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Customer Premises Equipment (CPE) Diagnostics Tool and Network Performance Analysis using Machine Learning

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Abstract: In today's era, DSL technology is growing rapidly which support high speed data transmission of a network between 2Hz to 20KHz as well as increase the fault rate. This project is mainly to determine the performance of the network based on the series data collection of different configuration setups of the CPE. Python programming is used to analyze the data measurement extracted from the GUI HG655m modem in VDSL2 network. The project is based on the equipment setup of real VDSL2 network in the lab consists of a network emulator, MSAN and CPE device. Ixia network emulator is used to emulate the real network condition for testing and measurement connected to MSAN and modem. The result of this project shows the relationship of the parameters which then are compared with the standard operation of the network to make observation of its performance. In the future, this project is recommended to perform artificial intelligence techniques using machine learning.

Keywords: DSL Technology, Customer Premises Equipment (CPE), Network Performance, Machine Learning, Python Programming

1. Introduction

Digital subscriber line (DSL) is known as telephone network which connect between central office and the customer premises equipment. DSL technology used the existing copper cable as transmission medium to transmit voice and data signal through the network with maximum data rate of 100Mbps [1]. In these days, the large volume of data and massive end devices in the network require constant monitoring from the server to maintain the network performance as well as to detect the fault [2]. The performance of the network can be affected with the presence of soft and hard fault which interfering with the equipment application and behavior [3]. The transmission line type of connection such as open and short circuit also important in determine the performance of the network

as stated from the previous study where higher impedance line increase the accuracy of the data transmission. Next, the performance can be observed by implementing diagnostic tools which analyzing the current network condition as well as providing analysis of machine learning in the CPE [4]. Diagnostic tools are a computer program sequence which used to provide fast response and repairing in the network [5]. So, the network performance parameters can be identified its pattern to make an analysis observation which based on the previous study are proven to be accurate in determining the performance of DSL system. Lastly, the technical data produce can be used by TM for future research.

This project is done to achieve the certain corresponding objectives which are to perform series of data collection based on different configuration setup of the network. Besides that, to perform a diagnostic tool base algorithm for analyzing the performance of the network as well as to evaluate the accuracy in using machine learning as diagnostic tool. At the end of this project machine learning method are expected to extract data parameters measured in .csv file and perform an analysis in determining the parameters affecting the network performance.

2. Methods

The methods required for this project are thoroughly explained in corresponding to determine the result of the study and cover the components required in completing the project. DSL2 HG655m modem is used at the end user to read and display the parameters value of the network connected to the MSAN. This project consists of several equipment setups which based on the real application purpose for testing and measurement of the network performance. The equipment's are Ixia Network, MSAN, VDSL2 HG655m modem, Copper wire, and Tag Block.

