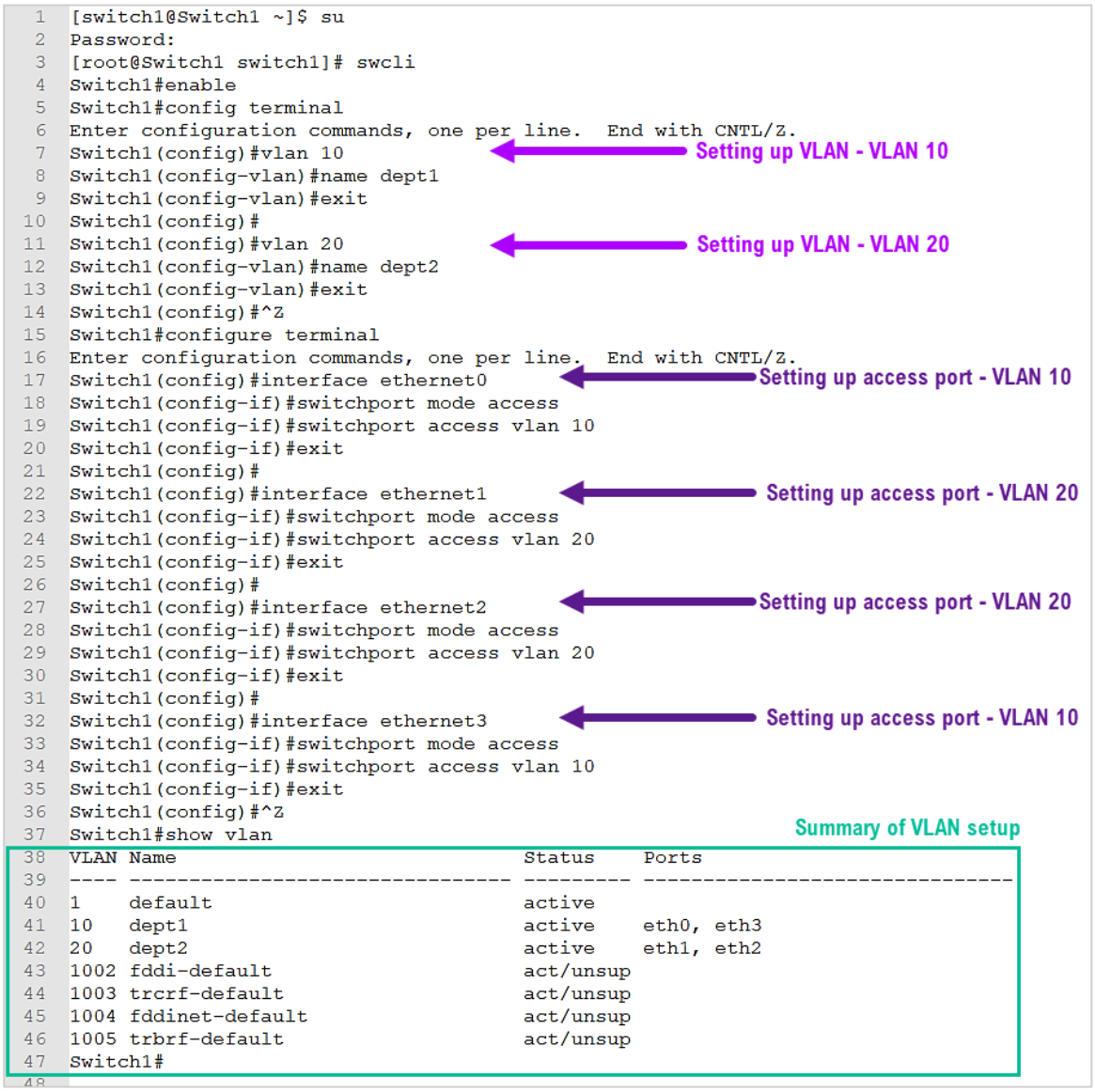


Figure 7: Configuration of the LISA hardware appliance on the Terminal with VLAN setup

4) Simulation of VLAN switching on a configuration with two switches with link aggregation on GNS3

i. A star topology configuration was constructed on GNS3 using the existing Ethernet switch as shown in Figure 8 below with straight-through cables connecting the VPCS (Virtual PC Simulator) with the switch and a crossover cable connecting the two switches.

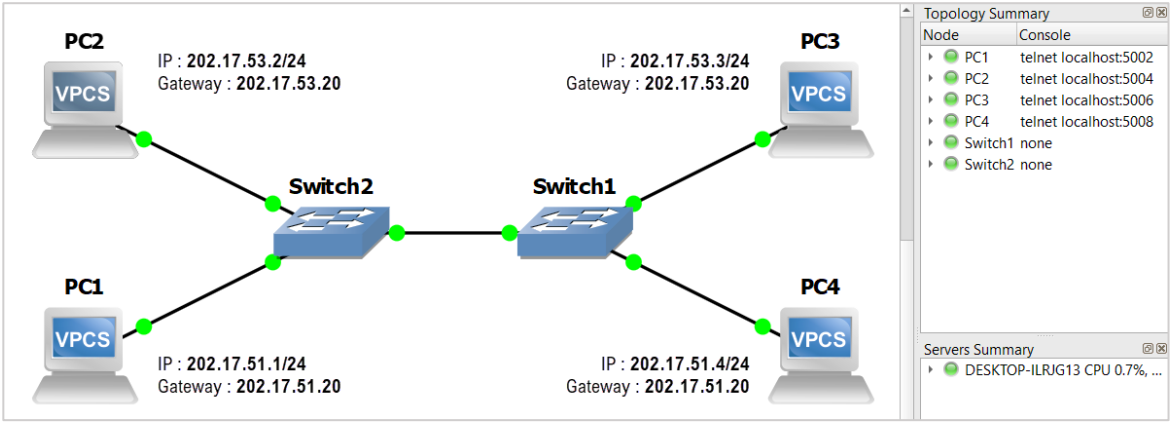


Figure 8: Configuration with two switches with link aggregation in star-topology configuration using GNS3 Ethernet switch for VLAN switching simulation

ii. PC1 and PC2 were connected to one switch while PC3 and PC4 were connected to another switch. The switches were connected with link aggregation. PC1 and PC4 were made to be connected in one VLAN while PC2 and PC3 were in another VLAN.

iii. The simulation was run and the console was opened. Each connection was also made to capture the packet transfer on Wireshark.

iv. The ping command was carried out between the PCs with each other to observe the behaviour of the VLAN connections.

5) Emulation of VLAN switching on a configuration with two switches with link aggregation on GNS3 using LISA

i. The LISA switch emulator was cloned on VM VirtualBox and the clone was then added to GNS3 and the necessary settings were set.

ii. A star topology configuration was constructed on GNS3 using the LISA emulator switch as shown in Figure 9 below with straight-through cables connecting the VPCS (Virtual PC Simulator) with the switch and a crossover cable connecting the two switches.

iii. The simulation was run and the console was opened. The LISA switch emulators were configured to have two different VLANs comprising of PC1 and PC4 in one and PC2 and PC3 in another. Figure 10 and Figure 11 below show the configuration that was carried out.

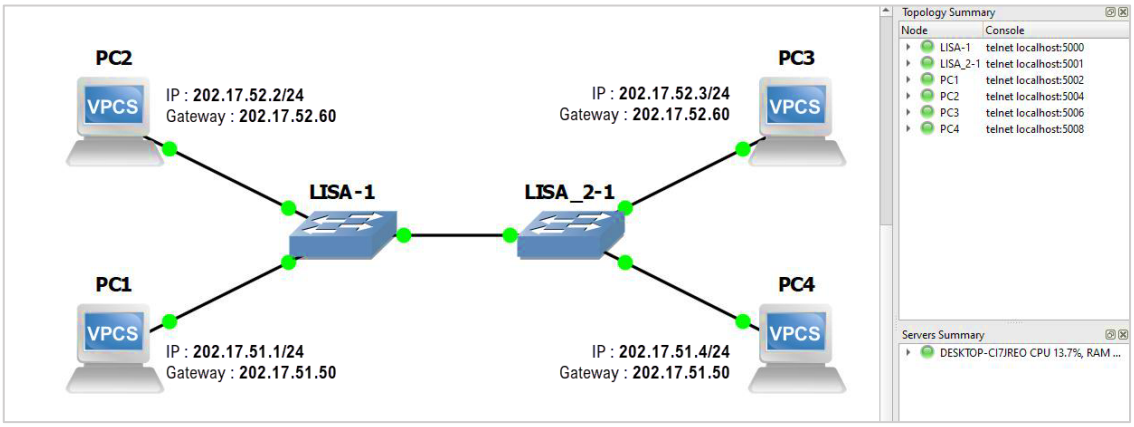


Figure 9: Configuration with two switches with link aggregation in star-topology configuration using GNS3 Ethernet switch for VLAN switching simulation

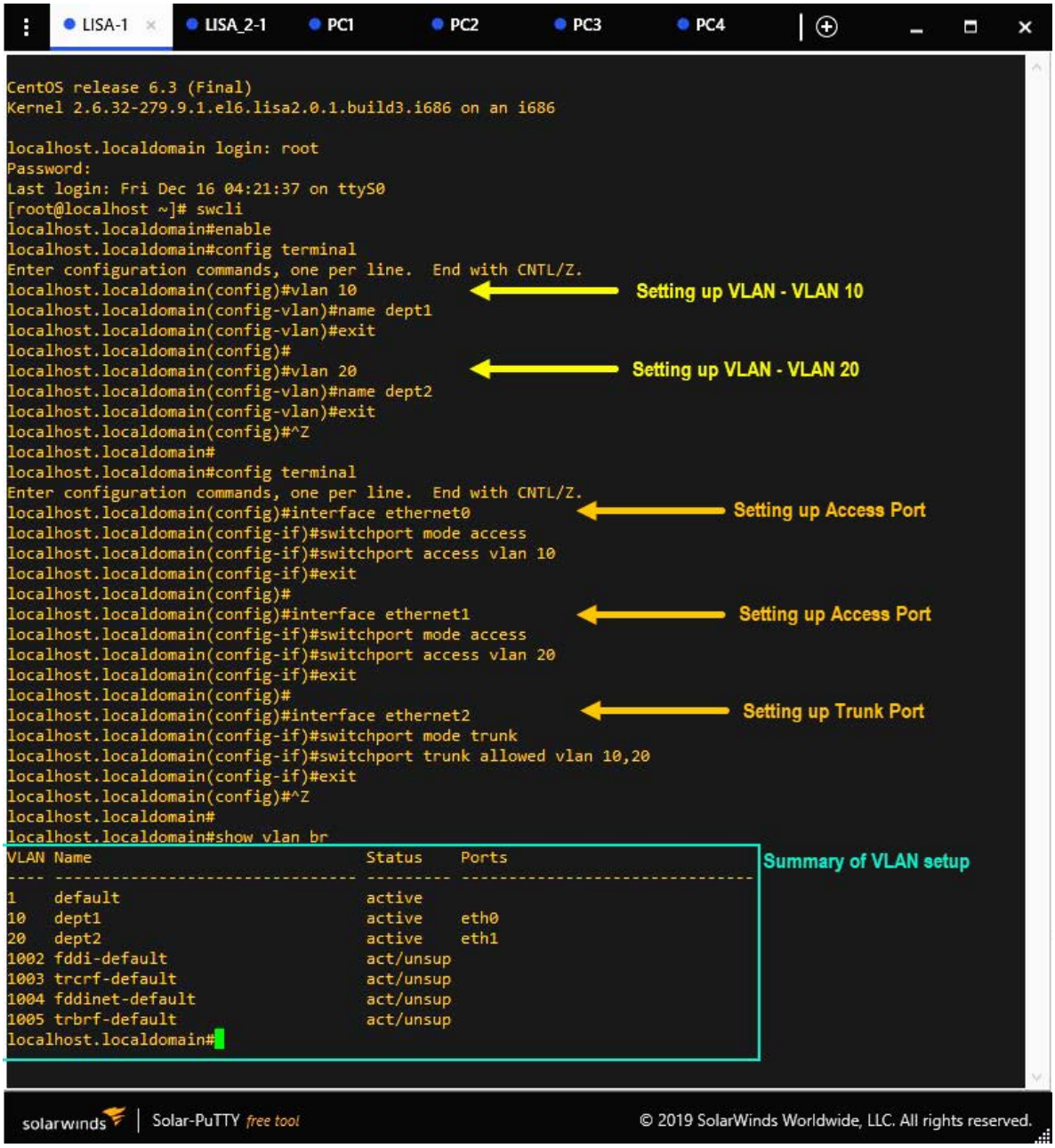


Figure 10: Configuration of LISA switch on console with VLAN setup (PC1 and PC2)

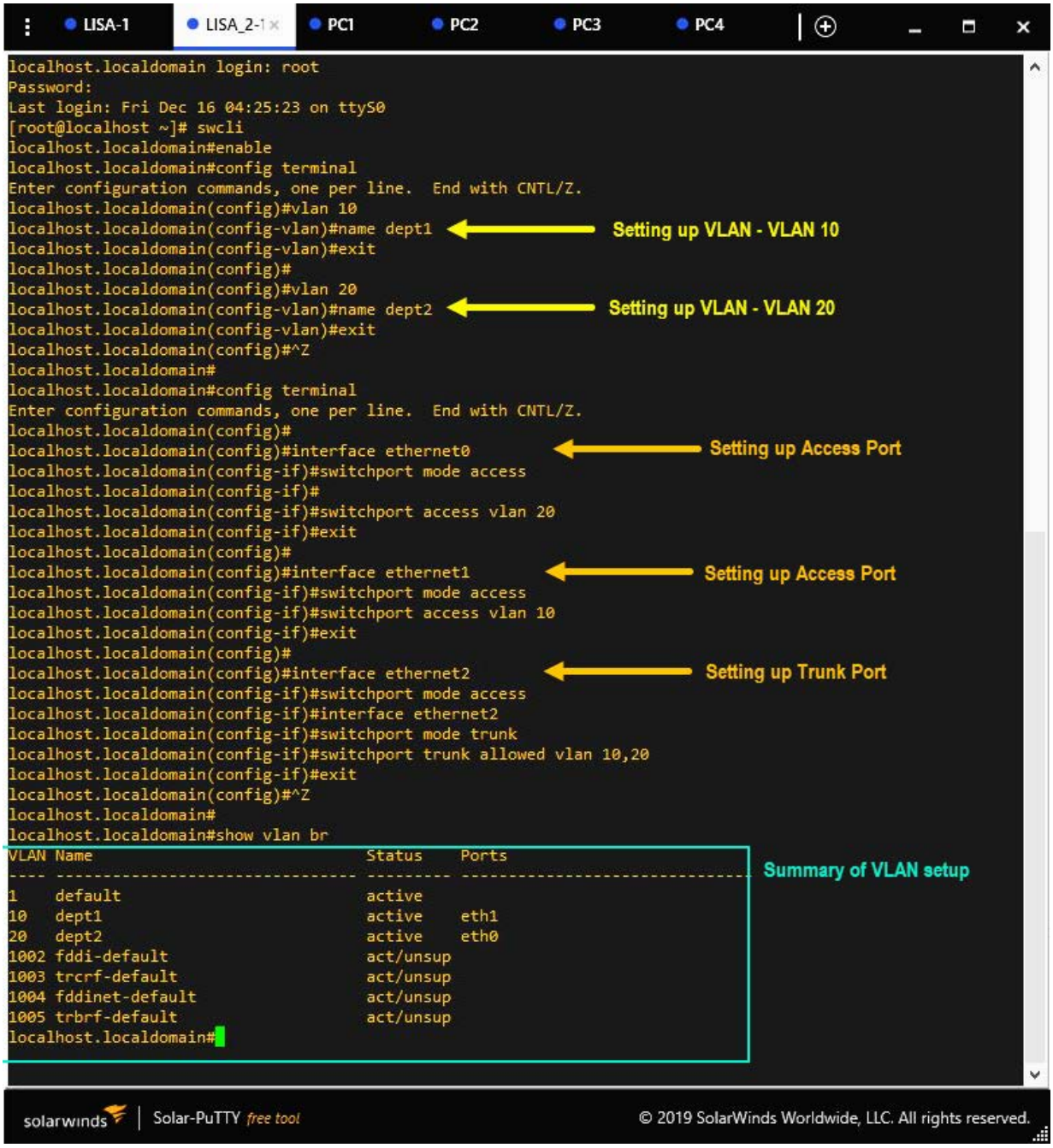


Figure 11: Configuration of LISA switch on console with VLAN setup (PC3 and PC4)

iv. Each connection was made to capture the packet transfer on Wireshark.

v. The ping command was carried out between the PCs with each other to observe the behaviour of the VLAN connections.

6) Hardware implementation of VLAN switching on a configuration with two switches with link aggregation using hardware LISA appliance

i. Similar to Task 3 above of the hardware implementation using a single switch, steps (i) to (iii) were carried out. However, two monitors were connected to two LISA hardware appliances along with two keyboards and two mice.

ii. After all the IP addresses were set for each PC, the LISA appliances were configured using the Terminal. Figure 11 below shows the configuration of the switch that connected PC1 and PC2. A similar configuration was used for the other switch for PC3 and PC4. Figure 12 shows the port connections of the switch to ensure the physical connections were correctly made.

```
[switch1@Switch1 ~]$ su
Password:
[root@Switch1 switch1]# swcli
Switch1#enable
Switch1#config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch1(config)#vlan 10                          <- Setting up VLAN - VLAN 10
Switch1(config-vlan)#name dept1
Switch1(config-vlan)#exit
Switch1(config)#
Switch1(config)#vlan 20                          <- Setting up VLAN - VLAN 20
Switch1(config-vlan)#name dept2
Switch1(config-vlan)#exit
Switch1(config)#^Z
Switch1#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch1(config)#interface ethernet0              <- Setting up access port - VLAN 10
Switch1(config-if)#switchport mode access
Switch1(config-if)#switchport access vlan 10
Switch1(config-if)#exit
Switch1(config)#
Switch1(config)#interface ethernet1              <- Setting up access port - VLAN 10
Switch1(config-if)#switchport mode access
Switch1(config-if)#switchport access vlan 20
Switch1(config-if)#exit
Switch1(config)#
Switch1(config)#interface ethernet2              <- Setting up trunk port
Switch1(config-if)#switchport mode trunk
Switch1(config-if)#switchport trunk allowed vlan 10,20
Switch1(config-if)#exit
Switch1(config)#^Z
Switch1#show vlan                                          Summary of VLAN setup
VLAN Name                              Status    Ports
---- --------------------------------- --------- -------------------------------
1    default                           active
10   dept1                             active    eth0
20   dept2                             active    eth1
1002 fddi-default                      act/unsup
1003 trcrf-default                     act/unsup
1004 fddinet-default                   act/unsup
1005 trbrf-default                     act/unsup
```

Figure 11: Configuration of the LISA hardware appliance on the Terminal with VLAN setup (PC1 and PC2)

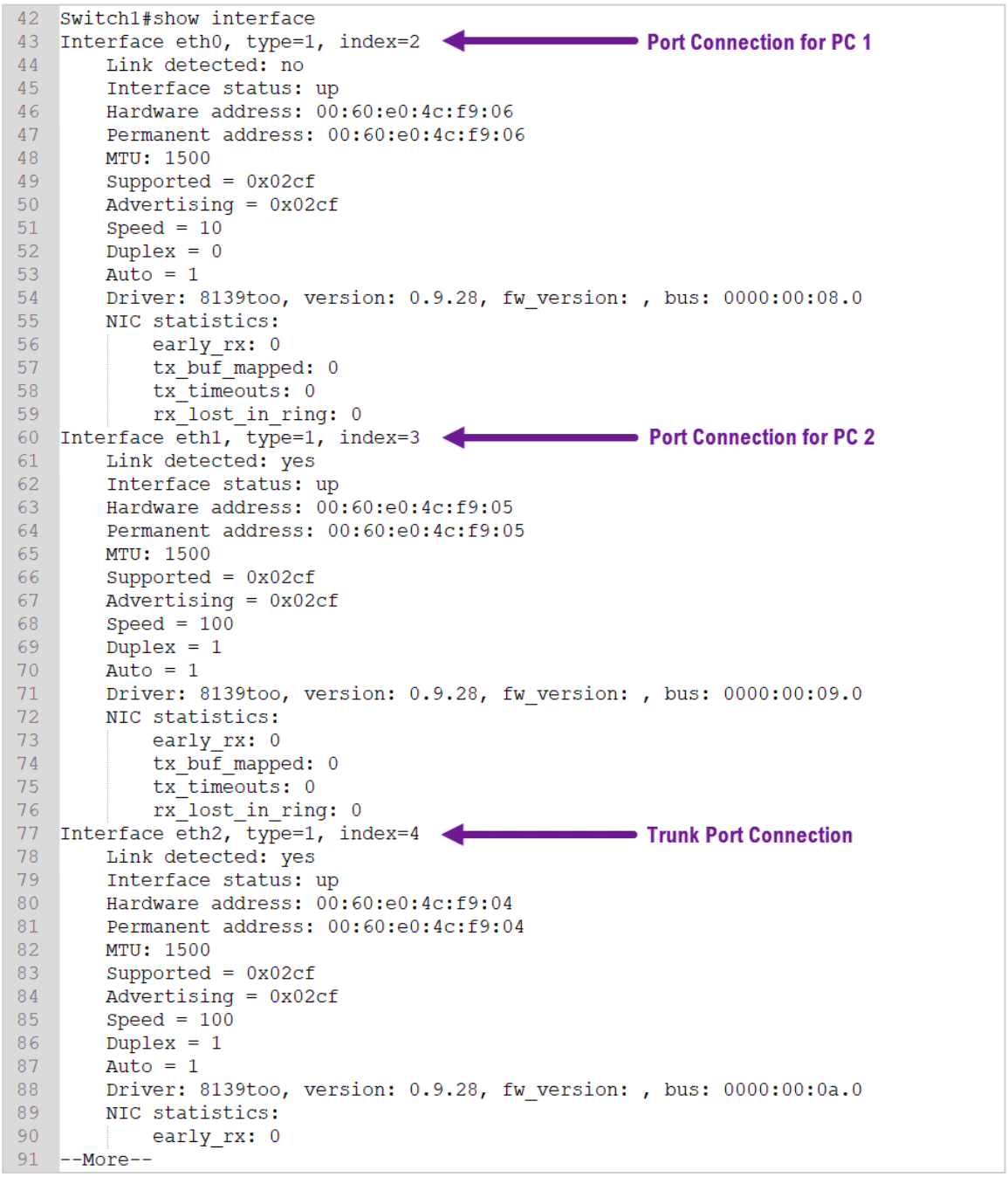


Figure 12: Checking interface or port connections of LISA hardware appliance

iii. The command prompt was then opened on all PCs along with Wireshark. The ping command was carried out among all PCs for each individual PC and the packet transfer was observed on Wireshark.

5.0 Results and Observations

1) Simulation of VLAN switching on a single switch star topology configuration on GNS3

Figure 13, Figure 14, Figure 15, and Figure 16 below show the screengrabs of the console window of the network simulation of the single switch star-topology configuration on GNS3 whereby the VPCSs were configured such that PC1 and PC4 were in one VLAN while PC2 and PC3 were in another VLAN. Figure 17, Figure 18, Figure 19 and Figure 20 below show the captured packets on Wireshark for PC1, PC2, PC3 and PC4 respectively. Lastly, a summary of the LAN address configurations for the GNS3 simulation is shown in Table 1 below.

