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Correlation Studies Among Line Operation Parameters Between CPE and MSAN

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Abstract: The purpose of this project is to studies the correlation between Line Operation Parameters (LOPs) between Customer Premises Equipment (CPE) and Multi-Service Access Node (MSAN). As focusing on CPE sites, the project also is developing data acquisition and extraction on the CPE device, which can observe various network parameters for preventing a total breakdown in the network system. Hence, through the data collection, the statistical performance of CPE devices based on the network parameters such as actual line rate, attainable rate, line and signal attenuation and Signal-to-Noise Ratio (SNR) margin were evaluated. This project focuses on a Very high-speed Digital Subscriber Line 2 (VDSL2) access network, in which the copper cable length varies between several distances, 100 m, 300 m, 500 m, 700 m and 1000 m. The copper cable is a twisted-pair type that bundles ten pairs, and from the ten pairs twisted-pair, only six-port from MSAN is used and connected to the load CPE, Huawei HG655m modem. A web scraping technique using Python programming script is developed to extract and collect LOP parameters and statistical performance data available on Graphical User Interface (GUI) for Huawei HG655m modem. The extracted and collected data is saved in comma-delimited (.csv) file format. The Huawei HG655m modem can achieve maximum data rate speed at 100 m of copper cable length with 100009 kbps and 41786 kbps downstream and upstream. At 300 m, the data rate speed drop by 7.7% and 8.8% for downstream and upstream. 14.1% and 22.5% of data rate speed drop downstream and upstream at 500 m copper cable length. As the distance between MSAN and CPE reaching 700 m and 1000 m, the data rate speed drop drastically with 37.% and 55.6% for downstream, while 51.5% and 77.7% for upstream.

Keywords: Line Operation, Access Network, Data Rate, VDSL2, MSAN

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1. Introduction

A Multi-Service Access Node (MSAN) is usually located in a telephone exchange but often in a roadside service area. This interfacing cabinet links customers' telephone lines to the central network to offer telephone, Integrated Services Digital Network (ISDN), and broadband networks such as Digital Subscriber Line (DSL) from a single platform [1]. Leading up to the implementation of MSANs, telecommunications providers usually had many separates equipment, including Digital Subscriber Line Access Multiplexer (DSLAM), to deliver diverse types of services to customers [2]. In Malaysia, especially in the suburban area, the Internet access network is still covered by the copper network. Due to the heavy utilisation of copper cables, it is necessary to enhance and improve the cable's performance to satisfy its high-speed data rate demand. Cable fault conditions, however, may cause line impairment that reduces the performance of the copper access network line.

Furthermore, the cable fault in the copper networks is a widespread concern. Suppose there is a cable fault in the transmission line; this problem will affect the data rate at the Customer Premises Equipment (CPE). In this case, the service provider will send their support team to solve the problem by detecting the transmission line or cable parameters such as short, partial short, open, partially open, and bridge tap. However, cable fault's precise location is often unknown, and the exact nature is still unknown [3].

CPE devices, such as a modem, do not guarantee fully operational and compatibility when connected with a particular public telecommunications network regarding signalling, transmission quality, and activation of various system features [4]. Even though the network access service provider can provide a high-speed internet data rate, the CPE types will affect the internet speed data rate. This project focuses on Very high bitrate DSL2 (VDSL2) technology development platform targets to assess fault diagnosis under the real conditions on the existing DSL infrastructure. Therefore, this research study is proposed to obtain the Line Operation Parameters (LOPs) data against copper cables' distance of the CPE. The emulation of ideal LOPs condition in copper cable connection between CPE and MSAN is conducted based on cable length for 100 m, 300 m, 500 m, 700 m, and 1000 m. It is expected that this research can help any telecommunication service provider such as Telekom Malaysia in studying the various types of CPE available in the market and their operational compatibilities, such as maximum downstream and upstream data rate.

2. Materials and Methods

Several stages are involved in this project to ensure that all the desired objectives can be achieved and completed. The LOPs data obtained from the VDSL2 access network technology were analysed and studied for future technology development. Figure 1 shows an overview of the project implementation, which comprises four stages: experimental setup, parameter categorisation, data collection and analysis of the data.