2.1 Equipment lab setup

The operation of this project is shown in the block diagram as Figure 1. The network system can be categorized in two parts which are central office and customer premises equipment. In the central office consists of components Ixia network, MSAN and switch port while in customer premises equipment it consists of VDSL2 modem. Ixia network used to emulate real application of network condition purpose for testing while MSAN is used to provide dedicated connection between the central offices to the customer premises equipment (CPE). At the end users, modem is used as transceiver to read and request information signal from the central office.
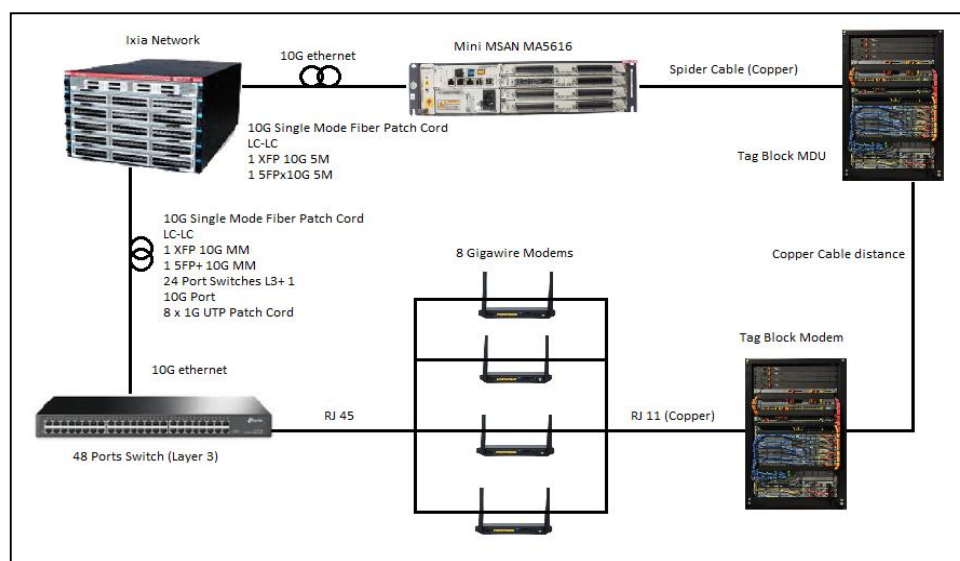

Figure 1: Equipment setup in lab

2.2 Flow process of data extraction

In this project, data parameters from GUI modem are extracted using the python programming language. Based on the Figure 2, shows the process flow of data extracting during the network testing and measurement in the lab. First of all, modem is connected to laptop to access the GUI interface via python. Then, Ixia network emulator is setup for measurement with duration 15 minute for each set with different cable distance. Next, the modem is reset for every measurement to refresh the measurement taken before. After that, the measurements parameters are taken and tabulated in excel.
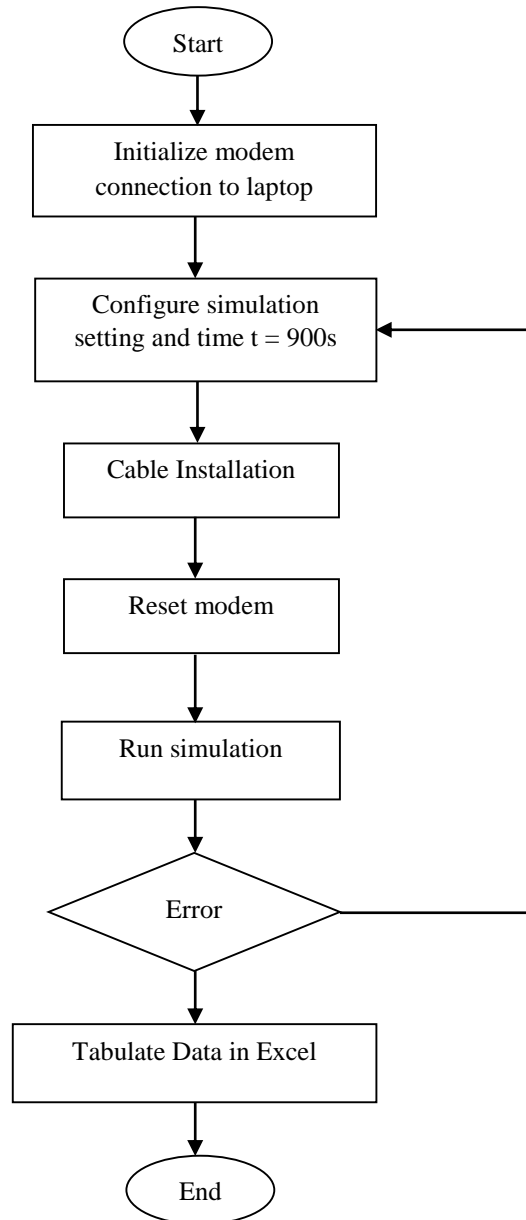
Figure 2: Flowchart of data collection