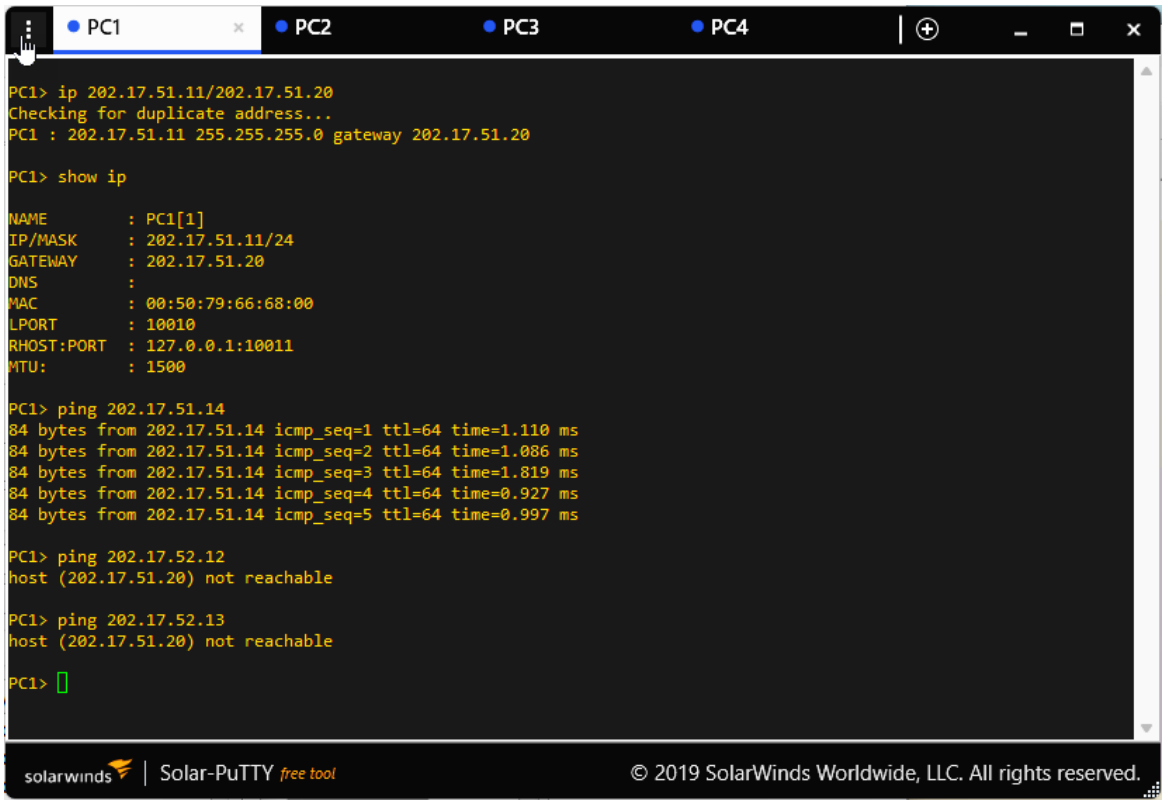


Figure 13: Setting up static IP address and execution of ping command for PC1 on GNS3 simulation using single switch

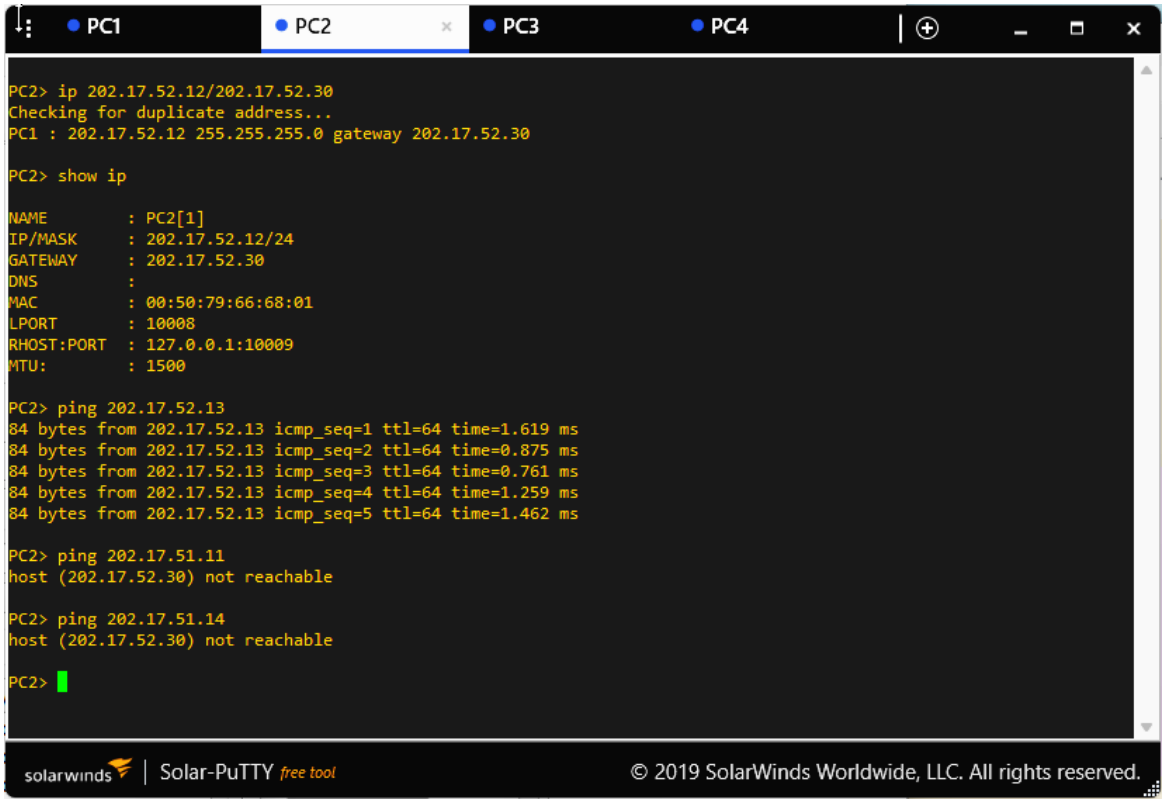


Figure 14: Setting up static IP address and execution of ping command for PC2 on GNS3 simulation using a single switch

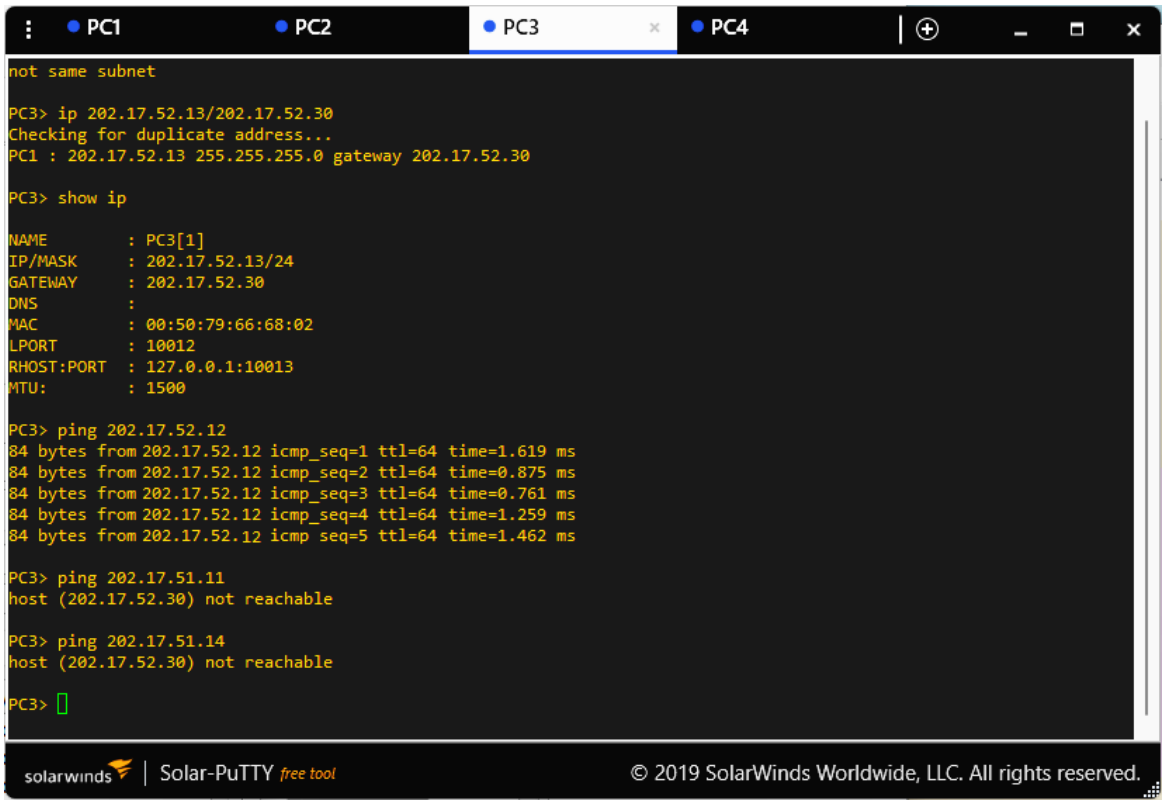


Figure 15: Setting up static IP address and execution of ping command for PC3 on GNS3 simulation using a single switch

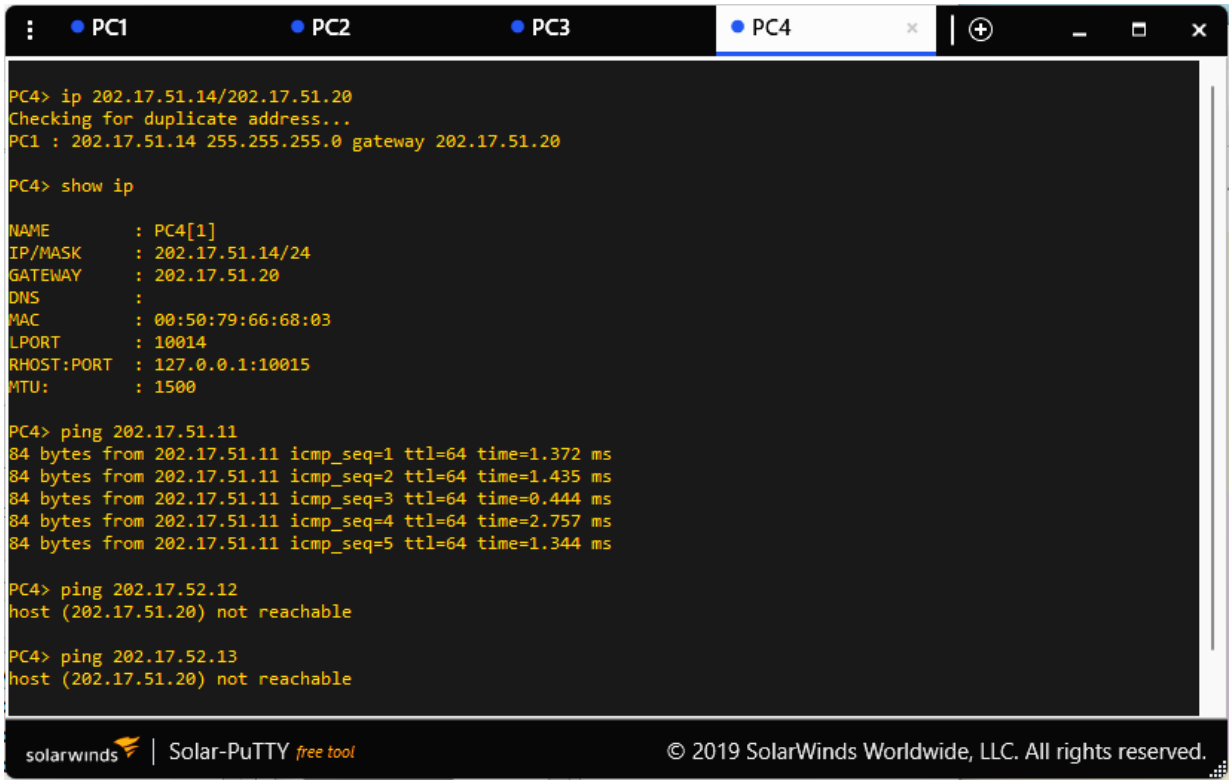
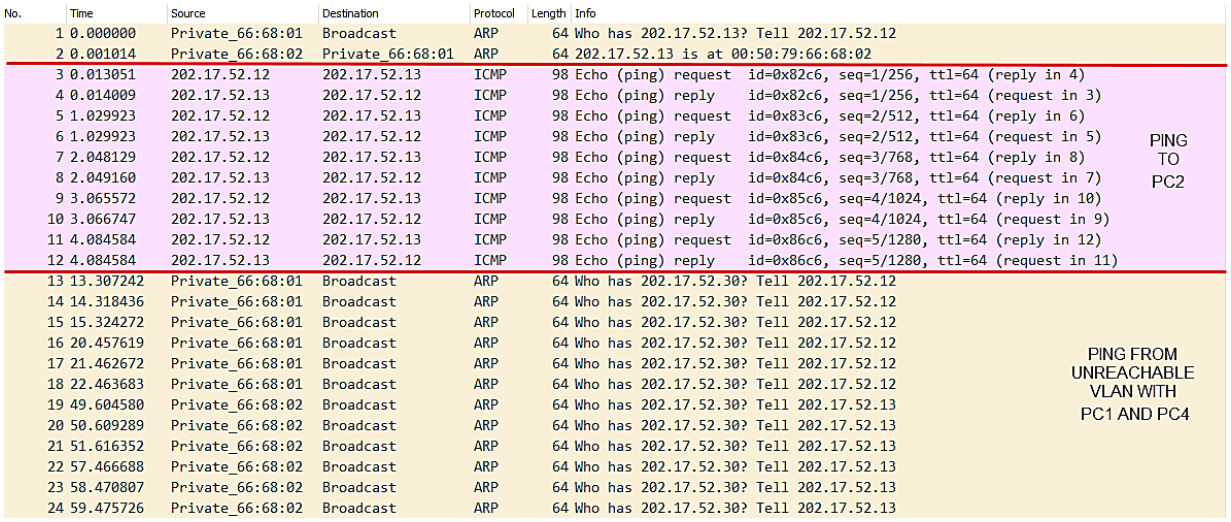


Figure 16: Setting up static IP address and execution of ping command for PC4 on GNS3 simulation using a single switch

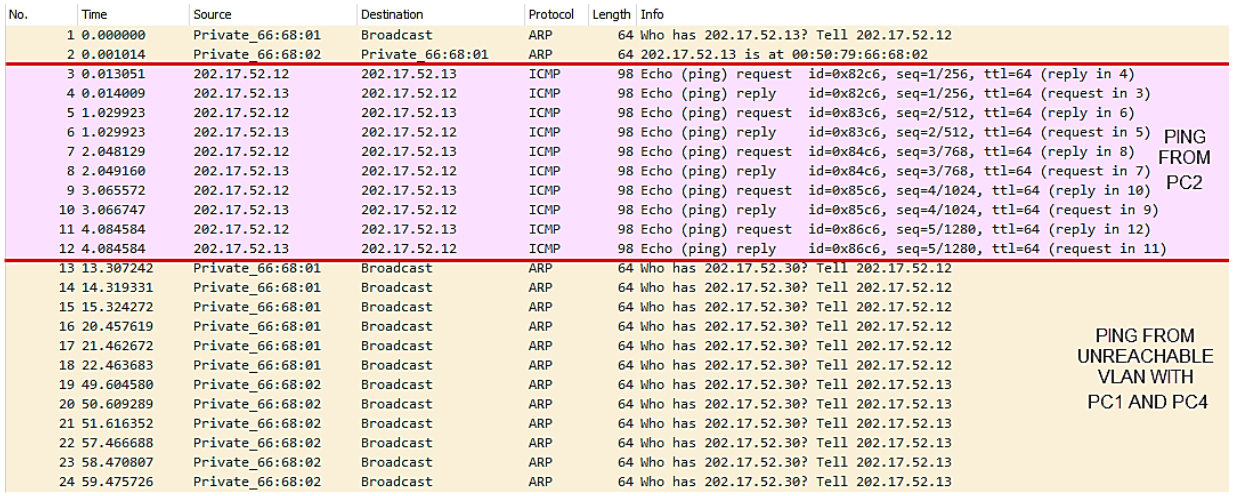
No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.14? Tell 202.17.51.11	
2	0.001011	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.14 is at 00:50:79:66:68:03	
3	0.014645	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x24c6, seq=1/256, ttl=64 (reply in 4)	PING TO PC4
4	0.015769	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x24c6, seq=1/256, ttl=64 (request in 3)	
5	1.031584	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x25c6, seq=2/512, ttl=64 (reply in 6)	
6	1.032682	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x25c6, seq=2/512, ttl=64 (request in 5)	
7	2.051061	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x26c6, seq=3/768, ttl=64 (reply in 8)	
8	2.052646	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x26c6, seq=3/768, ttl=64 (request in 7)	
9	3.072239	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x27c6, seq=4/1024, ttl=64 (reply in 10)	
10	3.072239	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x27c6, seq=4/1024, ttl=64 (request in 9)	
11	4.093793	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x28c6, seq=5/1280, ttl=64 (reply in 12)	
12	4.093793	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x28c6, seq=5/1280, ttl=64 (request in 11)	
13	15.781942	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	PING TO UNREACHABLE VLAN WITH PC2 AND PC3
14	16.786963	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
15	17.793247	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
16	22.424397	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
17	23.428385	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
18	24.428604	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
19	171.417732	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.11? Tell 202.17.51.14	
20	171.418771	Private_66:68:00	Private_66:68:03	ARP	64	202.17.51.11 is at 00:50:79:66:68:00	
21	171.432324	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xcfc6, seq=1/256, ttl=64 (reply in 22)	PING FROM PC4
22	171.433280	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xcfc6, seq=1/256, ttl=64 (request in 21)	
23	172.453715	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd0c6, seq=2/512, ttl=64 (reply in 24)	
24	172.454752	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd0c6, seq=2/512, ttl=64 (request in 23)	
25	173.470902	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd1c6, seq=3/768, ttl=64 (reply in 26)	
26	173.470902	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd1c6, seq=3/768, ttl=64 (request in 25)	
27	174.486642	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd2c6, seq=4/1024, ttl=64 (reply in 28)	
28	174.488191	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd2c6, seq=4/1024, ttl=64 (request in 27)	
29	175.503922	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd3c6, seq=5/1280, ttl=64 (reply in 30)	
30	175.504958	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd3c6, seq=5/1280, ttl=64 (request in 29)	
31	189.110155	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	PING FROM UNREACHABLE VLAN WITH PC2 AND PC3
32	190.126342	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	
33	191.128225	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	
34	206.327652	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
35	207.332890	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
36	208.337914	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
37	212.872655	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
38	213.879508	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
39	214.880187	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	

Figure 17: Packet capture on Wireshark for PC1 for GNS3 simulation using a single switch



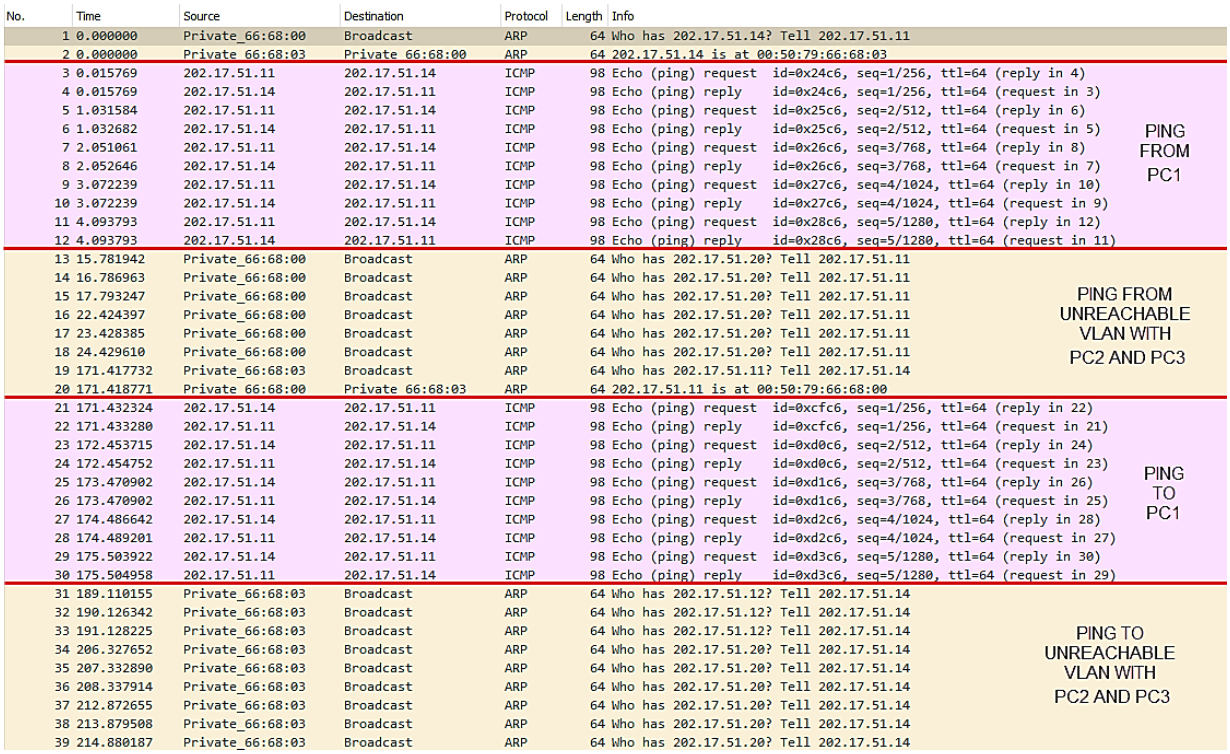
No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.13? Tell 202.17.52.12	
2	0.001014	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.13 is at 00:50:79:66:68:02	
3	0.013051	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x82c6, seq=1/256, ttl=64 (reply in 4)	
4	0.014009	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x82c6, seq=1/256, ttl=64 (request in 3)	
5	1.029923	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x83c6, seq=2/512, ttl=64 (reply in 6)	
6	1.029923	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x83c6, seq=2/512, ttl=64 (request in 5)	PING TO PC2
7	2.048129	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x84c6, seq=3/768, ttl=64 (reply in 8)	
8	2.049160	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x84c6, seq=3/768, ttl=64 (request in 7)	
9	3.065572	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x85c6, seq=4/1024, ttl=64 (reply in 10)	
10	3.066747	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x85c6, seq=4/1024, ttl=64 (request in 9)	
11	4.084584	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x86c6, seq=5/1280, ttl=64 (reply in 12)	
12	4.084584	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x86c6, seq=5/1280, ttl=64 (request in 11)	
13	13.307242	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
14	14.318436	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
15	15.324272	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
16	20.457619	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
17	21.462672	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	PING FROM UNREACHABLE VLAN WITH PC1 AND PC4
18	22.463683	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
19	49.604580	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
20	50.609289	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
21	51.616352	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
22	57.466688	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
23	58.470807	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
24	59.475726	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	

Figure 18: Packet capture on Wireshark for PC2 for GNS3 simulation using a single switch



No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.13? Tell 202.17.52.12	
2	0.001014	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.13 is at 00:50:79:66:68:02	
3	0.013051	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x82c6, seq=1/256, ttl=64 (reply in 4)	
4	0.014009	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x82c6, seq=1/256, ttl=64 (request in 3)	
5	1.029923	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x83c6, seq=2/512, ttl=64 (reply in 6)	
6	1.029923	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x83c6, seq=2/512, ttl=64 (request in 5)	PING FROM PC2
7	2.048129	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x84c6, seq=3/768, ttl=64 (reply in 8)	
8	2.049160	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x84c6, seq=3/768, ttl=64 (request in 7)	
9	3.065572	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x85c6, seq=4/1024, ttl=64 (reply in 10)	
10	3.066747	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x85c6, seq=4/1024, ttl=64 (request in 9)	
11	4.084584	202.17.52.12	202.17.52.13	ICMP	98	Echo (ping) request id=0x86c6, seq=5/1280, ttl=64 (reply in 12)	
12	4.084584	202.17.52.13	202.17.52.12	ICMP	98	Echo (ping) reply id=0x86c6, seq=5/1280, ttl=64 (request in 11)	
13	13.307242	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
14	14.319331	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
15	15.324272	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
16	20.457619	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
17	21.462672	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	PING FROM UNREACHABLE VLAN WITH PC1 AND PC4
18	22.463683	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.12	
19	49.604580	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
20	50.609289	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
21	51.616352	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
22	57.466688	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
23	58.470807	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	
24	59.475726	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.30? Tell 202.17.52.13	

