Comparative analysis of received optical powers in PON through measurements by power meters and telemetry

P. Chanclou, S. Le Huerou, M. Follain, J. Landos, F. Miet, A. Marie, F. Saliou, G. Simon

Orange Innovation, 2 Av. Pierre Marzin, 22300 Lannion, France philippe.chanclou@orange.com

Abstract *In the context of improving G-PON and XGS-PON diagnostic, we compare and analyse the quality of received optical power measured by PON power meters and network equipment at both ends.*

Introduction

For a Fibre To The Home (FTTH) network operator, it is crucial to quickly and efficiently diagnose problems that arise on the passive fibre infrastructure also named Optical Distribution Networks. The purpose of fibre diagnostics is to enable preventive and post-fault maintenance [1-4]. One-time and periodic tests results are processed to populate a database for fault diagnosis engines based on probabilistic model and machine learning [5, 6]. The quality of database is essential during network operations such as: installation, in-service monitoring, migration [7], …

In this paper, we will focus on the quality of the received optical power measurements [8] in upstream and downstream for G-PON and XGS-PON (Gigabit and 10 Gigabit Symmetrical capable Passive Optical Network). The received optical power values could be collected by a PON power meter (Px) and network equipment (PxONU at Optical Network Unit or PxOLT at Optical Line Terminal). For PON power meters, the data collection is done as a one-time test, during validation, installation, or restoration operations. Exceptionally, PON power meters can be used for periodic tests in the field by an on-site equipment for real-time monitoring. Data collection through the network equipment OLT and ONU is supported by Optical Layer Supervision (OLS) [9-12] with temperature, bias current, transmit and receive optical power parameters. Such values are available via the RSSI (Received Signal Strength Indication) of opto-electrical devices. In the table 1, we report the ITU-T parameters for received optical power at ONU and OLT (for different operating temperature range). Such received optical power telemetry could be collected periodically for a network surveillance.

We propose in this paper to compare experimental measurements of downstream and upstream received optical power on G-PON and XGS-PON modules obtained through several commercial PON power meters and RSSI.

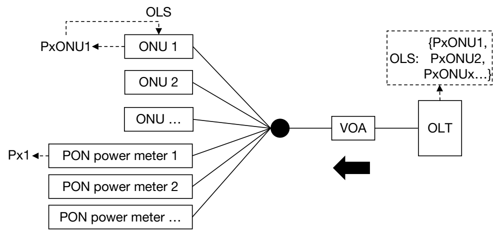

Fig. 1: Setup for downstream

Downstream received optical power accuracy

Figure 1 illustrates the experimental setup for downstream measurements using several vendors PON power meters and ONUs. We used a variable optical attenuator (VOA) to decrease the optical budget by a 1 dB step (the optical splitter was calibrated prior to measurements). Figure 2 shows the experimental measurements for G-PON and XGS-PON of the received optical power accuracy at 1490 nm and 1577 nm respectively. All measurements by the commercial PON power meters remain within an interval of ±1 dB. Through OLS, for G-PON, all ONUs provide a value within a range of ±2dB for optical power ≥-30dBm. For lower than -30 dBm optical power, we measured more variations in the received optical power measurements. For XGS-PON, we observed different behaviours depending on ONU vendors. We observed 3 ONUs with flat responses within an interval of ±2

Tab.1: Optical line supervision-related optical perceive power measurements G-PON and XGS-PON specifications

	Receive power	Typical range	Resolution	Accuracy	Repeatability	Typical response time
G-PON	ONU	-34 to -8 dBm	0.1 dB	±3 dB	±0.5 dB	300 ns
	OLT			±2 dB		
XGS-PON	ONU	-53 to -4.9 dBm		±3 dB		
	OLT	-32 to -4.9 dBm		±2 dB		