2.3 Python code development

In this research, python programming language is required to access and extract the parameter data in the GUI of the CPE. Selenium Web Driver library which known as open source APIs is applied to automate to the specific browser such as Mozilla Firefox which in this case used for the study to test the web application GUI. The frame of the web application is used to interact with the python code and allow the users to extract the information available on the web page. Figure 3, 4 and 5 show the

library used for data collecting and extracting on GUI webpage and the code used for interacting with the web. Web application Firefox is used to open the GUI webpage by accessing the IP address '192.168.1.1' which then interact with login interface on the web page and input the username and password for enter the page. Lastly, the parameters data are extracted and tabulated in excel file.

```
import os.path
import time
import pandas as pd
from selenium import webdriver as wb
from selenium.webdriver.common.keys import Keys
from selenium.webdriver.common.by import By
from selenium.webdriver.support.ui import WebDriverWait
from selenium.webdriver.support import expected_conditions as EC
```

Figure 3: Library package for web access and data extraction

```
print('START: '+time.strftime("%Y-%m-%d %H:%M:%S",
time.localtime())+'\n')
driver = webdriver.Firefox()
driver.get("http://192.168.2.5")
wait = WebDriverWait(driver,5)
username = wait.until(EC.presence_of_element_located
((By.ID, 'txt_Username')))username.send_keys("admin")
password = wait.until(EC.presence_of_element_located
((By.ID, 'txt_Password')))password.send_keys
("hs5711Bbvl")
signinBtn = driver.find_element_by_id('btnLogin')
signinBtn.click()
```

Figure 4: Accessing the GUI webpage

```
print('WAN Packet Status')
packetstatus = driver.find_element_by_id("WAN Packet").text
print(packetstatus)
print('Line Status')
linestatus = driver.find_element_by_id("Line Status").text
print(linestatus)
print('Statistics')
statstatus = driver.find_element_by_id("Statistics").text
print(statstatus)
```

Figure 5: Data parameters extraction to excel

3. Results and Discussion

The data parameters are extracted and store in excel during the measurement. Then, the data are used for analysis and further understanding of the performance of the network. Table 1 and 2 show the data parameters extracted from the GUI web page during the measurement of the network in lab. The parameters extracted include up time, attainable rate, send and receive byte, packet, line attenuation, line rate, snr margin and output power.

**Table 1: Parameters table data extracted from GUI**

	A	B	C	D	E	F	G	H	I
1	DSL Up Time CPE	Attainable Rate DS (kbits/s) C	Attainable Rate US (kbits/s) C	Send Byte CPE	Send Packet	Receive Byte C	Receive Packet	Line Attenuation DS (dB)	Line Attenuation US (dB)	Line
2	262	107285	41645	218421	3359	229827	4546	3.1	3.9
3	302	107289	41626	598331	9265	633202	12569	3.1	3.9
4	342	107285	41626	974183	15098	1025883	20378	3.1	3.9
5	383	107281	41614	1363613	21152	1442155	28652	3.1	3.9
6	423	107297	41614	1744205	27068	1845766	36679	3.1	3.9
7	468	107297	41622	2176979	33786	2301723	45748	3.1	3.9
8	510	107285	41610	2570285	39900	2717531	54012	3.1	3.9
9	555	107281	41626	3009448	46598	3173032	63072	3.1	3.9
10	598	107285	41622	3422874	53015	3613898	71835	3.1	3.9
11	644	107289	41602	3854534	59725	4067117	80849	3.1	3.9
12	689	107305	41622	4278324	66303	4520987	89871	3.1	3.9
13	730	107301	41610	4677638	72509	4939514	98195	3.1	3.9
14	770	107293	41622	5057810	78419	5343857	106237	3.1	3.9
15	810	107305	41614	5440552	84359	5750611	114321	3.1	3.9
16	853	107293	41626	5847370	90683	6184242	122946	3.1	3.9
17	896	107293	41622	6255672	97030	6616190	131531	3.1	3.9
18	943	107301	41614	6700376	103933	7087625	140908	3.1	3.9
19	987	107297	41626	7126749	110432	7526427	149629	3.1	3.9
20	1034	107309	41602	7562977	117213	7996614	158982	3.1	3.9
21	1078	107289	41614	7993069	123889	8453970	168073	3.1	3.9
22	1130	107301	41622	8474075	131366	8966591	178270	3.1	3.9
23	1175	107305	41626	8568121	132818	9068137	180279	3.1	3.9
24	1222	107293	41622	8568409	132821	9068486	180280	3.1	3.9
25	1269	107305	41602	8568409	132821	9069184	180282	3.1	3.9
26	1314	107305	41610	8569965	132829	9069882	180284	3.1	3.9
27	1363	107309	41622	8570305	132831	9070231	180285	3.1	3.9
28	1457	107289	41610	8831085	136709	9329963	185420	3.1	3.9
29	1501	107293	41633	9243955	143127	9770617	194179	3.1	3.9
30	1542	107273	41614	9641919	149304	10189594	202512	3.1	3.9