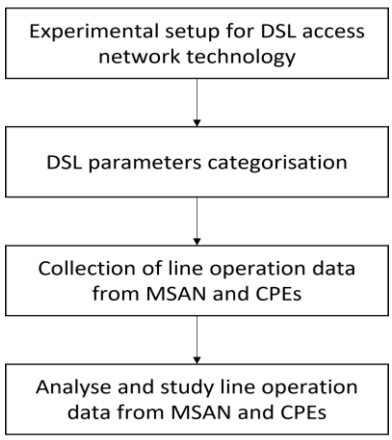

Figure 1: Project methodology

In the first stage, the experimental setup and cable configuration only focus on the ideal transmission line condition to obtain the LOPs data. The copper cable distances are varied from a short distance transmission to a maximum of 1000 m copper cable distances. The DSL parameters categorisation related to the network parameters indicates the current network conditions or performances is conducted in the second stage. The characteristics of CPE devices with specific technical specifications are studied to understand whether the CPE can work and perform well based on the network feature. In the third stage, all collection of the LOPs data from MSAN and CPE are experimentally conducted via several platforms such as Xshell and Phyton software. Lastly, in the fourth stage, all the collected LOPs data from MSAN and CPE are analysed and studied to classify the difference between LOPs data provided by MSAN and LOP data achieved by the CPE.

The experimental setup is configured to replicate the existing VDSL2 network provided by the TM. Figure 2 displays the schematic configuration of the components and equipment in the laboratory. The Mini MSAN is in a street cabinet usually built in a telephone exchange to connect customers' telephone lines to the core network. A distribution frame, or usually called tag block, is used in the laboratory setup configuration. The first tag block is usually located near and connected directly to the MSAN, and another tag block becomes the distribution point in TM networks connected directly to the customer's site. In this laboratory setup, tag blocks simulate the different transmission line distances, starting with a short distance (zero meter) to a maximum distance supported by the VDSL2 technology, which is less than 1500 m. The CPE considered in this project is a VDSL2 modem.

