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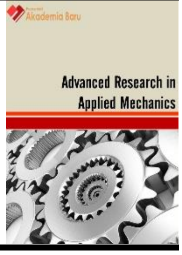

Copper line Pre-Qualification Assessment for High-Speed Broadband in Malaysia

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ABSTRACT

The copper access-network operators face the challenge of developing and maintaining the cost-effective digital subscriber line (DSL) services that are competitive to other broadband access technologies. The copper line quality assessment process is crucial to ensure the customers enjoy their speed subscription. Through this process, service providers can evaluate the capability of copper lines before deploying the broadband service. Furthermore, for the unstable condition of copper lines, the root cause of the problems can be identifying earlier, which helps the operators to do preventive action and avoid offering the service to customers using that copper lines. This paper discusses the proposed prequalification assessment method and the impact of every proposed stage. This proposed assessment showed that the speed performance would be dropped more than 50% if the impairments exit in the copper line. Thus, any service providers can avoid serving high-speed broadband to subscribers using the unstable cable condition. Through this preventive process, it will benefit the service providers.

Keywords:
Digital Subscriber Line (DSL), impairments, copper lines, speed

1. Introduction

Digital Subscriber Line (DSL) is a technology that uses the existing copper twisted-pair phone lines for transmitting high bandwidth data [1]. Malaysia started to leverage hybrid fiber-copper architectures either fiber to the cabinet (FTTC) or fiber to the building (FTTB) by using VDSL2 technology to provide high-speed broadband services nationwide. Higher data rates are available for subscribers located close to the cabinet, while subscribers with longer lines or with legacy equipment are served with the legacy service [2]. Figure 1 shows the adoption of DSL technologies for the copper access network in Malaysia.

Due to rapid competition, fiber broadband technology has overtaken traditional ADSL2+ slowly in offering fixed broadband in Malaysia. In 2018, take-up by ADSL2+ declined from 20.2 % to 0.91

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million and until now Telekom Malaysia as the main service provider in Malaysia is consistently upgrading its access network to support the initiatives [3].

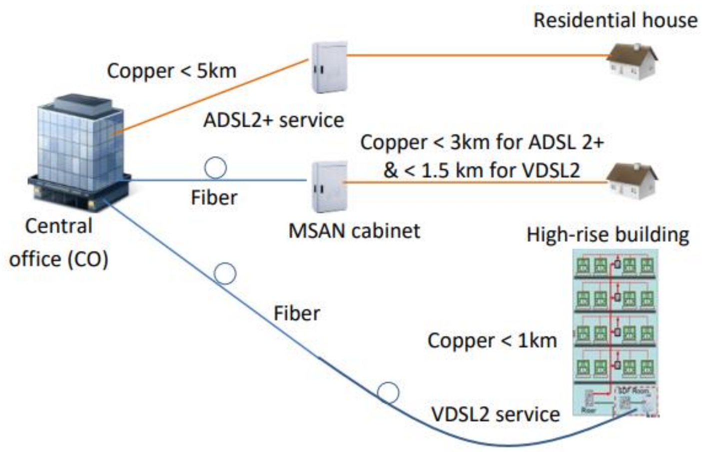

Fig. 1. The ADSL2+ and VDSL2 scenario deployment

However, to remain the legacy of the copper network, several vital strategies need to be considered by telecom providers [4]. The utilization and improvement of copper lines are essential due to the high-speed demand from customers. The maintenance of copper access network and migration processes from ADSL2+ to VDSL2 need to properly manage because the biggest drawback of DSL lines is the high risk of faults and disturbance existence [5]. Faults in the copper line introduce distortion in the DSL signal that causes the packet loss and transmission delays, which in turn lead to low data rates and degraded the quality of service (QoS). The faults in the copper lines can be detected and located using time domain reflectometry (TDR) technique [6].

TDR is a well-known technique that is typically used to measure the impedance of discontinuities as a function of time (or distance) in electronic systems. It consists of an oscilloscope and a test signal generator, where the test signal is traditionally a voltage step [7]. A pulse signal is sent down to the cable and the reflected signal will include information about changes in impedance used for wire fault detection [8]. Other than that, changes in reflection shape, size and time delay possible to determine the faultsthat probably caused by a splice, cable transition, transformer, short, open, fault, etc.