Figure 19: Packet capture on Wireshark for PC2 for GNS3 simulation using a single switch



No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.14? Tell 202.17.51.11	
2	0.000000	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.14 is at 00:50:79:66:68:03	
3	0.015769	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x24c6, seq=1/256, ttl=64 (reply in 4)	
4	0.015769	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x24c6, seq=1/256, ttl=64 (request in 3)	
5	1.031584	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x25c6, seq=2/512, ttl=64 (reply in 6)	
6	1.032682	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x25c6, seq=2/512, ttl=64 (request in 5)	PING FROM PC1
7	2.051061	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x26c6, seq=3/768, ttl=64 (reply in 8)	
8	2.052646	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x26c6, seq=3/768, ttl=64 (request in 7)	
9	3.072239	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x27c6, seq=4/1024, ttl=64 (reply in 10)	
10	3.072239	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x27c6, seq=4/1024, ttl=64 (request in 9)	
11	4.093793	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) request id=0x28c6, seq=5/1280, ttl=64 (reply in 12)	
12	4.093793	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) reply id=0x28c6, seq=5/1280, ttl=64 (request in 11)	
13	15.781942	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
14	16.786963	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
15	17.793247	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
16	22.424397	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	PING FROM UNREACHABLE VLAN WITH PC2 AND PC3
17	23.428385	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
18	24.429610	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.11	
19	171.417732	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.11? Tell 202.17.51.14	
20	171.418771	Private_66:68:00	Private_66:68:03	ARP	64	202.17.51.11 is at 00:50:79:66:68:00	
21	171.432324	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xcfc6, seq=1/256, ttl=64 (reply in 22)	
22	171.433280	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xcfc6, seq=1/256, ttl=64 (request in 21)	
23	172.453715	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd0c6, seq=2/512, ttl=64 (reply in 24)	
24	172.454752	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd0c6, seq=2/512, ttl=64 (request in 23)	
25	173.470902	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd1c6, seq=3/768, ttl=64 (reply in 26)	PING TO PC1
26	173.470902	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd1c6, seq=3/768, ttl=64 (request in 25)	
27	174.486642	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd2c6, seq=4/1024, ttl=64 (reply in 28)	
28	174.489201	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd2c6, seq=4/1024, ttl=64 (request in 27)	
29	175.503922	202.17.51.14	202.17.51.11	ICMP	98	Echo (ping) request id=0xd3c6, seq=5/1280, ttl=64 (reply in 30)	
30	175.504958	202.17.51.11	202.17.51.14	ICMP	98	Echo (ping) reply id=0xd3c6, seq=5/1280, ttl=64 (request in 29)	
31	189.110155	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	
32	190.126342	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	
33	191.128225	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.12? Tell 202.17.51.14	
34	206.327652	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	PING TO UNREACHABLE VLAN WITH PC2 AND PC3
35	207.332890	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
36	208.337914	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
37	212.872655	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
38	213.879508	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	
39	214.880187	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.14	

Figure 20: Packet capture on Wireshark for PC4 for GNS3 simulation using a single switch

Table 1: LAN address configuration for simulation on GNS3 using a single switch

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.51.11	202.17.51.20	255.255.255.0
PC2	202.17.52.12	202.17.52.30	255.255.255.0
PC3	202.17.52.13	202.17.52.30	255.255.255.0
PC4	202.17.51.14	202.17.51.20	255.255.255.0

2) ***Emulation of VLAN switching on a single switch star topology configuration on GNS3 using LISA***

Figure 21, Figure 22, Figure 23, and Figure 24 below show the screengrabs of the console window of the network emulation of the single switch star-topology configuration on GNS3 whereby the VPCSs were configured such that PC1 and PC4 were in one VLAN while PC2 and PC3 were in another VLAN. Figure 25, Figure 26, Figure 27, and Figure 28 below show the captured packets on Wireshark for PC1, PC2, PC3, and PC4 respectively. Lastly, a summary of the LAN address configurations for the GNS3 emulation is shown in Table 2 below.

Figure 21: Setting up static IP address and execution of ping command for PC1 on GNS3 emulation using LISA switch emulator for a single switch

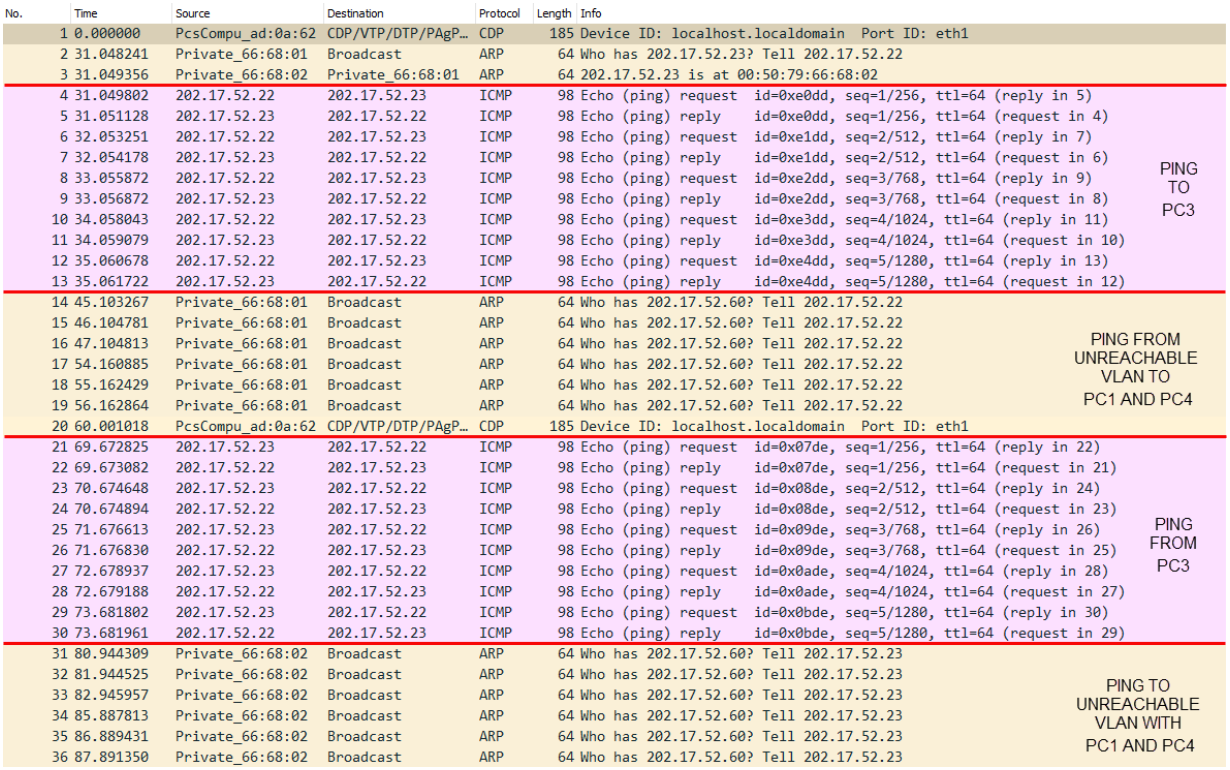
Figure 22: Setting up static IP address and execution of ping command for PC2 on GNS3 emulation using LISA switch emulator for a single switch

Figure 23: Setting up static IP address and execution of ping command for PC3 on GNS3 emulation using LISA switch emulator for a single switch

Figure 24: Setting up static IP address and execution of ping command for PC4 on GNS3 emulation using LISA switch emulator for a single switch

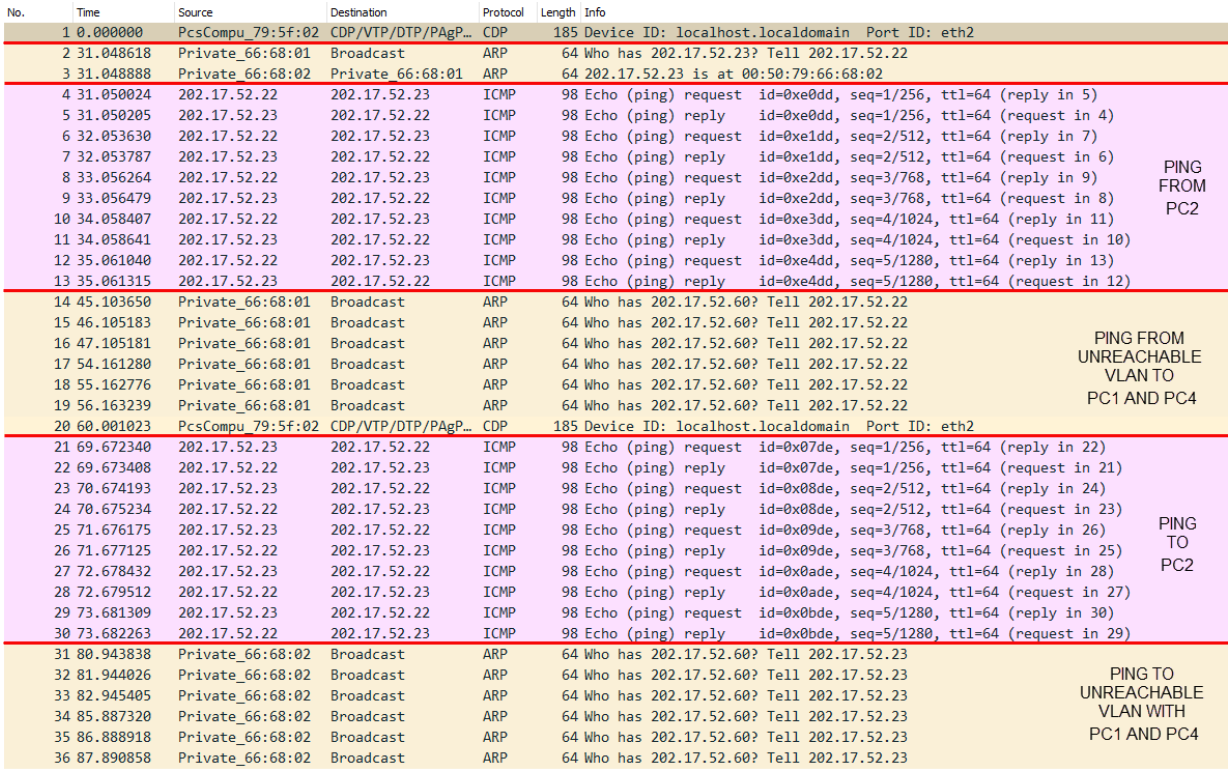
No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.24? Tell 202.17.51.21	
2	0.001115	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.24 is at 00:50:79:66:68:03	
3	0.001443	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbbdd, seq=1/256, ttl=64 (reply in 4)	PING TO PC4
4	0.002283	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbbdd, seq=1/256, ttl=64 (request in 3)	
5	1.006007	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbcdd, seq=2/512, ttl=64 (reply in 6)	
6	1.008100	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbcdd, seq=2/512, ttl=64 (request in 5)	
7	2.010623	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbddd, seq=3/768, ttl=64 (reply in 8)	
8	2.011767	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbddd, seq=3/768, ttl=64 (request in 7)	
9	3.013184	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbedd, seq=4/1024, ttl=64 (reply in 10)	
10	3.014186	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbedd, seq=4/1024, ttl=64 (request in 9)	
11	4.015590	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbfdd, seq=5/1280, ttl=64 (reply in 12)	
12	4.016652	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbfdd, seq=5/1280, ttl=64 (request in 11)	
13	6.057286	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
14	11.785975	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
15	12.787253	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
16	13.788851	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	PING FROM UNREACHABLE VLAN TO PC2 AND PC3
17	18.297626	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
18	19.299482	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
19	20.300512	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
20	66.058313	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
21	100.792299	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x20de, seq=1/256, ttl=64 (reply in 22)	PING FROM PC4
22	100.792516	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x20de, seq=1/256, ttl=64 (request in 21)	
23	101.794667	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x21de, seq=2/512, ttl=64 (reply in 24)	
24	101.794883	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x21de, seq=2/512, ttl=64 (request in 23)	
25	102.796703	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x22de, seq=3/768, ttl=64 (reply in 26)	
26	102.796965	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x22de, seq=3/768, ttl=64 (request in 25)	
27	103.798729	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x23de, seq=4/1024, ttl=64 (reply in 28)	
28	103.798953	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x23de, seq=4/1024, ttl=64 (request in 27)	
29	104.801226	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x24de, seq=5/1280, ttl=64 (reply in 30)	
30	104.801435	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x24de, seq=5/1280, ttl=64 (request in 29)	
31	114.481749	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
32	115.483228	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
33	116.483787	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
34	120.928993	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
35	121.929364	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
36	122.930712	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	PING FROM UNREACHABLE VLAN WITH PC2 AND PC3
37	126.060877	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
38	186.062083	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
39	246.064085	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
40	306.065484	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
41	366.066850	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
42	426.068545	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
43	486.070030	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	

Figure 25: Packet capture on Wireshark for PC1 for GNS3 emulation using LISA switch emulator for a single switch



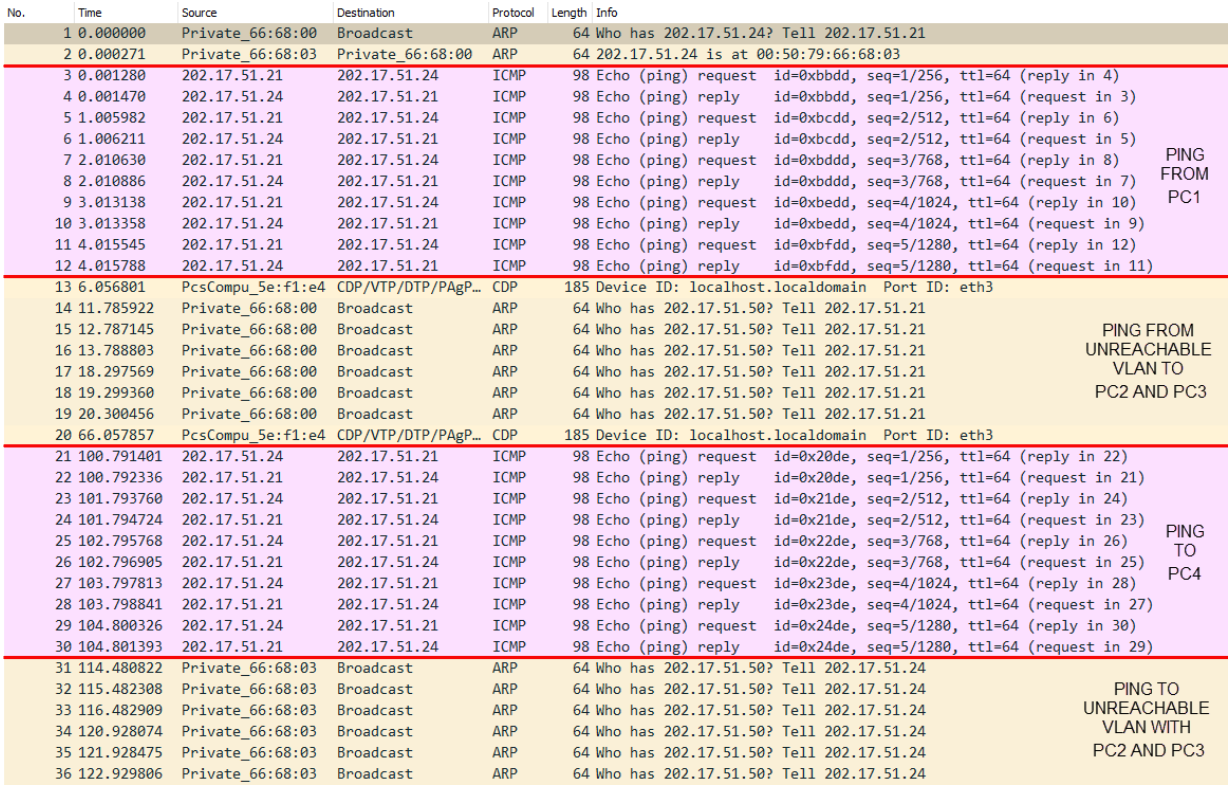
No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	PcsCompu_ad:0a:62	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
2	31.048241	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.23? Tell 202.17.52.22	
3	31.049356	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.23 is at 00:50:79:66:68:02	
4	31.049802	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe0dd, seq=1/256, ttl=64 (reply in 5)	PING TO PC3
5	31.051128	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe0dd, seq=1/256, ttl=64 (request in 4)	
6	32.053251	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe1dd, seq=2/512, ttl=64 (reply in 7)	
7	32.054178	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe1dd, seq=2/512, ttl=64 (request in 6)	
8	33.055872	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe2dd, seq=3/768, ttl=64 (reply in 9)	
9	33.056872	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe2dd, seq=3/768, ttl=64 (request in 8)	
10	34.058043	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe3dd, seq=4/1024, ttl=64 (reply in 11)	
11	34.059079	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe3dd, seq=4/1024, ttl=64 (request in 10)	
12	35.060678	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe4dd, seq=5/1280, ttl=64 (reply in 13)	
13	35.061722	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe4dd, seq=5/1280, ttl=64 (request in 12)	
14	45.103267	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	PING FROM UNREACHABLE VLAN TO PC1 AND PC4
15	46.104781	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
16	47.104813	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
17	54.160885	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
18	55.162429	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
19	56.162864	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
20	60.001018	PcsCompu_ad:0a:62	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
21	69.672825	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x07de, seq=1/256, ttl=64 (reply in 22)	PING FROM PC3
22	69.673082	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x07de, seq=1/256, ttl=64 (request in 21)	
23	70.674648	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x08de, seq=2/512, ttl=64 (reply in 24)	
24	70.674894	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x08de, seq=2/512, ttl=64 (request in 23)	
25	71.676613	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x09de, seq=3/768, ttl=64 (reply in 26)	
26	71.676830	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x09de, seq=3/768, ttl=64 (request in 25)	
27	72.678937	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x0ade, seq=4/1024, ttl=64 (reply in 28)	
28	72.679188	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x0ade, seq=4/1024, ttl=64 (request in 27)	
29	73.681802	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x0bde, seq=5/1280, ttl=64 (reply in 30)	
30	73.681961	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x0bde, seq=5/1280, ttl=64 (request in 29)	
31	80.944309	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	PING TO UNREACHABLE VLAN WITH PC1 AND PC4
32	81.944525	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
33	82.945957	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
34	85.887813	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
35	86.889431	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
36	87.891350	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	

Figure 26: Packet capture on Wireshark for PC2 for GNS3 emulation using LISA switch emulator for a single switch



No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	PcsCompu_79:5f:02	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth2	
2	31.048618	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.23? Tell 202.17.52.22	
3	31.048888	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.23 is at 00:50:79:66:68:02	
4	31.050024	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe0dd, seq=1/256, ttl=64 (reply in 5)	PING FROM PC2
5	31.050205	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe0dd, seq=1/256, ttl=64 (request in 4)	
6	32.053630	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe1dd, seq=2/512, ttl=64 (reply in 7)	
7	32.053787	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe1dd, seq=2/512, ttl=64 (request in 6)	
8	33.056264	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe2dd, seq=3/768, ttl=64 (reply in 9)	
9	33.056479	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe2dd, seq=3/768, ttl=64 (request in 8)	
10	34.058407	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe3dd, seq=4/1024, ttl=64 (reply in 11)	
11	34.058641	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe3dd, seq=4/1024, ttl=64 (request in 10)	
12	35.061040	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) request id=0xe4dd, seq=5/1280, ttl=64 (reply in 13)	
13	35.061315	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) reply id=0xe4dd, seq=5/1280, ttl=64 (request in 12)	
14	45.103650	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	PING FROM UNREACHABLE VLAN TO PC1 AND PC4
15	46.105183	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
16	47.105181	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
17	54.161280	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
18	55.162776	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
19	56.163239	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.22	
20	60.001023	PcsCompu_79:5f:02	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth2	
21	69.672340	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x07de, seq=1/256, ttl=64 (reply in 22)	PING TO PC2
22	69.673408	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x07de, seq=1/256, ttl=64 (request in 21)	
23	70.674193	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x08de, seq=2/512, ttl=64 (reply in 24)	
24	70.675234	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x08de, seq=2/512, ttl=64 (request in 23)	
25	71.676175	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x09de, seq=3/768, ttl=64 (reply in 26)	
26	71.677125	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x09de, seq=3/768, ttl=64 (request in 25)	
27	72.678432	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x0ade, seq=4/1024, ttl=64 (reply in 28)	
28	72.679512	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x0ade, seq=4/1024, ttl=64 (request in 27)	
29	73.681309	202.17.52.23	202.17.52.22	ICMP	98	Echo (ping) request id=0x0bde, seq=5/1280, ttl=64 (reply in 30)	
30	73.682263	202.17.52.22	202.17.52.23	ICMP	98	Echo (ping) reply id=0x0bde, seq=5/1280, ttl=64 (request in 29)	
31	80.943838	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	PING TO UNREACHABLE VLAN WITH PC1 AND PC4
32	81.944026	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
33	82.945405	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
34	85.887320	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
35	86.888918	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	
36	87.890858	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.23	

Figure 27: Packet capture on Wireshark for PC3 for GNS3 emulation using LISA switch emulator for a single switch



No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.24? Tell 202.17.51.21	
2	0.000271	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.24 is at 00:50:79:66:68:03	
3	0.001280	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbbdd, seq=1/256, ttl=64 (reply in 4)	PING FROM PC1
4	0.001470	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbbdd, seq=1/256, ttl=64 (request in 3)	
5	1.005982	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbcdd, seq=2/512, ttl=64 (reply in 6)	
6	1.006211	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbcdd, seq=2/512, ttl=64 (request in 5)	
7	2.010630	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbddd, seq=3/768, ttl=64 (reply in 8)	
8	2.010886	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbddd, seq=3/768, ttl=64 (request in 7)	
9	3.013138	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbedd, seq=4/1024, ttl=64 (reply in 10)	
10	3.013358	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbedd, seq=4/1024, ttl=64 (request in 9)	
11	4.015545	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) request id=0xbfdd, seq=5/1280, ttl=64 (reply in 12)	
12	4.015788	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) reply id=0xbfdd, seq=5/1280, ttl=64 (request in 11)	
13	6.056801	PcsCompu_5e:f1:e4	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth3	
14	11.785922	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
15	12.787145	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	PING FROM UNREACHABLE VLAN TO PC2 AND PC3
16	13.788803	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
17	18.297569	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
18	19.299360	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
19	20.300456	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.21	
20	66.057857	PcsCompu_5e:f1:e4	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth3	
21	100.791401	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x20de, seq=1/256, ttl=64 (reply in 22)	PING TO PC4
22	100.792336	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x20de, seq=1/256, ttl=64 (request in 21)	
23	101.793760	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x21de, seq=2/512, ttl=64 (reply in 24)	
24	101.794724	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x21de, seq=2/512, ttl=64 (request in 23)	
25	102.795768	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x22de, seq=3/768, ttl=64 (reply in 26)	
26	102.796905	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x22de, seq=3/768, ttl=64 (request in 25)	
27	103.797813	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x23de, seq=4/1024, ttl=64 (reply in 28)	
28	103.798841	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x23de, seq=4/1024, ttl=64 (request in 27)	
29	104.800326	202.17.51.24	202.17.51.21	ICMP	98	Echo (ping) request id=0x24de, seq=5/1280, ttl=64 (reply in 30)	
30	104.801393	202.17.51.21	202.17.51.24	ICMP	98	Echo (ping) reply id=0x24de, seq=5/1280, ttl=64 (request in 29)	
31	114.480822	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
32	115.482308	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	PING TO UNREACHABLE VLAN WITH PC2 AND PC3
33	116.482909	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
34	120.928074	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
35	121.928475	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	
36	122.929806	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.24	

