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Computer Networks
2nd Lab Assignment: Download Application and Network Configuration

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Contents

1 Summary

This report was elaborated to complement and better explain the practical work developed for the second lab assignment. The first part consists in the development of a download application, focused on FTP. The second part was about the configuration and study of a computer network, through the realization of some experiments regarding the Cisco Router and the Cisco Switch.

2 Introduction

The two main purposes of this lab assignment are to configure a network and develop a simple FTP application. It is then expected to test the developed download application on tux3 using the lab network we configured. For the application we provide details on its architecture and behaviour, meanwhile, for the second part of the lab we provide detailed analysis for each of the experiments and answers to the provided questions.

3 Download Application

The goal was to develop a download application that could download a file through FTP given an url with the following format:

`ftp://[<user>:<password>@]<host>/<url-path>`

3.1 Architecture of the download application

The FTP download application is subdivided into four modules: download, queue, server_commands, url_parser.

3.1.1 url_parser

This module is responsible for parsing the url given as an argument and filling the ftp_information struct with its values.

```
typedef struct {
   bool anonymous;
   char *user;
   char *password;
   char *host;
   char *url_path;
} ftp_information;
```

3.1.2 queue

As the name suggests, this module implements a queue data structure used to store and read FTP replies in an organized manner.

```
typedef struct{
   int code;
   char *message;
} ftp_reply;
```

3.1.3 server_commands

Includes the main functions to communicate with the FTP server, such as commands to send the user's information, activate the passive mode or retrieve the file.

3.1.4 download

This is the main module, it will open the FTP server connection and communicate with it. This communication happens in the main cycle

```
bool connection_finished = false;
   reply_queue reply_queue = create_queue(16);
   while(!connection_finished && readFTP(fd, &reply_queue) >= 0){
       while(!is_empty(&reply_queue)){
           ftp_reply reply = dequeue(&reply_queue);
           connection_finished = handle_reply(reply, fd, ftp_info);
       }
   }
```

which reads replies from the server, storing them onto the reply queue, and afterwards handles each of them.

After receiving a reply with code 227 (Opening passive mode) the function handle_reply will fork and create a child (the client) that will open the data connection and download the necessary file.

3.1.5 Report of a successful download

```
./download ftp://rcom:rcom@netlab1.fe.up.pt/files/crab.mp4

---------------------------------
Parameters:
  user : rcom
  password : rcom
  host : netlab1.fe.up.pt
  url_path : /files/crab.mp4
  host_name  : netlab1.fe.up.pt
  ip_address : 192.168.109.136
---------------------------------

220 Welcome to netlab-FTP server
331 Please specify the password.
230 Login successful.
227 Entering Passive Mode (192,168,109,136,164,71).
150 Opening BINARY mode data connection for /files/crab.mp4 (88123184 bytes).
226 Transfer complete.
```

Figure 1: Successful Download

4 Network configuration and analysis

4.1 Experiment 1 - IP Configuration

The main objective of this experiment is to learn the basics of ip configuration, MAC addresses and ARP and how they interact with each other, our goal network architecture includes both tux3 and tux4 connected through the switch with ip addresses 172.16.20.1 and 172.16.20.254 respectively.

ARP (Address Resolution Protocol) packets are used to convert network layers ip address into data link layer MAC addresses, by analysing the captured packets, we noted the computer making the ping (tux3) sent an ARP message with Target MAC address : 00:00:00:00:00:00 and Target IP Address: 172.16.20.254, which immediately afterwards received another ARP message as an answer from the other computer Sender MAC address: 00:22:64:a6:a4:f1 and Sender IP Address: 172.16.20.254. To summarize, the sender sets the Sender IP/MAC addresses and Target IP address to the correct values, and waits for an answer with the MAC address of the target.

From our captures we could see the ping command generates ICMP packets, these had the following ip/mac addresses Source: ip=172.16.20.1 MAC=00:21:5a:5a:7d:12 / Dest: ip=172.16.20.254 MAC=00:22:64:a6:a4:f1 for the request pings, the reply pings, as expected, had the Source and Destination addresses switched.

The type of frame received could be distinguished through some parameters, like it's type (0x0806 for ARP and 0x0800 for IPv4), their frame length, and their content. Additionally, the ICMP packets can be identified through the Protocol parameter (value 1 corresponds to ICMP) in an IPv4 header.

Finally, we analysed the loopback interface, which is a virtual interface useful for communication between processes on the same device and for troubleshooting since it's always up (as long as there's a route to it).

4.1.1 Main configuration commands

```
[tux3] ip addr add 172.16.20.1/24 dev eth0
[tux4] ip addr add 172.16.20.254/24 dev eth0
[both] ip route show
[both] ip neigh
[tux3] ip neigh del 172.16.20.254/24
```

4.2 Experiment 2 - Virtual LANs

The main objective of this experiment was to learn and use VLANs to achieve our desired network architecture, which consists in two separate VLANS, vlan20, to which tux3 and tux4 belong, and vlan21 where tux2 is connected.

The vlan20 can be created by using the configuration commands presented on the next section, through switch's console which can be accessed by serial connection. After achieving the desired network configuration and capturing the broadcast pings and non-broadcast pings among the 3 computers we came to the conclusion that as expected both VLANs were completely isolated, therefore there's two separate broadcast domains, the one that includes tux3 and tux 4 (from which tux2 can't be pinged) and the one that exclusively contains tux2 which cannot broadcast to any other computer.

4.2.1 Main configuration commands

Create vlan:

```
Switch# configure terminal
Switch(config)# vlan 20
Switch(config)# end
Switch# configure terminal
Switch(config)# vlan 21
Switch(config)# end
```

Add port to vlan:

```
Switch# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
```

```
Switch(config)# interface fastethernet 0/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 20
Switch(config-if)# end
...
[repeated for the next 2 computers, changing the vlan to 21 for
↪  tux2]
```

4.3 Experiment 3 - Router Configuration

4.3.1 Router Configuration

After analyzing the configuration file, we obtained the following information:

- Router Name: gnu-rtr1
- Ethernet Ports available: The ethernet ports available are FastEthernet0/0 and FastEthernet0/1.
- FastEthernet0/0: `172.16.30.1 255.255.255.0 (ip_address mask)`
- FastEthernet0/1: `172.16.254.45 255.255.255.0`
- Configured routes: `ip route 0.0.0.0 0.0.0.0 172.16.254.1` and `ip route 172.16.40.0 255.255.255.0 172.16.30.2` (destination_ip_address mask ip_address)

So, to configure a static ip route we can use the command
`ip route destination_ip_address mask ip_address`
Where destination_ip_address can be reached by hopping through ip_address.

The NAT (Network Address Translation) allows us to map private addresses to public addresses, the most common example is a home router that maps all the network's private addresses into a single public address. To configure NAT on a Cisco router we need to define a inside and a outside interface, by using the command `ip nat inside/ip nat outside`, NAT overloading can be configured with the example commands shown below. In the example configuration file we can see that the interface FastEthernet0/1 is the one connected to the internet and NAT overloading is being used with a single ip address, 172.16.254.45.

4.3.2 DNS

For this part of the experiment we concluded that the DNS service can be modified by modifying the /etc/hosts file, when pinging an address configured in this manner a DNS packet isn't sent, or through the /etc/resolv.conf which modifies the DNS resolver. Upon pinging 'enisa.europa.eu' a ping capture shows DNS query (UDP) being sent to 10.0.2.3 (nameserver configured in /etc/resolv.conf), containing the name 'enisa.europa.eu', this query was followed by an response with the desired ip address. Lastly after adding the nameserver 9.9.9.9, a ping to 'parlamento.pt' yields another query like the last time, with the only change being the destination address which was updated to 9.9.9.9 as expected.

4.3.3 Routing

After executing the traceroute command we analysed many UDP packets being sent from 10.0.2.15 (host ip address) to (104.17.113.188), and ICMP with Time-to-live exceeded messages responses with source from each of the hops along the route and 10.0.2.15 as destination. The last responses received are ICMP with Destination unreachable (Port unreachable) coming from 104.17.113.188 to 10.0.2.15.

```
traceroute to 104.17.113.188 (104.17.113.188), 30 hops max, 60 byte
↪  packets
 1  10.0.2.2  0.255 ms  0.201 ms  0.171 ms
 2  192.168.1.1  8.310 ms  25.430 ms  25.400 ms
 3  10.196.255.254  43.001 ms  42.985 ms  42.969 ms
 4  10.137.213.113  42.954 ms  42.939 ms  42.903 ms
 5  10.255.48.82  45.972 ms  44.122 ms  63.015 ms
 6  195.23.124.121  66.323 ms  65.163 ms  67.088 ms
 7  104.17.113.188  61.874 ms  55.706 ms  45.393 ms
```

Ip routes of the computer at the end of this section:

```
ip route
9.9.9.9 dev eth0 scope link
10.0.2.0/24 dev eth0 proto kernel scope link src 10.0.2.15 metric
↪  100
104.17.113.188 via 10.0.2.2 dev eth0
```

4.3.4 Main configuration commands

Configure NAT Overloading

```
ip nat pool ovrld ip_addr1 ip_addr2 prefix-length 24
ip nat inside source list 1 pool ovrld overload
```

For the DNS section the only configuration required was modifying files

```
sudo vim /etc/hosts
sudo vim /etc/resolv.conf
```

Routing:

```
sudo ip route del default via 10.0.2.2
sudo ip route add 104.17.113.188 via 10.0.2.2 dev eth0
```

4.4 Experiment 4 - Router Configuration (Lab)

Throughout this experiment our goal will be configuring a cisco router to achieve the desired network architecture.

After the initial configuration here's the routes available on each computer:

```
root@tux22:~# ip route
172.16.20.0/24 via 172.16.21.253 dev eth0
172.16.21.0/24 dev eth0 proto kernel scope link src 172.16.21.1

root@tux23:~# ip route
172.16.20.0/24 dev eth0 proto kernel scope link src 172.16.20.1
172.16.21.0/24 via 172.16.20.254 dev eth0

root@tux24:~# ip route
172.16.20.0/24 dev eth0 proto kernel scope link src 172.16.20.254
172.16.21.0/24 dev eth1 proto kernel scope link src 172.16.21.253
```

As we can see, each forwarding table entry contains at least one associated ip address and a device (e.g dev eth0). The routes with 'proto kernel scope link' are created automatically upon setting up the interfaces with 'ip addr add'. The other routes added on tux2 and tux3 allow the connection to the opposite vlan (vlan20 for tux2 and vlan21 for tux3) by going through tux4, which is simultaneously connected to both vlans.

Pinging 172.16.20.254, 172.16.21.253, 172.16.21.1 from tux3 yields the following ARP messages:

ARP Type	Sender IP	Sender MAC	Target IP	Target MAC
Request	172.16.20.1	00:21:5a:5a:7d:12	172.16.20.254	00:00:00:00:00:00
Reply	172.16.20.254	00:22:64:a6:a4:f1	172.16.20.1	00:21:5a:5a:7d:12
Request	172.16.20.254	00:22:64:a6:a4:f1	172.16.20.1	00:00:00:00:00:00
Reply	172.16.20.1	00:21:5a:5a:7d:12	172.16.20.254	00:22:64:a6:a4:f1

From this capture we can conclude the packets sent to vlan21 don't require an ARP message from tux3 to the target, only to the next hop (which is the eth0 interface from tux4), which makes sense since ARP messages convert Network Layer information to Data Link Layer addresses.