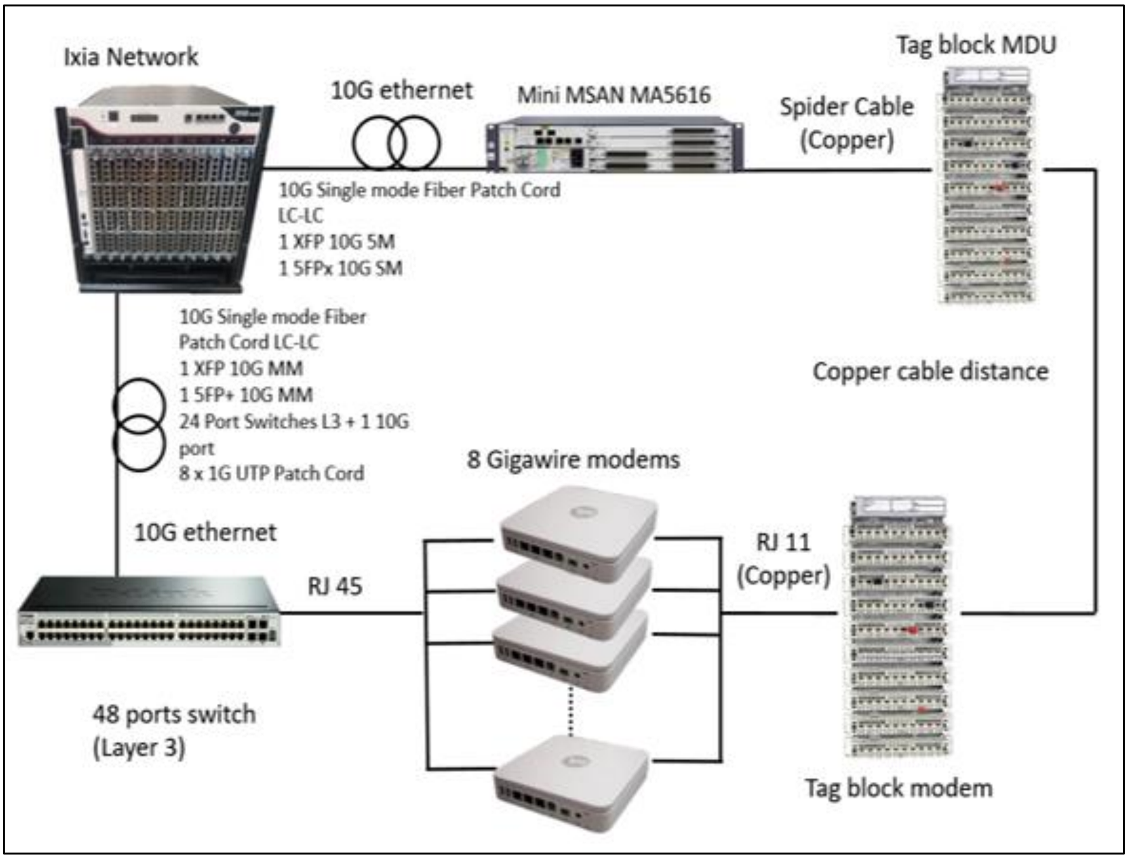

Figure 2: Access network experimental setup in laboratory

In general, a DSL modem is hardware that converts the transmission data into a suitable format for accessing to the network system. Basically, there are two main types of DSL technology connections: The ADSL and VDSL. The xDSL modem allows end-user to connect their devices such as computers to Internet access. In this project, 30 ports are provided and available from the MSAN, and only six ports are used to connect six VDSL2 modems, which is Huawei HG655m modem via six pairs of unshielded twisted-pair copper cables. Ixia network and switch equipment are added to the configuration setup. It will be used to inject a real data traffic network with necessary parameters at the customer's site. The main parameters configured are the timing record, and bytes send per timing record. The real data traffic network means the Internet access usage by customers such as accessing the web browser, streaming in social media such as Facebook, and others. The data traffic is divided into three categories: low-performance throughput, medium-performance throughput, and high-performance throughput. Low-performance throughput has the smallest bandwidth in a single transmission medium compared to medium-performance throughput, while high-performance throughput has the largest transmission bandwidth. Hence, the transmission line can provide more packet data during a single transaction. Figure 3 shows the differences between low, medium and high-performance throughput applied for this project.

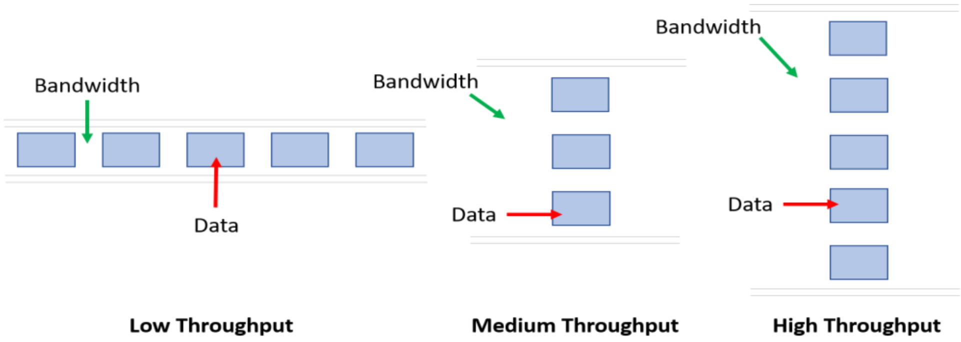

Figure 3: Differences between low, medium and high throughput based on data amount per transaction and bandwidth

Meanwhile, the throughput measures the actual amount of packet data that can be transmitted within a period [5]. The larger the throughput, the more packet data can be transmitted and received. This equipment is essential as it helps in the research and development department. However, these two types of equipment are usually not provided in the existing TM on-site networks.

