Optical Diagnostic Challenges in BPON Networks – Subsystem Vendor Perspective

White Paper

Abstract: Unlike conventional point-to-point optical networks, passive optical networks require dedicated test and measurement techniques of the optical modules. The point-to-multipoint configuration in conjunction with the bidirectional and multi-wavelength implementation of the optical transceiver necessitates implicit measurement methods to extract those parameters.

1. Introduction

Fiber-to-the-home (FTTH) networks that are based on passive optical network (PON) architecture raise some specific diagnostic challenges in the network, system, and component level.

Conventional optical networks for the long-haul or metro regions are typically based on point-to-point architectures and therefore there is a clear distinction between the different network layers. For example, as shown in [1], DWDM networks are subdivided to optical transport (OTS), optical multiplexing (OMS), and optical channel (OCH) layers. That subdivision enables modular equipment design and simplifies network installation and diagnostics.

PON architecture is a point-to-multipoint architecture. Since many users are connected to one central optical line terminal (OLT) a shared time-domain multiplexing (TDM) channel is used in the downstream direction. In the upstream a time-domain multiple access (TDMA) approach is used to allow each optical network unit (ONU) to transmit its traffic during its dedicated timeslot.

The transmission and reception of optical signals in several wavelengths and in both directions over a single fiber complicates the optical diagnostics and fault isolation of PON architectures and network elements.

2. Network Architecture and Layer Separation

Fig. 1 depicts the architecture of the PON and the functional partitioning of the OLT and ONU elements. The PON is based on a optical passive splitter to form the point-to-multipoint configuration. The network elements are partitioned to the following functions: (i) Optical distribution network (ODN), (ii) a physical (PHY) layer function that includes the PON transceiver; (iii) Medium access control (MAC) that aggregates both services and control cells; (iv) Service adaptation function (SAF) that translates specific services (e.g., voice, data) into ATM cells; (v) and management and control function.

The ODN diagnostics is based on measurements of optical parameters using optical time-domain reflectometer (OTDR) and optical loss testers (OLTS). The system service layer is subject to service-specific operational testing (e.g., voice, Ethernet LAN, CATV, etc.). PON-specific functional testing relates to the MAC and PHY functions, PON operations and maintenance, and also includes support of quality of service (QoS), dynamic bandwidth allocation (DBA), and ONU discovery and auto-ranging.

However, between the two extreme ODN and service layers there is a gap. Subsystem and module testing is not always based on standardized test equipment. The reason for that is threefold:

- Lack of mature and standard interfaces. For example, UTOPIA interface is available between the SAF and MAC but there is no definition for the interface between the MAC and PHY, yet.
- PON optical front-ends (e.g., diplexers, triplexers) integrate the laser transmitter, PIN diode receiver and the wavelength (de)multiplexer. Thus, direct measurement of optical isolation and crosstalk parameters is feasible only during module assembly.
- The shared nature of point-to-multipoint architectures requires that some subsystem parameters can be measured employing higher level system functionality. For, example OLT receiver sensitivity is measured in conjunction with ONU discovery and auto ranging process.

The above reason (in addition to economic considerations) leads to the lack of fully conformed test equipment, and forces system vendors to develop PON specific diagnostic procedures.