The ability to qualify copper lines will allow telco service providers to offer a whole range of new services, reduce expenses that cause by faults, and also generate new revenues [9]. Mostly, DSL operators are using the copper length rule and relate with speed performance as their indicator during initial broadband deployment. Even though this approach is not optimal but it is valuable as an initial approach and the operators started to adjusts their deployment rules when actual operational performance is significantly better than the initial rule [10]. After a lot of VDSL2 systems are being deployed, the DSL operator adjusts the deployment rules when the operational performance is significantly better than the initial deployment rule [10]. In that sense, many tools are developed to help the telco providers to solve this issue [4,11 and 12]. Some of the tools able to estimate achievable bit rates [12] as well as fault detection in the lines and it becomes important for access network planning [11].

Copper line pre-qualification assessment is crucial especially when the service providers have to upgrade their access network to cater to high-speed broadband during migration from ADSL2+ to VDSL2. Other than that, this proposed assessment process needs to be embedded in the standard operating procedure (SOP) in access network planning or maintenance division for any telco's providers. Different service providers apply a different method to qualify the copper line before offering high-speed broadband. On-site measurement is crucial for the technical operation team either for network access planning or maintenance team. The study describes a strategy for the copper line quality assessment process to monetize the copper network for high-speed broadband either at HSBB, SUBB or RBB areas. The typical copper access network architecture will also be elaborated.

2. Method and Procedure

The proposed copper line pre-qualification assessment in this study consists of three stages as depicted in Figure 2.

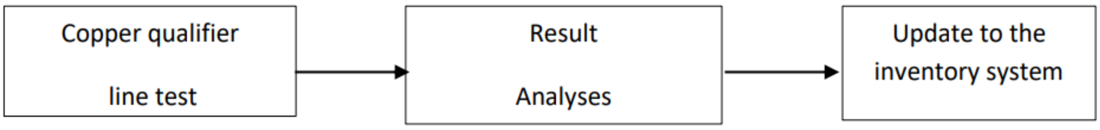

Fig. 2. Stages in copper pre-qualification assessment

Copper line qualifier test is proposed using commercial test gear, (EXFO Copper Qualifier Test Gear MAX610, Canada) to check the quality of the copper line and the capability of the copper access network to serve high-speed broadband. The test gear measured physical lines parameters results; Time Domain Reflectometer (TDR) data, isolation-resistance (IR), digital-multimeter (DMM) parameters, load coil information and wideband parameters (WB) with frequency up to 17 MHz. These parameters are such as longitudinal balance (LB), attenuation, power spectrum density (PSD) noise.

Figure 3 shows the test gear for the copper line qualifier test and the illustration of the on-site physical copper line measurement. The measurement is done at the multi-service access node (MSAN) cabinet or equipment's location at the central office (CO).

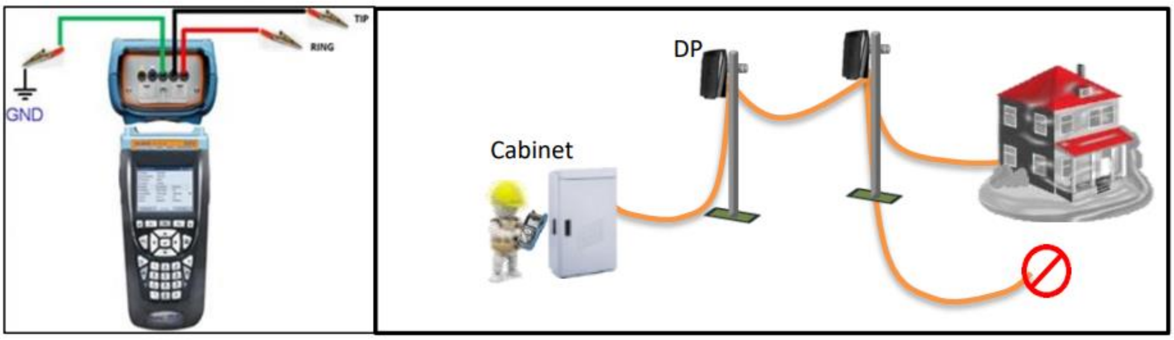

Fig. 3. Copper qualifier test gear and on-site physical line measurement

After the on-site measurement, the test result is analyzed before an update to the inventory system. Figure 4 shows the parameters of every stage for the overall copper line pre-qualification assessment processes.