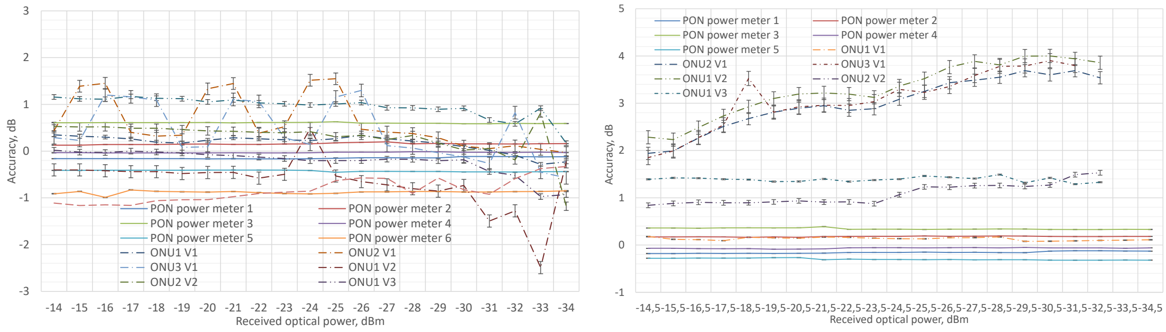

Fig.2: Received optical power measured for downstream of G-PON (left) and XGS-PON (right) by several PON power meter (solid lines) and several ONUs OLS (RSSI) (dashed lines)

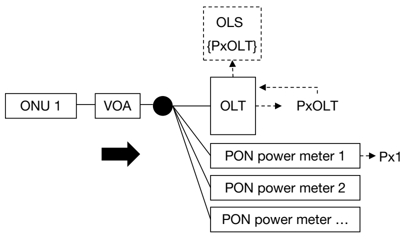

Fig. 3: Setup for upstream

dB and 3 other ONUs with divergent responses increasing conversely to the received optical power (variation up to 4 dB).

Upstream received optical power accuracy

Figure 3 illustrates the experimental setup for upstream power measurements from a single ONU for G-PON and then for XGS-PON using several vendors power meters or the OLT OLS. We used a VOA to decrease by a 1 dB step the ONU output optical power. In upstream, PON is working in burst mode. Optical power measurements must be done only during the time slot of the optical burst. To analyse the capability of PON power meter and OLT RSSI to support burst measurements, we configured the upstream bandwidth allocation with a T-Cont (Transmission Container) type 1 (corresponding to a fixed bandwidth) for several bandwidth allocations (BWA): 1 Gbit/s, 750, 500 and then 250 Mbit/s for G-PON and 9.953 (subsequently named 10), 7.5, 5 and then 2.5 Gbit/s for XGS-PON. For the maximum BWA value, the burst time condition is approaching a continuous optical signal (except for ranging window, inter-frame each 125 µs, …) like in downstream measurement.

Figures 4 and 5 show the experimental measurements for G-PON and XGS-PON for “maximum BWA” (1 and 10 Gbit/s, respectively) and “quarter BWA” (250 Mbit/s and 2.5 Gbit/s)

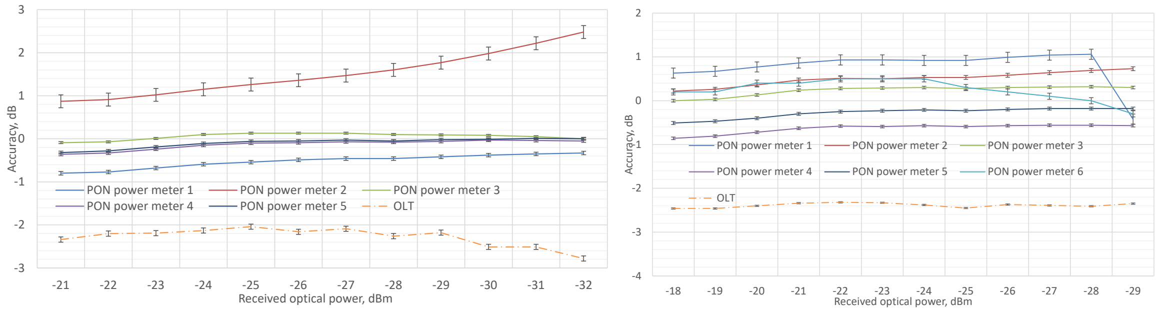

Fig.5: Received optical power measured for upstream of G-PON (left) with 250Mbit/s BW and XGS-PON (right) with 2.5Gbit/s BW by several PON power meters (solid lines) and the OLT OLS (RSSI) (dashed lines)

