CS & ECE444/544 - LAB 1

Introduction to Networked Data Communication

Due Date for Short Lab Report

Due Session 20 (March 29)

Terms

- IED: Intelligent Electronic Device
- SEL: Schweitzer Engineering Laboratories
- RPI: Raspberry PI B 2 microcontroller
- ICMP: Internet Control Message Protocol
- BPDU: Bridge Protocol Data Unit

Objectives

In this lab we will learn the fundamentals of interacting with a substation network; connecting with system IEDs, changing IED settings, SEL-2730M (Managed Ethernet Switch) features, monitoring network statistics, and a method for generating network congestion in order to observe system performance.

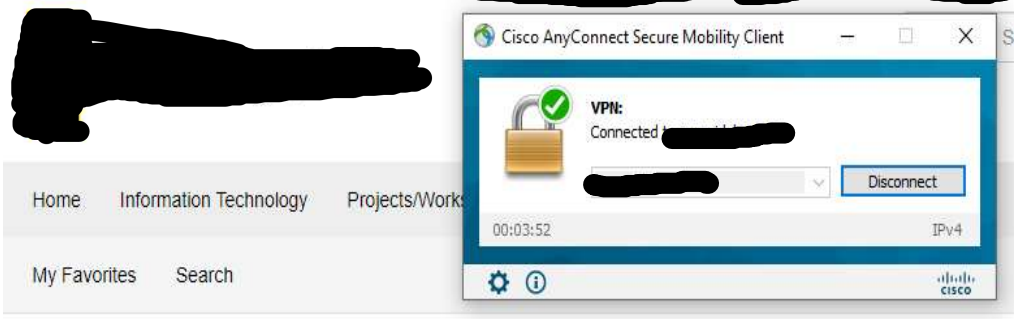
Procedure:

Log into System Computer

For EO Students and students at remote campuses:

Contact for help or complaints: [redacted]

1) If Cisco AnyConnect – VPN is not installed, then follow the instructions listed in the following link: [redacted]



Course instructor will add you to the VPN group with access for this lab.

2) Windows OS – Using Remote Desktop Connection, which is pre-installed, connect to:
   ID provided in e-mail to class
3) Next connect to the remote PC.
   User: remote
   Pass: **TA will provide**
4) From here you will remote into the AMPS computer following the instructions below:

*Do not connect outside of your scheduled lab times

Log into System Computer

Username: [redacted]
Password: **TA will provide**

Establish Remote Desktop Connection with Raspberry PI 2 (A & B)

Raspberry PI Microcontroller Functions (labeled on aluminum casing)

A. PI (A) has static IP address [redacted] PI (A) is used to monitor network performance using the Linux-based ICMP 'ping' protocol. PI (A) can be interfaced though a remote desktop connection.
B. PI (B) has static IP address [redacted] PI (B) is used to inject meaningless datagrams (Ethernet frames) into the network for simulated network congestion. PI (B) can be interfaced though a remote desktop connection.
C. PI (C) has static IP address [redacted] PI (C) is used as a 'packet sniffer.' A mirrored port re-directs datagrams to PI (C). Using Ostinato, datagrams are captured & analyzed using WireShark. PI (C) uses a dedicated monitor & cannot be connected with a remote desktop connection.

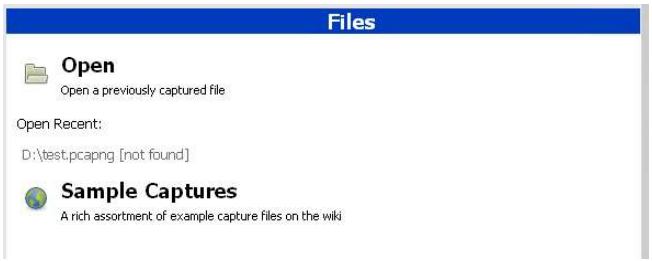
5) Navigate to the following file path:
   a) [redacted]Remote Desktop Connection with Raspberry PIs
6) Double-check all Raspberry Pi are powered on (or we won't be able to establish a connection).
7) Establish remote desktop connection with RPI (A)
   a) Computer: [redacted](Raspberry PI (A) static IP address)
   Credentials
   User[redacted]
   Password: **TA will provide**
8) Establish remote desktop connection with RPI (B)
   a) Computer: [redacted](Raspberry PI (B) static IP address)
   *Same Credentials

Capture and inspect port Traffic using Wireshark on the PI (C)

We can use Wireshark to show us what sort of information is being exchanged in the network.

1) On the PI (C) open a terminal window.
   a) Execute the following command: *sudo ostinato*
      i) The "sudo" Linux command stands for 'Super User DO" and gives the user administrator privileges.
2) This opens the network traffic generator program "Ostinato." Ostinato can capture packets to be viewed in Wireshark.
3) Port 0 is the Ethernet port associated with the mirrored traffic.
4) Highlight the Port 0-0 column.
5) Click the 'Start Capture' icon to start capturing Ethernet frames.
6) Capture for a short time (3 second).
7) Click the 'Stop Capture' icon to stop capturing Ethernet frames.

8) Open another terminal window.
   a) Execute the following command: *sudo wireshark*
9) To view the Ethernet frames in Wireshark, click 'Open' icon under Files and select the most recent capture.