There are five categories of parameters tested from the test gear, which represented overall information of physical copper line condition and covered frequency from narrowband up to wideband. Thus, the output from on-site measurement was analyzed using the developed algorithm to get overall copper line health condition with the speed estimation and fault detection as well as its location. Speed estimation calculation is based on three WB test parameters such as parameters attenuation, LB, and PSD noise [12]. For fault detection and its location, the information was analyzed using TDR data and DMM parameters such as capacitance, resistance, isolation, etc.

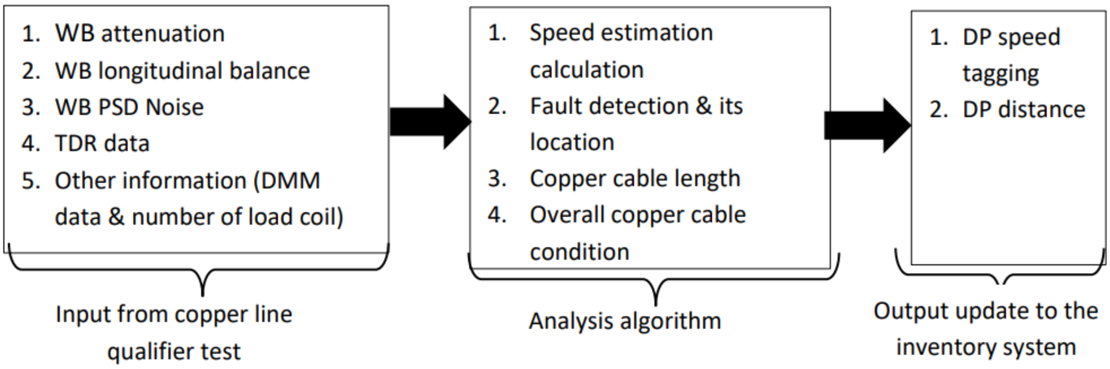

Fig. 4. Input and output parameters for each stages in copper line pre-qualification assessment process

The overall summary of the copper line health condition was based on fault identification and speed estimation modules. Business requirement criteria also being considered in this analysis algorithm when calculating the speed estimation. For example, the operation team measured a few lines for each DP and the results from each line will be evaluated and summarized to get DP speed estimation. This information is important for front liners when having a demand from customers because they need to check the capability of the copper line for high-speed broadband. Thus, the output from these analysis algorithms such as DP speed estimation and cable distance is important and needs to be updated immediately to the inventory system for beneficial of front liners.

3. Result and analysis

Figure 5 depicted the TDR results from the copper line qualifier test at high rise building with a hybrid copper-fiber access network, FTTB using VDSL2 technology. A few copper lines had been measured at the same DP for quality physical check purposes before offering high-speed broadband to the subscribers. From the three physical lines measured, it showed that no reflection been observed due to impedance discontinuity [13]. The electrical signal is sent down to the copper line until the end of the cable and the pulse continues down the end with gradual attenuation as shown in Figure 5. Hence, all tested lines considered having an excellent copper line condition.