Sheet1

Table 2: Parameters table data extracted from GUI

	K	L	M	N	O	P	Q	R	S
1	Line Rate US (kbit/s) CPE	SNR Margin DS (dB) CPE	SNR Margin US (dB) CPE	Output Power DS (dBmV) CPE	Output Power US (dBmV) CPE	Ixchariot CPE	Distance		
2	41540	6.8	6.1	12.2	-11.6	1	100		
3	41540	6.8	6	12.2	-11.6	1	100		
4	41540	6.7	6	12.2	-11.6	1	100		
5	41540	6.8	6	12.2	-11.6	1	100		
6	41540	6.8	6	12.2	-11.6	1	100		
7	41540	6.8	6	12.2	-11.6	1	100		
8	41540	6.8	6.1	12.2	-11.6	1	100		
9	41540	6.7	6	12.2	-11.6	1	100		
10	41540	6.8	6	12.2	-11.6	1	100		
11	41540	6.7	6	12.2	-11.6	1	100		
12	41540	6.7	6	12.2	-11.6	1	100		
13	41540	6.7	6	12.2	-11.6	1	100		
14	41540	6.8	6	12.2	-11.6	1	100		
15	41540	6.8	6	12.2	-11.6	1	100		
16	41540	6.7	6	12.2	-11.6	1	100		
17	41540	6.8	6	12.2	-11.6	1	100		
18	41540	6.8	6	12.2	-11.6	1	100		
19	41540	6.8	6	12.2	-11.6	1	100		
20	41540	6.7	6.1	12.2	-11.6	1	100		
21	41540	6.7	6	12.2	-11.6	1	100		
22	41540	6.7	6	12.2	-11.6	1	100		
23	41540	6.8	6	12.2	-11.6	1	100		
24	41540	6.7	6	12.2	-11.6	1	100		
25	41540	6.8	6	12.2	-11.6	1	100		
26	41540	6.8	6	12.2	-11.6	1	100		
27	41540	6.7	6	12.2	-11.6	1	100		
28	41540	6.7	6	12.2	-11.6	1	100		
29	41540	6.7	6	12.2	-11.6	1	100		
30	41540	6.7	6	12.2	-11.6	1	100		