We got the following messages while capturing on both of tux4's interfaces in the middle of a ping directed from tux3 to tux2.

Interface	ARP Type	Sender IP	Sender MAC	Target IP	Target MAC
eth1	Request	172.16.21.253	00:08:54:50:3f:2c	172.16.21.1	00:00:00:00:00:00
eth1	Reply	172.16.21.1	00:21:5a:61:2b:72	172.16.21.253	00:08:54:50:3f:2c
eth0	Request	172.16.20.1	00:21:5a:5a:7d:12	172.16.20.254	00:00:00:00:00:00
eth0	Reply	172.16.20.254	00:22:64:a6:a4:f1	172.16.20.1	00:21:5a:5a:7d:12

From this capture we can conclude that, in order to ping tux2 from tux3, the computer tux3 must send an ARP packet to tux4's interface on vlan20 and then tux4 must send an ARP packet from it's vlan21 interface to tux2. Additionally, we can see that the ICMP request packets contain the ip address of tux3 (172.16.20.1) as source and the ip address of tux2 (172.16.21.1) as destination.

During the experience, the route will be used by the packets if it exists. Otherwise, they will be sent through the default route, which passes by the router and the router will inform they should be sent through tux4.

4.4.1 Main configuration commands

```
[tux4] ip addr add 172.16.Y1.253/24 dev eth1
[tux3] ip route add 172.16.21.0/24 via 172.16.20.254
[tux2] ip route add 172.16.20.0/24 via 172.16.21.253
[router] show running-config
[tux2, tux4] ip route add default via 172.16.21.254
```

5 Conclusions

Both parts of the lab were concluded with success and we consider its realization improved our understanding of the subjects presented in the classes.

6 References

[1] Catalyst 3560 switch software configuration guide, release 12.2(55)se. https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst3560/software/release/12-2_55_se/configuration/guide/3560_scg.html, Apr 2016.

[2] Ip addressing: Nat configuration guide, cisco ios release 15&t. https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/ipaddr_nat/configuration/15-mt/nat-15-mt-book.html, Nov 2019.

7 Annexes

7.1 Configuration Commands

7.1.1 Tux2

```
#!/bin/bash

ip addr flush eth0
ip addr add 172.16.21.1/24 dev eth0
ip route add 172.16.20.0/24 via 172.16.21.253
ip route add default via 172.16.21.254
```

7.1.2 Tux3

```
#!/bin/bash

ip addr flush eth0
ip addr add 172.16.20.1/24 dev eth0
ip route add 172.16.21.0/24 via 172.16.20.254
ip route add default via 172.16.20.254
```

7.1.3 Tux4

```
#!/bin/bash

ip addr flush eth0
ip addr flush eth1
ip addr add 172.16.20.254/24 dev eth0
ip addr add 172.16.21.253/24 dev eth1
ip route add default via 172.16.21.254
```

```
echo 1 > /proc/sys/net/ipv4/ip_forward
echo 0 > /proc/sys/net/ipv4/icmp_echo_ignore_broadcasts
```

7.1.4 Router

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
service password-encryption
!
hostname gnu-rtr2
!
boot-start-marker
boot-end-marker
!
! card type command needed for slot/vwic-slot 0/0
logging message-counter syslog
logging buffered 51200 warnings
enable secret 5 $1$u53Q$vBawpP8.1YpCT6ypap1zX.
!
no aaa new-model
dot11 syslog
ip source-route
!
!
!
!
ip cef
no ip domain lookup
no ipv6 cef
!
multilink bundle-name authenticated
!
!
!
!
!
username root privilege 15 secret 5 $1$8AFR$bNAYevxPFjXFExpnZI2fj.
username cisco password 7 02050D480809
archive
 log config
  hidekeys
!
```

```
!
!
!
!
!
!
!
interface GigabitEthernet0/0
 description $ETH-LAN$$ETH-SW-LAUNCH$$INTF-INFO-FE 0$
 ip address 172.16.W.Y9 255.255.255.0
 ip nat outside
 no shutdown
 ip virtual-reassembly
 duplex auto
 speed auto
!
interface GigabitEthernet0/1
 ip address 172.16.Y1.254 255.255.255.0
 ip nat inside
 no shutdown
 ip virtual-reassembly
 duplex auto
 speed auto
!
ip forward-protocol nd
ip route 0.0.0.0 0.0.0.0 172.16.W.254
ip route 172.16.Y0.0 255.255.255.0 172.16.Y1.253
ip http server
ip http access-class 23
ip http authentication local
ip http secure-server
ip http timeout-policy idle 60 life 86400 requests 10000
!
!
ip nat pool ovrld 172.16.W.Y9 172.16.W.Y9 prefix-length 24
ip nat inside source list 1 pool ovrld overload
!
access-list 1 permit 172.16.Y0.0 0.0.0.7
access-list 1 permit 172.16.Y1.0 0.0.0.7
!
!
!
!
!
!
```

```
control-plane
!
!
!
line con 0
 login local
line aux 0
line vty 0 4
 access-class 23 in
 privilege level 15
 login local
 transport input telnet ssh
line vty 5 15
 access-class 23 in
 privilege level 15
 login local
 transport input telnet ssh
!
scheduler allocate 20000 1000
end
```

7.2 Download application code

7.2.1 download.c

```
#include <stdio.h>
#include <sys/socket.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include <netdb.h>
#include <stdlib.h>
#include <unistd.h>
#include <fcntl.h>
#include <string.h>
#include <stdbool.h>
#include <libgen.h>

#include "url_parser.h"
#include "queue.h"
#include "server_commands.h"

// ftp://[<user>:<password>@]<host>/<url-path>
```

```c
#define FTP_PORT 21
#define REPLY_FILE_OK 150
#define REPLY_COMMAND_OK 200
#define REPLY_SERVICE_READY 220
#define REPLY_CLOSING_DATA 226
#define REPLY_ENTERING_PASV 227
#define REPLY_LOGGED_IN 230
#define REPLY_REQUIRE_PASSWORD 331
#define REPLY_ANONYMOUS_ONLY 530
#define REPLY_FAILED_OPEN_FILE 550

typedef struct {
    in_addr_t address;
    int port;
} connection_info;

int print_usage(char *program_name){
    printf("Usage: %s
    ↪  ftp://[<user>:<password>@]<host>/<url-path>\n",
    ↪  program_name);
    return 0;
}

int print_parameters(ftp_information *ftp_info, struct hostent
↪  *host){
    printf("\n-----------------------------------\n");
    printf("Parameters:\n");
    if(ftp_info->anonymous){
        printf("  host : %s\n  url_path : %s\n", ftp_info->host,
        ↪  ftp_info->url_path);
    } else {
        printf("  user : %s\n  password : %s\n  host : %s\n
        ↪  url_path : %s\n", ftp_info->user, ftp_info->password,
        ↪  ftp_info->host, ftp_info->url_path);
    }
    printf("  host_name  : %s\n", host->h_name);
    printf("  ip_address : %s\n", inet_ntoa(*((struct in_addr *)
    ↪  host->h_addr)));
    printf("-----------------------------------\n\n");
    return 0;
}

// Open socket with given ip address / port and return it's file
↪  descriptor
int init_socket(in_addr_t *ip_addr, unsigned int port) {
```

```
    int sockfd;
    struct sockaddr_in server_addr;

    /*server address handling*/
    bzero((char *) &server_addr, sizeof(server_addr));
    server_addr.sin_family = AF_INET;

    server_addr.sin_addr.s_addr = *ip_addr;    /*32 bit Internet
    ↪  address network byte ordered*/
    server_addr.sin_port = htons(port);        /*server TCP port
    ↪  must be network byte ordered */

    /*open a TCP socket*/
    if ((sockfd = socket(AF_INET, SOCK_STREAM, 0)) < 0) {
        perror("socket()");
        exit(-1);
    }
    /*connect to the server*/
    if (connect(sockfd,
                (struct sockaddr *) &server_addr,
                sizeof(server_addr)) < 0) {
        perror("connect()");
        exit(-1);
    }
    return sockfd;
}

// Parse line and get it's reply code
int get_reply_code(char *line){
    if(strlen(line) >= 3){
        char replyCode[3];
        memcpy(replyCode, line, 3);
        return atoi(replyCode);
    }
    return -1;
}

// Read FTP server replies
int readFTP(int fd, reply_queue *reply_queue){
    size_t read_size = 0;
    char buf[1024];
    read_size = read(fd, &buf, 1024);
    if(read_size > 0){
        buf[read_size] = 0;
        char *line = strtok(buf, "\n");
```

```
        while(line != NULL){
            ftp_reply reply;
            reply.message = malloc((sizeof(char))*strlen(line));
            strcpy(reply.message, line);

            reply.code = get_reply_code(line);
            enqueue(reply_queue, reply);
            line = strtok(NULL, "\n");
        }
        return 0;
    }
    return -1;
}

// Read data from the given file descriptor into a file
int read_data_to_file(int fd, char *filename){
    int outputfd = -1;
    char buffer[4098];
    size_t bytes_read;
    while((bytes_read = read(fd, buffer, 4098)) > 0){
        if(outputfd < 0){ // Only create file after receiving some
        ↪  data
            outputfd = open(filename, O_WRONLY | O_CREAT, 0644);
            if(outputfd < 0){ perror("open()"); exit(-1); }
        }
        buffer[bytes_read] = 0;
        write(outputfd, buffer, bytes_read);
    }
}

// Parse entering passive mode response and return ip address +
↪  port
connection_info parse_pasv_ip(char *message){
    int h1,h2,h3,h4;
    int p1,p2;
    sscanf(message, "227 Entering Passive Mode
    ↪  (%d,%d,%d,%d,%d,%d).", &h1, &h2, &h3, &h4, &p1, &p2);

    connection_info info;
    info.port = p1*256 + p2;
    info.address = (h4 << 24) | (h3 << 16) | (h2 << 8)| h1;
    return info;
}

// Run client connection and output to file
```

```
int run_client(connection_info *connection_info, char *filename){
    int fd = init_socket(&connection_info->address,
    ↪  connection_info->port);

    if(read_data_to_file(fd, filename) < 0){
        exit(-1);
    }

    if(close(fd) < 0){
        perror("close()");
        exit(-1);
    }
    exit(0);
}

// Create a fork and run the client
int fork_and_run_client(connection_info *connection_info, char
↪  *filename){
    if(fork() == 0){
        return run_client(connection_info, filename);
    }
    return 0;
}

// Setup data connection by sending appropriate command to server
↪  and starting the client
int open_data_connection(char *reply_message, int fd, char
↪  *url_path){
    retrieve_file(fd, url_path);
    connection_info client_connection_info =
    ↪  parse_pasv_ip(reply_message);
    char *filename = basename(url_path);
    fork_and_run_client(&client_connection_info, filename);
    return 0;
}