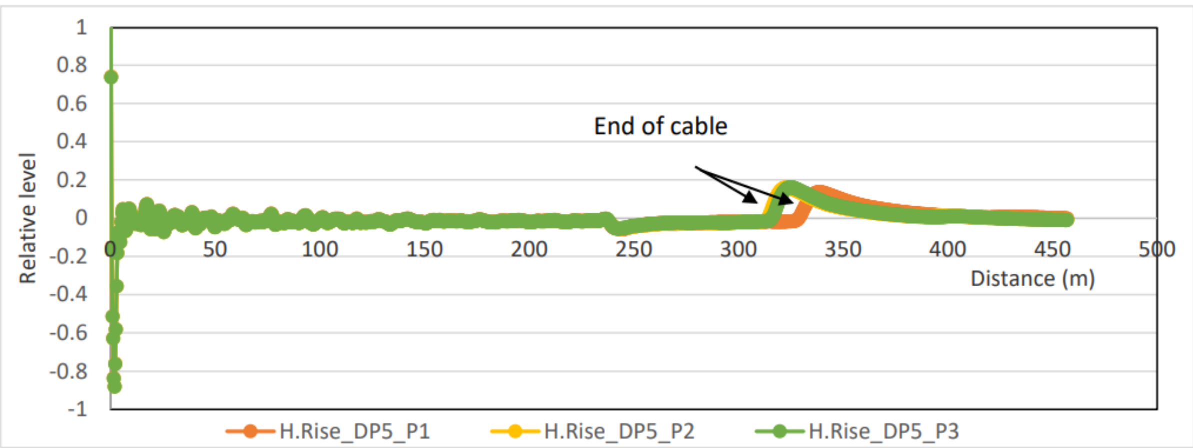

Fig. 5. TDR results for three different pairs at the same DP in FTTB network scenario

Meanwhile, for unstable copper line conditions, the impairments have been found in the copper line when performing tests at FTTC architecture, which serve connectivity to the landed premises. Figure 6 shows the result of TDR for measured lines and reflection detected when impedance discontinuity is identified in the line. A common type of impairment has been found in the measured lines which are open and short. DP2_P3 results display significant peak reflection at a distance of about ~230m, but DP1_P3 detected shortly at two different places, ~ 100m and 500m. Ghost reflection normally exists when the measured lines have a lot of impedance discontinuity and the accuracy of the copper line (end of cable). Thus, these results would assist the technical operation team in fixing the first impairment found in the cables. Verification is made by repeating the test until the result shows the standard pattern of good lines, as shown in Figure 6.

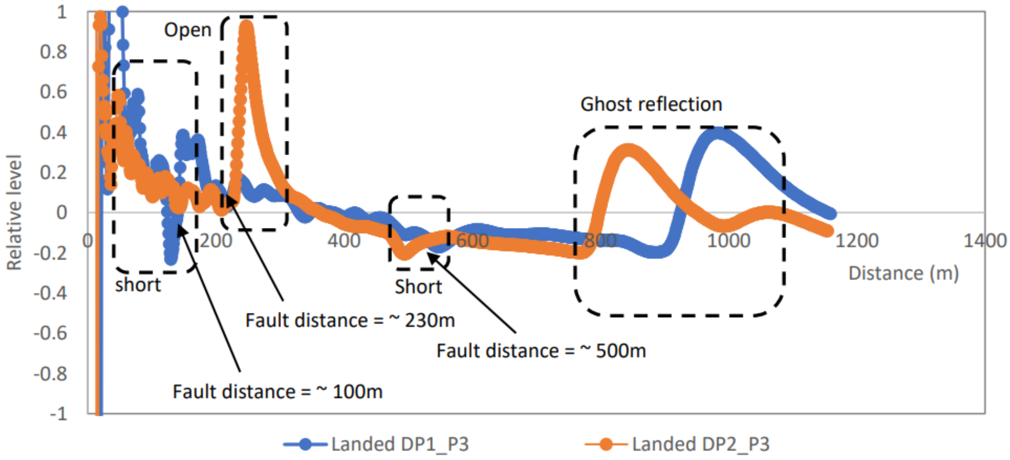

Fig. 6. TDR results from lines measured in FTTC architecture

The WB parameters from test gear such as WB attenuation, LB, and PSD noise are useful for speed estimation calculation by algorithm analysis. Other parameters from test gear such as metallic characteristics or DMM or no of load coil also being considered from the analysis algorithm besides TDR results. A significant impact towards speed performance can be observed when there were impairments in the lines as shown in Figure 7. The actual speed measurement had been done at a controlled environment and benchmarking for speed estimation calculation algorithm. Hence, the comparison of speed estimation calculation was performed based on the distance difference from 200m up to 1500m for VDSL2 technology.