3. Results and Discussion

The data acquisition and extraction platform were designed based on Python programming language script using the web scraping technique. Web scraping technique is a process to extract content or data available from a website using bots, and the data export directly from the website in comma-delimited (.csv) file format. The Python programming script helps in ensuring that the desired LOPs data and statistic performance data can be extracted and captured from the Huawei HG655m modem webpage GUI. The Python programming script is designed and developed based on the web scraping technique. The LOPs data and network performance data from the Huawei HG655m GUI are extracted and exported in comma-delimited (.csv) file format, which is suitable for storing the data in tabulated form. Figure 4 shows the tabulated data in the comma-delimited (.csv) file format that consists of LOPs and network performance data, respectively.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Timestamp	Mode	DSL Up Tir	Attainable	Attainable	SNR Margi	SNR Margi	Line Atter	Line Atter	Output Pc	Output Pc	Line Rate	Line Rate	CRC Errors	CRC Errors
2	30/5/2021 9:57	VDSL2	297	46135	10198	6.3	5.7	18.8	38.9	13.5	6	46085	10234	0	0
3	30/5/2021 10:03	VDSL2	664	46155	10183	6.3	5.8	18.8	38.9	13.5	6	46085	10234	0	0
4	30/5/2021 10:05	VDSL2	767	46151	10201	6.3	5.8	18.8	38.9	13.5	6	46085	10234	0	0
5	30/5/2021 10:08	VDSL2	971	46166	10209	6.3	5.8	18.8	38.9	13.5	6	46085	10234	0	0
6	30/5/2021 10:10	VDSL2	1074	46147	10157	6.3	5.7	18.8	38.9	13.5	6	46085	10234	0	0
7	30/5/2021 10:11	VDSL2	1146	46151	10164	6.3	5.7	18.8	38.9	13.5	6	46085	10234	0	0

Figure 4: Example of collected and extracted data in comma-delimited file format

3.1 Results

The correlation heatmap represented in Figure 5 shows that various correlation values between two variables were obtained based on the LOPs data collected. The range or scale of the correlation between two variables referring to the correlation heatmap is varied from -1 to 0 or 0 to +1, and the values are declared as absolute values. There is no correlation or association between two of the gathered variables when the correlation value is zero. Meanwhile, there is a correlation between two variables if their correlation value is closer to ±1 in either the positive or negative direction [6]. Furthermore, the strength of the correlation is not determined by the direction or sign (positive or negative). A positive correlation can be defined as a relationship in which an increase in the first variable increases in the second variable. As a result, there is a direct relationship between the two variables. On the other hand, a negative correlation depicts an inverse relationship between the two variables; when the first variable's data rises, the second falls [7]. Table 1 shows the rule of thumb for interpreting the range or scale of a correlation coefficient [8].