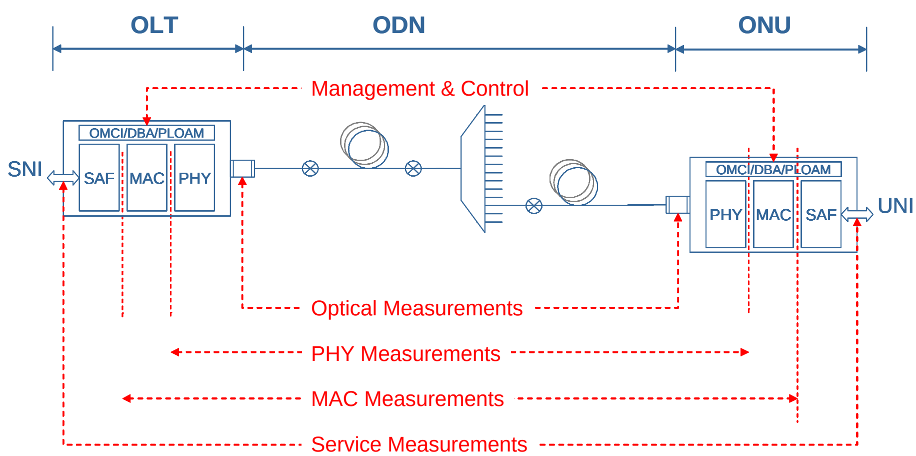

Fig. 1. The diagnostic layers and interfaces in a PON architecture.

3. Optical Diagnostics Procedures

Our focus in this section is on optical measurements and diagnostics that differentiate from standard procedures.

In the upstream direction, OLT receiver sensitivity and bit-error rate (BER) differs from regular point-to-point links. Conventional links can be measured regardless of the higher layer protocol (e.g., Ethernet, SONET/SDH, PON downstream direction) due to their continuous transmission mode. In the upstream direction of PON architectures we have to take into account the bursty nature of the data and the distinguished distances of each ONU. Thus, when we characterize the OLT receiver sensitivity we have to do so as part of a PON in conjunction with several ONUs and not only as a stand-alone link. Fig. 2 shows a test setup for OLT receiver sensitivity. It includes two ONUs, one is placed near the OLT and the second far down the link. Thus, the OLT receiver has to capture a weak upstream burst that follows a strong one. We measured the OLT sensitivity in three scenarios – continuous-mode measurement, single ONU burst-mode measurement, and dual ONU burst-mode measurement – and found out up to 1dB difference between these methods.

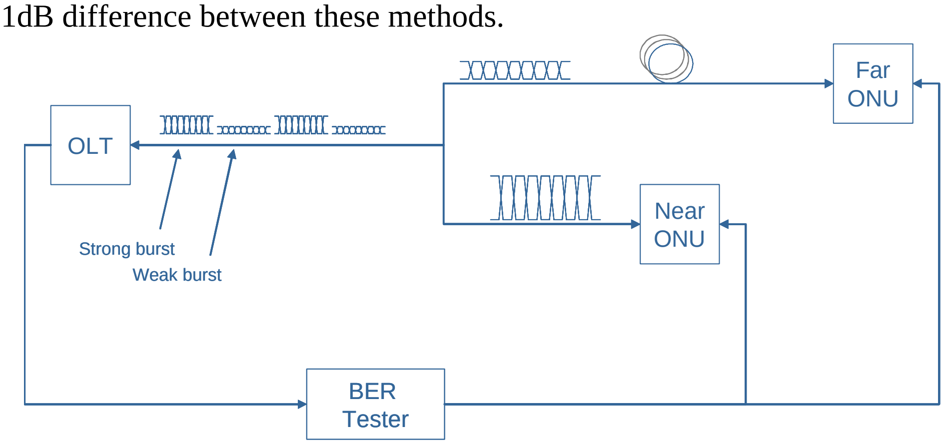

Fig. 2. Test setup of OLT receiver sensitivity.

PON architectures could also support an RF video overlay using additional wavelength. That emphasizes the optical isolation parameters between the two wavelengths of the ONU receiver in the downstream direction. Direct measurement is feasible only during the triplexer assembly. Once it forms an integrated electro-optic unit we have to sift these parameters through BER measurements of the digital signal and carrier-to-noise (CNR) measurements of the video signal. Based on the isolation calculation model that was proposed by Schoop et al. [2] we run a test procedure that characterizes BER and CNR under crosstalk situation and extract isolation parameters after curve fitting of the results. Fig. 3 depicts the test setup for that procedure. We use a BER tester to characterize the digital baseband link while a network analyzer is used to generate the equivalent video signal. Optical attenuators control the power levels of both signals and hence determine the crosstalk level.