// Check reply and do appropriate action
int handle_reply(ftp_reply reply, int fd, ftp_information
↪  *ftp_info){
    printf("%s\n", reply.message);
    bool connection_finished = false;
    switch(reply.code){
        case REPLY_REQUIRE_PASSWORD:
            send_password(fd, ftp_info);
            break;
```

```
        case REPLY_LOGGED_IN:
            activate_passive_mode(fd);
            break;
        case REPLY_ENTERING_PASV:
            open_data_connection(reply.message, fd,
            ↪  ftp_info->url_path);
            break;
        case REPLY_ANONYMOUS_ONLY:
        case REPLY_FAILED_OPEN_FILE:
        case REPLY_CLOSING_DATA:
            connection_finished = true;
            break;
    }
    free(reply.message);
    return connection_finished;
}

// Run server connection
int run_server(int fd, ftp_information *ftp_info){
    send_user(fd, ftp_info);

    bool connection_finished = false;
    reply_queue reply_queue = create_queue(16);
    while(!connection_finished && readFTP(fd, &reply_queue) >= 0){
        while(!is_empty(&reply_queue)){
            ftp_reply reply = dequeue(&reply_queue);
            connection_finished = handle_reply(reply, fd,
            ↪  ftp_info);
        }
    }
    return 0;
}

int download(ftp_information *ftp_info){
    struct hostent *host;
    if ((host = gethostbyname(ftp_info->host)) == NULL) {
        herror("gethostbyname()");
        exit(-1);
    }

    print_parameters(ftp_info, host);
    int serverfd = init_socket((in_addr_t *) host->h_addr,
    ↪  FTP_PORT);

    if(run_server(serverfd, ftp_info) < 0){
```

```
        return -1;
    }

    if (close(serverfd) < 0) {
        perror("close()");
        exit(-1);
    }
    return 0;
}

int main(int argc, char **argv) {
    if(argc != 2){
        printf("Insuficient arguments\n");
        print_usage(argv[0]);
        return -1;
    }
    ftp_information ftp_info;
    if(parse_url(argv[1], &ftp_info) != 0){
        printf("Invalid URL\n");
        print_usage(argv[0]);
        return -1;
    }

    return download(&ftp_info);
}
```

7.2.2 queue.h

```
#ifndef __queue__
#define __queue__

#include <stdlib.h>

typedef struct{
    int code;
    char *message;
} ftp_reply;

typedef struct{
    ftp_reply *queue;
    int capacity;
    int current_size;
    size_t front;
    size_t back;
```

```
} reply_queue;


reply_queue create_queue(int capacity);

void destroy_queue(reply_queue *queue);

int enqueue(reply_queue *queue, ftp_reply value);

ftp_reply dequeue(reply_queue *queue);

int is_full(reply_queue *queue);

int is_empty(reply_queue *queue);

#endif
```

7.2.3 queue.c

```
#include "queue.h"

reply_queue create_queue(int capacity){
    reply_queue queue;
    queue.queue = malloc((sizeof(ftp_reply))*capacity);
    queue.front = 0;
    queue.back = -1;
    queue.current_size = 0;
    queue.capacity = capacity;
    return queue;
}

void destroy_queue(reply_queue *queue){
    free(queue->queue);
}

int enqueue(reply_queue *queue, ftp_reply value){
    if(!is_full(queue)){
        queue->back = (queue->back+1) % queue->capacity;
        queue->queue[queue->back] = value;
        queue->current_size++;
        return 0;
    }
    return -1;
}
```

```
ftp_reply dequeue(reply_queue *queue){
    if(queue->current_size > 0){
        ftp_reply value = queue->queue[queue->front];
        queue->front = (queue->front + 1) % queue->capacity;
        queue->current_size--;
        return value;
    }
    ftp_reply invalid_reply = {-1, NULL};
    return invalid_reply;
}

int is_full(reply_queue *queue) {
    return (queue->capacity == queue->current_size);
}

int is_empty(reply_queue *queue){
    return queue->current_size == 0;
}
```

7.2.4 server_commands.h

```
#ifndef __server_commands__
#define __server_commands__

#include "url_parser.h"

int activate_passive_mode(int fd);
int retrieve_file(int fd, char *url_path);
int send_user(int fd, ftp_information *ftp_info);
int send_password(int fd, ftp_information *ftp_info);

#endif
```

7.2.5 server_commands.c

```
#include "server_commands.h"
#include <stdlib.h>
#include <stdio.h>

// Send pasv mode command to server
int activate_passive_mode(int fd){
    size_t bytes = dprintf(fd, "pasv\n");
    if(bytes < 0) {
```

```
        perror("dprintf()");
        exit(-1);
    }
}

// Retrieve file with url_path
int retrieve_file(int fd, char *url_path){
    size_t bytes = dprintf(fd, "retr %s\n", url_path);
    if(bytes <= 0){
        perror("dprintf()");
        exit(-1);
    }
    return 0;
}

// Send username command to server
int send_user(int fd, ftp_information *ftp_info){
    size_t bytes;
    if(ftp_info->anonymous){
        bytes = dprintf(fd, "USER anonymous\n");
    } else {
        bytes = dprintf(fd, "USER %s\n", ftp_info->user);
    }
    if(bytes < 0){
        perror("dprintf()");
        exit(-1);
    }
    return 0;
}

// Send password command to server
int send_password(int fd, ftp_information *ftp_info){
    size_t bytes;
    if(ftp_info->anonymous){
        bytes = dprintf(fd, "PASS anonymous\n");
    } else {
        bytes = dprintf(fd, "PASS %s\n", ftp_info->password);
    }
    if(bytes < 0){
        perror("dprintf()");
        exit(-1);
    }
    return 0;
}
```

7.2.6 url_parser.h

```c
#ifndef __url_parser__
#define __url_parser__

#include <stdbool.h>

typedef struct {
    bool anonymous;
    char *user;
    char *password;
    char *host;
    char *url_path;
} ftp_information;

char *check_protocol(char *url);

char *parse_password(char *url, ftp_information *ftp);

char *parse_login(char *url, ftp_information *ftp);

char *parse_host(char *url, ftp_information *ftp);

int parse_url(char *str, ftp_information *ftp);

#endif
```

7.2.7 url_parser.c

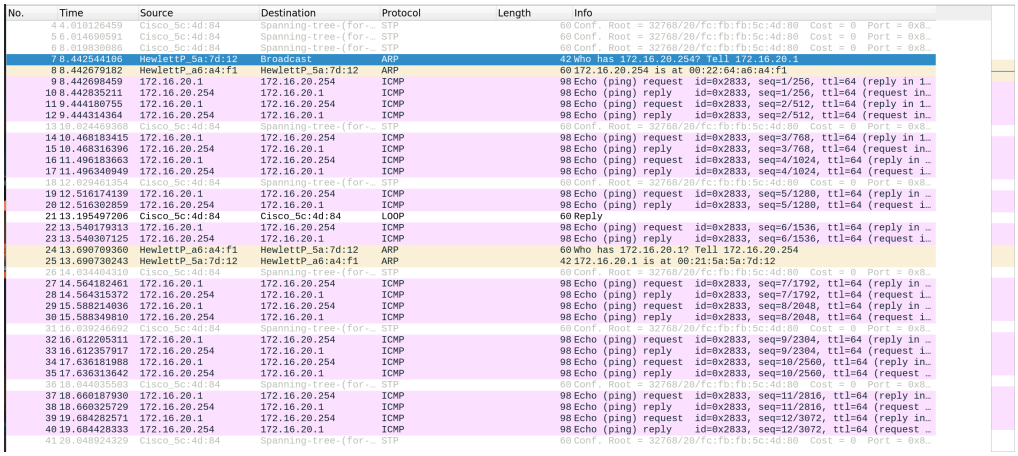
```c
#include "url_parser.h"

#include <stdlib.h>
#include <string.h>

// Check if url starts with 'ftp://', returns string without prefix
↪  if true, null otherwise.
char *check_protocol(char *url){
    if(strncmp(url, "ftp://", 6) != 0){
        return NULL;
    }
    url += 6;
    return url;
}
```

```
// Parse password
char *parse_password(char *url, ftp_information *ftp){
    size_t password_size = strcspn(url, "@");
    if(password_size == strlen(url)){
        return NULL;
    } else {
        ftp->password = malloc(sizeof(char)*password_size);
        memcpy(ftp->password, url, password_size);
        url += password_size+1;
        return url;
    }
}

// Parse username and password, removing them from the string if
↪  found
char *parse_login(char *url, ftp_information *ftp){
    size_t username_size = strcspn(url, ":");
    if(strlen(url) == username_size){ // There's no ':' character,
    ↪  therefore there's no username.
        ftp->anonymous = true;
    } else {
        ftp->anonymous = false;
        ftp->user = malloc(sizeof(char)*username_size);
        memcpy(ftp->user, url, username_size);
        url += username_size + 1;
        url = parse_password(url, ftp);

        if(url == NULL){ // Username defined but no password error
            free(ftp->user);
            return NULL;
        }
    }
    return url;
}

char *parse_host(char *url, ftp_information *ftp){
    size_t host_size = strcspn(url, "/");
    if(host_size == strlen(url)){
        return NULL;
    } else {
        ftp->host = malloc(sizeof(char)* host_size);
        memcpy(ftp->host, url, host_size);
        url += host_size;
    }
    return url;
```