10) Document a few protocols you see in use below.

Observed Protocol in Use: STP, GOOSE, etc. . . .

Monitor IED throughput (data rate) using Ostinato on the PI (C).

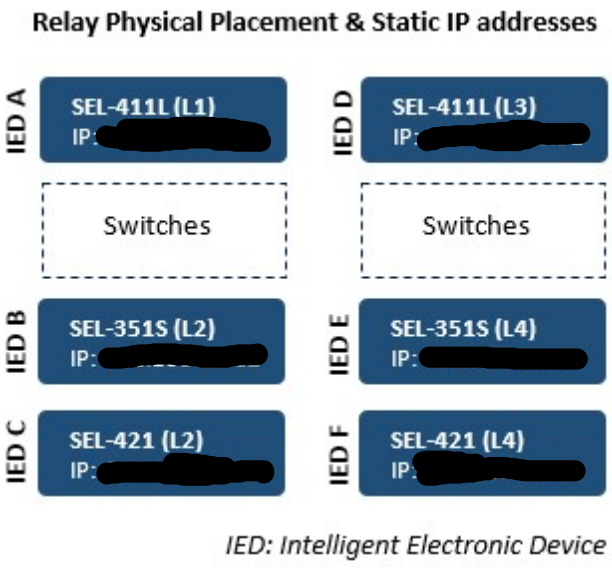
Ostinato provides network 'steady-state' performance statistics. We want to measure the SEL-411L (L1)'s data throughput. Under 'Statistics' in Ostinato we see 'Byte Receive Rate (Bps)' this value represents the SEL-411L's throughput in Bps (Bytes per second) since we've mirrored traffic to the PI (C). Remember, to get bps (bits per second) we have to multiply by 8 (1 byte = 8 bits).

Record the observed throughput for the SEL-411L under normal load:

SEL-411L (L1) Throughput (normal behavior) [Mbps] = should be small

Start 'flood' PING test on PI (A)

1) Open the remote desktop connection with PI (A) (IP:[redacted]).
2) Open 6 Terminal windows (1 for each SEL relay on the network) & resize them so all windows are displayed.
3) It is recommended to read more about the Linux-based ICMP ping test by entering the command 'info ping' on the terminal command line. Read about the "-f" option 'flood ping.'
4) In each terminal window start the 'flood' ping test for each IED using the following terminal command: sudo ping -f (IPAddress)
   a) example: sudo ping -f[redacted]
5) The flood ping test prints a decimal/period for each echo request sent & deletes the period for every echo response. If packets are lost, you will see periods printed to the terminal.
6) To complete the ping test press "Ctrl"+ "c".
7) Record the 'steady-state' AVG & MAX latency and packet loss % for the SEL-411L (L1) relay.



Performance Stats.	**SEL-411L(L1)**
AVG Latency [ms]	
MAX Latency [ms]	
No. of packets lost	

Simulate Network Congestion using 'Ostinato' on PI (B)

1) Open the remote desktop connection with PI (B) (IP:[redacted]).
2) Open a terminal window & start Ostinato: **pi@raspberrypi ~ $** sudo Ostinato
3) In the 'Ports' window (top left) select Port 0: eth0.
4) This will open the 'streams' window (top right).
5) Right-click in the 'streams' window and select 'Open Streams…' from the menu.
6) Navigate to /home/pi/Desktop/ECE444.
7) Open 'Substation Network_Streams.'
8) Above the 'streams' window we can control the data injection rate.
9) Select the 'radio-button' for Avg bps and change it to 20 Mbps.
10) We have to click 'Apply' for any changes to be saved & applied the next time we start transmission.
11) In the 'Statistics' window (bottom) highlight the 'Port 0-0' column.
12) Press 'Start TX' to begin datagram transmission (Play button).
13) We should see the 'Byte Send Rate (Bps)' statistic jump up when we start transmission.

Observe impact of network congestion on network performance

With the PI (B) injecting network congestion datagrams into the system, observe IED 'steady-state' performance statistics for each SEL relay using the 'flood' ping test.

1) Start the 'flood' ping test (PI (A)) for each IED using the following terminal command: sudo ping -f (IPAddress).

   With 20 Mbps of injected network congestion, run the flood ping test for each IED (together) for 15s, then stop ("Ctrl" + "c") the test or use the following terminal command: (sudo ping –f –i 0.001 –w15 (IPAddress) and record performance metrics.

Congestion: 20 Mbps	**IED-A**	**IED-B**	**IED-C**	**IED-D**	**IED-E**	**IED-F**
MAX Latency (mS)						
AVG Latency (mS)						
No. of packets lost						

2) Increase simulated network congestion to 40 Mbps and repeat the test in step 2).

Congestion: 60 Mbps	**IED-A**	**IED-B**	**IED-C**	**IED-D**	**IED-E**	**IED-F**
MAX Latency (mS)						
AVG Latency (mS)						
No. of packets lost						

3) Increase simulated network congestion to 100 Mbps and repeat the test in step 2).

Congestion: 100 Mbps	**IED-A**	**IED-B**	**IED-C**	**IED-D**	**IED-E**	**IED-F**
MAX Latency (mS)						
AVG Latency (mS)						
No. of packets lost						