Sheet1

3.1 Correlation study based heatmap visualization

The performance of CPE is measured through the network equipment setup which accessing the data of GUI web base using the automated open source APIs selenium web driver. The measurement are consists a series of multiple repeated data collecting of distances 100m, 500m and 1000m with throughput of low, medium and high. As a result in Figure 6 shows the heatmap correlation of different parameters measured by CPE.
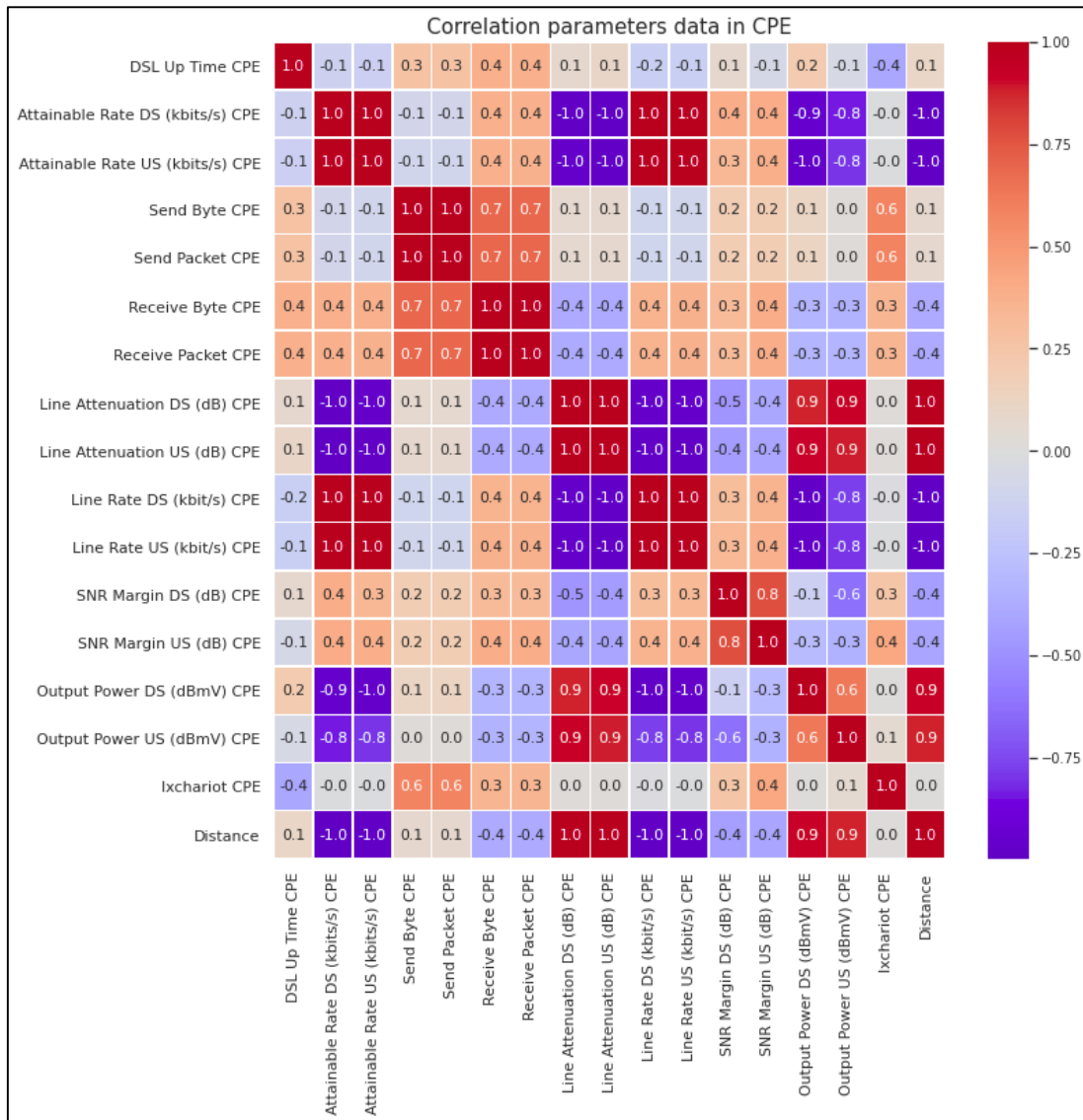
Figure 6: Heatmap correlation parameters in CPE

Table 3 shows the correlation coefficient interpretation of the heatmap. The correlation coefficient will determine the relationship strength between the two parameters in the CPE. By referring to the table the coefficient <0.1 will indicate no correlation and >0.9 will indicate a very strong correlation of the parameters. The values between them are referred as moderate correlation which may or may not have a significant effect on the relationship between parameters. Although, this table is just a reference and don't apply with the certain relationship that cannot be inference with this method.