Figure 28: Packet capture on Wireshark for PC4 for GNS3 emulation using LISA switch emulator for a single switch

Table 2: LAN address configuration for emulation on GNS3 using LISA switch emulator for single switch configuration

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.51.21	202.17.51.50	255.255.255.0
PC2	202.17.52.22	202.17.52.60	255.255.255.0
PC3	202.17.52.23	202.17.52.60	255.255.255.0
PC4	202.17.51.24	202.17.51.50	255.255.255.0

3) *Hardware implementation of VLAN switching on a single switch star topology configuration using hardware LISA appliance*

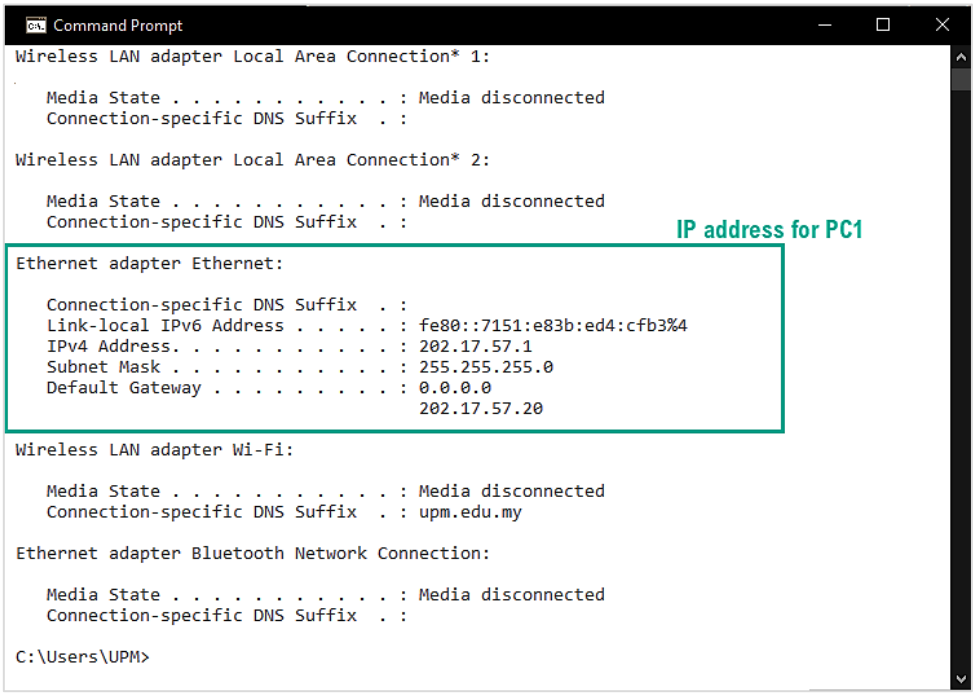


Figure 29: IP configuration summary of PC1 for the hardware implementation of the single switch star topology configuration

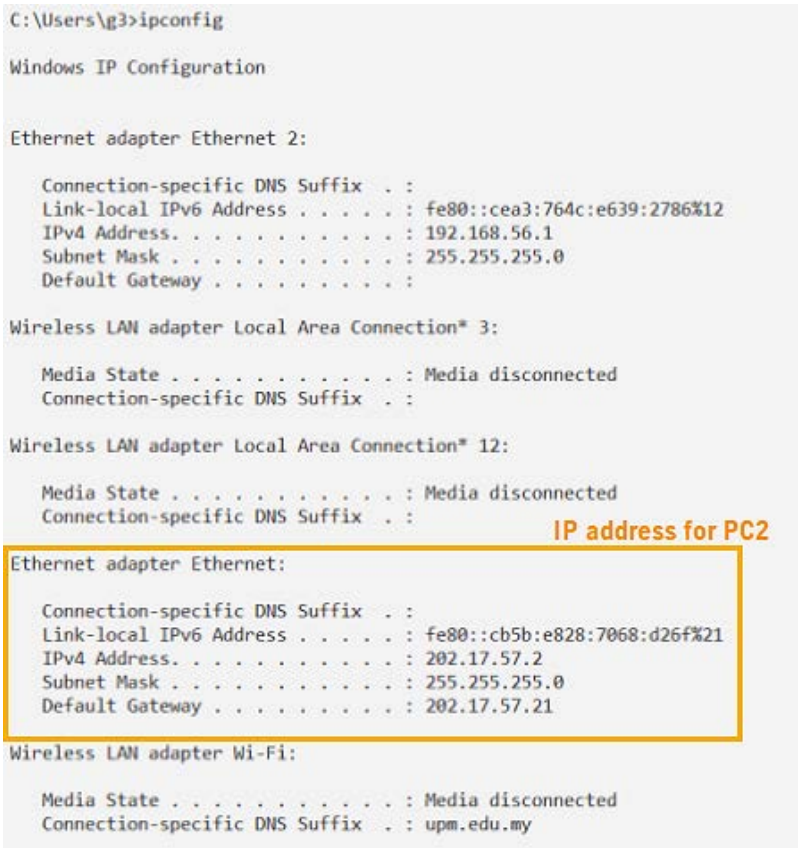


Figure 30: IP configuration summary of PC2 for the hardware implementation of the single switch star topology configuration

A summary of the LAN address configurations is shown in Table 3 below for the hardware implementation of the single switch configuration. Figure 29 and Figure 30 above show the IP configurations of PC1 and PC2 which are in different VLANs respectively. Figure 31, Figure 32, and Figure 33 show the ping commands that were carried out for PC1, PC2, and PC3 respectively. Figure 34, Figure 35, Figure 36, and Figure 37 show the Wireshark captures from carrying out the ping commands between PCs for PC1, PC2, PC3, and PC4 respectively.

Table 3: LAN address configuration for hardware implementation for single switch configuration

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.57.1	202.17.57.20	255.255.255.0
PC2	202.17. 57.2	202.17.57.21	255.255.255.0
PC3	202.17. 57.3	202.17.57.21	255.255.255.0
PC4	202.17. 57.4	202.17.57.20	255.255.255.0

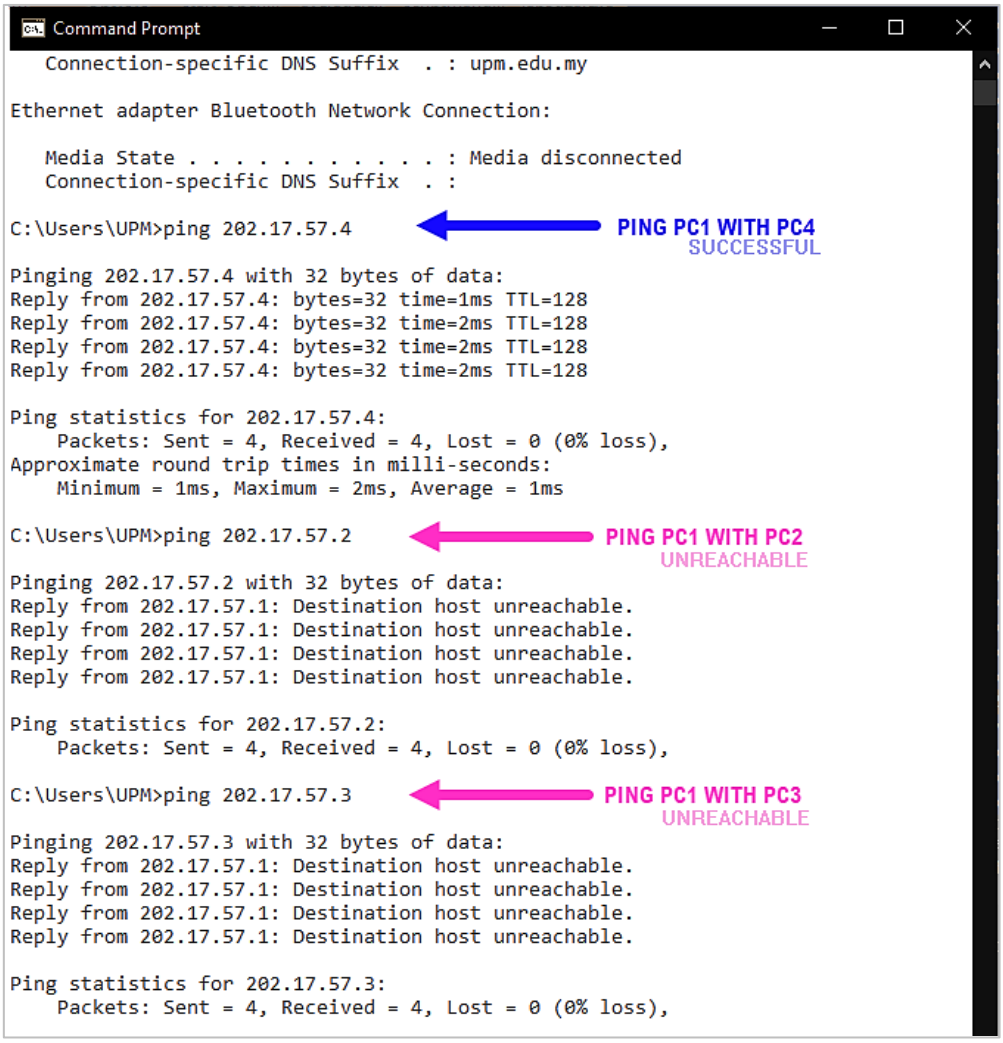


Figure 31: Ping commands executed from PC1 on hardware to the other PCs

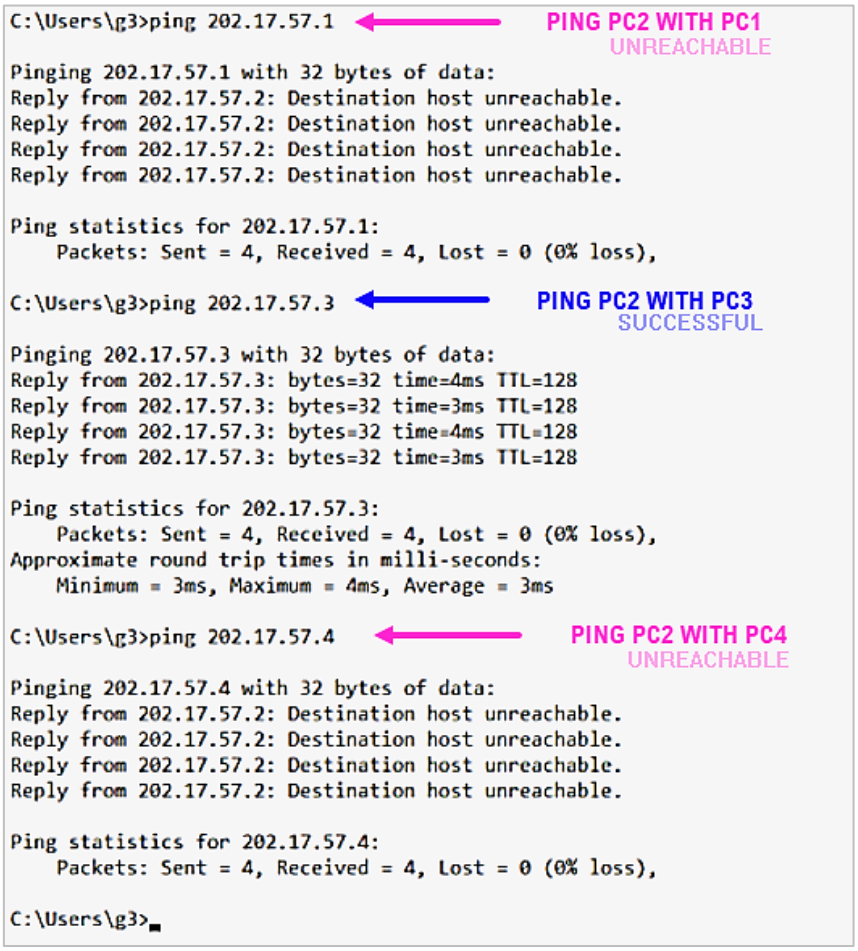


Figure 32: Ping commands executed from PC2 on hardware to the other PCs

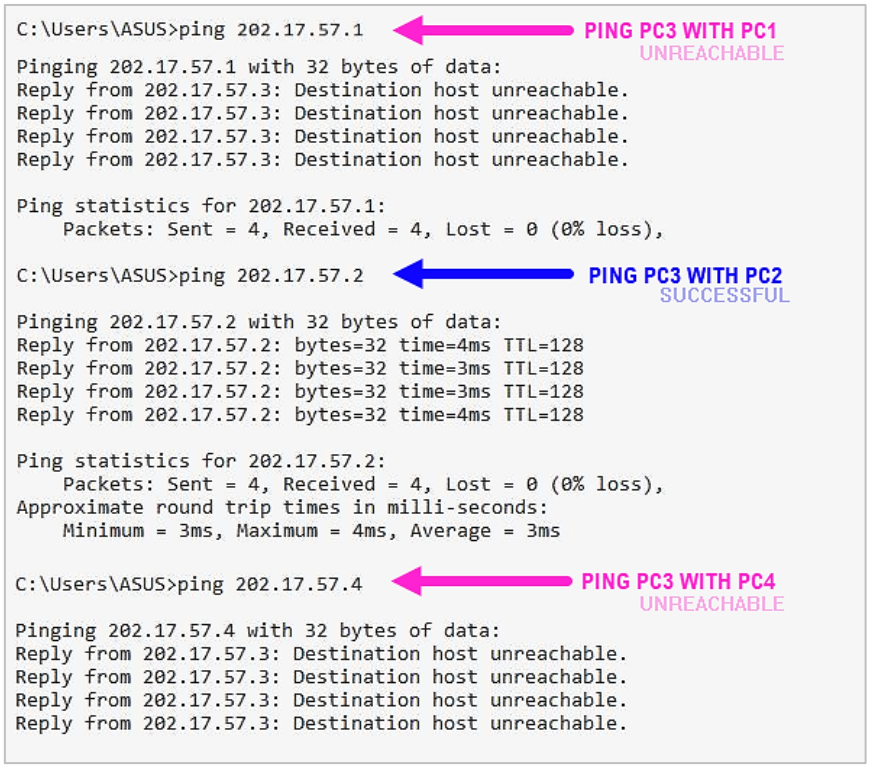
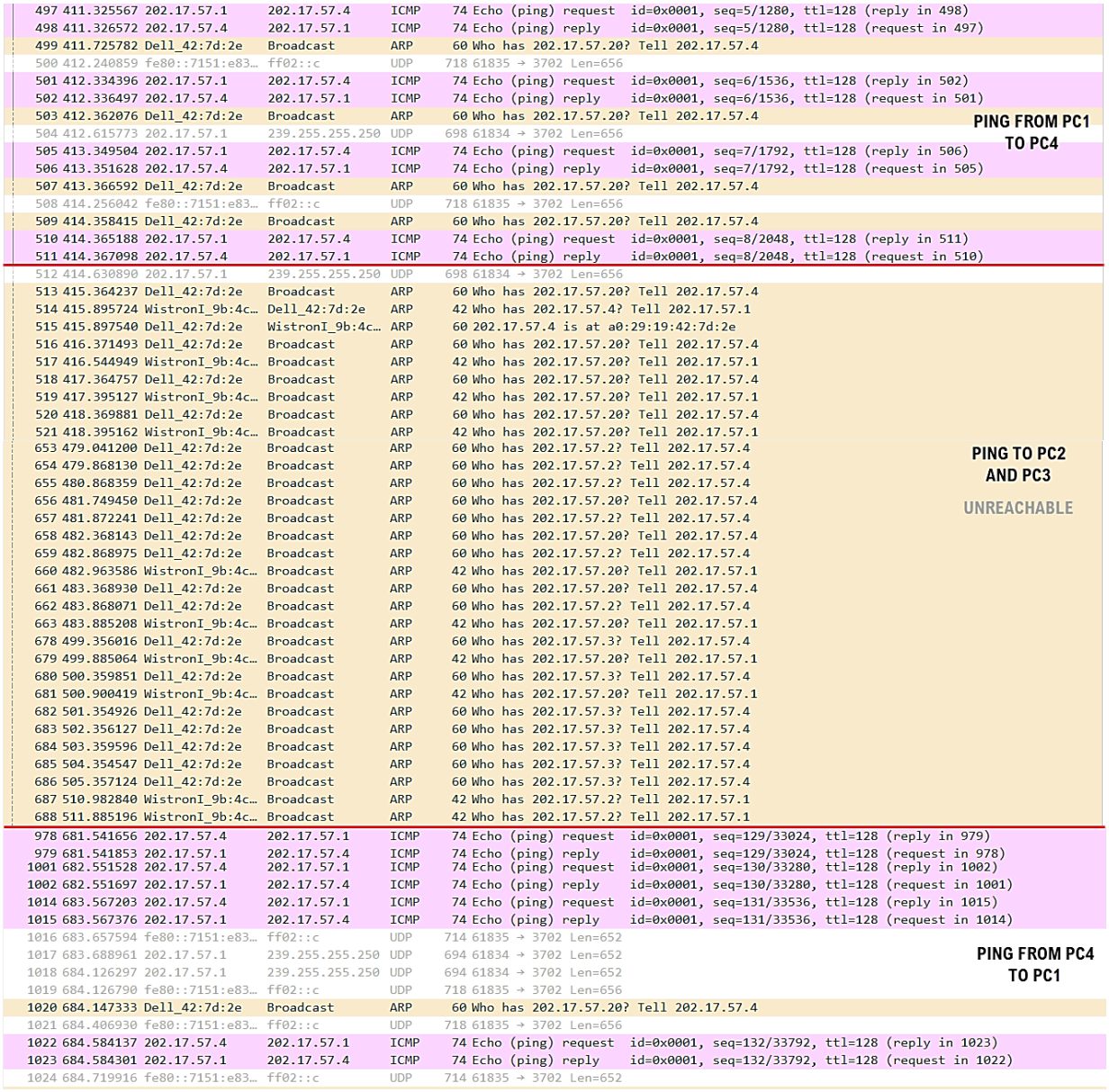


Figure 33: Ping commands executed from PC3 on hardware to the other PCs



497	411.325567	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) request id=0x0001, seq=5/1280, ttl=128 (reply in 498)
498	411.326572	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) reply id=0x0001, seq=5/1280, ttl=128 (request in 497)
499	411.725782	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
500	412.240859	fe80::7151:e83…	ff02::c	UDP	718	61835 → 3702 Len=656
501	412.334396	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) request id=0x0001, seq=6/1536, ttl=128 (reply in 502)
502	412.336497	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) reply id=0x0001, seq=6/1536, ttl=128 (request in 501)
503	412.362076	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
504	412.615773	202.17.57.1	239.255.255.250	UDP	698	61834 → 3702 Len=656
505	413.349504	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) request id=0x0001, seq=7/1792, ttl=128 (reply in 506)
506	413.351628	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) reply id=0x0001, seq=7/1792, ttl=128 (request in 505)
507	413.366592	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
508	414.256042	fe80::7151:e83…	ff02::c	UDP	718	61835 → 3702 Len=656
509	414.358415	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
510	414.365188	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) request id=0x0001, seq=8/2048, ttl=128 (reply in 511)
511	414.367098	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) reply id=0x0001, seq=8/2048, ttl=128 (request in 510)
512	414.630890	202.17.57.1	239.255.255.250	UDP	698	61834 → 3702 Len=656
513	415.364237	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
514	415.895724	WistronI_9b:4c…	Dell_42:7d:2e	ARP	42	Who has 202.17.57.4? Tell 202.17.57.1
515	415.897540	Dell_42:7d:2e	WistronI_9b:4c…	ARP	60	202.17.57.4 is at a0:29:19:42:7d:2e
516	416.371493	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
517	416.544949	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
518	417.364757	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
519	417.395127	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
520	418.369881	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
521	418.395162	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
653	479.041200	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
654	479.868130	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
655	480.868359	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
656	481.749450	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
657	481.872241	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
658	482.368143	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
659	482.868975	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
660	482.963586	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
661	483.368930	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
662	483.868071	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.2? Tell 202.17.57.4
663	483.885208	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
678	499.356016	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
679	499.885064	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
680	500.359851	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
681	500.900419	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.1
682	501.354926	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
683	502.356127	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
684	503.359596	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
685	504.354547	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
686	505.357124	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.3? Tell 202.17.57.4
687	510.982840	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.1
688	511.885196	WistronI_9b:4c…	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.1
978	681.541656	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=129/33024, ttl=128 (reply in 979)
979	681.541853	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=129/33024, ttl=128 (request in 978)
1001	682.551528	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=130/33280, ttl=128 (reply in 1002)
1002	682.551697	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=130/33280, ttl=128 (request in 1001)
1014	683.567203	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=131/33536, ttl=128 (reply in 1015)
1015	683.567376	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=131/33536, ttl=128 (request in 1014)
1016	683.657594	fe80::7151:e83…	ff02::c	UDP	714	61835 → 3702 Len=652
1017	683.688961	202.17.57.1	239.255.255.250	UDP	694	61834 → 3702 Len=652
1018	684.126297	202.17.57.1	239.255.255.250	UDP	694	61834 → 3702 Len=652
1019	684.126790	fe80::7151:e83…	ff02::c	UDP	718	61835 → 3702 Len=656
1020	684.147333	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4
1021	684.406930	fe80::7151:e83…	ff02::c	UDP	718	61835 → 3702 Len=656
1022	684.584137	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=132/33792, ttl=128 (reply in 1023)
1023	684.584301	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=132/33792, ttl=128 (request in 1022)
1024	684.719916	fe80::7151:e83…	ff02::c	UDP	714	61835 → 3702 Len=652

Figure 34: Packet capture on Wireshark for PC1 for hardware implementation of single switch star topology configuration

No.	Time	Source	Destination	Protocol	Length	Info	
26	18.615098	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.2	PING TO PC1 UNREACHABLE
27	19.110717	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
28	19.631456	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.2	
29	20.115319	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
30	20.592615	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
31	20.616336	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.2	
32	21.504862	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
33	21.614611	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.2	
34	22.501167	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
35	24.341719	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
36	25.116881	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
37	26.111134	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
38	32.352905	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
39	32.542638	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=78/19968, ttl=128 (reply in 40)	
40	32.546567	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=78/19968, ttl=128 (request in 39)	
41	33.108975	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
42	33.548911	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=79/20224, ttl=128 (reply in 43)	
43	33.552222	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=79/20224, ttl=128 (request in 42)	
44	34.114748	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	PING TO PC3 FROM PC2
45	34.566439	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=80/20480, ttl=128 (reply in 46)	
46	34.570031	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=80/20480, ttl=128 (request in 45)	
47	35.122937	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.2	
48	35.591587	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=81/20736, ttl=128 (reply in 49)	
49	35.594714	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=81/20736, ttl=128 (request in 48)	
50	37.109620	LCFCHeFe_fa:a1:94	D-LinkIn_d2:1c:7e	ARP	42	Who has 202.17.57.3? Tell 202.17.57.2	
51	37.112934	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	60	202.17.57.3 is at bc:0f:9a:d2:1c:7e	
52	37.503744	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	60	Who has 202.17.57.2? Tell 202.17.57.3	
53	37.503858	LCFCHeFe_fa:a1:94	D-LinkIn_d2:1c:7e	ARP	42	202.17.57.2 is at 00:2b:67:fa:a1:94	
54	39.822094	0.0.0.0	255.255.255.255	HIP	102	HIP I1 (HIP Initiator Packet)	
55	41.117657	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	PING TO PC4 UNREACHABLE
56	42.118520	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
57	43.121964	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
58	44.097900	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
59	44.115781	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
60	45.006705	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
61	45.132016	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
62	46.000464	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.3	
63	46.115164	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
64	47.117408	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
65	48.117446	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	
66	49.121867	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.2	