```
}

int parse_url(char *url, ftp_information *ftp){
    if((url = check_protocol(url)) == NULL){
        return -1;
    }

    if((url = parse_login(url, ftp)) == NULL){
        return -1;
    }

    if((url = parse_host(url, ftp)) == NULL){
        if(!ftp->anonymous){
            free(ftp->user);
            free(ftp->password);
        }
        return -1;
    }
    ftp->url_path = url;
    return 0;
}
```

7.3 Network logs

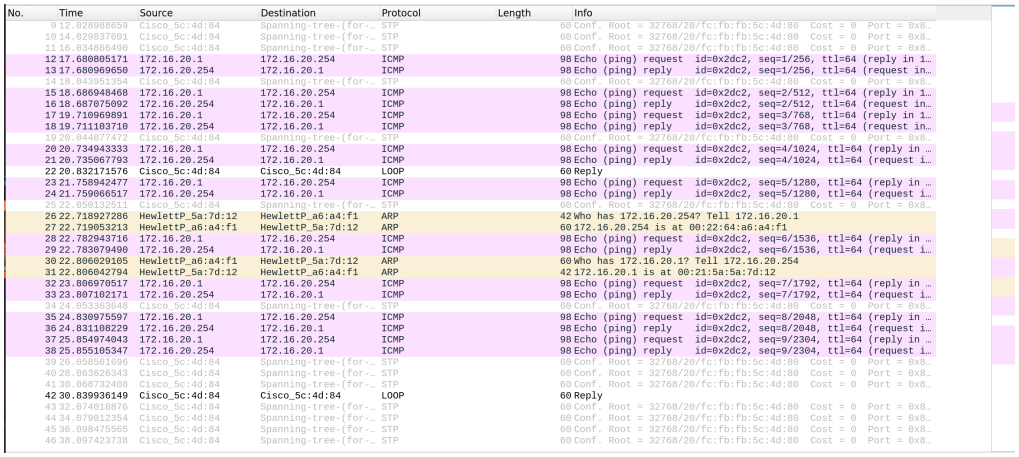
7.3.1 Experiment 1



No.	Time	Source	Destination	Protocol	Length	Info
4	4.018126459	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	6.014690591	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
6	8.019830886	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
7	8.442544106	HewlettP_5a:7d:12	Broadcast	ARP	42	Who has 172.16.20.254? Tell 172.16.20.1
8	8.442679182	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	172.16.20.254 is at 00:22:64:a6:a4:f1
9	8.442698459	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=1/256, ttl=64 (reply in 1…
10	8.442835211	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=1/256, ttl=64 (request in…
11	9.444180755	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=2/512, ttl=64 (reply in 1…
12	9.444314364	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=2/512, ttl=64 (request in…
13	10.024461405	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
14	10.468183415	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=3/768, ttl=64 (reply in 1…
15	10.468316396	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=3/768, ttl=64 (request in…
16	11.496183663	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=4/1024, ttl=64 (reply in …
17	11.496340949	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=4/1024, ttl=64 (request i…
18	12.029451359	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
19	12.516174139	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=5/1280, ttl=64 (reply in …
20	12.516302859	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=5/1280, ttl=64 (request i…
21	13.195497206	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
22	13.540179313	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=6/1536, ttl=64 (reply in …
23	13.540307125	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=6/1536, ttl=64 (request i…
24	13.690709360	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	Who has 172.16.20.1? Tell 172.16.20.254
25	13.690730243	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	172.16.20.1 is at 00:21:5a:5a:7d:12
26	14.034404310	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	14.564182461	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=7/1792, ttl=64 (reply in …
28	14.564315372	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=7/1792, ttl=64 (request i…
29	15.588214036	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=8/2048, ttl=64 (reply in …
30	15.588349810	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=8/2048, ttl=64 (request i…
31	16.039246692	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
32	16.612205311	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=9/2304, ttl=64 (reply in …
33	16.612357917	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=9/2304, ttl=64 (request i…
34	17.636181988	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=10/2560, ttl=64 (reply in…
35	17.636313642	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=10/2560, ttl=64 (request …
36	18.044035503	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
37	18.660187930	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=11/2816, ttl=64 (reply in…
38	18.660325729	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=11/2816, ttl=64 (request …
39	19.684282571	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2833, seq=12/3072, ttl=64 (reply in…
40	19.684428333	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2833, seq=12/3072, ttl=64 (request …
41	20.048924329	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…

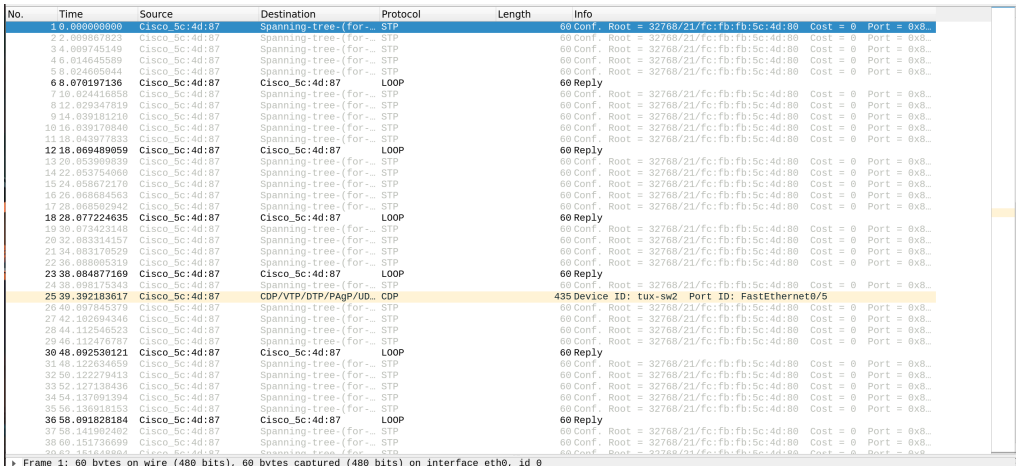
Figure 2: Tux 3 Network Capture

7.3.2 Experiment 2



No.	Time	Source	Destination	Protocol	Length	Info
9	12.028988659	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
10	14.029837601	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	16.884806499	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	17.680885171	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=1/256, ttl=64 (reply in 1…
13	17.680969650	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=1/256, ttl=64 (request in…
14	18.043951354	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
15	18.686948468	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=2/512, ttl=64 (reply in 1…
16	18.687075092	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=2/512, ttl=64 (request in…
17	19.710969891	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=3/768, ttl=64 (reply in 1…
18	19.711103710	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=3/768, ttl=64 (request in…
19	20.044877472	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
20	20.734943333	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=4/1024, ttl=64 (reply in …
21	20.735067793	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=4/1024, ttl=64 (request i…
22	20.832171576	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
23	21.758942477	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=5/1280, ttl=64 (reply in …
24	21.759066517	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=5/1280, ttl=64 (request i…
25	22.050132511	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
26	22.718927286	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	Who has 172.16.20.254? Tell 172.16.20.1
27	22.719053213	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	172.16.20.254 is at 00:22:64:a6:a4:f1
28	22.782943716	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=6/1536, ttl=64 (reply in …
29	22.783079490	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=6/1536, ttl=64 (request i…
30	22.806029105	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	Who has 172.16.20.1? Tell 172.16.20.254
31	22.806042794	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	172.16.20.1 is at 00:21:5a:5a:7d:12
32	23.806970517	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=7/1792, ttl=64 (reply in …
33	23.807102171	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=7/1792, ttl=64 (request i…
34	24.053363648	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
35	24.830975597	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=8/2048, ttl=64 (reply in …
36	24.831108229	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=8/2048, ttl=64 (request i…
37	25.854974043	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x2dc2, seq=9/2304, ttl=64 (reply in …
38	25.855105347	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2dc2, seq=9/2304, ttl=64 (request i…
39	26.058561696	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
40	28.063626343	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
41	30.069732408	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
42	30.839936149	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
43	32.074018876	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
44	34.079012354	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
45	36.098475565	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
46	38.097423738	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…

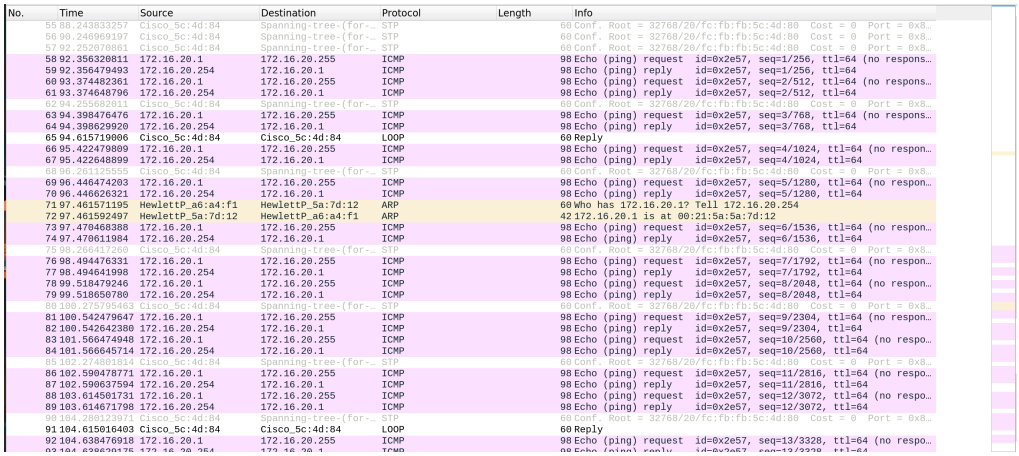
Figure 3: Step 5, Tux 2 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
2	2.009867823	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
3	4.009745149	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
4	6.014645589	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	8.024605044	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
6	8.070197136	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
7	10.024416858	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
8	12.029347819	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
9	14.039181210	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
10	16.039170840	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	18.043977833	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	18.069489059	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
13	20.053909839	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
14	22.053754060	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
15	24.058672170	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
16	26.068684963	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
17	28.068502942	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
18	28.077224635	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
19	30.073423148	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
20	32.083314157	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
21	34.083170529	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
22	36.088005319	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
23	38.084877169	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
24	38.098175343	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
25	39.392183617	Cisco_5c:4d:87	CDP/VTP/DTP/PAgP/UD…	CDP	435	Device ID: tux-sw2 Port ID: FastEthernet0/5