Table 3: Correlation Coefficient value and their Interpretation

| Correlation Coefficient for Direct Relationship	Correlation coefficient for indirect relationship	Relationship Strength of the Variable
0.0 – 0.1	-0.0 – 0.1	No correlation
0.1 – 0.39	-0.1 – 0.39	Weak correlation
0.4 – 0.69	-0.4 – 0.69	Moderate correlation
0.7 – 0.89	-0.7 – 0.89	Strong correlation
0.9 – 1.0	-0.9 – 1.0	Very strong correlation

3.2 Parameter relationship determination

Figure 7 shows a negative relationship between the attainable rate downstream and upstream over the distance parameters of the CPE. The attainable rate of the CPE reduces as distance increases in the network. The maximum attainable speed can be achieved from the measurement is 107Mbps for downstream and 41Mbps for upstream.


| (a) | (b) |
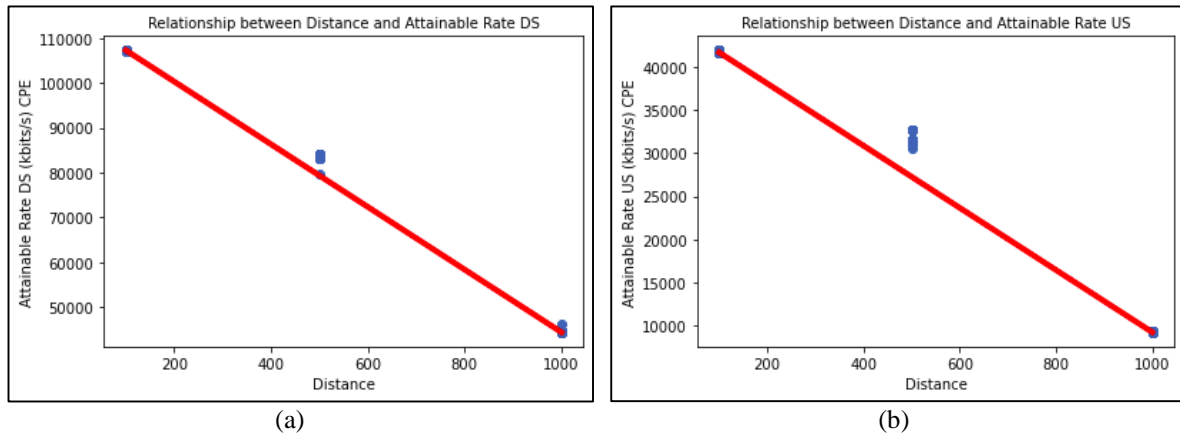
Figure 7: (a) Relationship between distance and attainable rate downstream showing very strong linear regression line. (b) Relationship between distance and attainable rate upstream showing strong linear regression line

Figure 8 shows the relationship of line attenuation between upstream and downstream over the distance. From the scatter plot can be observe the line attenuation downstream increase linearly while line attenuation upstream increase regularly. At distance of 1000m the maximum line attenuation for downstream is 18.9dB while for upstream is 39.4dB. Line attenuation upstream is higher than the line attenuation downstream because the noise exists in the transmission network is higher.
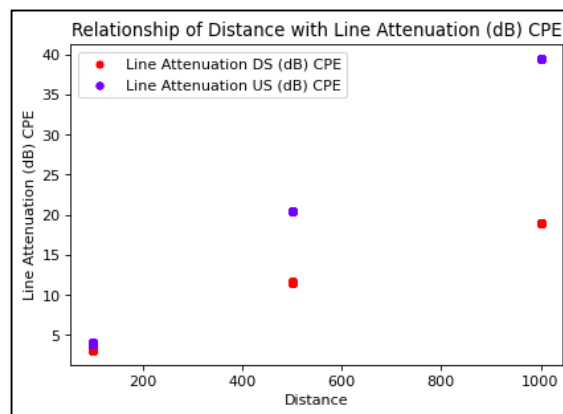