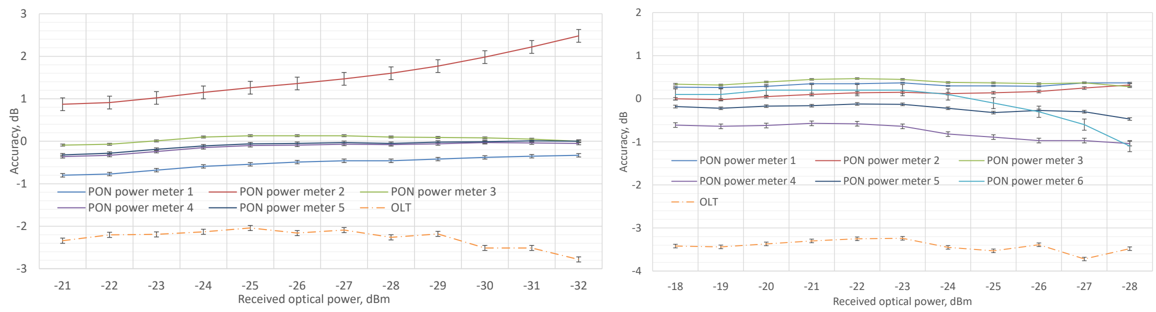

Fig.4: Received optical power measured for upstream of G-PON (left) with 1Gbit/s BW and XGS-PON (right) with 10Gbit/s BW by several PON power meter (solid lines) and the OLT OS (RSSI) (dashed lines)

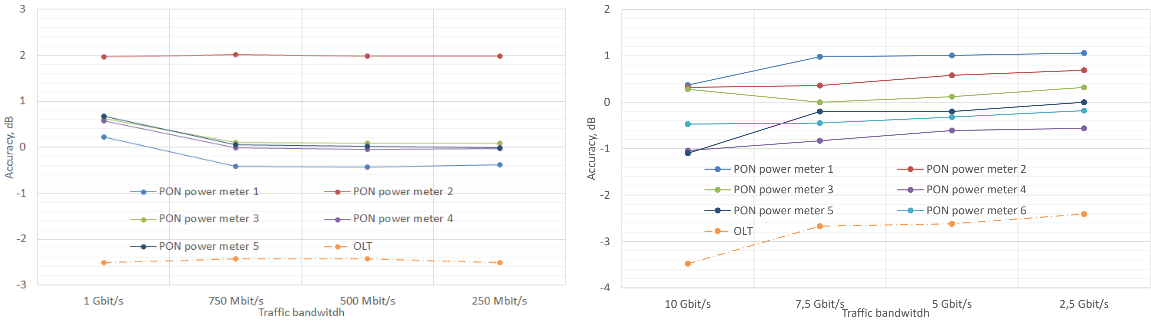

Fig.6: Received optical power measured for upstream of G-PON (left) at -30 dBm and XGS-PON (right) at -28dBm in function of BW by several PON power meter (solid lines) and the OLT OLS RSSI (dashed lines)

traffic BW. Except for one, all the commercial PON power meters upstream G-PON and XGS-PON were in an interval of ±1 dB. One commercial PON power meter which supports G-PON and XGS-PON, had a deviation for low optical power G-PON. For G-PON and XGS-PON, the OLS at OLT provide a received optical power value outside the ±2 dB required accuracy specifications. Also, the difference of received optical powers as a function of traffic BW for the two PON technologies are shown on Figure 6. The variation of the optical power may be due to either the ONU launched power difference for long or short bursts, or to the performance of the time window integration of the PON power meter. We observed a variation of the received optical power measurements between “maximum BWA” and “reduced BWA”.

ONU received optical power repeatability

Every 3 minutes for 58 and 48 hours, we collected the RSSI parameters and especially the received optical powers of several G-PON and XGS-PON ONUs, respectively. Figure 7 illustrates the repeatability of these measurements. The repeatability remained under ±0.1 dB for 11 G-PON and 2 XGS-PON ONUs.

Conclusions

Before concluding, we insist on the fact that the quality of the network data monitoring collection is critical for the efficiency of diagnosis and other operations. The evolution f modern OLT interface dedicated to monitoring like IPFIX (IP Flow Information Export) or gRPC (Remote Procedure Call) trends to increase the quantity and the frequency of the data collection.

The monitoring of the ONU and OLT optical performances allows to also monitor the ODN. Received optical power is one of prominent parameter to monitor. This study shows that even PON power meters might have measurement deviations for low optical powers. A typical measurement is within ±1 dB accuracy. OLS provides for G-PON downstream about ±2 dB in adequation with ITU-T recommendations. For XGS-PON downstream, there is a lack of accuracy observed for several ONU vendors. For G-PON & XGS-PON upstream, the measured accuracies do not follow the ITU-T recommendations.

Now, HS-PON (Higher Speed PON) is coming with a new metrology methodology based on TDEC (Transmission Dispersion Eye Closure) and OMA (Optical Modulation Amplitude) which needs to have ever finer monitoring due to reduced operational margins. In addition, physical layer eye analysis is a potential parameter that could be included in the future of PON telemetry.