Figure 35: Packet capture on Wireshark for PC2 for hardware implementation of single switch star topology configuration

No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
2	1.185362	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
3	2.004616	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
4	2.992871	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
5	2.992945	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
6	3.991975	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
7	4.195144	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
8	4.999861	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
9	4.999912	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
10	5.990988	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	**PING TO PC4**
11	5.991041	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
12	6.998185	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
13	7.995056	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	**UNREACHABLE**
14	8.175405	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
15	8.996152	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
16	8.996196	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
17	9.988624	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
18	9.991344	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
19	10.988701	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
20	10.988749	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
21	11.989351	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.4? Tell 202.17.57.3	
22	12.265026	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
23	12.995758	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
24	13.995420	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
25	14.994410	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
26	15.990588	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
27	16.990877	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
28	18.985228	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	**PING FROM PC1 OR PC4**
29	19.493538	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
30	20.490858	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
31	22.160475	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
32	22.994429	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	**UNREACHABLE**
33	23.989606	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
34	25.167244	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
35	26.001829	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
36	26.991714	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
37	29.140069	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
38	29.991429	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
39	30.809689	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=282/6657, ttl=128 (reply in 40)	
40	30.813359	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=282/6657, ttl=128 (request in 39)	
41	30.988175	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
42	31.821624	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=283/6913, ttl=128 (reply in 43)	**PING TO PC2**
43	31.824595	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=283/6913, ttl=128 (request in 42)	
44	32.827379	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=284/7169, ttl=128 (reply in 45)	
45	32.830880	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=284/7169, ttl=128 (request in 44)	
46	33.152108	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
47	33.839891	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=285/7425, ttl=128 (reply in 48)	
48	33.843967	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=285/7425, ttl=128 (request in 47)	
49	33.999480	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
50	34.996411	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
51	35.489728	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	42	Who has 202.17.57.2? Tell 202.17.57.3	
52	35.499813	LCFCHeFe_fa:a1:94	D-LinkIn_d2:1c:7e	ARP	60	202.17.57.2 is at 00:2b:67:fa:a1:94	
53	35.601779	LCFCHeFe_fa:a1:94	D-LinkIn_d2:1c:7e	ARP	60	Who has 202.17.57.3? Tell 202.17.57.2	
54	35.601805	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	42	202.17.57.3 is at bc:0f:9a:d2:1c:7e	
55	35.989641	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
56	35.989694	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	**PING TO PC1**
57	37.003077	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	
58	37.725483	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
59	37.991363	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	**UNREACHABLE**
60	38.495779	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
61	38.992990	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	
62	39.494029	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
63	39.992598	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	
64	40.070172	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
65	40.490596	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	
66	40.995139	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3	
67	41.501085	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3	

Figure 36: Packet capture on Wireshark for PC3 for hardware implementation of single switch star topology configuration

No.	Time	Source	Destination	Protocol	Length	Info	
155	39.027962	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
156	40.127125	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
157	40.675904	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=129/33024, ttl=128 (reply in 158)	
158	40.677952	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=129/33024, ttl=128 (request in 157)	
180	41.685802	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=130/33280, ttl=128 (reply in 181)	
181	41.688478	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=130/33280, ttl=128 (request in 180)	
193	42.701494	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=131/33536, ttl=128 (reply in 194)	
194	42.704177	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=131/33536, ttl=128 (request in 193)	
195	42.794537	fe80::7151:e83b:…	ff02::c	UDP	714	61835 → 3702 Len=652	PING TO PC1
196	42.825815	202.17.57.1	239.255.255.250	UDP	694	61834 → 3702 Len=652	
197	43.262696	202.17.57.1	239.255.255.250	UDP	694	61834 → 3702 Len=652	
198	43.263090	fe80::7151:e83b:…	ff02::c	UDP	718	61835 → 3702 Len=656	
199	43.281701	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
200	43.543407	fe80::7151:e83b:…	ff02::c	UDP	718	61835 → 3702 Len=656	
201	43.718440	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=132/33792, ttl=128 (reply in 202)	
202	43.721127	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=132/33792, ttl=128 (request in 201)	
203	43.856880	fe80::7151:e83b:…	ff02::c	UDP	714	61835 → 3702 Len=652	
204	43.999080	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
238	48.985295	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
239	49.485224	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
240	49.985446	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
241	50.487794	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
242	51.476382	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
243	51.485766	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
244	51.986328	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
245	52.107135	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
246	52.486213	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
247	52.986504	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
248	53.028215	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
249	53.490409	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	PING TO PC2 AND PC3
250	54.028188	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
251	54.487619	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
252	55.270714	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
253	55.488302	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.2? Tell 202.17.57.4	
254	56.028063	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	UNREACHABLE
255	56.619595	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
256	57.027880	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.1	
257	57.488359	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
258	57.933195	202.17.57.1	239.255.255.250	SSDP	179	M-SEARCH * HTTP/1.1	
259	58.488260	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
260	59.497195	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
261	60.487177	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
262	60.934632	202.17.57.1	239.255.255.250	SSDP	179	M-SEARCH * HTTP/1.1	
263	60.987479	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
264	61.997015	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
265	62.988144	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
266	63.949231	202.17.57.1	239.255.255.250	SSDP	179	M-SEARCH * HTTP/1.1	
267	63.994581	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
268	64.993989	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
269	65.989945	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
270	66.661388	192.168.0.10	192.168.0.10	SNMP	154	trap iso.3.6.1.4.1.3183.1.1 1.3.6.1.4.1.3183.1.1.1	
271	66.989817	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
272	67.992676	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
273	68.998404	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	
274	69.998292	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.3? Tell 202.17.57.4	

Figure 37: Packet capture on Wireshark for PC4 for hardware implementation of single switch star topology configuration

4) Simulation of VLAN switching on a configuration with two switches with link aggregation on GNS3

Figure 38, Figure 39, Figure 40, and Figure 41 below show the screengrabs of the console window of the network simulation of the two-switch star-topology configuration with link aggregation on GNS3 whereby the VPCSs were configured such that PC1 and PC4 were in one VLAN while PC2 and PC3 were in another VLAN. Figure 42, Figure 43, Figure 44, and Figure 45 below show the captured packets on Wireshark for PC1, PC2, PC3, and PC4 respectively. Lastly, a summary of the LAN address configurations for the GNS3 simulation is shown in Table 4 below.

Figure 38: Setting up static IP address and execution of ping command for PC1 on GNS3 simulation for two switches with link aggregation

Figure 39: Setting up static IP address and execution of ping command for PC2 on GNS3 simulation for two switches with link aggregation

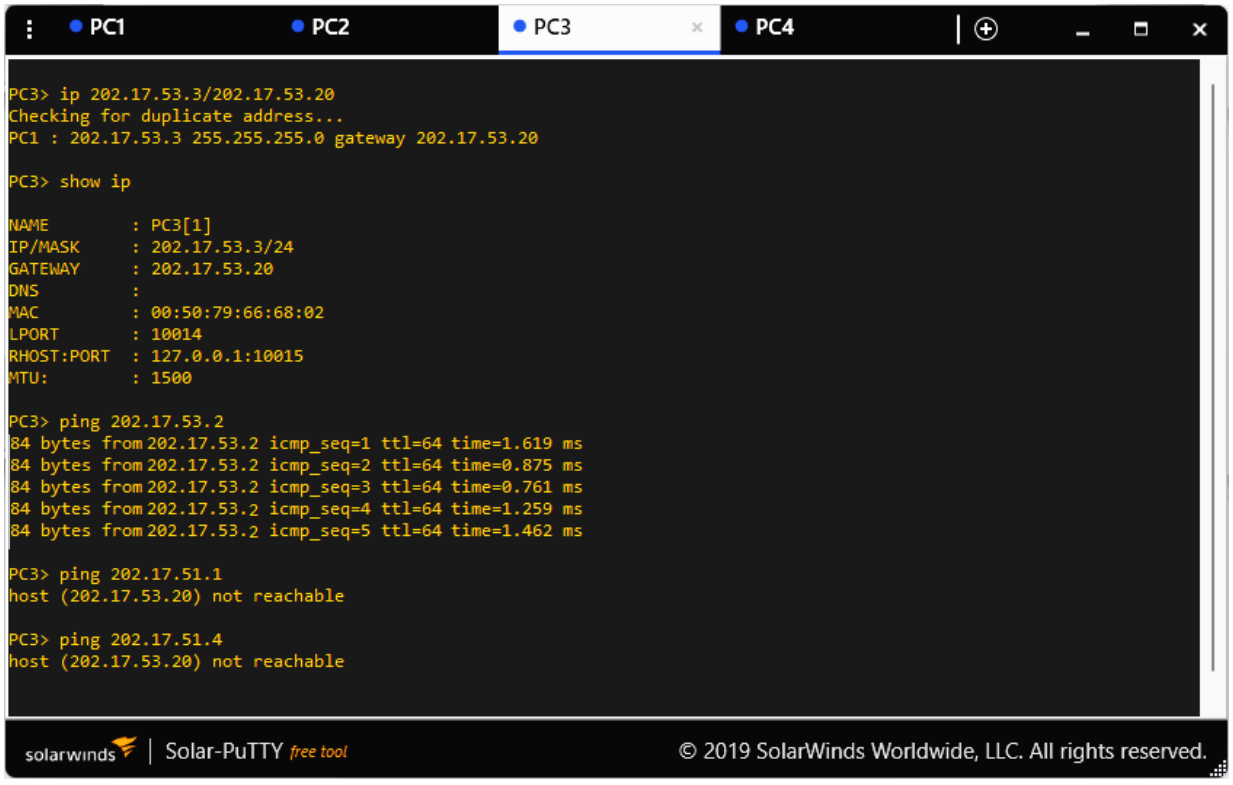


Figure 40: Setting up static IP address and execution of ping command for PC3 on GNS3 simulation for two switches with link aggregation

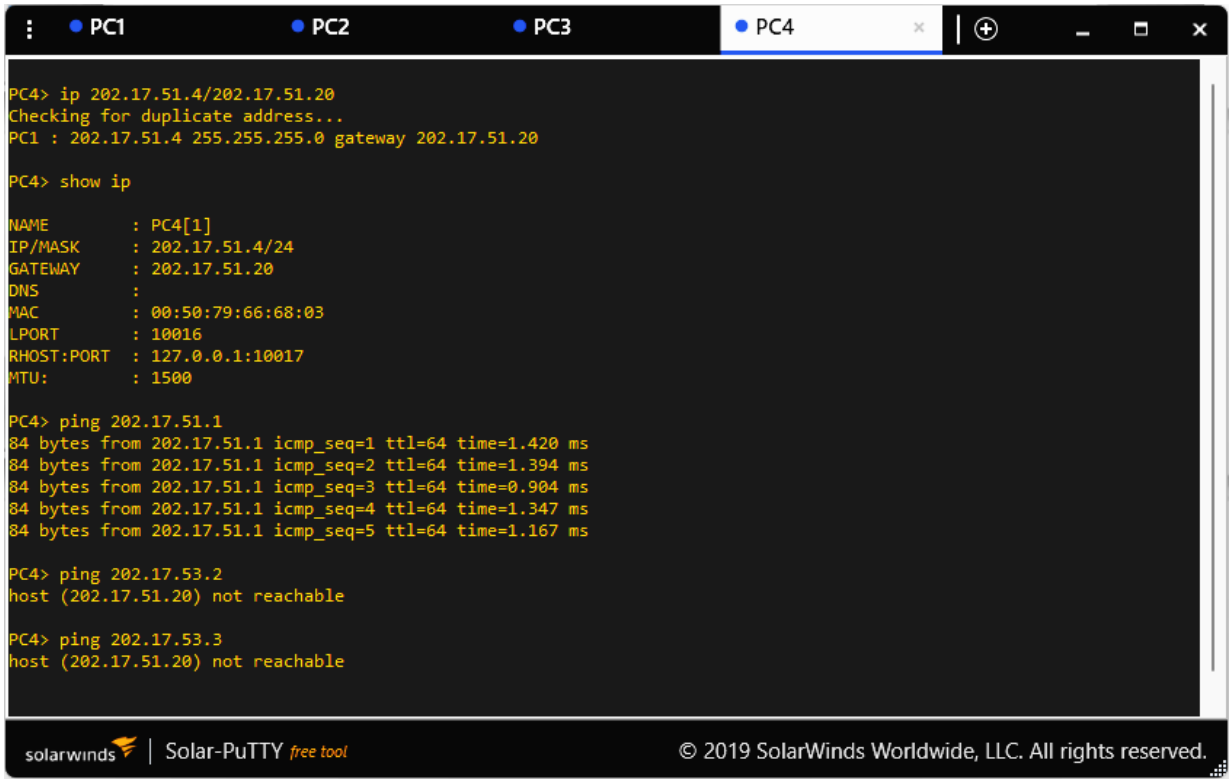
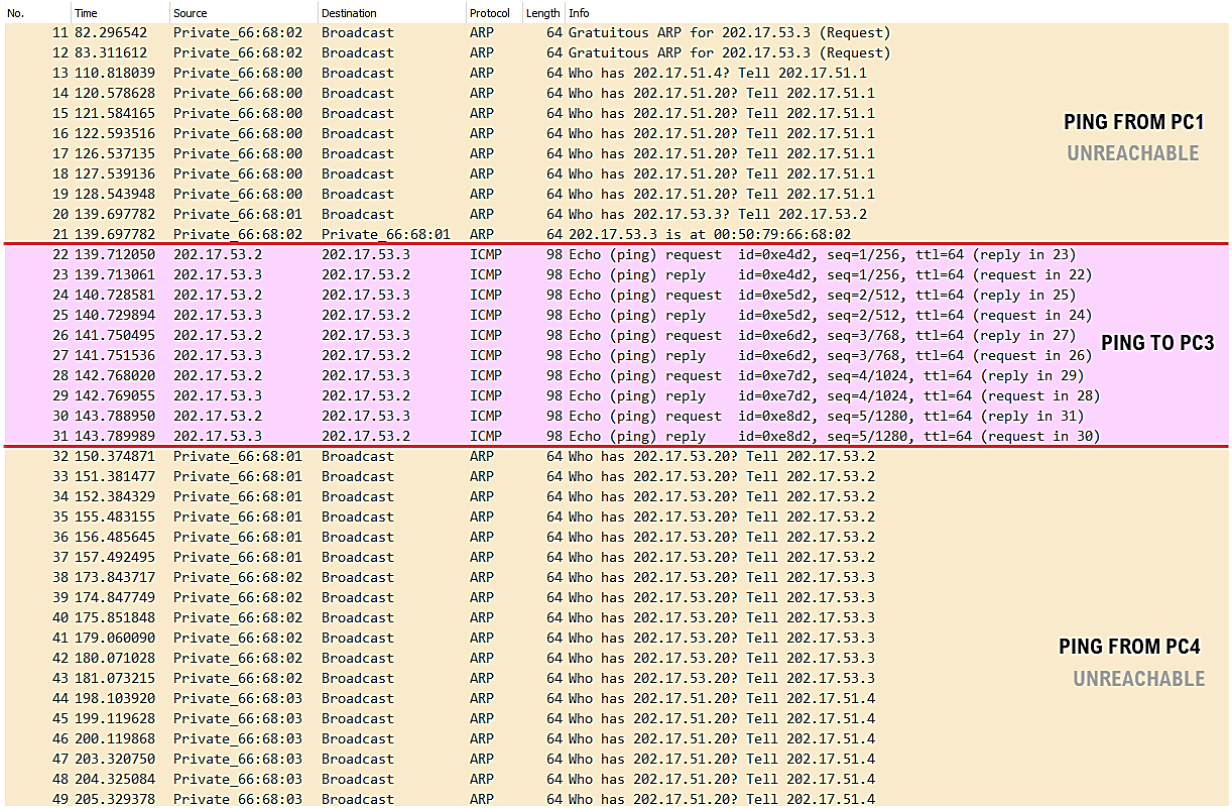


Figure 41: Setting up static IP address and execution of ping command for PC4 on GNS3 simulation for two switches with link aggregation

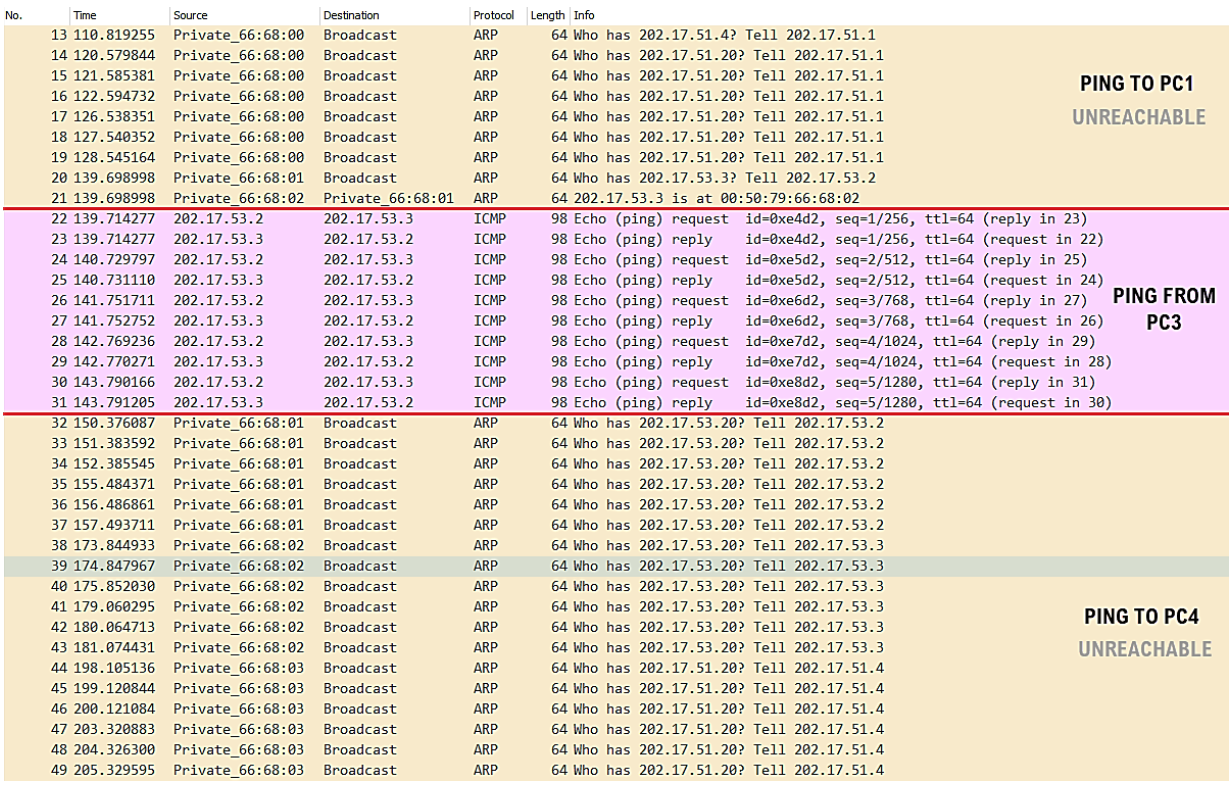
No.	Time	Source	Destination	Protocol	Length	Info	
14	110.818039	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.4 is at 00:50:79:66:68:03	
15	110.832435	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc7d2, seq=1/256, ttl=64 (reply in 16)	PING TO PC4
16	110.833334	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc7d2, seq=1/256, ttl=64 (request in 15)	
17	111.852285	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc8d2, seq=2/512, ttl=64 (reply in 18)	
18	111.853381	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc8d2, seq=2/512, ttl=64 (request in 17)	
19	112.871240	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc9d2, seq=3/768, ttl=64 (reply in 20)	
20	112.871240	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc9d2, seq=3/768, ttl=64 (request in 19)	
21	113.893407	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xcad2, seq=4/1024, ttl=64 (reply in 22)	
22	113.894447	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xcad2, seq=4/1024, ttl=64 (request in 21)	
23	114.916658	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xcbd2, seq=5/1280, ttl=64 (reply in 24)	
24	114.917694	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xcbd2, seq=5/1280, ttl=64 (request in 23)	
25	120.577592	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
26	121.584165	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
27	122.592509	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
28	126.536097	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
29	127.539136	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
30	128.542913	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
31	139.697782	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.3? Tell 202.17.53.2	PING TO PC2 AND PC3 UNREACHABLE
32	150.374871	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
33	151.381477	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
34	152.384329	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
35	155.483155	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
36	156.485645	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
37	157.492495	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
38	173.843717	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
39	174.847749	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
40	175.851848	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
41	179.060090	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
42	180.071028	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
43	181.073215	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
44	187.858152	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x14d3, seq=1/256, ttl=64 (reply in 45)	PING FROM PC4
45	187.859145	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x14d3, seq=1/256, ttl=64 (request in 44)	
46	188.874333	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x15d3, seq=2/512, ttl=64 (reply in 47)	
47	188.875329	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x15d3, seq=2/512, ttl=64 (request in 46)	
48	189.890837	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x16d3, seq=3/768, ttl=64 (reply in 49)	
49	189.890837	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x16d3, seq=3/768, ttl=64 (request in 48)	
50	190.919801	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x17d3, seq=4/1024, ttl=64 (reply in 51)	
51	190.920796	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x17d3, seq=4/1024, ttl=64 (request in 50)	
52	191.937602	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x19d3, seq=5/1280, ttl=64 (reply in 53)	
53	191.937602	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x19d3, seq=5/1280, ttl=64 (request in 52)	

Figure 42: Packet capture on Wireshark for PC1 for GNS3 simulation using two switches with link aggregation



No.	Time	Source	Destination	Protocol	Length	Info	
11	82.296542	Private_66:68:02	Broadcast	ARP	64	Gratuitous ARP for 202.17.53.3 (Request)	
12	83.311612	Private_66:68:02	Broadcast	ARP	64	Gratuitous ARP for 202.17.53.3 (Request)	
13	110.818039	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.4? Tell 202.17.51.1	
14	120.578628	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
15	121.584165	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	PING FROM PC1
16	122.593516	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	UNREACHABLE
17	126.537135	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
18	127.539136	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
19	128.543948	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
20	139.697782	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.3? Tell 202.17.53.2	
21	139.697782	Private_66:68:02	Private_66:68:01	ARP	64	202.17.53.3 is at 00:50:79:66:68:02	
22	139.712050	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe4d2, seq=1/256, ttl=64 (reply in 23)	
23	139.713061	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe4d2, seq=1/256, ttl=64 (request in 22)	
24	140.728581	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe5d2, seq=2/512, ttl=64 (reply in 25)	
25	140.729894	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe5d2, seq=2/512, ttl=64 (request in 24)	
26	141.750495	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe6d2, seq=3/768, ttl=64 (reply in 27)	PING TO PC3
27	141.751536	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe6d2, seq=3/768, ttl=64 (request in 26)	
28	142.768020	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe7d2, seq=4/1024, ttl=64 (reply in 29)	
29	142.769055	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe7d2, seq=4/1024, ttl=64 (request in 28)	
30	143.788950	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe8d2, seq=5/1280, ttl=64 (reply in 31)	
31	143.789989	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe8d2, seq=5/1280, ttl=64 (request in 30)	
32	150.374871	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
33	151.381477	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
34	152.384329	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
35	155.483155	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
36	156.485645	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
37	157.492495	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
38	173.843717	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
39	174.847749	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
40	175.851848	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
41	179.060090	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	PING FROM PC4
42	180.071028	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	UNREACHABLE
43	181.073215	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
44	198.103920	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
45	199.119628	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
46	200.119868	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
47	203.320750	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
48	204.325084	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
49	205.329378	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	