26	40.097845179	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	42.102694346	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
28	44.112546523	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
29	46.112476787	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
30	48.092530121	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
31	48.122034404	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
32	50.122279413	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
33	52.127138436	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
34	54.137091394	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
35	56.136818183	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
36	58.091828184	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
37	58.141902402	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
38	60.151736699	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…

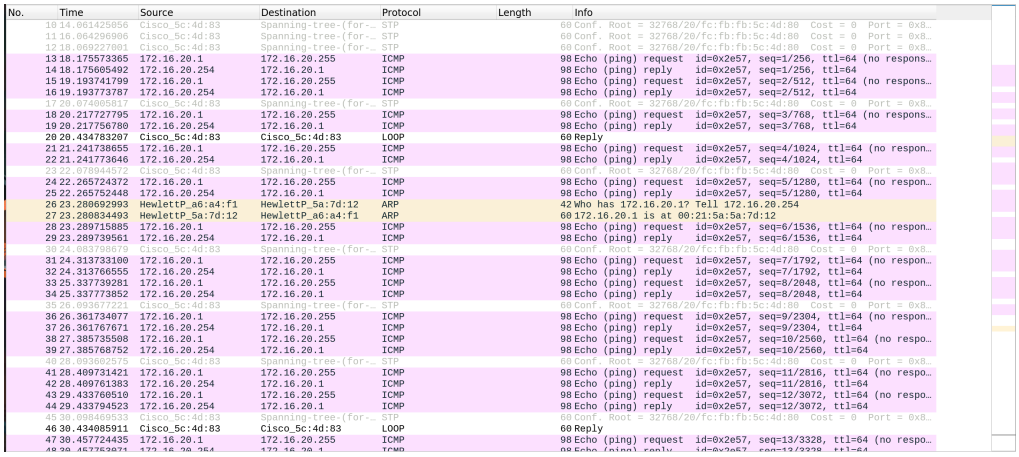
▸ Frame 1: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface eth0, id 0

Figure 4: Step 7, Tux 2 Network Capture



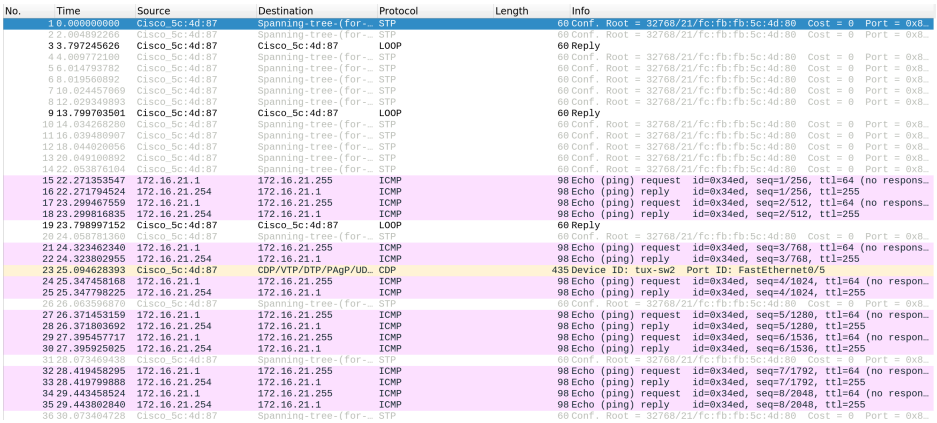
No.	Time	Source	Destination	Protocol	Length	Info
55	88.243833257	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
56	90.246969197	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
57	92.252070861	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
58	92.356320811	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=1/256, ttl=64 (no respons…
59	92.356479493	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=1/256, ttl=64
60	93.374482361	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=2/512, ttl=64 (no respons…
61	93.374648796	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=2/512, ttl=64
62	94.256652011	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
63	94.398476476	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=3/768, ttl=64 (no respons…
64	94.398629920	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=3/768, ttl=64
65	94.615719006	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
66	95.422479809	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=4/1024, ttl=64 (no respon…
67	95.422648899	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=4/1024, ttl=64
68	96.261125555	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
69	96.446474203	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=5/1280, ttl=64 (no respon…
70	96.446626321	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=5/1280, ttl=64
71	97.461571195	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	Who has 172.16.20.1? Tell 172.16.20.254
72	97.461592497	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	172.16.20.1 is at 00:21:5a:5a:7d:12
73	97.470468388	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=6/1536, ttl=64 (no respon…
74	97.470611984	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=6/1536, ttl=64
75	98.266417260	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
76	98.494476331	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=7/1792, ttl=64 (no respon…
77	98.494641998	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=7/1792, ttl=64
78	99.518479246	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=8/2048, ttl=64 (no respon…
79	99.518650780	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=8/2048, ttl=64
80	100.275795463	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
81	100.542479647	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=9/2304, ttl=64 (no respon…
82	100.542642380	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=9/2304, ttl=64
83	101.566474948	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=10/2560, ttl=64 (no respo…
84	101.566645714	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=10/2560, ttl=64
85	102.274801814	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
86	102.590478771	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=11/2816, ttl=64 (no respo…
87	102.590637594	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=11/2816, ttl=64
88	103.614501731	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=12/3072, ttl=64 (no respo…
89	103.614671798	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=12/3072, ttl=64
90	104.289123971	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
91	104.615016403	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
92	104.638476918	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=13/3328, ttl=64 (no respo…
93	104.638639176	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=13/3328, ttl=64

Figure 5: Step 7, Tux 3 Network Capture



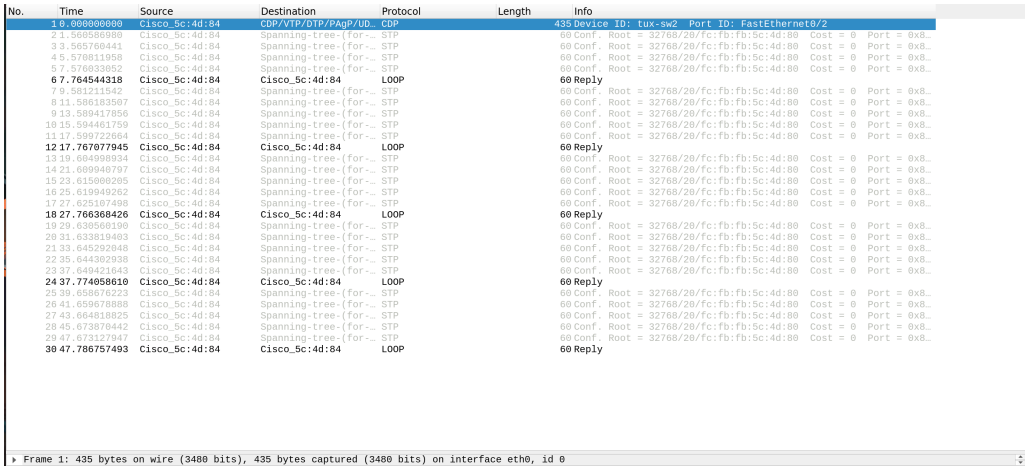
No.	Time	Source	Destination	Protocol	Length	Info
10	14.061425056	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	16.064296906	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	18.069227001	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
13	18.175573365	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=1/256, ttl=64 (no respons…
14	18.175605492	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=1/256, ttl=64
15	19.193741799	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=2/512, ttl=64 (no respons…
16	19.193773787	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=2/512, ttl=64
17	20.074605617	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
18	20.217727795	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=3/768, ttl=64 (no respons…
19	20.217756780	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=3/768, ttl=64
20	20.434783207	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
21	21.241738655	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=4/1024, ttl=64 (no respon…
22	21.241773646	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=4/1024, ttl=64
23	22.078044072	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
24	22.265724372	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=5/1280, ttl=64 (no respon…
25	22.265752448	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=5/1280, ttl=64
26	23.280692993	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	42	Who has 172.16.20.1? Tell 172.16.20.254
27	23.280834493	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	60	172.16.20.1 is at 00:21:5a:5a:7d:12
28	23.289715885	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=6/1536, ttl=64 (no respon…
29	23.289739561	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=6/1536, ttl=64
30	24.083798679	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
31	24.313733100	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=7/1792, ttl=64 (no respon…
32	24.313766555	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=7/1792, ttl=64
33	25.337739281	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=8/2048, ttl=64 (no respon…
34	25.337773852	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=8/2048, ttl=64
35	26.093677221	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
36	26.361734077	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=9/2304, ttl=64 (no respon…
37	26.361767671	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=9/2304, ttl=64
38	27.385735508	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=10/2560, ttl=64 (no respo…
39	27.385768752	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=10/2560, ttl=64
40	28.093602575	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
41	28.409731421	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=11/2816, ttl=64 (no respo…
42	28.409761383	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=11/2816, ttl=64
43	29.433760510	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=12/3072, ttl=64 (no respo…
44	29.433794523	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=12/3072, ttl=64
45	30.098469533	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
46	30.434085911	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
47	30.457724435	172.16.20.1	172.16.20.255	ICMP	98	Echo (ping) request id=0x2e57, seq=13/3328, ttl=64 (no respo…
48	30.457762971	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x2e57, seq=13/3328, ttl=64

Figure 6: Step 7, Tux 4 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
2	2.004892260	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
3	3.797245626	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
4	4.009772100	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	6.014793782	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
6	8.019560892	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
7	10.024457069	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
8	12.029349893	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
9	13.799703501	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
10	14.034268280	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	16.039480907	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	18.044020056	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
13	20.049100892	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
14	22.053876104	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
15	22.271353547	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=1/256, ttl=64 (no respons…
16	22.271794524	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=1/256, ttl=255