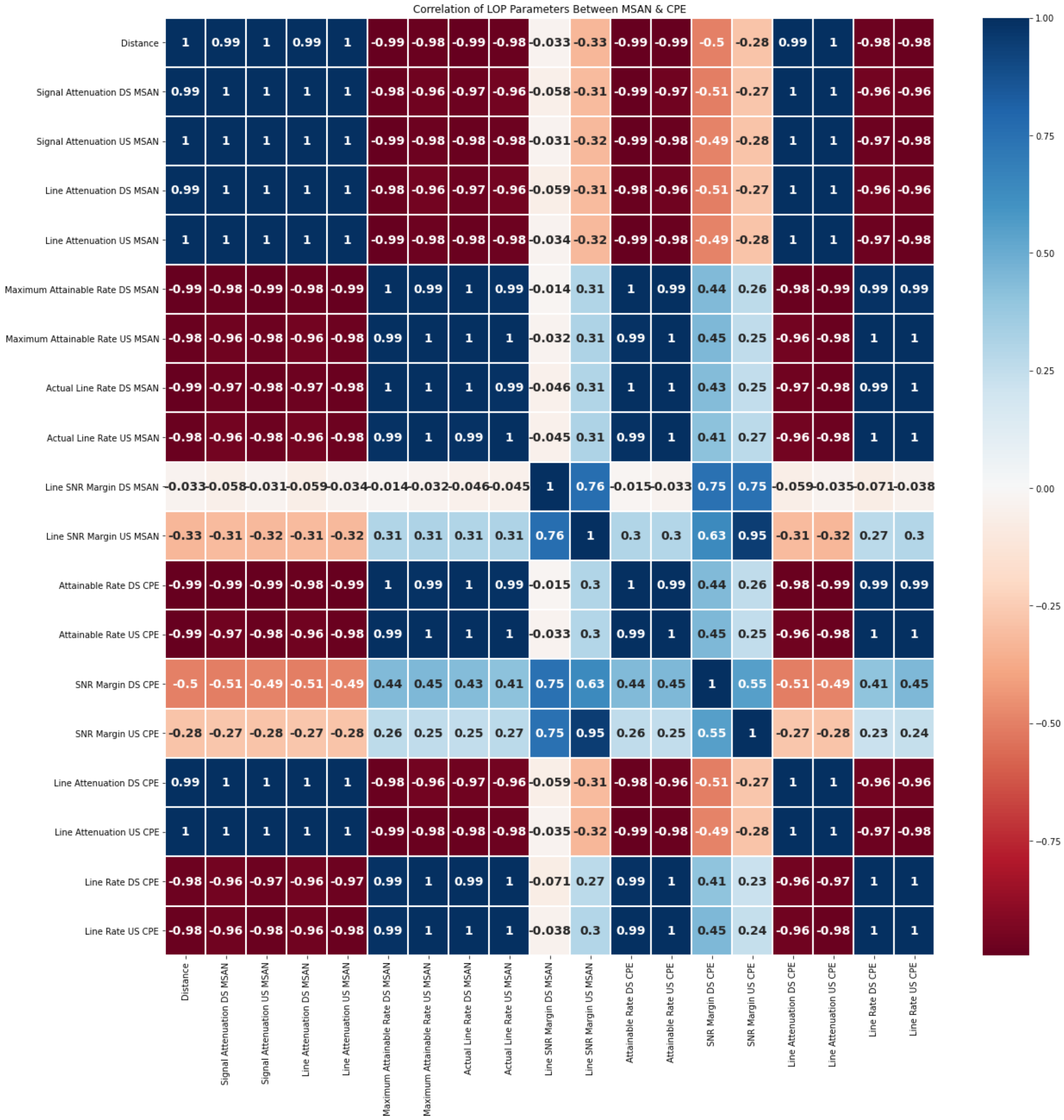

Figure 5: Correlation heatmap of LOPs data between MSAN and Huawei HG655m modem

Table 1: The scale of the correlation with the interpretation [8]

Scale of Correlation	Interpretation
± 0.90 to ± 1.00	Very high positive/negative correlation
± 0.70 to ± 0.89	High positive/negative correlation
± 0.50 to ± 0.69	Moderate positive/negative correlation
± 0.30 to ± 0.49	Low positive/negative correlation
0.00 to ± 0.29	Negligible/No correlation

Based on the correlation heatmap visualised in Figure 5, the correlation values between the LOPs data collected are observed and obtained, referring to the Table 1. Hence, the correlation for each of the variables is summarised and tabulated as shown in Table 2.

Table 2: Summarised of the correlation heatmap between the LOPs data

Variables	Size of Correlation	Correlation between Variables
Actual Line Rate MSAN Max. Attainable Rate MSAN Attainable Rate CPE Line Rate CPE	+ 0.99 to + 1.00	Very high positive correlation
Signal Attenuation MSAN Line Attenuation MSAN Line Attenuation CPE	+ 0.99 to + 1.00	Very high positive correlation
Line SNR Margin MSAN SNR Margin CPE	+ 0.55 to + 0.95	Moderate to very high positive correlation
Distance Rate MSAN/CPE	− 0.98 to − 0.99	Very high negative correlation
Distance Attenuation MSAN/CPE	+ 0.99 to + 1.00	Very high positive correlation
Distance SNR Margin MSAN/CPE	− 0.033 to − 0.50	Low negative to no correlation
Rate MSAN/CPE Attenuation MSAN/CPE	− 0.96 to − 0.99	Very high negative correlation
Rate MSAN/CPE SNR Margin MSAN/CPE	− 0.071 to + 0.45	Low positive to no correlation
Attenuation MSAN/CPE SNR Margin MSAN/CPE	− 0.059 to − 0.51	Low negative to no correlation

The summary of the correlation data represented in Table 2 shows that the data rate between MSAN and the CPE has a very high positive correlation. The data rate from both MSAN and CPE has a very high negative correlation between the distance or the attenuation from both MSAN and CPE. Other than that, the signal and line attenuation between MSAN and CPE also has a very high positive correlation. Moreover, the attenuation from both MSAN and CPE also has a very high positive correlation with the distance. As for the line SNR margin between MSAN and CPE, the correlation between these two variables seems to have a moderate to a very high positive correlation. However, the SNR margin for both MSAN and CPE has approximately no correlation towards the other LOPs data: the data rate, attenuation, and distance.

3.2 Correlation between Actual Line Rate, Attainable Rate and Distance

There is a very high positive correlation (+0.99 to +1.00) between the actual line rate provided by the MSAN and the attainable rate from MSAN and CPE. Besides that, the distance and the data rate from both MSAN and CPE has a very high negative correlation (−0.98 to −0.99). Figure 6 shows the difference between the actual line rate from MSAN and the attainable rate from MSAN and CPE for downstream and upstream traffics against the distance. Meanwhile, Table 3 represented the percentage difference between each of the variables.