Fig. 4 (left) demonstrates the impact of the CATV crosstalk component on the BER degradation of the digital signal. We performed the calculations for sensitivity of -30 dBm. We add CATV noise component in the range of -50 ÷ -30 dBm and plot the receiver BER while setting the digital power level to its sensitivity level, sensitivity level -1 dB, and sensitivity level +1dB.

Fig. 4 (right) demonstrates the impact of the digital signal crosstalk component on the CNR degradation of the CATV receiver. Using a CATV receiver that has CNR = 44 dB at -6 dBm we add average digital signal power at the range of -50 ÷ -30 dBm and plot the receiver CNR while setting the CATV power level to its minimum sensitivity level (-6 dBm), sensitivity level -1 dB, and sensitivity level +1dB.

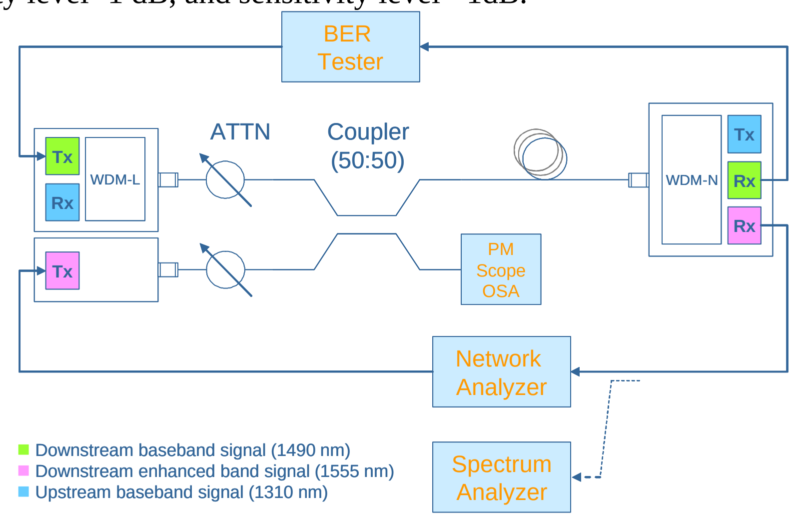

Fig. 3. Test setup for ONU optical isolation.

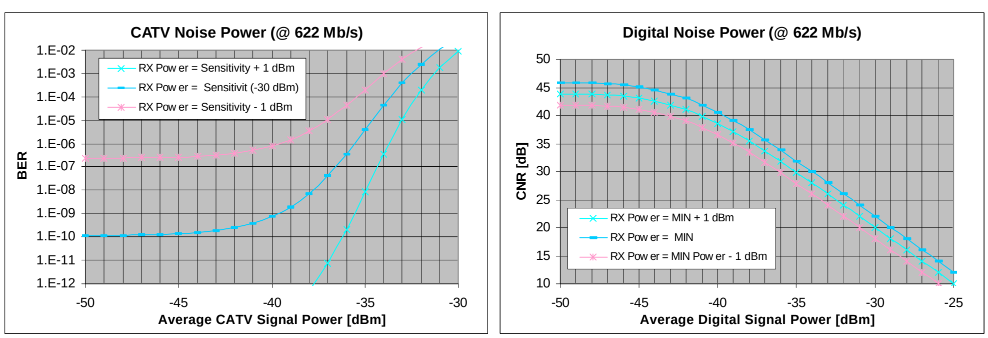

Fig. 4. Influence of CATV signal on BER of the digital receiver (left): Influence of digital signal crosstalk on the CNR of CATV receiver (right).

4. Conclusions

PON architectures raise the need for PON-specific test methods that differ from conventional optical test methods, to characterize the parameters of their subsystems and modules.

5. References

1. GR-2918, DWDM Network Transport Systems with Digital Tributaries for Use in Metropolitan Area Applications: Common Generic Criteria, Issue 6 (Telecordia Technologies, January 2003).
2. ECOC: R. Schoop, F. Fredricx, T. Koonen, C. Hardalov, “WDM Isolation Requirements for CATV in BPON”, in Proc. ECOC 02 conference, (ECOC, Copenhagen, Denmark, 9-12 September 2002) pp. 1-2.