17	23.299467559	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=2/512, ttl=64 (no respons…
18	23.299816835	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=2/512, ttl=255
19	23.798997152	Cisco_5c:4d:87	Cisco_5c:4d:87	LOOP	60	Reply
20	24.058781360	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
21	24.323462340	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=3/768, ttl=64 (no respons…
22	24.323802955	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=3/768, ttl=255
23	25.094628393	Cisco_5c:4d:87	CDP/VTP/DTP/PAgP/UD…	CDP	435	Device ID: tux-sw2 Port ID: FastEthernet0/5
24	25.347458168	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=4/1024, ttl=64 (no respon…
25	25.347798225	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=4/1024, ttl=255
26	26.903998570	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	26.371453159	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=5/1280, ttl=64 (no respon…
28	26.371803692	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=5/1280, ttl=255
29	27.395457717	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=6/1536, ttl=64 (no respon…
30	27.395925025	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=6/1536, ttl=255
31	28.073468908	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
32	28.419458295	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=7/1792, ttl=64 (no respon…
33	28.419799888	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=7/1792, ttl=255
34	29.443458524	172.16.21.1	172.16.21.255	ICMP	98	Echo (ping) request id=0x34ed, seq=8/2048, ttl=64 (no respon…
35	29.443802840	172.16.21.254	172.16.21.1	ICMP	98	Echo (ping) reply id=0x34ed, seq=8/2048, ttl=255
36	30.073404728	Cisco_5c:4d:87	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…

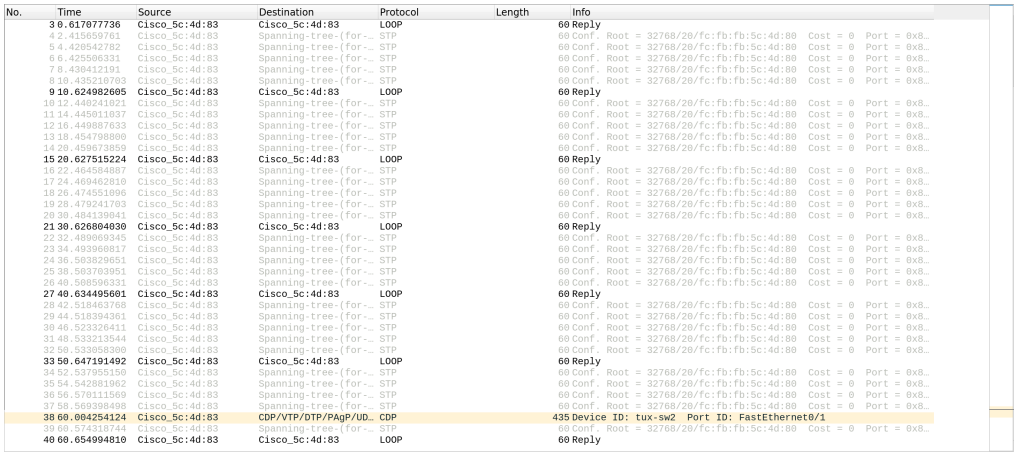
Figure 7: Step 10, Tux 2 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	Cisco_5c:4d:84	CDP/VTP/DTP/PAgP/UD…	CDP	435	Device ID: tux-sw2 Port ID: FastEthernet0/2
2	1.568880400	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
3	3.565760441	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
4	5.570811958	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	7.570833852	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
6	7.764544318	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
7	9.581211142	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
8	11.586183507	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
9	13.589417856	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
10	15.594461759	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	17.590729664	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	17.767077945	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
13	19.604998934	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
14	21.609940797	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
15	23.615000205	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
16	25.619949262	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
17	27.625107498	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
18	27.766368426	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
19	29.630560190	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
20	31.633819403	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
21	33.645292048	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
22	35.644302938	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
23	37.649421643	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
24	37.774058610	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
25	39.658676223	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
26	41.659678888	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	43.664818825	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
28	45.673870442	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
29	47.673127947	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
30	47.786757493	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply

▸ Frame 1: 435 bytes on wire (3480 bits), 435 bytes captured (3480 bits) on interface eth0, id 0

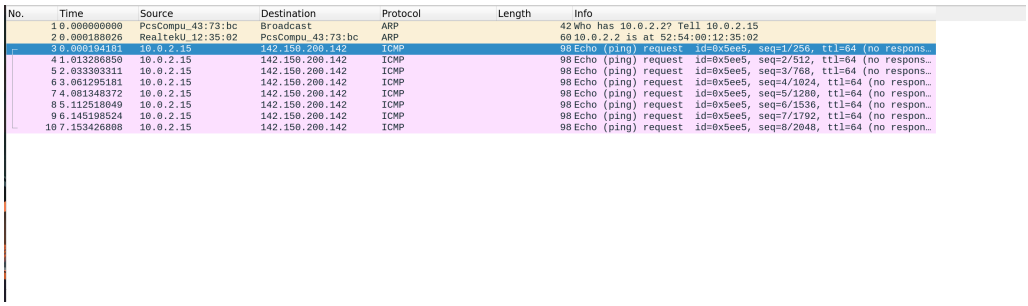
Figure 8: Step 10, Tux 3 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
3	0.617077736	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
4	2.415659761	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	4.420542782	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
6	6.425506331	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
7	8.430412191	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
8	10.435210703	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
9	10.624982605	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
10	12.440241021	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
11	14.445011037	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	16.449887633	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
13	18.454798800	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
14	20.459673850	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
15	20.627515224	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
16	22.464584887	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
17	24.469462810	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
18	26.474551096	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
19	28.479241703	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
20	30.484139041	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
21	30.626804030	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
22	32.489069345	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
23	34.493960817	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
24	36.503829651	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
25	38.503703951	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
26	40.508596331	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	40.634495601	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
28	42.518463768	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
29	44.518394361	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
30	46.523326411	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
31	48.533213544	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
32	50.533058300	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
33	50.647191492	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
34	52.537955150	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
35	54.542881962	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
36	56.570111569	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
37	58.569398498	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
38	60.004254124	Cisco_5c:4d:83	CDP/VTP/DTP/PAgP/UD…	CDP	435	Device ID: tux-sw2 Port ID: FastEthernet0/1
39	60.574534744	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
40	60.654994810	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply

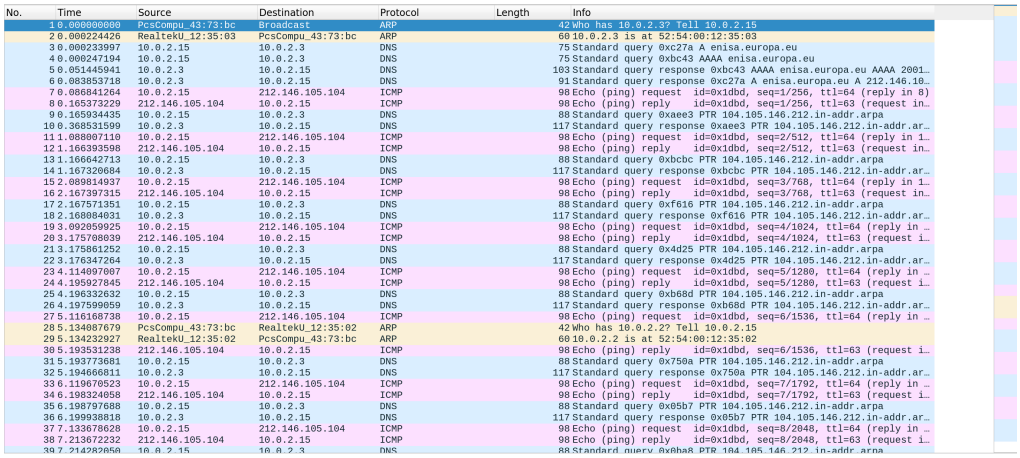
Figure 9: Step 10, Tux 4 Network Capture

7.3.3 Experiment 3



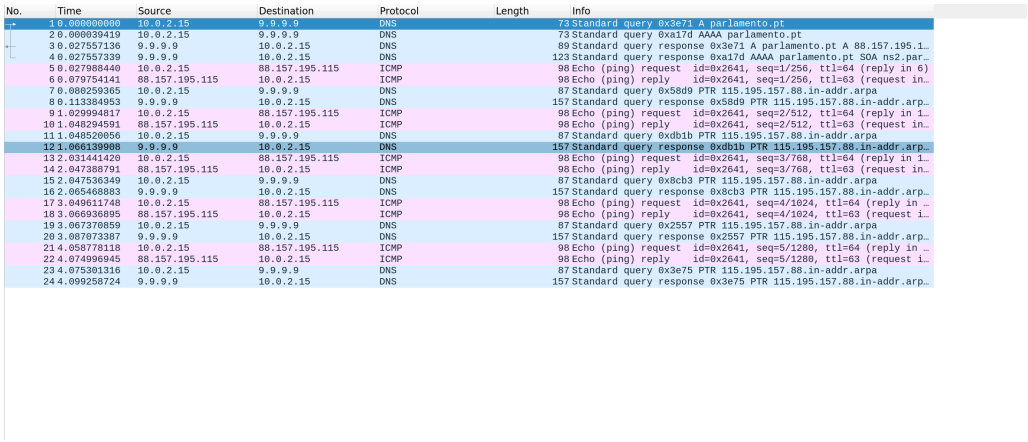
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	PcsCompu_43:73:bc	Broadcast	ARP	42	Who has 10.0.2.2? Tell 10.0.2.15
2	0.000188026	RealtekU_12:35:02	PcsCompu_43:73:bc	ARP	60	10.0.2.2 is at 52:54:00:12:35:02
3	0.000194101	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=1/256, ttl=64 (no respons…
4	1.013286850	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=2/512, ttl=64 (no respons…
5	2.033303311	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=3/768, ttl=64 (no respons…
6	3.061295181	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=4/1024, ttl=64 (no respon…
7	4.081348372	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=5/1280, ttl=64 (no respon…
8	5.112518049	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=6/1536, ttl=64 (no respon…
9	6.145198524	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=7/1792, ttl=64 (no respon…
10	7.153426808	10.0.2.15	142.150.200.142	ICMP	98	Echo (ping) request id=0x5ee5, seq=8/2048, ttl=64 (no respon…

Figure 10: DNS, Step 2 Network Capture



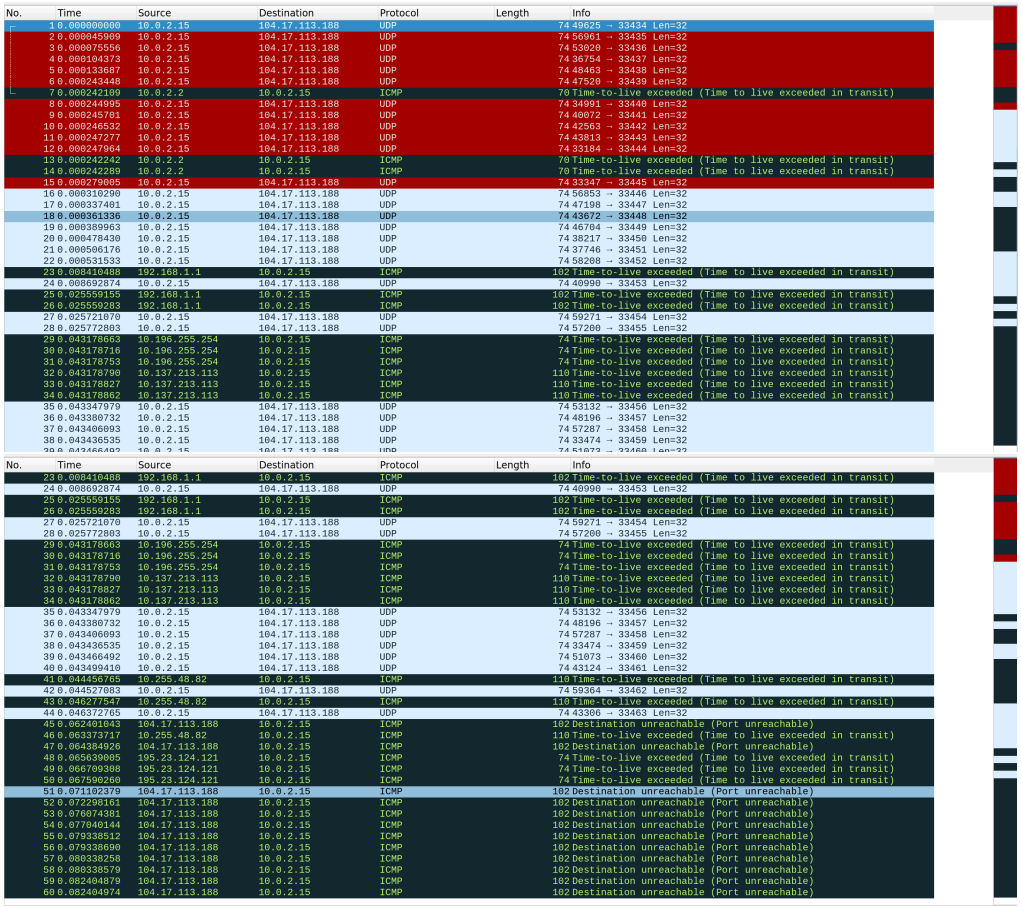
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	PcsCompu_43:73:bc	Broadcast	ARP	42	Who has 10.0.2.3? Tell 10.0.2.15
2	0.000224426	RealtekU_12:35:03	PcsCompu_43:73:bc	ARP	60	10.0.2.3 is at 52:54:00:12:35:03
3	0.000233997	10.0.2.15	10.0.2.3	DNS	75	Standard query 0xc27a A enisa.europa.eu
4	0.000247194	10.0.2.15	10.0.2.3	DNS	75	Standard query 0xbc43 AAAA enisa.europa.eu
5	0.051445941	10.0.2.3	10.0.2.15	DNS	103	Standard query response 0xbc43 AAAA enisa.europa.eu AAAA 2001…
6	0.083853718	10.0.2.3	10.0.2.15	DNS	91	Standard query response 0xc27a A enisa.europa.eu A 212.146.10…
7	0.086841264	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=1/256, ttl=64 (reply in 8)
8	0.165373229	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=1/256, ttl=63 (request in…
9	0.165934435	10.0.2.15	10.0.2.3	DNS	88	Standard query 0xaee3 PTR 104.105.146.212.in-addr.arpa
10	0.368531599	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0xaee3 PTR 104.105.146.212.in-addr.ar…
11	1.088007110	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=2/512, ttl=64 (reply in 1…
12	1.166393598	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=2/512, ttl=63 (request in…