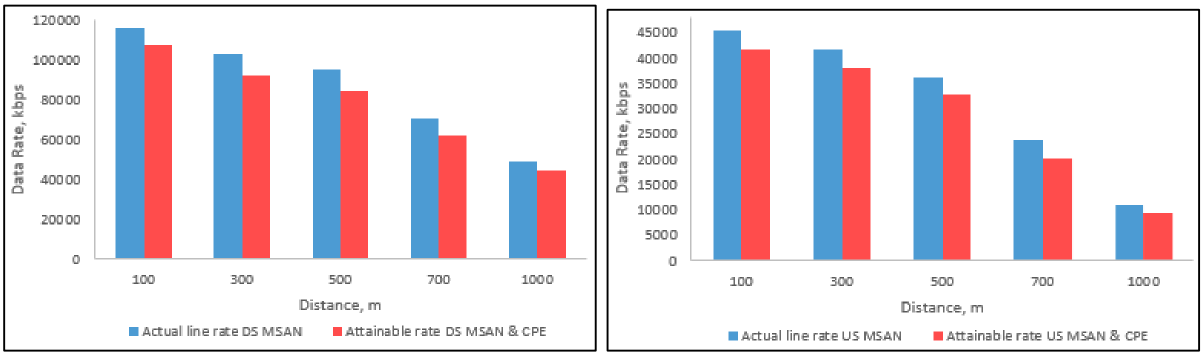

Figure 6: MSAN actual line rate and MSAN/CPE attainable rate down/upstream against distance

Table 3: Percentage difference between MSAN actual line rate and MSAN/CPE attainable rate

	Type	Percentage difference
100 m	Downstream (kbits/s)	7.4 %
	Upstream (kbits/s)	7.8 %
300 m	Downstream (kbits/s)	10 %
	Upstream (kbits/s)	8.6 %
500 m	Downstream (kbits/s)	11.5 %
	Upstream (kbits/s)	9.8 %
700 m	Downstream (kbits/s)	11.7 %
	Upstream (kbits/s)	15.3 %
1000 m	Downstream (kbits/s)	9.5 %
	Upstream (kbits/s)	15 %

Referring to the graphs in Figure 6, the speed of data rate for downstream and upstream traffics decreases as the distance between MSAN and CPE increases. Besides that, the Huawei HG655m modem can obtain the exact attainable data rate speed for downstream and upstream directions supplied by the service provider, MSAN. However, at a distance of 100 m between MSAN and the CPE, the modem can only support up to 100009 kbps for downstream direction, while upstream data rate up to 41921 kbps, and it shows that it is the maximum capability of Huawei HG655m modem can be achieved. From Table 3, as the distance increases from 100 m to 1000 m, the percentage differences between the actual line rate from MSAN and the attainable rate from MSAN and CPE is also increasing, with the lowest percentage differences is 7.8% and the highest is 15.3%. The condition is applied for both downstream and upstream traffic.

3.3 Correlation between Signal and Line Attenuation, Data Rate and Distance

The degradation of the overall data rate from MSAN and CPE devices is due to the increment of signal and line attenuation along the transmission line as the distance between MSAN and CPE devices increases. The signal and line attenuation can also be described as noise and loss along the transmission line between the transmitter and receiver. Figure 7 shows the line attenuation scatter plot and regression line graph against distance, comparing variables that have been collected and identified at MSAN and from the CPE device itself, the Huawei HG655m modem.

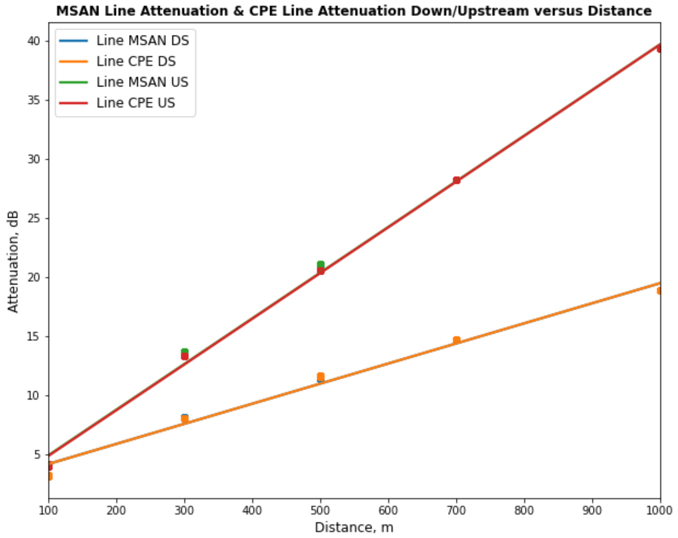

Figure 7: Graph of MSAN line attenuation and CPE line attenuation down/upstream versus distance