Figure 43: Packet capture on Wireshark for PC2 for GNS3 simulation using two switches with link aggregation



No.	Time	Source	Destination	Protocol	Length	Info	
13	110.819255	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.4? Tell 202.17.51.1	
14	120.579844	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
15	121.585381	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	PING TO PC1
16	122.594732	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	UNREACHABLE
17	126.538351	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
18	127.540352	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
19	128.545164	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
20	139.698998	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.3? Tell 202.17.53.2	
21	139.698998	Private_66:68:02	Private_66:68:01	ARP	64	202.17.53.3 is at 00:50:79:66:68:02	
22	139.714277	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe4d2, seq=1/256, ttl=64 (reply in 23)	
23	139.714277	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe4d2, seq=1/256, ttl=64 (request in 22)	
24	140.729797	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe5d2, seq=2/512, ttl=64 (reply in 25)	
25	140.731110	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe5d2, seq=2/512, ttl=64 (request in 24)	
26	141.751711	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe6d2, seq=3/768, ttl=64 (reply in 27)	PING FROM PC3
27	141.752752	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe6d2, seq=3/768, ttl=64 (request in 26)	
28	142.769236	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe7d2, seq=4/1024, ttl=64 (reply in 29)	
29	142.770271	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe7d2, seq=4/1024, ttl=64 (request in 28)	
30	143.790166	202.17.53.2	202.17.53.3	ICMP	98	Echo (ping) request id=0xe8d2, seq=5/1280, ttl=64 (reply in 31)	
31	143.791205	202.17.53.3	202.17.53.2	ICMP	98	Echo (ping) reply id=0xe8d2, seq=5/1280, ttl=64 (request in 30)	
32	150.376087	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
33	151.383592	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
34	152.385545	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
35	155.484371	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
36	156.486861	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
37	157.493711	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
38	173.844933	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
39	174.847967	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
40	175.852030	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
41	179.060295	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	PING TO PC4
42	180.064713	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	UNREACHABLE
43	181.074431	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
44	198.105136	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
45	199.120844	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
46	200.121084	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
47	203.320883	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
48	204.326300	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	
49	205.329595	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.4	

Figure 44: Packet capture on Wireshark for PC3 for GNS3 simulation using two switches with link aggregation

No.	Time	Source	Destination	Protocol	Length	Info	
14	110.819255	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.4 is at 00:50:79:66:68:03	
15	110.834550	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc7d2, seq=1/256, ttl=64 (reply in 16)	
16	110.834550	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc7d2, seq=1/256, ttl=64 (request in 15)	
17	111.854597	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc8d2, seq=2/512, ttl=64 (reply in 18)	
18	111.854597	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc8d2, seq=2/512, ttl=64 (request in 17)	PING FROM PC1
19	112.872456	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xc9d2, seq=3/768, ttl=64 (reply in 20)	
20	112.872456	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xc9d2, seq=3/768, ttl=64 (request in 19)	
21	113.895663	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xcad2, seq=4/1024, ttl=64 (reply in 22)	
22	113.895663	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xcad2, seq=4/1024, ttl=64 (request in 21)	
23	114.918910	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xcbd2, seq=5/1280, ttl=64 (reply in 24)	
24	114.918910	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xcbd2, seq=5/1280, ttl=64 (request in 23)	
25	120.579844	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
26	121.585381	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
27	122.594732	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
28	126.538351	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
29	127.540352	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
30	128.545164	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.20? Tell 202.17.51.1	
31	139.698998	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.3? Tell 202.17.53.2	
32	150.377192	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
33	151.383592	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
34	152.385545	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
35	155.484371	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
36	156.487891	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	
37	157.493711	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.2	PING FROM PC2 AND PC3 UNREACHABLE
38	173.844933	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
39	174.847967	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
40	175.853064	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
41	179.061306	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
42	180.072244	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
43	181.074431	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.53.20? Tell 202.17.53.3	
44	187.859368	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x14d3, seq=1/256, ttl=64 (reply in 45)	
45	187.860361	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x14d3, seq=1/256, ttl=64 (request in 44)	
46	188.875549	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x15d3, seq=2/512, ttl=64 (reply in 47)	
47	188.876545	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x15d3, seq=2/512, ttl=64 (request in 46)	
48	189.892053	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x16d3, seq=3/768, ttl=64 (reply in 49)	PING TO PC1
49	189.892053	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x16d3, seq=3/768, ttl=64 (request in 48)	
50	190.921017	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x17d3, seq=4/1024, ttl=64 (reply in 51)	
51	190.922012	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x17d3, seq=4/1024, ttl=64 (request in 50)	
52	191.938818	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0x19d3, seq=5/1280, ttl=64 (reply in 53)	
53	191.939810	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0x19d3, seq=5/1280, ttl=64 (request in 52)	

Figure 45: Packet capture on Wireshark for PC4 for GNS3 simulation using two switches with link aggregation

Table 4: LAN address configuration for GNS3 simulation for the two-switch star topology configuration with link aggregation

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.51.1	202.17.51.20	255.255.255.0
PC2	202.17.53.2	202.17.53.20	255.255.255.0
PC3	202.17.53.3	202.17.53.20	255.255.255.0
PC4	202.17.51.4	202.17.51.20	255.255.255.0

5) ***Emulation of VLAN switching on a configuration with two switches with link aggregation on GNS3 using LISA***

Figure 46, Figure 47, Figure 48, and Figure 49 below show the screengrabs of the console window of the network emulation of the two-switch star-topology configuration with link aggregation on GNS3 whereby the VPCSs were configured such that PC1 and PC4 were in one VLAN while PC2 and PC3 were in another VLAN. Figure 50, Figure 51, Figure 52, and Figure 53 below show the captured packets on Wireshark for PC1, PC2, PC3, and PC4 respectively. Lastly, a summary of the LAN address configurations for the GNS3 emulation is shown in Table 5 below.

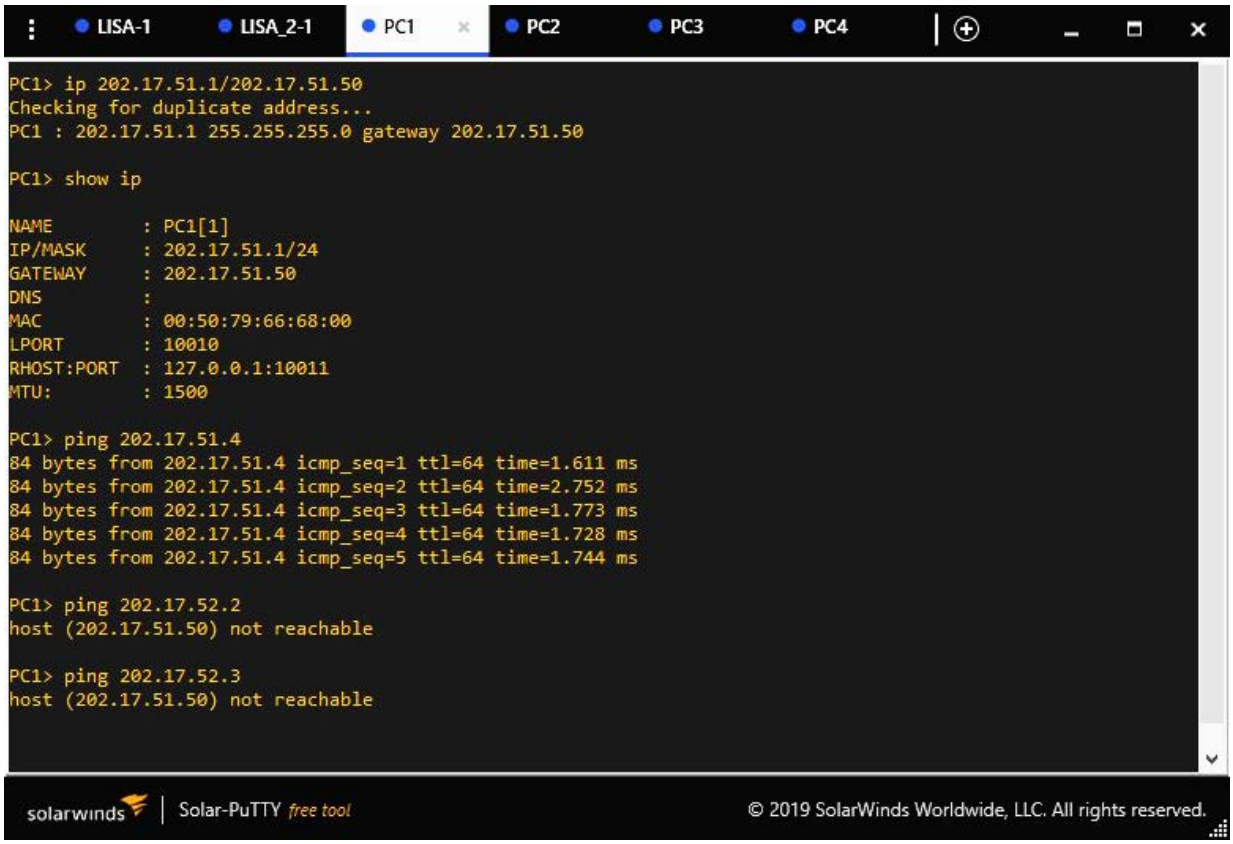


Figure 46: Setting up static IP address and execution of ping command for PC1 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

Figure 47: Setting up static IP address and execution of ping command for PC2 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

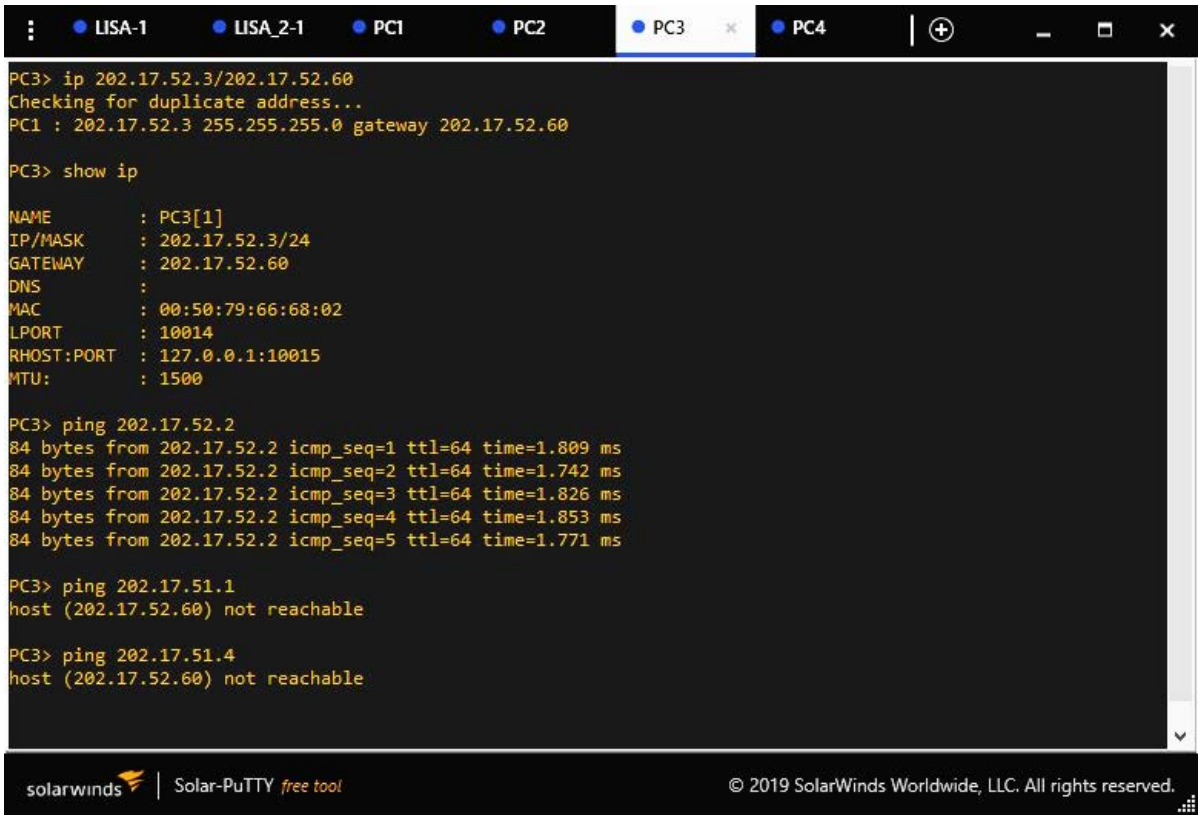


Figure 48: Setting up static IP address and execution of ping command for PC3 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

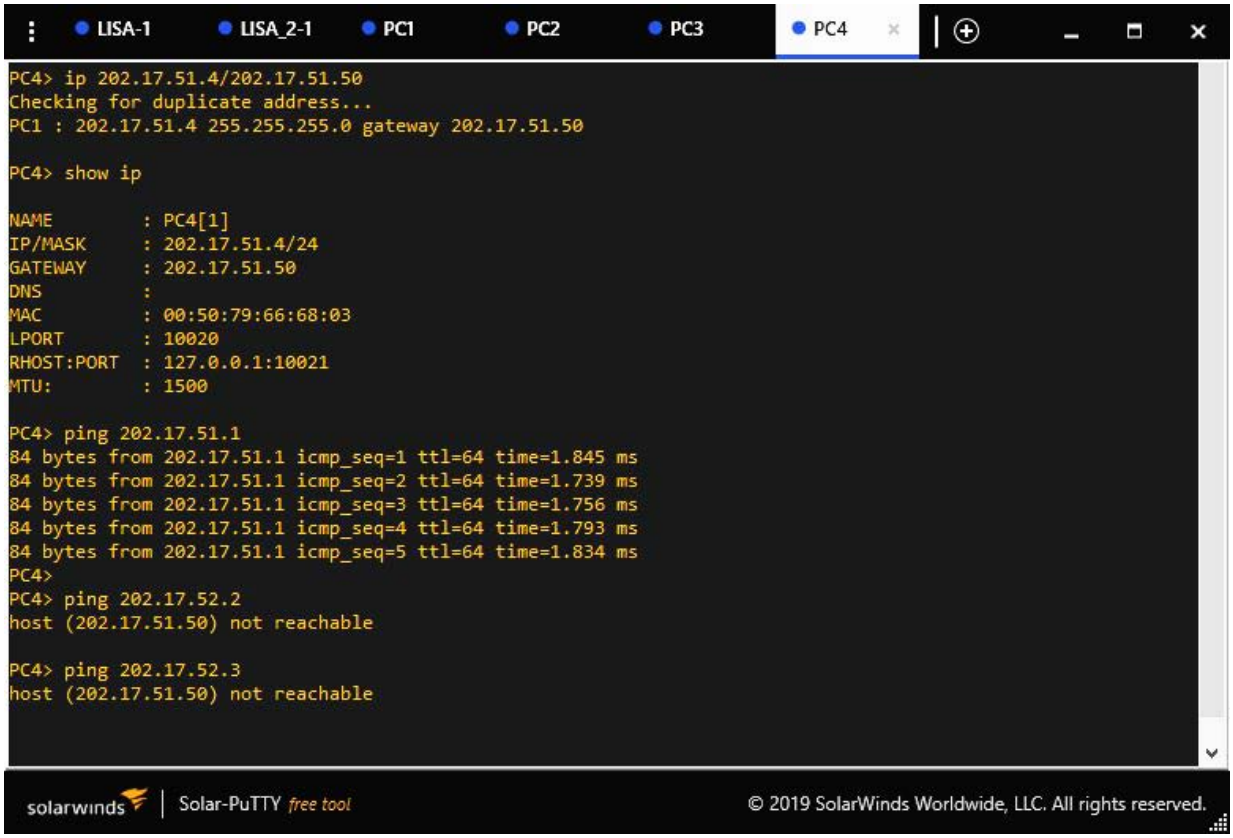


Figure 49: Setting up static IP address and execution of ping command for PC4 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.4? Tell 202.17.51.1	
2	0.001616	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.4 is at 00:50:79:66:68:03	
3	0.003824	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa2ea, seq=1/256, ttl=64 (reply in 4)	PING TO PC4
4	0.005217	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa2ea, seq=1/256, ttl=64 (request in 3)	
5	1.006205	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa3ea, seq=2/512, ttl=64 (reply in 6)	
6	1.008419	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa3ea, seq=2/512, ttl=64 (request in 5)	
7	2.010484	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa4ea, seq=3/768, ttl=64 (reply in 8)	
8	2.012042	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa4ea, seq=3/768, ttl=64 (request in 7)	
9	3.012831	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa5ea, seq=4/1024, ttl=64 (reply in 10)	
10	3.014334	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa5ea, seq=4/1024, ttl=64 (request in 9)	
11	4.015180	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa6ea, seq=5/1280, ttl=64 (reply in 12)	
12	4.016706	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa6ea, seq=5/1280, ttl=64 (request in 11)	
13	9.849778	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
14	10.850161	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
15	11.851480	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
16	14.841010	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	UNREACHABLE
17	15.841344	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
18	16.842804	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
19	29.667570	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
20	87.554730	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfaea, seq=1/256, ttl=64 (reply in 21)	
21	87.554917	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfaea, seq=1/256, ttl=64 (request in 20)	
22	88.556952	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfbea, seq=2/512, ttl=64 (reply in 23)	
23	88.557169	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfbea, seq=2/512, ttl=64 (request in 22)	
24	89.559360	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfcea, seq=3/768, ttl=64 (reply in 25)	PING FROM PC4
25	89.559528	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfcea, seq=3/768, ttl=64 (request in 24)	
26	89.668165	PcsCompu_4a:8b:7f	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
27	90.561743	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfdea, seq=4/1024, ttl=64 (reply in 28)	
28	90.561947	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfdea, seq=4/1024, ttl=64 (request in 27)	
29	91.564080	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfeea, seq=5/1280, ttl=64 (reply in 30)	
30	91.564310	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfeea, seq=5/1280, ttl=64 (request in 29)	
31	102.675798	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
32	103.677194	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
33	104.678584	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
34	108.843141	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	UNREACHABLE
35	109.844573	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
36	110.845844	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	

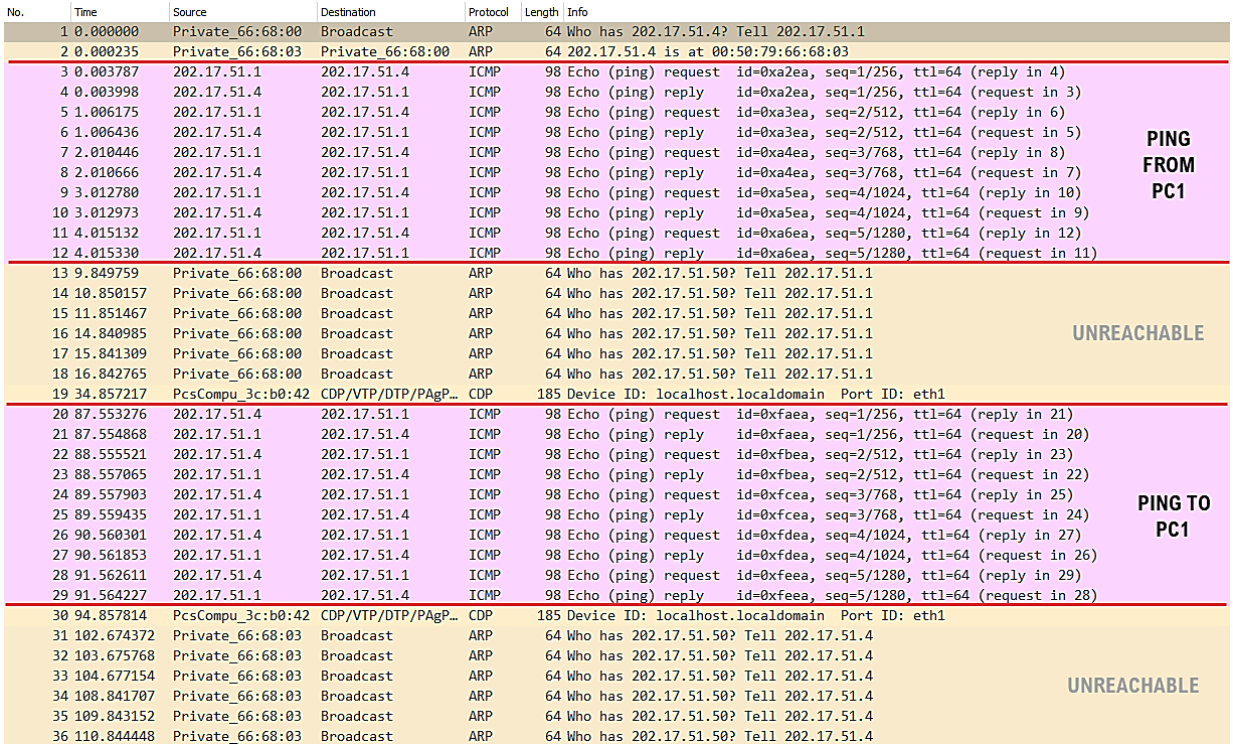
Figure 50: Wireshark capture for PC1 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	PcsCompu_ad:0a:62	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
2	53.618378	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.3? Tell 202.17.52.2	
3	53.620029	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.3 is at 00:50:79:66:68:02	
4	53.621219	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbaea, seq=1/256, ttl=64 (reply in 5)	
5	53.622722	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbaea, seq=1/256, ttl=64 (request in 4)	
6	54.636306	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbbea, seq=2/512, ttl=64 (reply in 7)	
7	54.638477	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbbea, seq=2/512, ttl=64 (request in 6)	
8	55.639618	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbcea, seq=3/768, ttl=64 (reply in 9)	PING TO PC3
9	55.641176	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbcea, seq=3/768, ttl=64 (request in 8)	
10	56.641910	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbdea, seq=4/1024, ttl=64 (reply in 11)	
11	56.643505	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbdea, seq=4/1024, ttl=64 (request in 10)	
12	57.644278	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbeea, seq=5/1280, ttl=64 (reply in 13)	
13	57.645839	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbeea, seq=5/1280, ttl=64 (request in 12)	
14	60.000531	PcsCompu_ad:0a:62	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
15	62.405261	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
16	63.405595	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
17	64.406989	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	UNREACHABLE
18	67.486321	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
19	68.487631	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
20	69.489009	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
21	87.537019	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdcea, seq=1/256, ttl=64 (reply in 22)	
22	87.537222	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdcea, seq=1/256, ttl=64 (request in 21)	
23	88.539261	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xddea, seq=2/512, ttl=64 (reply in 24)	
24	88.539460	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xddea, seq=2/512, ttl=64 (request in 23)	
25	89.541618	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdeea, seq=3/768, ttl=64 (reply in 26)	PING FROM PC3
26	89.541880	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdeea, seq=3/768, ttl=64 (request in 25)	
27	90.544042	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdfea, seq=4/1024, ttl=64 (reply in 28)	
28	90.544275	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdfea, seq=4/1024, ttl=64 (request in 27)	
29	91.546352	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xe0ea, seq=5/1280, ttl=64 (reply in 30)	
30	91.546596	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xe0ea, seq=5/1280, ttl=64 (request in 29)	
31	95.774427	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
32	96.775786	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
33	97.776129	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	UNREACHABLE
34	102.898311	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
35	103.899639	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
36	104.900024	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	