13	1.166642713	10.0.2.15	10.0.2.3	DNS	88	Standard query 0xbcbc PTR 104.105.146.212.in-addr.arpa
14	1.167320684	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0xbcbc PTR 104.105.146.212.in-addr.ar…
15	2.089814937	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=3/768, ttl=64 (reply in 1…
16	2.167397315	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=3/768, ttl=63 (request in…
17	2.167571351	10.0.2.15	10.0.2.3	DNS	88	Standard query 0xf616 PTR 104.105.146.212.in-addr.arpa
18	2.168084031	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0xf616 PTR 104.105.146.212.in-addr.ar…
19	3.092059925	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=4/1024, ttl=64 (reply in …
20	3.175708039	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=4/1024, ttl=63 (request i…
21	3.175861252	10.0.2.15	10.0.2.3	DNS	88	Standard query 0x4d25 PTR 104.105.146.212.in-addr.arpa
22	3.176347264	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0x4d25 PTR 104.105.146.212.in-addr.ar…
23	4.114097007	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=5/1280, ttl=64 (reply in …
24	4.195927845	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=5/1280, ttl=63 (request i…
25	4.196332632	10.0.2.15	10.0.2.3	DNS	88	Standard query 0xb68d PTR 104.105.146.212.in-addr.arpa
26	4.197599059	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0xb68d PTR 104.105.146.212.in-addr.ar…
27	5.116168738	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=6/1536, ttl=64 (reply in …
28	5.134087679	PcsCompu_43:73:bc	RealtekU_12:35:02	ARP	42	Who has 10.0.2.2? Tell 10.0.2.15
29	5.134232927	RealtekU_12:35:02	PcsCompu_43:73:bc	ARP	60	10.0.2.2 is at 52:54:00:12:35:02
30	5.193531238	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=6/1536, ttl=63 (request i…
31	5.193773681	10.0.2.15	10.0.2.3	DNS	88	Standard query 0x750a PTR 104.105.146.212.in-addr.arpa
32	5.194666811	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0x750a PTR 104.105.146.212.in-addr.ar…
33	6.119670523	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=7/1792, ttl=64 (reply in …
34	6.198324058	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=7/1792, ttl=63 (request i…
35	6.198797688	10.0.2.15	10.0.2.3	DNS	88	Standard query 0x05b7 PTR 104.105.146.212.in-addr.arpa
36	6.199938818	10.0.2.3	10.0.2.15	DNS	117	Standard query response 0x05b7 PTR 104.105.146.212.in-addr.ar…
37	7.133678628	10.0.2.15	212.146.105.104	ICMP	98	Echo (ping) request id=0x1dbd, seq=8/2048, ttl=64 (reply in …
38	7.213672232	212.146.105.104	10.0.2.15	ICMP	98	Echo (ping) reply id=0x1dbd, seq=8/2048, ttl=63 (request i…
39	7.214282050	10.0.2.15	10.0.2.3	DNS	88	Standard query 0x0ba8 PTR 104.105.146.212.in-addr.arpa

Figure 11: DNS, Step 3 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.2.15	9.9.9.9	DNS	73	Standard query 0x3e71 A parlamento.pt
2	0.000039419	10.0.2.15	9.9.9.9	DNS	73	Standard query 0xa17d AAAA parlamento.pt
3	0.027557136	9.9.9.9	10.0.2.15	DNS	89	Standard query response 0x3e71 A parlamento.pt A 88.157.195.1…
4	0.027557339	9.9.9.9	10.0.2.15	DNS	123	Standard query response 0xa17d AAAA parlamento.pt SOA ns2.par…
5	0.027988440	10.0.2.15	88.157.195.115	ICMP	98	Echo (ping) request id=0x2641, seq=1/256, ttl=64 (reply in 6)
6	0.079754141	88.157.195.115	10.0.2.15	ICMP	98	Echo (ping) reply id=0x2641, seq=1/256, ttl=63 (request in…
7	0.080259365	10.0.2.15	9.9.9.9	DNS	87	Standard query 0x58d9 PTR 115.195.157.88.in-addr.arpa
8	0.113384953	9.9.9.9	10.0.2.15	DNS	157	Standard query response 0x58d9 PTR 115.195.157.88.in-addr.arp…
9	1.029994817	10.0.2.15	88.157.195.115	ICMP	98	Echo (ping) request id=0x2641, seq=2/512, ttl=64 (reply in 1…
10	1.048294591	88.157.195.115	10.0.2.15	ICMP	98	Echo (ping) reply id=0x2641, seq=2/512, ttl=63 (request in…
11	1.048520056	10.0.2.15	9.9.9.9	DNS	87	Standard query 0xdb1b PTR 115.195.157.88.in-addr.arpa
12	1.066139908	9.9.9.9	10.0.2.15	DNS	157	Standard query response 0xdb1b PTR 115.195.157.88.in-addr.arp…
13	2.031441420	10.0.2.15	88.157.195.115	ICMP	98	Echo (ping) request id=0x2641, seq=3/768, ttl=64 (reply in 1…
14	2.047388791	88.157.195.115	10.0.2.15	ICMP	98	Echo (ping) reply id=0x2641, seq=3/768, ttl=63 (request in…
15	2.047536349	10.0.2.15	9.9.9.9	DNS	87	Standard query 0x8cb3 PTR 115.195.157.88.in-addr.arpa
16	2.065468883	9.9.9.9	10.0.2.15	DNS	157	Standard query response 0x8cb3 PTR 115.195.157.88.in-addr.arp…
17	3.049611748	10.0.2.15	88.157.195.115	ICMP	98	Echo (ping) request id=0x2641, seq=4/1024, ttl=64 (reply in …
18	3.066936895	88.157.195.115	10.0.2.15	ICMP	98	Echo (ping) reply id=0x2641, seq=4/1024, ttl=63 (request i…
19	3.067370859	10.0.2.15	9.9.9.9	DNS	87	Standard query 0x2557 PTR 115.195.157.88.in-addr.arpa
20	3.087073387	9.9.9.9	10.0.2.15	DNS	157	Standard query response 0x2557 PTR 115.195.157.88.in-addr.arp…
21	4.058778118	10.0.2.15	88.157.195.115	ICMP	98	Echo (ping) request id=0x2641, seq=5/1280, ttl=64 (reply in …
22	4.074996945	88.157.195.115	10.0.2.15	ICMP	98	Echo (ping) reply id=0x2641, seq=5/1280, ttl=63 (request i…
23	4.075301316	10.0.2.15	9.9.9.9	DNS	87	Standard query 0x3e75 PTR 115.195.157.88.in-addr.arpa
24	4.099258724	9.9.9.9	10.0.2.15	DNS	157	Standard query response 0x3e75 PTR 115.195.157.88.in-addr.arp…

Figure 12: DNS, Step 4 Network Capture

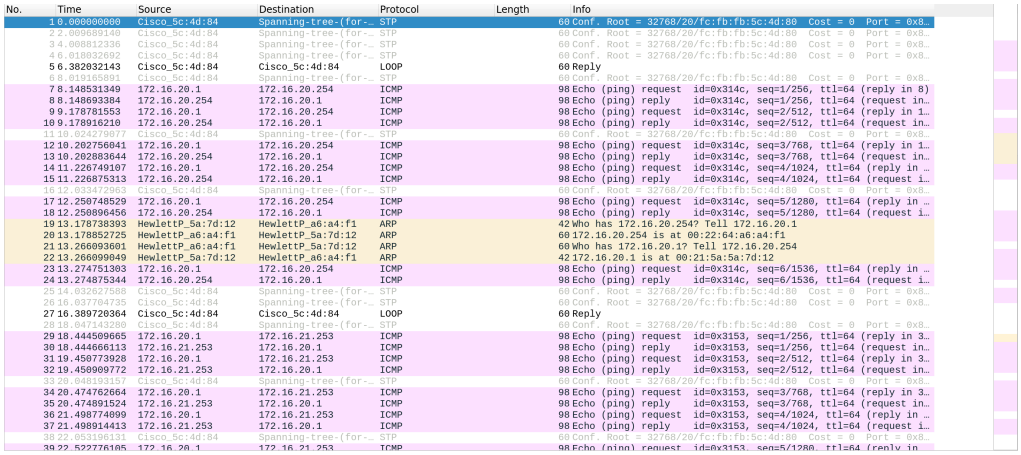


No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.2.15	104.17.113.188	UDP	74	49625 → 33434 Len=32
2	0.000045909	10.0.2.15	104.17.113.188	UDP	74	56961 → 33435 Len=32
3	0.000075556	10.0.2.15	104.17.113.188	UDP	74	53020 → 33436 Len=32
4	0.000104373	10.0.2.15	104.17.113.188	UDP	74	36754 → 33437 Len=32
5	0.000133687	10.0.2.15	104.17.113.188	UDP	74	48463 → 33438 Len=32
6	0.000243448	10.0.2.15	104.17.113.188	UDP	74	47520 → 33439 Len=32
7	0.000242109	10.0.2.2	10.0.2.15	ICMP	70	Time-to-live exceeded (Time to live exceeded in transit)
8	0.000244995	10.0.2.15	104.17.113.188	UDP	74	34991 → 33440 Len=32
9	0.000245701	10.0.2.15	104.17.113.188	UDP	74	40072 → 33441 Len=32
10	0.000246532	10.0.2.15	104.17.113.188	UDP	74	42563 → 33442 Len=32
11	0.000247277	10.0.2.15	104.17.113.188	UDP	74	43813 → 33443 Len=32
12	0.000247964	10.0.2.15	104.17.113.188	UDP	74	33184 → 33444 Len=32
13	0.000242242	10.0.2.2	10.0.2.15	ICMP	70	Time-to-live exceeded (Time to live exceeded in transit)
14	0.000242289	10.0.2.2	10.0.2.15	ICMP	70	Time-to-live exceeded (Time to live exceeded in transit)
15	0.000279005	10.0.2.15	104.17.113.188	UDP	74	33347 → 33445 Len=32
16	0.000310290	10.0.2.15	104.17.113.188	UDP	74	56853 → 33446 Len=32
17	0.000337401	10.0.2.15	104.17.113.188	UDP	74	47198 → 33447 Len=32
18	0.000361336	10.0.2.15	104.17.113.188	UDP	74	43672 → 33448 Len=32
19	0.000389963	10.0.2.15	104.17.113.188	UDP	74	46704 → 33449 Len=32
20	0.000478430	10.0.2.15	104.17.113.188	UDP	74	38217 → 33450 Len=32
21	0.000506176	10.0.2.15	104.17.113.188	UDP	74	37746 → 33451 Len=32
22	0.000531533	10.0.2.15	104.17.113.188	UDP	74	58208 → 33452 Len=32
23	0.008410488	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
24	0.008692874	10.0.2.15	104.17.113.188	UDP	74	40990 → 33453 Len=32
25	0.025559155	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
26	0.025559283	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
27	0.025721070	10.0.2.15	104.17.113.188	UDP	74	59271 → 33454 Len=32
28	0.025772803	10.0.2.15	104.17.113.188	UDP	74	57200 → 33455 Len=32
29	0.043178663	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
30	0.043178716	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
31	0.043178753	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
32	0.043178790	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
33	0.043178827	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
34	0.043178862	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
35	0.043347979	10.0.2.15	104.17.113.188	UDP	74	53132 → 33456 Len=32
36	0.043380732	10.0.2.15	104.17.113.188	UDP	74	48196 → 33457 Len=32
37	0.043406093	10.0.2.15	104.17.113.188	UDP	74	57287 → 33458 Len=32
38	0.043436535	10.0.2.15	104.17.113.188	UDP	74	33474 → 33459 Len=32
39	0.043466492	10.0.2.15	104.17.113.188	UDP	74	51073 → 33460 Len=32

No.	Time	Source	Destination	Protocol	Length	Info
23	0.008410488	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
24	0.008692874	10.0.2.15	104.17.113.188	UDP	74	40990 → 33453 Len=32
25	0.025559155	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
26	0.025559283	192.168.1.1	10.0.2.15	ICMP	102	Time-to-live exceeded (Time to live exceeded in transit)
27	0.025721070	10.0.2.15	104.17.113.188	UDP	74	59271 → 33454 Len=32
28	0.025772803	10.0.2.15	104.17.113.188	UDP	74	57200 → 33455 Len=32
29	0.043178663	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
30	0.043178716	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
31	0.043178753	10.196.255.254	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
32	0.043178790	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
33	0.043178827	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
34	0.043178862	10.137.213.113	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
35	0.043347979	10.0.2.15	104.17.113.188	UDP	74	53132 → 33456 Len=32
36	0.043380732	10.0.2.15	104.17.113.188	UDP	74	48196 → 33457 Len=32
37	0.043406093	10.0.2.15	104.17.113.188	UDP	74	57287 → 33458 Len=32
38	0.043436535	10.0.2.15	104.17.113.188	UDP	74	33474 → 33459 Len=32