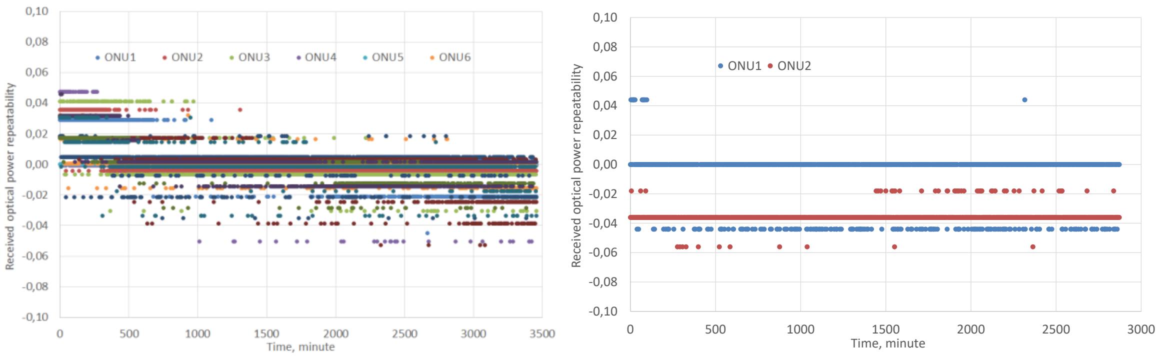

Fig.7: Received optical power repeatability for downstream of G-PON (left) and XGS-PON (right) at several ONUs

References

[1] F. Caviglia and V. C. Di Biase, "Optical maintenance in PONs," 24th European Conference on Optical Communication. ECOC '98 (IEEE Cat. No.98TH8398), 1998, pp. 621-625 vol.1, DOI: 10.1109/ECOC.1998.732752.

[2] A. Ehrhardt et al., "PON measurements and monitoring solutions for FTTH networks during deployment and operation," 2011 13th International Conference on Transparent Optical Networks, 2011, pp. 1-6, DOI: 10.1109/ICTON.2011.5970861.

[3] A. Ehrhardt, H. -. Foisel, F. Escher, A. Templin and M. Adamy, "Monitoring of the transparent fibre infrastructure for FTTx networks: An operator's view," 2010 12th International Conference on Transparent Optical Networks, 2010, pp. 1-5, DOI: 10.1109/ICTON.2010.5549138.

[4] N. F. Naim, M. S. Ab-Rahman, S. S. Sarnin and A. A. A. Bakar, "Real-time monitoring system for ethernet passive optical access network," 2015 IEEE 11th International Colloquium on Signal Processing & Its Applications (CSPA), 2015, pp. 30-33, DOI: 10.1109/CSPA.2015.7225613.

[5] A. Echraibi, J. Flocon-Cholet, S. Gosselin and S. Vaton, "Deep Infinite Mixture Models for Fault Discovery in GPON-FTTH Networks," in IEEE Access, vol. 9, pp. 90488-90499, 2021,DOI: 10.1109/ACCESS.2021.3091328

[6] S. Gosselin, J. Courant, S. R. Tembo and S. Vaton, "Application of probabilistic modeling and machine learning to the diagnosis of FTTH GPON networks," 2017 International Conference on Optical Network Design and Modeling (ONDM), 2017, pp. 1-3, DOI: 10.23919/ONDM.2017.7958529.

[7] G. Simon, P. Chanclou, F. Saliou, J. Potet and M. Wang, "Clustering G-PON Field Data to Improve Flexibility in Next Generation PON Systems," 2021 European Conference on Optical Communication (ECOC), 2021, pp. 1-4, DOI: 10.1109/ECOC52684.2021.9606075.

[8] A. Maslo, N. Goran, M. Hodžić, E. Škaljo and A. Mujčić, "A practical analysis of attenuation in segment of home installation of FTTH networks," 2020 28th Telecommunications Forum (TELFOR), 2020, pp. 1-4, DOI: 10.1109/TELFOR51502.2020.9306628.

[9] ITU-T, L.25: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT (01/2015)

[10] ITU-T, G.984.2 (08/2019), Annex B “Description of physical layer measurements to support optical layer supervision”

[11] ITU-T, G.9807.1 Amendment 2 (10/2020), Appendix B.II “Physical layer measurements required to support optical layer supervision”

[12] ITU-T, G.984.3 Amendment 3 (04/2012), Annex C « PON-ID maintenance »