Figure 51: Wireshark capture for PC2 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.3? Tell 202.17.52.2	
2	0.000252	Private_66:68:02	Private_66:68:01	ARP	64	202.17.52.3 is at 00:50:79:66:68:02	
3	0.002732	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbaea, seq=1/256, ttl=64 (reply in 4)	
4	0.002965	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbaea, seq=1/256, ttl=64 (request in 3)	
5	1.017876	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbbea, seq=2/512, ttl=64 (reply in 6)	
6	1.018095	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbbea, seq=2/512, ttl=64 (request in 5)	
7	2.021205	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbcea, seq=3/768, ttl=64 (reply in 8)	PING FROM PC3
8	2.021416	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbcea, seq=3/768, ttl=64 (request in 7)	
9	3.023510	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbdea, seq=4/1024, ttl=64 (reply in 10)	
10	3.023734	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbdea, seq=4/1024, ttl=64 (request in 9)	
11	4.025857	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) request id=0xbeea, seq=5/1280, ttl=64 (reply in 12)	
12	4.026089	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) reply id=0xbeea, seq=5/1280, ttl=64 (request in 11)	
13	8.786837	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
14	9.787177	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
15	10.788571	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
16	11.571757	PcsCompu_ae:03:c5	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	UNREACHABLE
17	13.867912	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
18	14.869251	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
19	15.870587	Private_66:68:01	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.2	
20	33.917192	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdcea, seq=1/256, ttl=64 (reply in 21)	
21	33.918762	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdcea, seq=1/256, ttl=64 (request in 20)	
22	34.919468	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xddea, seq=2/512, ttl=64 (reply in 23)	
23	34.920976	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xddea, seq=2/512, ttl=64 (request in 22)	
24	35.921818	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdeea, seq=3/768, ttl=64 (reply in 25)	
25	35.923410	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdeea, seq=3/768, ttl=64 (request in 24)	PING TO PC2
26	36.924214	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xdfea, seq=4/1024, ttl=64 (reply in 27)	
27	36.925828	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xdfea, seq=4/1024, ttl=64 (request in 26)	
28	37.926557	202.17.52.3	202.17.52.2	ICMP	98	Echo (ping) request id=0xe0ea, seq=5/1280, ttl=64 (reply in 29)	
29	37.928119	202.17.52.2	202.17.52.3	ICMP	98	Echo (ping) reply id=0xe0ea, seq=5/1280, ttl=64 (request in 28)	
30	42.154619	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
31	43.155975	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
32	44.156338	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
33	49.278450	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
34	50.279800	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
35	51.280173	Private_66:68:02	Broadcast	ARP	64	Who has 202.17.52.60? Tell 202.17.52.3	
36	71.572358	PcsCompu_ae:03:c5	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	UNREACHABLE
37	131.573039	PcsCompu_ae:03:c5	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
38	191.573648	PcsCompu_ae:03:c5	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	
39	251.574263	PcsCompu_ae:03:c5	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth0	

Figure 52: Wireshark capture for PC3 on GNS3 emulation for two switches with link aggregation using LISA switch emulator



No.	Time	Source	Destination	Protocol	Length	Info	
1	0.000000	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.4? Tell 202.17.51.1	
2	0.000235	Private_66:68:03	Private_66:68:00	ARP	64	202.17.51.4 is at 00:50:79:66:68:03	
3	0.003787	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa2ea, seq=1/256, ttl=64 (reply in 4)	PING FROM PC1
4	0.003998	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa2ea, seq=1/256, ttl=64 (request in 3)	
5	1.006175	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa3ea, seq=2/512, ttl=64 (reply in 6)	
6	1.006436	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa3ea, seq=2/512, ttl=64 (request in 5)	
7	2.010446	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa4ea, seq=3/768, ttl=64 (reply in 8)	
8	2.010666	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa4ea, seq=3/768, ttl=64 (request in 7)	
9	3.012780	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa5ea, seq=4/1024, ttl=64 (reply in 10)	
10	3.012973	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa5ea, seq=4/1024, ttl=64 (request in 9)	
11	4.015132	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) request id=0xa6ea, seq=5/1280, ttl=64 (reply in 12)	
12	4.015330	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) reply id=0xa6ea, seq=5/1280, ttl=64 (request in 11)	
13	9.849759	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
14	10.850157	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
15	11.851467	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
16	14.840985	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	UNREACHABLE
17	15.841309	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
18	16.842765	Private_66:68:00	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.1	
19	34.857217	PcsCompu_3c:b0:42	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
20	87.553276	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfaea, seq=1/256, ttl=64 (reply in 21)	PING TO PC1
21	87.554868	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfaea, seq=1/256, ttl=64 (request in 20)	
22	88.555521	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfbea, seq=2/512, ttl=64 (reply in 23)	
23	88.557065	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfbea, seq=2/512, ttl=64 (request in 22)	
24	89.557903	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfcea, seq=3/768, ttl=64 (reply in 25)	
25	89.559435	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfcea, seq=3/768, ttl=64 (request in 24)	
26	90.560301	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfdea, seq=4/1024, ttl=64 (reply in 27)	
27	90.561853	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfdea, seq=4/1024, ttl=64 (request in 26)	
28	91.562611	202.17.51.4	202.17.51.1	ICMP	98	Echo (ping) request id=0xfeea, seq=5/1280, ttl=64 (reply in 29)	
29	91.564227	202.17.51.1	202.17.51.4	ICMP	98	Echo (ping) reply id=0xfeea, seq=5/1280, ttl=64 (request in 28)	
30	94.857814	PcsCompu_3c:b0:42	CDP/VTP/DTP/PAgP…	CDP	185	Device ID: localhost.localdomain Port ID: eth1	
31	102.674372	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
32	103.675768	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
33	104.677154	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
34	108.841707	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	UNREACHABLE
35	109.843152	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	
36	110.844448	Private_66:68:03	Broadcast	ARP	64	Who has 202.17.51.50? Tell 202.17.51.4	

Figure 53: Wireshark capture for PC4 on GNS3 emulation for two switches with link aggregation using LISA switch emulator

Table 5: LAN address configuration for GNS3 emulation using the LISA switch emulator for the two-switch star topology configuration with link aggregation

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.51.1	202.17.51.50	255.255.255.0
PC2	202.17.52.2	202.17.52.60	255.255.255.0
PC3	202.17.52.3	202.17.52.60	255.255.255.0
PC4	202.17.51.4	202.17.51.50	255.255.255.0

6) *Hardware implementation of VLAN switching on a configuration with two switches with link aggregation using hardware LISA appliance*

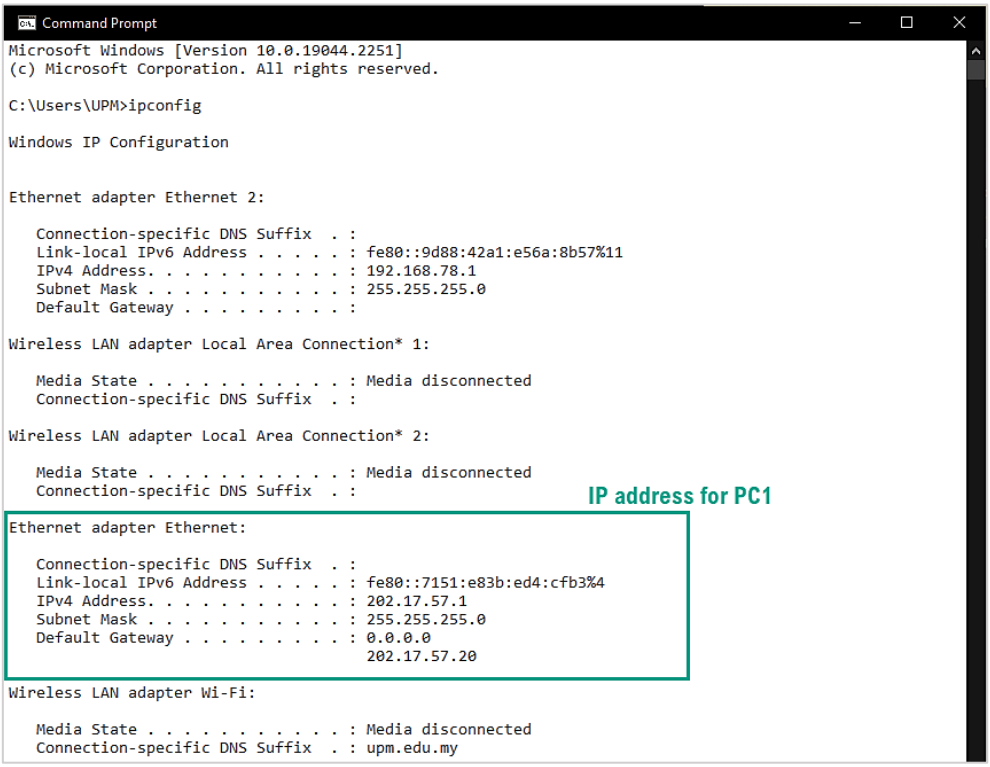


Figure 54: IP configuration summary of PC1 for the hardware implementation of two switches with link aggregation

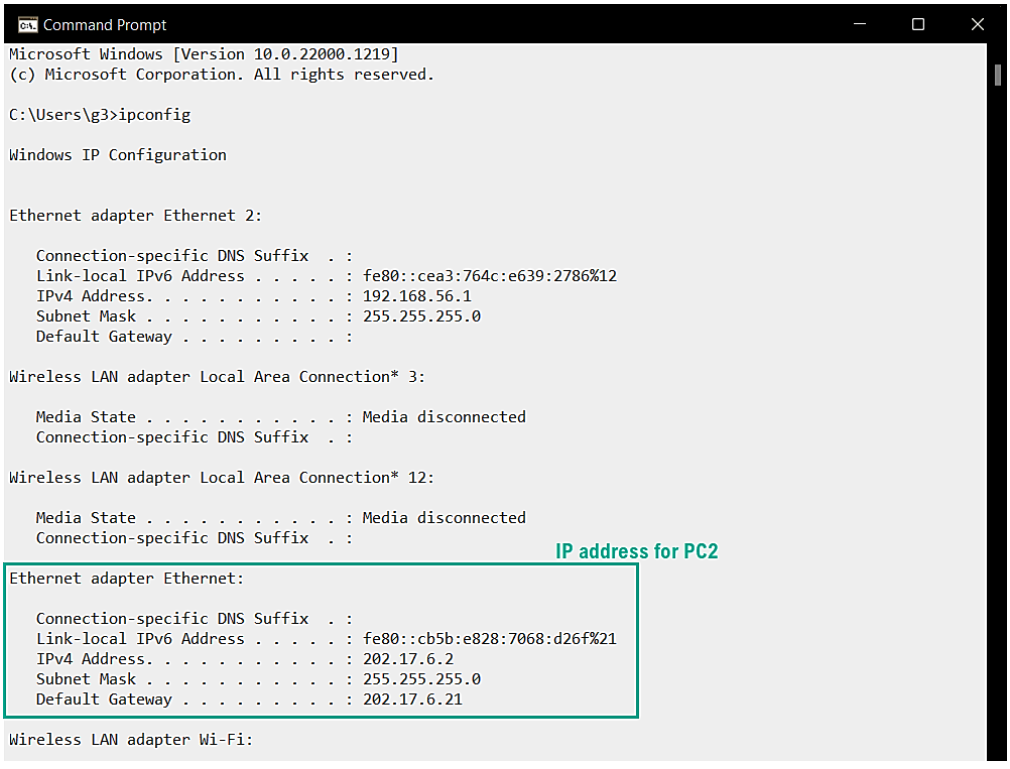


Figure 55: IP configuration summary of PC2 for the hardware implementation of two switches with link aggregation

A summary of the LAN address configurations is shown in Table 6 below for the hardware implementation of a two-switch configuration with link aggregation. Figure 54 and Figure 55 above show the IP configurations of PC1 and PC3 which are in different VLANs respectively.

Figure 56 and Figure 57 show the ping commands that were carried out for PC2 and PC3 respectively. Figure 58, Figure 59, Figure 60, and Figure 61 show the Wireshark captures from carrying out the ping commands between PCs for PC1, PC2, PC3, and PC4 respectively.

Table 6: LAN address configuration for hardware implementation for the two-switch configuration with link aggregation

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.57.1	202.17.57.20	255.255.255.0
PC2	202.17.6.2	202.17.6.21	255.255.255.0
PC3	202.17.6.3	202.17.6.21	255.255.255.0
PC4	202.17.57.4	202.17.57.20	255.255.255.0

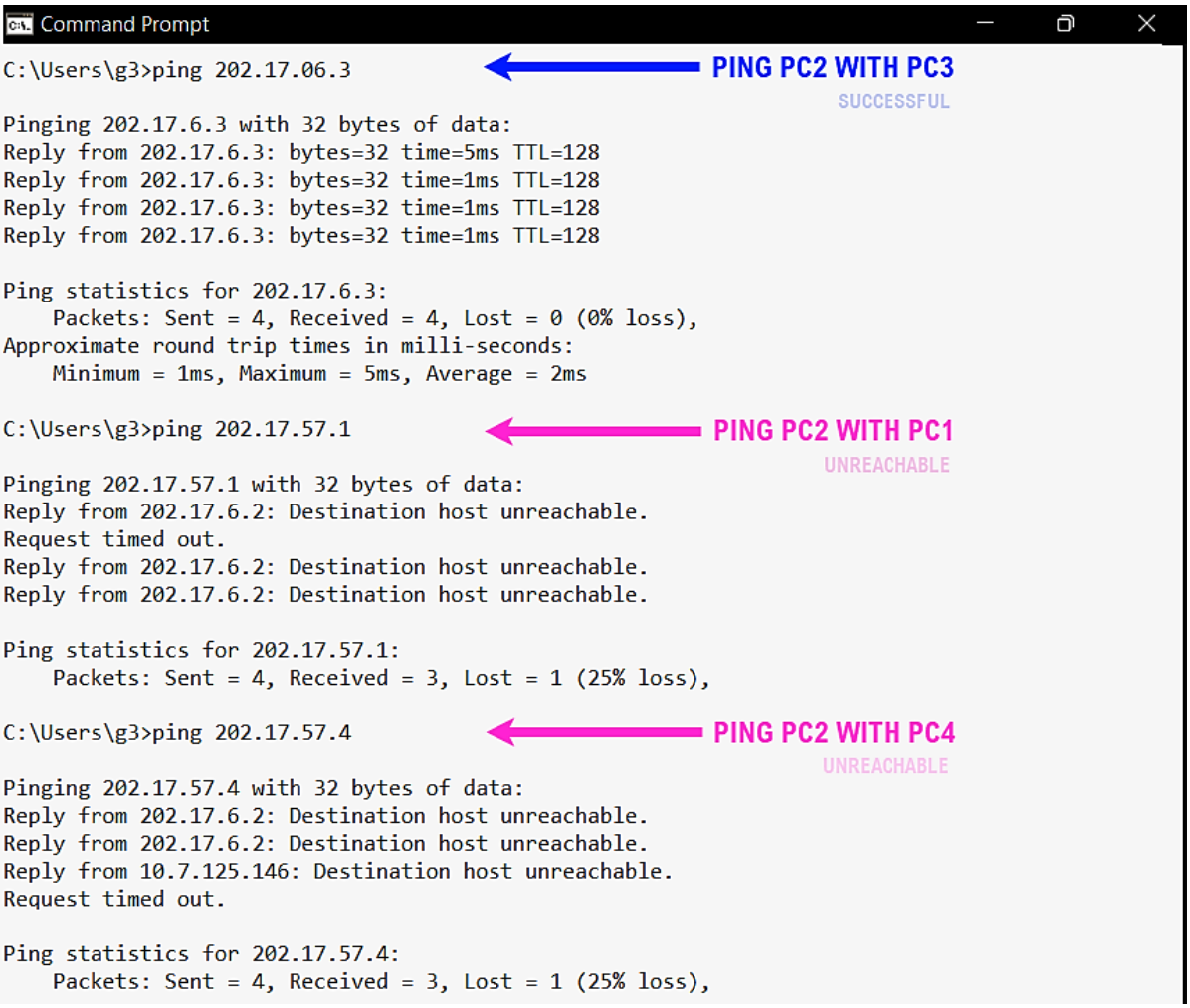


Figure 56: Ping commands executed from PC2 on hardware to the other PCs

```
C:\Users\ASUS>ping 202.17.57.1

Pinging 202.17.57.1 with 32 bytes of data:
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.

Ping statistics for 202.17.57.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),

C:\Users\ASUS>ping 202.17.57.2

Pinging 202.17.57.2 with 32 bytes of data:
Reply from 202.17.57.2: bytes=32 time=1ms TTL=128
Reply from 202.17.57.2: bytes=32 time=2ms TTL=128
Reply from 202.17.57.2: bytes=32 time=1ms TTL=128
Reply from 202.17.57.2: bytes=32 time=2ms TTL=128

Ping statistics for 202.17.57.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 2ms, Average = 1ms

C:\Users\ASUS>ping 202.17.57.4

Pinging 202.17.57.4 with 32 bytes of data:
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.
Reply from 202.17.57.3: Destination host unreachable.

Ping statistics for 202.17.57.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
```

PING PC3 WITH PC1 UNREACHABLE

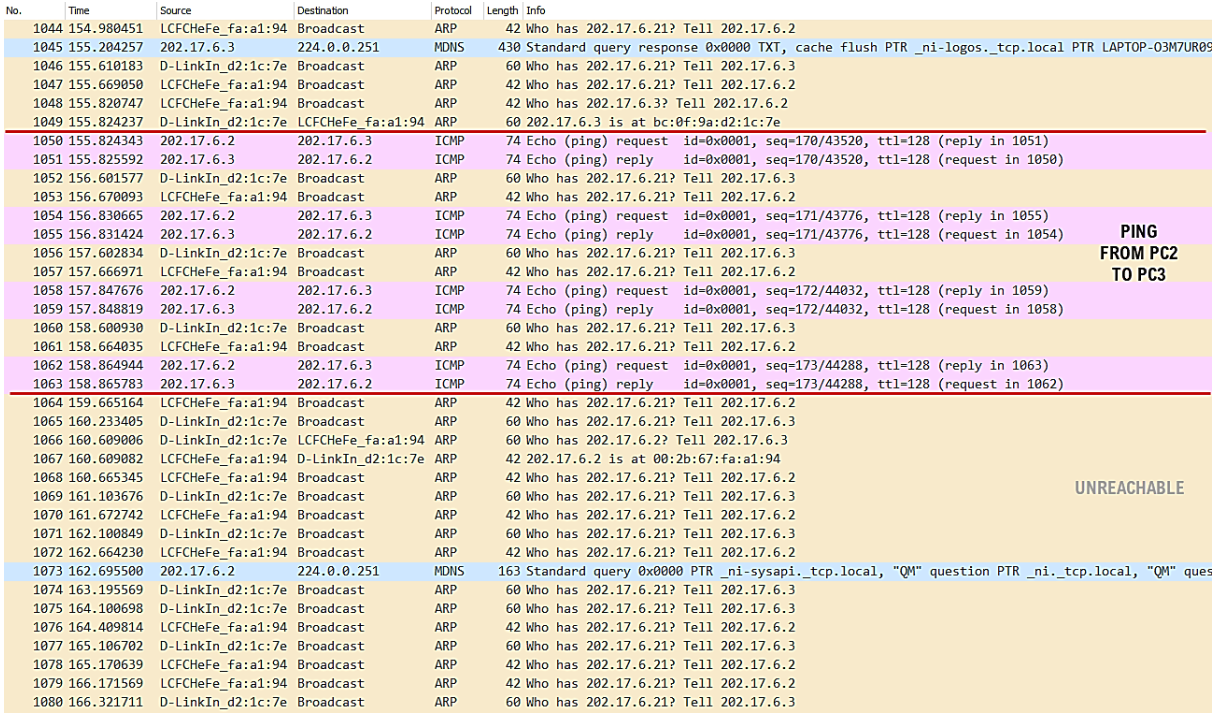
PING PC3 WITH PC2 SUCCESSFUL

PING PC3 WITH PC4 UNREACHABLE

Figure 57: Ping commands executed from PC3 on hardware to the other PCs

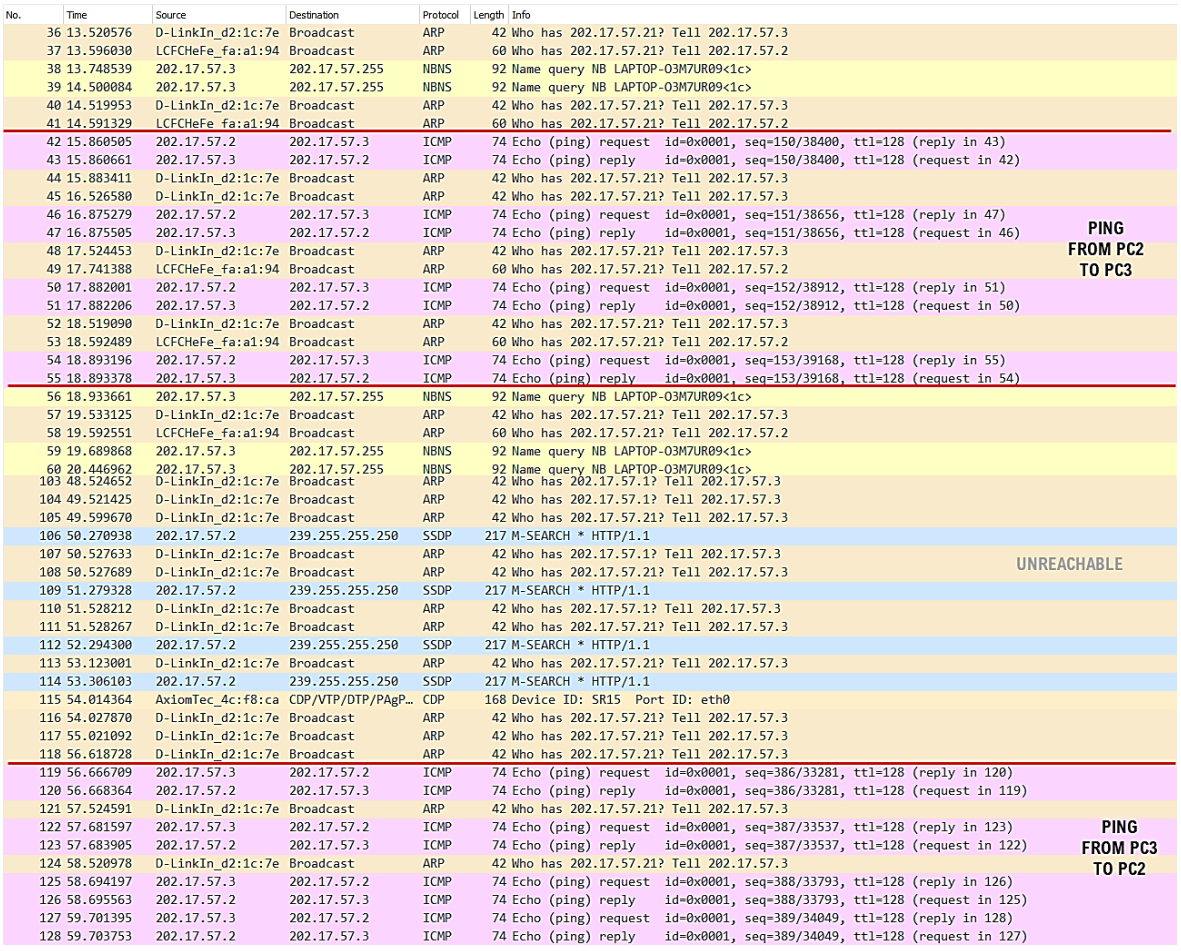
No.	Time	Source	Destination	Protocol	Length	Info	
66	56.478422	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
67	57.481913	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
68	59.789553	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=201/51456, ttl=128 (reply in 69)	
69	59.789740	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=201/51456, ttl=128 (request in 68)	
70	60.800294	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=202/51712, ttl=128 (reply in 71)	
71	60.800460	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=202/51712, ttl=128 (request in 70)	PING FROM PC4 TO PC1
72	60.963950	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
73	61.477136	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
74	61.824569	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=203/51968, ttl=128 (reply in 75)	
75	61.824638	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=203/51968, ttl=128 (request in 74)	
76	62.484470	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
77	62.829662	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=204/52224, ttl=128 (reply in 78)	
78	62.829724	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=204/52224, ttl=128 (request in 77)	
79	63.918101	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
80	64.484042	Dell_42:7d:2e	WistronI_9b:4c:d4	ARP	60	Who has 202.17.57.1? Tell 202.17.57.4	
81	64.484043	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
82	64.484068	WistronI_9b:4c:d4	Dell_42:7d:2e	ARP	42	202.17.57.1 is at 98:ee:cb:9b:4c:d4	
83	64.695255	WistronI_9b:4c:d4	Dell_42:7d:2e	ARP	42	Who has 202.17.57.4? Tell 202.17.57.1	
84	64.697276	Dell_42:7d:2e	WistronI_9b:4c:d4	ARP	60	202.17.57.4 is at a0:29:19:42:7d:2e	
85	65.242236	202.17.57.1	202.17.57.255	UDP	82	57534 → 1947 Len=40	
86	65.488383	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
87	67.143654	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
88	67.986026	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	UNREACHABLE
89	68.975415	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
90	72.318841	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
91	72.988859	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
92	73.979055	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
93	75.439429	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
94	75.973699	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
95	76.979842	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	
96	77.987330	Dell_42:7d:2e	Broadcast	ARP	60	Who has 202.17.57.20? Tell 202.17.57.4	