39	0.043466492	10.0.2.15	104.17.113.188	UDP	74	51073 → 33460 Len=32
40	0.043499410	10.0.2.15	104.17.113.188	UDP	74	43124 → 33461 Len=32
41	0.044456765	10.255.48.82	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
42	0.044527083	10.0.2.15	104.17.113.188	UDP	74	59364 → 33462 Len=32
43	0.046277547	10.255.48.82	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
44	0.046372765	10.0.2.15	104.17.113.188	UDP	74	43306 → 33463 Len=32
45	0.062401043	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
46	0.063373717	10.255.48.82	10.0.2.15	ICMP	110	Time-to-live exceeded (Time to live exceeded in transit)
47	0.064384926	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
48	0.065639005	195.23.124.121	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
49	0.066709308	195.23.124.121	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
50	0.067590260	195.23.124.121	10.0.2.15	ICMP	74	Time-to-live exceeded (Time to live exceeded in transit)
51	0.071102379	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
52	0.072298161	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
53	0.076074381	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
54	0.077040144	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
55	0.079338512	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
56	0.079338690	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
57	0.080338258	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
58	0.080338579	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
59	0.082404879	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)
60	0.082404974	104.17.113.188	10.0.2.15	ICMP	102	Destination unreachable (Port unreachable)

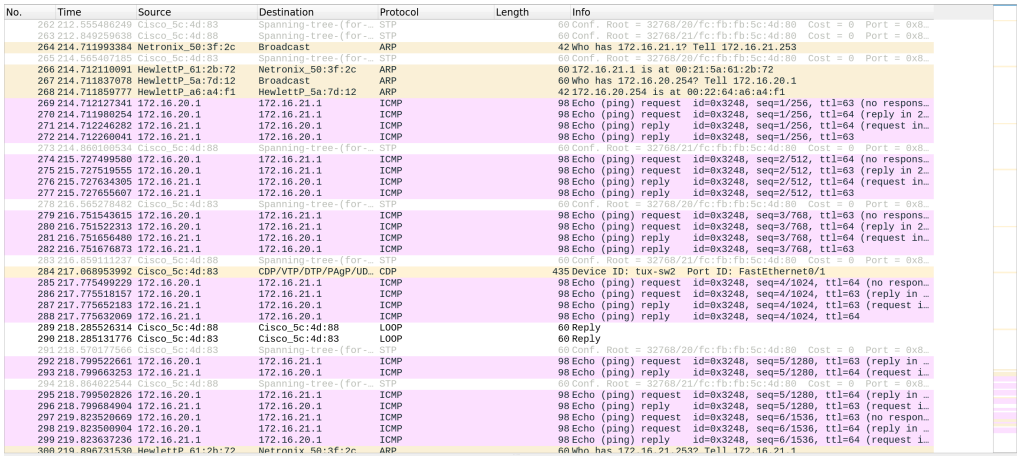
Figure 13: Routing, Step 5 Network Capture

7.3.4 Experiment 4



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
2	2.009689140	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
3	4.008812236	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
4	6.018032692	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
5	6.382032143	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
6	8.019165891	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
7	8.148531340	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=1/256, ttl=64 (reply in 8)
8	8.148693384	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=1/256, ttl=64 (request in…
9	9.178781553	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=2/512, ttl=64 (reply in 1…
10	9.178916210	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=2/512, ttl=64 (request in…
11	10.024279877	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
12	10.202756041	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=3/768, ttl=64 (reply in 1…
13	10.202883644	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=3/768, ttl=64 (request in…
14	11.226749107	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=4/1024, ttl=64 (reply in …
15	11.226875313	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=4/1024, ttl=64 (request i…
16	12.033472963	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
17	12.250748529	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=5/1280, ttl=64 (reply in …
18	12.250896456	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=5/1280, ttl=64 (request i…
19	13.178738393	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	Who has 172.16.20.254? Tell 172.16.20.1
20	13.178852725	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	172.16.20.254 is at 00:22:64:a6:a4:f1
21	13.266093601	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	60	Who has 172.16.20.1? Tell 172.16.20.254
22	13.266099049	HewlettP_5a:7d:12	HewlettP_a6:a4:f1	ARP	42	172.16.20.1 is at 00:21:5a:5a:7d:12
23	13.274751303	172.16.20.1	172.16.20.254	ICMP	98	Echo (ping) request id=0x314c, seq=6/1536, ttl=64 (reply in …
24	13.274875344	172.16.20.254	172.16.20.1	ICMP	98	Echo (ping) reply id=0x314c, seq=6/1536, ttl=64 (request i…
25	14.032627588	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
26	16.037704735	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
27	16.389720364	Cisco_5c:4d:84	Cisco_5c:4d:84	LOOP	60	Reply
28	18.041442789	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
29	18.444509665	172.16.20.1	172.16.21.253	ICMP	98	Echo (ping) request id=0x3153, seq=1/256, ttl=64 (reply in 3…
30	18.444666113	172.16.21.253	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3153, seq=1/256, ttl=64 (request in…
31	19.450773928	172.16.20.1	172.16.21.253	ICMP	98	Echo (ping) request id=0x3153, seq=2/512, ttl=64 (reply in 3…
32	19.450909772	172.16.21.253	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3153, seq=2/512, ttl=64 (request in…
33	20.048168157	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
34	20.474762664	172.16.20.1	172.16.21.253	ICMP	98	Echo (ping) request id=0x3153, seq=3/768, ttl=64 (reply in 3…
35	20.474891524	172.16.21.253	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3153, seq=3/768, ttl=64 (request in…
36	21.498774099	172.16.20.1	172.16.21.253	ICMP	98	Echo (ping) request id=0x3153, seq=4/1024, ttl=64 (reply in …
37	21.498914413	172.16.21.253	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3153, seq=4/1024, ttl=64 (request i…
38	22.054196131	Cisco_5c:4d:84	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
39	22.522776105	172.16.20.1	172.16.21.253	ICMP	98	Echo (ping) request id=0x3153, seq=5/1280, ttl=64 (reply in …

Figure 14: Step 8, Tux 3 Network Capture



No.	Time	Source	Destination	Protocol	Length	Info
262	212.555486249	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
263	212.849259638	Cisco_5c:4d:88	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
264	214.711993384	Netronix_50:3f:2c	Broadcast	ARP	42	Who has 172.16.21.1? Tell 172.16.21.253
265	214.565407256	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
266	214.712110091	HewlettP_61:2b:72	Netronix_50:3f:2c	ARP	60	172.16.21.1 is at 00:21:5a:61:2b:72
267	214.711837078	HewlettP_5a:7d:12	Broadcast	ARP	60	Who has 172.16.20.254? Tell 172.16.20.1
268	214.711859777	HewlettP_a6:a4:f1	HewlettP_5a:7d:12	ARP	42	172.16.20.254 is at 00:22:64:a6:a4:f1
269	214.712127341	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=1/256, ttl=63 (no respons…
270	214.711980254	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=1/256, ttl=64 (reply in 2…
271	214.712246282	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=1/256, ttl=64 (request in…
272	214.712260041	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=1/256, ttl=63
273	214.860100534	Cisco_5c:4d:88	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
274	215.727499580	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=2/512, ttl=64 (no respons…
275	215.727519555	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=2/512, ttl=63 (reply in 2…
276	215.727634305	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=2/512, ttl=64 (request in…
277	215.727655607	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=2/512, ttl=63
278	216.565278482	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
279	216.751543615	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=3/768, ttl=63 (no respons…
280	216.751522313	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=3/768, ttl=64 (reply in 2…
281	216.751656408	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=3/768, ttl=64 (request in…
282	216.751676873	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=3/768, ttl=63
283	216.859111237	Cisco_5c:4d:88	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
284	217.068953992	Cisco_5c:4d:83	CDP/VTP/DTP/PAgP/UD…	CDP	435	Device ID: tux-sw2 Port ID: FastEthernet0/1
285	217.775499229	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=4/1024, ttl=64 (no respon…
286	217.775518157	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=4/1024, ttl=63 (reply in …
287	217.775652183	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=4/1024, ttl=63 (request i…
288	217.775632069	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=4/1024, ttl=64
289	218.285526314	Cisco_5c:4d:88	Cisco_5c:4d:88	LOOP	60	Reply
290	218.285131776	Cisco_5c:4d:83	Cisco_5c:4d:83	LOOP	60	Reply
291	218.570177666	Cisco_5c:4d:83	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/20/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
292	218.799522661	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=5/1280, ttl=63 (reply in …
293	218.799663253	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=5/1280, ttl=64 (request i…
294	218.864922544	Cisco_5c:4d:88	Spanning-tree-(for-…	STP	60	Conf. Root = 32768/21/fc:fb:fb:5c:4d:80 Cost = 0 Port = 0x8…
295	218.799582826	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=5/1280, ttl=64 (reply in …
296	218.799684904	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=5/1280, ttl=63 (request i…
297	219.823520669	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=6/1536, ttl=63 (no respon…
298	219.823500904	172.16.20.1	172.16.21.1	ICMP	98	Echo (ping) request id=0x3248, seq=6/1536, ttl=64 (reply in …
299	219.823637236	172.16.21.1	172.16.20.1	ICMP	98	Echo (ping) reply id=0x3248, seq=6/1536, ttl=64 (request i…
300	219.896731530	HewlettP_61:2b:72	Netronix_50:3f:2c	ARP	60	Who has 172.16.21.253? Tell 172.16.21.1

Figure 15: Step 11, Tux 4 Network Capture