From the line attenuation scatter plot and regression line graph, it is clearly shown that as the distance between access network service provider, MSAN towards the modem, the signal or data rate achieved at the modem will surely be degraded. Besides that, the signal attenuation and line attenuation data provided from MSAN for downstream and upstream traffic have a very high positive correlation with the line attenuation data provided at the Huawei HG655m GUI platform. At 100 m of distance, the MSAN data shows that the line attenuation for downstream and upstream is at an average of 3.14 dB and 3.98 dB. Meanwhile, from Huawei HG655m modem GUI, the same value of line attenuation is obtained. As the distance between MSAN and the modem increases from 100m to 1000 m, the line attenuation becomes greater with approximately 90% increment for upstream line attenuation, 39.4 dB, and 83% increment for downstream line attenuation 18.9 dB.

In addition, as summarised in Table 2, there is a very high negative correlation (−0.96 to −0.99) between the line attenuation and the data rate from both MSAN and CPE. Figure 8 shows the scatter plot and regression line graphs between the line attenuation at the CPE against the line rate for downstream and upstream.

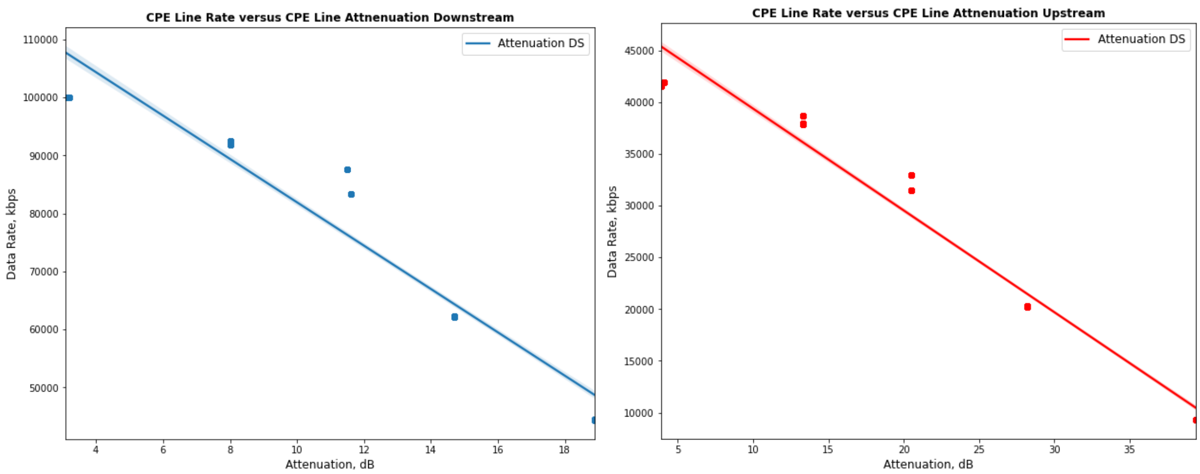

Figure 8: Graph of CPE line rate versus CPE line attenuation for down/upstream traffics

Based on the scatter plot and regression line graph shown in Figure 8, the CPE downstream and upstream line rate have an inverse linear correlation with the CPE line attenuation. As the CPE line rate decreases, the line attenuation in the transmission line will directly increase.

3.4 SNR Margin

Referring to Table 2, the SNR margin has the lowest or no correlation towards the other LOPs data that have been collected. The SNR margin downstream and upstream of the VDSL2 access network is plotted against the network line distance, as shown in Figure 9.