Figure 58: Packet capture on Wireshark for PC1 for hardware implementation for the two-switch configuration with link aggregation



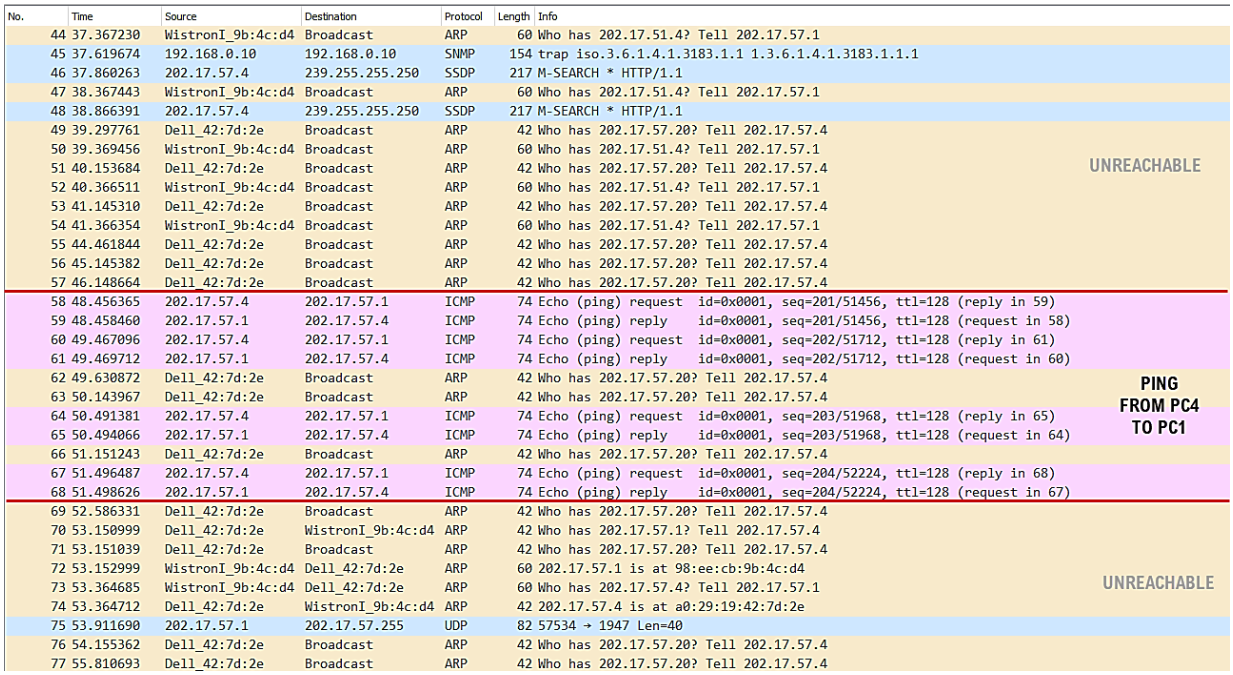
No.	Time	Source	Destination	Protocol	Length	Info
1044	154.980451	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1045	155.204257	202.17.6.3	224.0.0.251	MDNS	430	Standard query response 0x0000 TXT, cache flush PTR _ni-logos._tcp.local PTR LAPTOP-O3M7UR09
1046	155.610183	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1047	155.669050	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1048	155.820747	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.3? Tell 202.17.6.2
1049	155.824237	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	60	202.17.6.3 is at bc:0f:9a:d2:1c:7e
1050	155.824343	202.17.6.2	202.17.6.3	ICMP	74	Echo (ping) request id=0x0001, seq=170/43520, ttl=128 (reply in 1051)
1051	155.825592	202.17.6.3	202.17.6.2	ICMP	74	Echo (ping) reply id=0x0001, seq=170/43520, ttl=128 (request in 1050)
1052	156.601577	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1053	156.670093	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1054	156.830665	202.17.6.2	202.17.6.3	ICMP	74	Echo (ping) request id=0x0001, seq=171/43776, ttl=128 (reply in 1055)
1055	156.831424	202.17.6.3	202.17.6.2	ICMP	74	Echo (ping) reply id=0x0001, seq=171/43776, ttl=128 (request in 1054)
1056	157.602834	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1057	157.666971	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1058	157.847676	202.17.6.2	202.17.6.3	ICMP	74	Echo (ping) request id=0x0001, seq=172/44032, ttl=128 (reply in 1059)
1059	157.848819	202.17.6.3	202.17.6.2	ICMP	74	Echo (ping) reply id=0x0001, seq=172/44032, ttl=128 (request in 1058)
1060	158.600930	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1061	158.664035	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1062	158.864944	202.17.6.2	202.17.6.3	ICMP	74	Echo (ping) request id=0x0001, seq=173/44288, ttl=128 (reply in 1063)
1063	158.865783	202.17.6.3	202.17.6.2	ICMP	74	Echo (ping) reply id=0x0001, seq=173/44288, ttl=128 (request in 1062)
1064	159.665164	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1065	160.233405	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1066	160.609006	D-LinkIn_d2:1c:7e	LCFCHeFe_fa:a1:94	ARP	60	Who has 202.17.6.2? Tell 202.17.6.3
1067	160.609082	LCFCHeFe_fa:a1:94	D-LinkIn_d2:1c:7e	ARP	42	202.17.6.2 is at 00:2b:67:fa:a1:94
1068	160.665345	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1069	161.103676	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1070	161.672742	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1071	162.100849	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1072	162.664230	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1073	162.695500	202.17.6.2	224.0.0.251	MDNS	163	Standard query 0x0000 PTR _ni-sysapi._tcp.local, "QM" question PTR _ni._tcp.local, "QM" ques
1074	163.195569	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1075	164.100698	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1076	164.409814	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1077	165.106702	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3
1078	165.170639	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1079	166.171569	LCFCHeFe_fa:a1:94	Broadcast	ARP	42	Who has 202.17.6.21? Tell 202.17.6.2
1080	166.321711	D-LinkIn_d2:1c:7e	Broadcast	ARP	60	Who has 202.17.6.21? Tell 202.17.6.3

Figure 59: Packet capture on Wireshark for PC2 for hardware implementation for the two-switch configuration with link aggregation



No.	Time	Source	Destination	Protocol	Length	Info
36	13.520576	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
37	13.596030	LCFCHeFe_fa:a1:94	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.2
38	13.748539	202.17.57.3	202.17.57.255	NBNS	92	Name query NB LAPTOP-O3M7UR09<1c>
39	14.500084	202.17.57.3	202.17.57.255	NBNS	92	Name query NB LAPTOP-O3M7UR09<1c>
40	14.519953	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
41	14.591329	LCFCHeFe_fa:a1:94	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.2
42	15.860505	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=150/38400, ttl=128 (reply in 43)
43	15.860661	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=150/38400, ttl=128 (request in 42)
44	15.883411	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
45	16.526580	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
46	16.875279	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=151/38656, ttl=128 (reply in 47)
47	16.875505	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=151/38656, ttl=128 (request in 46)
48	17.524453	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
49	17.741388	LCFCHeFe_fa:a1:94	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.2
50	17.882001	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=152/38912, ttl=128 (reply in 51)
51	17.882206	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=152/38912, ttl=128 (request in 50)
52	18.519090	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
53	18.592489	LCFCHeFe_fa:a1:94	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.2
54	18.893196	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) request id=0x0001, seq=153/39168, ttl=128 (reply in 55)
55	18.893378	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) reply id=0x0001, seq=153/39168, ttl=128 (request in 54)
56	18.933661	202.17.57.3	202.17.57.255	NBNS	92	Name query NB LAPTOP-O3M7UR09<1c>
57	19.533125	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
58	19.592551	LCFCHeFe_fa:a1:94	Broadcast	ARP	60	Who has 202.17.57.21? Tell 202.17.57.2
59	19.689868	202.17.57.3	202.17.57.255	NBNS	92	Name query NB LAPTOP-O3M7UR09<1c>
60	20.446962	202.17.57.3	202.17.57.255	NBNS	92	Name query NB LAPTOP-O3M7UR09<1c>
103	48.524652	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3
104	49.521425	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3
105	49.599670	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
106	50.270938	202.17.57.2	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1
107	50.527633	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3
108	50.527689	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
109	51.279328	202.17.57.2	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1
110	51.528212	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.1? Tell 202.17.57.3
111	51.528267	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
112	52.294300	202.17.57.2	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1
113	53.123001	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
114	53.306103	202.17.57.2	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1
115	54.014364	AxiomTec_4c:f8:ca	CDP/VTP/DTP/PAgP…	CDP	168	Device ID: SR15 Port ID: eth0
116	54.027870	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
117	55.021092	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
118	56.618728	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
119	56.666709	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=386/33281, ttl=128 (reply in 120)
120	56.668364	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=386/33281, ttl=128 (request in 119)
121	57.524591	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
122	57.681597	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=387/33537, ttl=128 (reply in 123)
123	57.683905	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=387/33537, ttl=128 (request in 122)
124	58.520978	D-LinkIn_d2:1c:7e	Broadcast	ARP	42	Who has 202.17.57.21? Tell 202.17.57.3
125	58.694197	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=388/33793, ttl=128 (reply in 126)
126	58.695563	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=388/33793, ttl=128 (request in 125)
127	59.701395	202.17.57.3	202.17.57.2	ICMP	74	Echo (ping) request id=0x0001, seq=389/34049, ttl=128 (reply in 128)
128	59.703753	202.17.57.2	202.17.57.3	ICMP	74	Echo (ping) reply id=0x0001, seq=389/34049, ttl=128 (request in 127)

Figure 60: Packet capture on Wireshark for PC3 for hardware implementation for the two-switch configuration with link aggregation



No.	Time	Source	Destination	Protocol	Length	Info	
44	37.367230	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.51.4? Tell 202.17.57.1	
45	37.619674	192.168.0.10	192.168.0.10	SNMP	154	trap iso.3.6.1.4.1.3183.1.1 1.3.6.1.4.1.3183.1.1.1	
46	37.860263	202.17.57.4	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1	
47	38.367443	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.51.4? Tell 202.17.57.1	
48	38.866391	202.17.57.4	239.255.255.250	SSDP	217	M-SEARCH * HTTP/1.1	
49	39.297761	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
50	39.369456	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.51.4? Tell 202.17.57.1	
51	40.153684	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	UNREACHABLE
52	40.366511	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.51.4? Tell 202.17.57.1	
53	41.145310	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
54	41.366354	WistronI_9b:4c:d4	Broadcast	ARP	60	Who has 202.17.51.4? Tell 202.17.57.1	
55	44.461844	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
56	45.145382	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
57	46.148664	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
58	48.456365	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=201/51456, ttl=128 (reply in 59)	
59	48.458460	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=201/51456, ttl=128 (request in 58)	
60	49.467096	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=202/51712, ttl=128 (reply in 61)	
61	49.469712	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=202/51712, ttl=128 (request in 60)	
62	49.630872	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	PING FROM PC4 TO PC1
63	50.143967	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
64	50.491381	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=203/51968, ttl=128 (reply in 65)	
65	50.494066	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=203/51968, ttl=128 (request in 64)	
66	51.151243	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
67	51.496487	202.17.57.4	202.17.57.1	ICMP	74	Echo (ping) request id=0x0001, seq=204/52224, ttl=128 (reply in 68)	
68	51.498626	202.17.57.1	202.17.57.4	ICMP	74	Echo (ping) reply id=0x0001, seq=204/52224, ttl=128 (request in 67)	
69	52.586331	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
70	53.150999	Dell_42:7d:2e	WistronI_9b:4c:d4	ARP	42	Who has 202.17.57.1? Tell 202.17.57.4	
71	53.151039	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
72	53.152999	WistronI_9b:4c:d4	Dell_42:7d:2e	ARP	60	202.17.57.1 is at 98:ee:cb:9b:4c:d4	
73	53.364685	WistronI_9b:4c:d4	Dell_42:7d:2e	ARP	60	Who has 202.17.57.4? Tell 202.17.57.1	UNREACHABLE
74	53.364712	Dell_42:7d:2e	WistronI_9b:4c:d4	ARP	42	202.17.57.4 is at a0:29:19:42:7d:2e	
75	53.911690	202.17.57.1	202.17.57.255	UDP	82	57534 → 1947 Len=40	
76	54.155362	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	
77	55.810693	Dell_42:7d:2e	Broadcast	ARP	42	Who has 202.17.57.20? Tell 202.17.57.4	

Figure 61: Packet capture on Wireshark for PC4 for hardware implementation for the two-switch configuration with link aggregation

6.0 Discussion

a) What is the purpose of VLAN switching?

VLAN switching segments devices and traffic within a single LAN or network. VLANs encapsulate packets and allow traffic to move between the VLAN-tagged ports and devices. This is done for three main reasons as listed below [1]:

- *Improvement of performance* – The use of VLANs improves the performance of linked devices by reducing the traffic that a particular endpoint encounters and processes. VLANs 'break up' broadcast domains thus reducing the number of hosts from which other devices are able to see the broadcasts.
- *Tightening security* – The partitioning of the devices allows better control over access of devices with each other.
- *Easing administration* – The partitioning also allows the grouping of endpoints which means administrators can group particular devices for administrative purposes, for instance, grouping all the devices from one department into a single VLAN.

b) What is port-based VLAN?

Port-based VLAN is also known as static VLAN. Ports or interfaces are assigned on a switch to groups or separate VLANs [1][2] by a network manager. Figure 62 below shows the ports on a switch divided into two groups or VLANs whereby the broadcast traffic from one port can only reach the other ports in the group, also called a broadcast domain [2]. So the devices connected to VLAN ports 2 to 8 are unable to communicate with the devices that are connected to ports 9 to 15 which are on another VLAN.

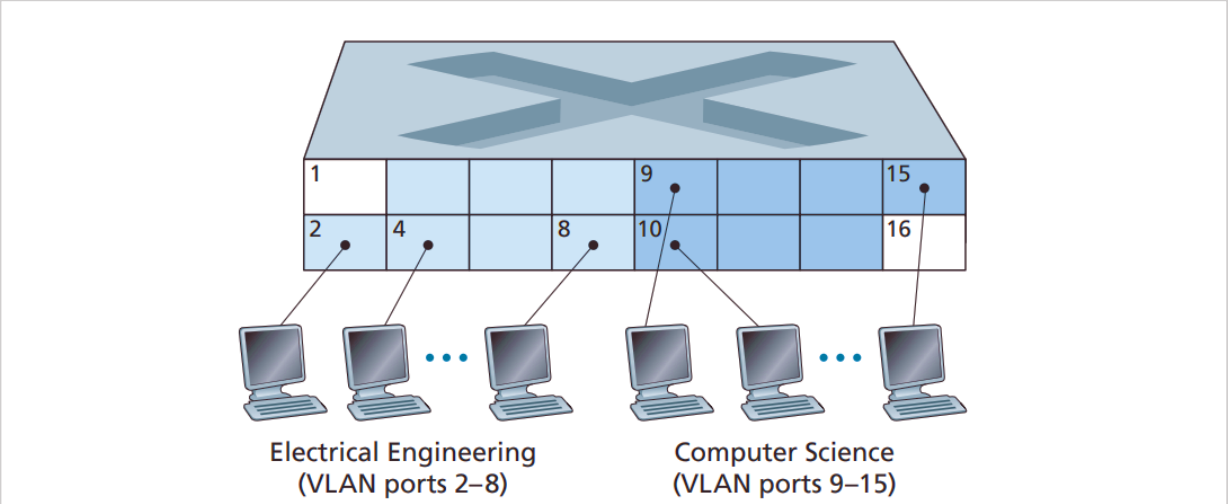


Figure 62: A single switch with two configured VLANs [2]

c) Discuss on VLAN mode of switching.

There are three types of VLAN modes of switching as listed below [3]:

- *Access* – The access mode is used for ports connected to end devices and is the default mode for all ports. The access ports only allow untagged (u) traffic with a specific VLAN ID to flow in and out [3]. The straight-through cables are used for this purpose.
- *Trunk* – The trunk mode is used to connect switches to each other. Only tagged (t) traffic with a specific set of VLAN IDs is allowed in and out of the ports and can only be connected

to other trunk ports with the same specified set of VLAN IDs [3]. The crossover cables are used for this purpose.

- *Local* – The local access mode only allows untagged (u) traffic with no VLAN ID to flow in and out of ports that are also configured to the local mode and only on the same edge switch. Ports on other edge switches can be configured to the local mode but only will be able to pass traffic between themselves on the same switch and not across other switches [3].

d) What is link aggregation or trunking and why it is needed?

Link aggregation is the combination of multiple Ethernet links into a single logical link between two networked devices [4]. It is also called by other terms such as; port trunking, Ethernet bonding, Ethernet teaming, and port aggregation. Link aggregation is used to achieve the following; increased bandwidth due to the capacity of multiple links being combined into one logical link, improved administration due to all underlying kinks being administered as a single unit, automatic failover and failback feature whereby the traffic from a failed link is automatically switched to other functioning links in the aggregation thus achieving a high level of availability, and better use of the physical resources as the traffic can be load-balanced across the physical links. [4][5].

e) What is the protocol used being used to enable VLAN capability?

The most prevalently used protocol for configuration is the IEEE 802.1Q protocol [6].

f) Elaborate on how this protocol helps to enable trunking capability in VLAN?

A trunk port or interface is considered to be a member of all VLANs and will accept and forward traffic on any VLAN ID. It is typically configured for the uplink and downlink ports between switches and routers [6]. The 802.1Q VLAN trunking protocol allows physical network interfaces in a computing environment to be shared [7]. Data centers are becoming more complex with the increase in the number of interconnected services which results in providing dedicated cabling and network switch ports being more expensive and complex. VLAN trunking allows for multiple virtual network connections to be maintained by a small number of physical adapters. Each VLAN gets a unique VLAN tag and each packet in the network is also tagged. The network devices only interact with the correctly tagged packets which allows for multiple logical networks to run on the same cable and switch infrastructure [7].

g) Is it a good idea to maximize the number of computer nodes inside a VLAN? Discuss.

On a single-segment Ethernet network which is a half-duplex media, the broadcast domain is the same as the collision domain. In the case of VLAN, multiple Ethernet segments are connected to a switch from an extended broadcast domain that is made up of multiple collision domains. [8]. The problem arises when a loop is encountered and a broadcast packet gets caught in it. The single broadcast packet will prevent other valid broadcasts from being propagated which would result in a DoS attack on the whole layer-2 domain. The copies of the single broadcast packet would be delivered to the CPU of all the switches in the layer-2 domain which would eventually interfere with the control-plane protocol [9]. For the above-

mentioned reason, VLANs are not maximised and the recommended nodes are as follows; 1000 hosts that just carry out ARP, DHCP, etc but not broadcast applications, 500 for general IP with broadcast/multicast applications, 200 to 500 for Apple, DECnet and CLNP and 200 for NetBEUI [10].

h) What is a port mirroring capability? Give two examples of scenarios when we need this capability.

Port mirroring is a form of network observability that provides a tool that detects malicious intruders [11]. When configuring a switch, one port is to be reserved as a 'mirror' whereby it 'mirrors' all the traffic to the reserved port. Whenever a packet is processed by the switch, a copy is sent to this reserved port and sent to a system that monitors traffic on that switch [11]. Port mirroring is used by network engineers to analyse and diagnose errors on a network [12]. For example, in the case of a network outage, this high-quality of observability will allow quick diagnosis also bottlenecks can be identified to allow improved performance for the end-users of the network [11].

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

All the intended objectives of the laboratory session were successfully accomplished. VLAN switching was carried out in two configurations; a single-switch configuration and a two-switch configuration using link aggregation. For both configurations, the star topology configuration with four end devices and two VLANs was used. Simulation, emulation, and hardware implementation were carried out for both configurations. There were no major setbacks and the ping commands were carried out successfully between the devices in the same VLAN. The packet transfer was also monitored using Wireshark. It is apparent from the packet captures that successful 'pings' within a VLAN used the ICMP (Internet Control Message Protocol) protocol and the unreachable request from another VLAN were shown to use the ARP (Address Resolution Protocol) protocol.

For the hardware implementation of the single-switch configuration, there was human error in setting the IP addresses for the different VLANs. From Table 3 it is apparent that the PCs are all part of the subnet which is erroneous. The purpose of using VLAN is to partition networks therefore subnetting is necessary and two VLANs cannot have the same IP range as it would defeat the purpose of having different VLANs. The desired results were obtained as there were multiple gateways which are permitted. Table 7 below shows a summary of a projected set of IP addresses for the 'correct' implementation of VLAN switching using the single switch configuration.

Table 7: Projected LAN address configuration for hardware implementation for single switch configuration

Computer	IP Address	Gateway Address	Netmask Address
PC1	202.17.57.1	202.17.57.20	255.255.255.0
PC2	202.17. 58.22	202.17.58.30	255.255.255.0
PC3	202.17. 58.23	202.17.58.30	255.255.255.0
PC4	202.17. 57.4	202.17.57.20	255.255.255.0

Other than the human error in the third task, there were no major issues faced throughout the six tasks of the laboratory session. The simulation and emulation for both configurations were carried out with no problems. There was a minor issue with the hardware implementation regarding the port arrangement of the NA-810C LISA hardware appliance. On some of the appliances, the ports were in a reversed order than what was labelled on the device, which led to undesirable results even with the proper configurations. To identify the port connectivity, the '`show interface`' command shown in Figure 12 was carried out on the Terminal of the LISA hardware appliance. From Figure 12, in lines 44, 62, and 78, the '`Link detected:`' status showed if there was a connection made to that particular port. Assuming that all the cables used were not faulty if the status showed '`no`' as in Line 44, it meant that the ports on that particular port were reversed. The physical connections were reconnected accordingly and the '`show interface`' was carried out again to verify the connections followed by the ping commands.

7.0 Conclusion

The objectives of the laboratory session were fulfilled successfully as the desired results were obtained. Simulation, emulation, and hardware implementation of two different scenarios of VLAN switching were completed namely; a single-switch configuration and a two-switch configuration using link aggregation. The functionality of the link aggregation was understood. Ping commands were carried out for all the laboratory tasks and it was found that the devices within the same VLAN could communicate with each other and the devices on another VLAN were unreachable. For all the experiments, PC1 and PC4 were in one VLAN *(VLAN 10 for LISA emulator and hardware implementation)* and PC2 and PC3 were in another VLAN *(VLAN 20 for LISA emulator and hardware implementation)*. The packets were monitored using Wireshark and the difference was observed between the successful and unreachable 'pings'.

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