Figure 8: Relationship between line attenuation over distance

Figure 9 shows the parameters of attainable rate and line rate which are inversely proportional with the distance. Based on the observation, at distance 500m the maximum value of attainable rate and line rate for downstream are 84Mbps and 83Mbps while in upstream the value are 32Mbps and 31Mbps which close to each other. This proves that the network is in good condition as the measured value is more or less the same as the theoretical value and also the packet loss at a tolerable value.
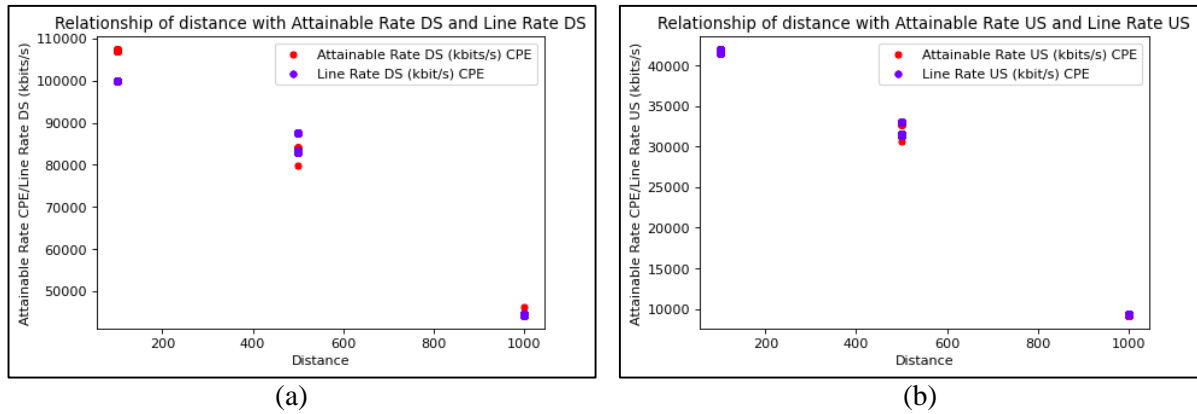
Figure 9: (a) Relationship of distance compare with attainable rate and line rate downstream. (b) Relationship of distance compare with attainable rate and line rate upstream