The proposed algorithm analysis will tag the measured copper lines to unstable conditions whenever the result of TDR shows many reflections in the lines due to faults which can reduce the calculated speed. Figure 7 demonstrates the comparison of speed performance between the calculated and actual data of the FTTB and FTTC area measured lines. The copper line qualifier test at both lines in FTTB and FTTC shows only two different DPsin FTTC architecture gave the condition of one unstable line.

All measured copper lines with a good condition such as DP5 for high rise building with a distance of approximately 300m would be eligible to offer high-speed broadband. The significant impact from impairments towards speed performance when comparing result between different pairs at the same DP were also identified. Based on six copper lines measured at the landed house, DP1 and DP2 and four of the copper lines were able to offer maximum speed between 42Mbps to 50 Mbps and 8.2 Mbps to 19 Mbps for both downstream and upstream at a distance about 650m and 760m. However, the unstable lines at the landed house, (DP1_P1 and DP2_P3), show a significant loss of more than 50% due to impairments in the lines. Algorithm analysis showed that one of the measured line (DP1_P1) gave wrong a copper line distance due to faults exits (open) in the lines, as shown in Figure 7. Upon updating and tagging of unstable results to the inventory system, the front copper lines can avoid using that particular DP connected to the new subscribers for high-speed broadband. Meanwhile, action for rectification can be taken by the maintenance team division towards that area.

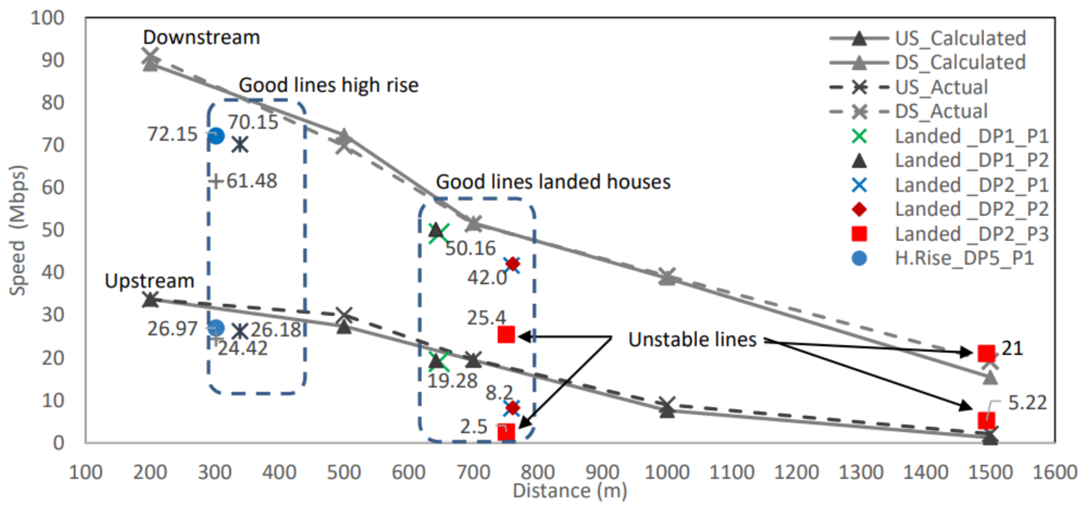

Fig. 7. Calculated and actual speed performance based on the different distance at control environment with speed performance calculated from copper line qualifier test

4. Conclusion

It can be concluded that the first step towards successful provisioning of high-speed broadband services is critical especially after a new deployment area or after the migration process from fully copper access network to hybrid coper-fiber networks, FTTC or FTTB architecture. Thus, copper line pre-qualification assessment method been proposed to meet this service requirement and considered as preventive initiatives which able to reduce maintenance cost, as well as a decreased number of customers, churn due to unsatisfactory with the service quality.

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