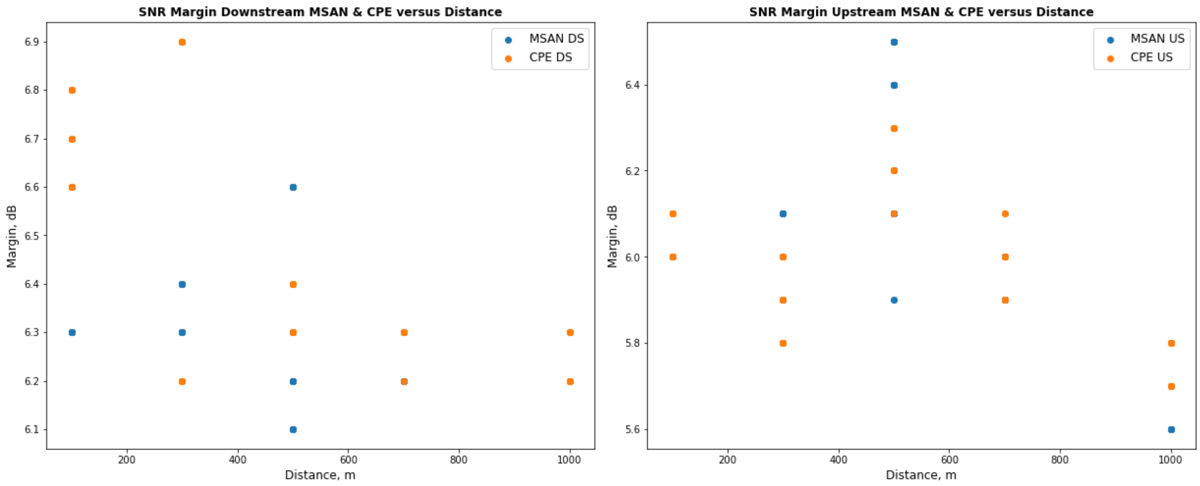

Figure 9: Scatter graph for MSAN and CPE SNR margin down/upstream versus distance

From the graphs shown in Figure 9, the SNR margin for downstream of the access network system is between 6.1 dB to 6.9 dB. Meanwhile, for the upstream traffic, the SNR margin is between 5.6 dB to 6.5 dB. As mentioned, the SNR margin has the lowest or no correlation towards the other LOPs data and the network line distance, and it is clarified from the graphs shown, as the distance increases from 100 m to 1000 m, the SNR margin of the access network system has remained constant. However, the SNR margin is essential in maintaining and obtaining good performance for data rate speed in a communication transmission line, especially for the downstream purpose. SNR margin can be defined as the minimal limit at which the signal level is above the noise level, which is utilised as a line condition evaluation criterion. In order to obtain good parameters and performance for data and signal transmission, a greater SNR margin which is more than 6 dB, is better because the signal has more strength compared to the noise strength [9]. In the configuration setup between the MSAN and CPE, the correlation between the SNR margin and the other LOPs variables can be classified into three conditions [9]:

i. Fixed SNR margin in an access network system, the data rate decreases as the transmission line distance increases, and vice versa.

ii. Fixed transmission line distance, the SNR margin limit decreases as the data rate increases, and vice versa.

iii. Fixed data rate speed, the transmission line distance must be shortened to increase the SNR margin in the system.

4. Conclusion

In a nutshell, data acquisition and extraction using the web scraping technique in Python programming language script is successfully designed. The script designed focusing on collecting LOPs data from the VDSL2 access network, which consists of actual line rate, attainable rate, line attenuation and SNR margin. Based on the results obtained, a correlation analysis among the LOPs data between MSAN and CPE is made, and the correlation between the parameters (actual line rate, attainable rate, signal and line attenuation, and network line distances) showed that each of the parameters has a very high correlation towards the other. However, the SNR margin of the VDSL2 access network seems to have no correlation towards the other LOPs variable collected. It can be said that copper cable length has a huge effect on the access network connection's overall performance in terms of the speed of the data rate that the CPE can achieve. Even though SNR margin has the lowest or no correlation and relationship with the other LOPs data, SNR margin remained an essential parameter to keep and maintain the access network to obtain good overall performance. However, the correlation between the LOPs data may have different possibilities if any faults in the network line. For example, the LOPs data variation would become more difficult to analyse due to emulation of faults in the network line. Therefore, it is recommended to include and introduce several types of faults into the transmission line for future work. The network line faults can be classified into several types: partial short, short, partial open, open, and bridge tap.

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