Figure 10 show the comparison parameters of attainable rate of different working temperature against the distance. The value of temperature at normal condition is between 32°C to 35°C while in high condition the value is over 40°C. Based on the observation, the attainable rate is inversely proportional with the distance. The maximum attainable rate achieved during normal and high condition are 31.08Mbps and 31.03Mbps for upstream while for downstream the value are 83.1Mbps and 83.02Mbps which close to each other's. This is because the temperature of the CPE raised is not very significant which will show the effect on its performance.
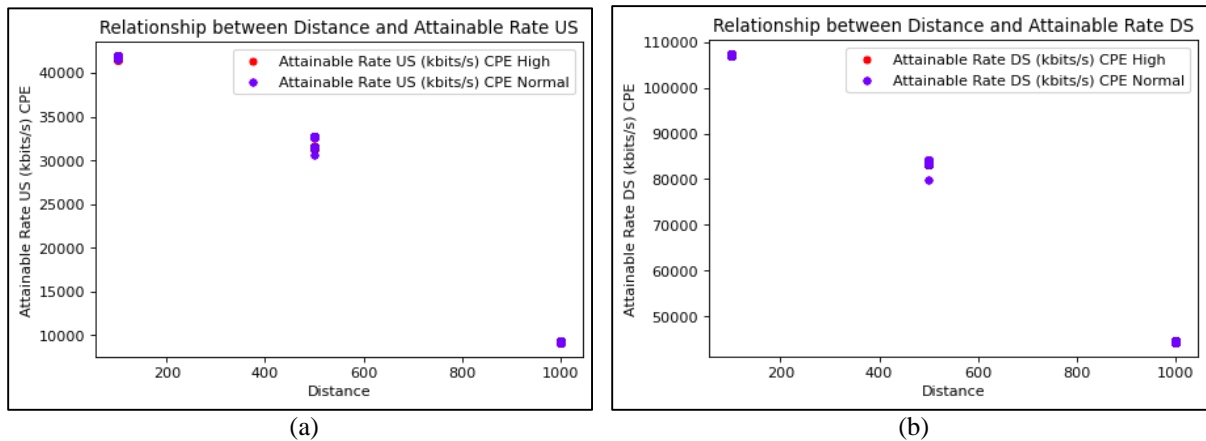
Figure 10: (a) Relationship between distance and attainable rate upstream of different working temperature. (b) Relationship between distance and attainable rate downstream of different working temperature

Figure 11 shows the relationship of attainable rate and line rate over the output power. From the scatter plot can be observe the attainable rate and line rate is fairly strong negative relationship with the output power. The attainable rate and line rate decrease as the distance increase but the output power increases. As example at distance 100m the output power for downstream and upstream are 12.2dBmV and -11.4dBmV while in distance 1000m the output power are 13.5dBmV and 6.dBmV. This is because as the distance increase the noise in the transmission line also increases which required the output power to be increase so data can be transmit successfully within the network without any loss.

(a) (b)
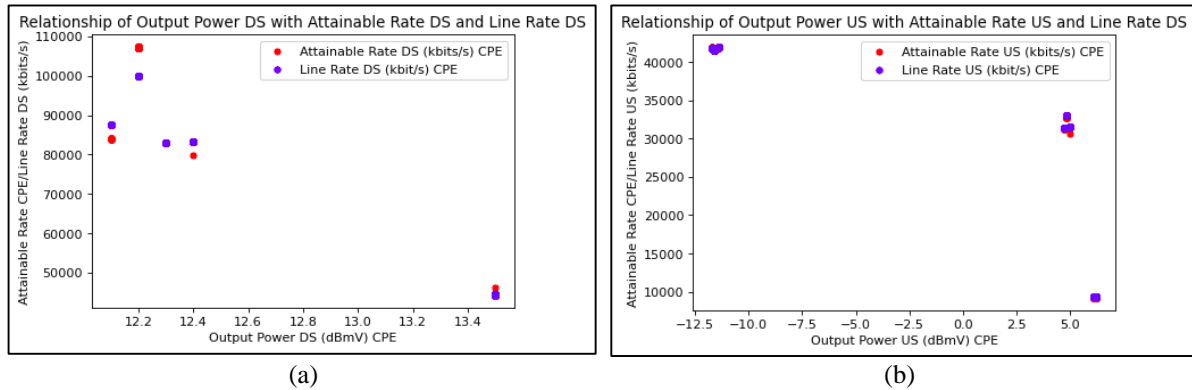
Figure 11: (a) Relationship of output power compare with attainable rate and line rate downstream. (b) Relationship of output power compare with attainable rate and line rate upstream

Conclusion

In conclusion, overall of the project are determining the performance of the network of real world application based equipment setup which used for testing and measurement. This project focused on the testing and measurement of network parameters as well as data tabulation in .csv file. All the measurement will be based on testing the network transmission between the MSAN and the CPE at different throughput and distance. Based on the result, the performance of the network can be determined to be working in normal condition. All the parameters plotted show the network are working in the range of standard which is in no faulty condition.

Acknowledgement

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