10A2-2

# Performance of Wavelength Shared Hybrid PON

**Paparao Palacharla, Martin Bouda, Youichi Akasaka, Alexander Umnov, Takao Naito**

*Fujitsu Laboratories of America, Inc., 2801 Telecom Parkway, Richardson, TX 75082*

Tel: +1-972-479-2450, Fax: +1-972-479-4482, Email: paparao.palacharla@us.fujitsu.com

## Abstract

Wavelength shared hybrid PON provides seamless evolution from existing TDMA PONs to deliver high bandwidth triple play services. The associated transmission convergence layer protocol and performance of analog video overlay are presented.

## 1 Introduction

The demand for bandwidth in the last mile access network is constantly increasing due to new applications such as HDTV, P2P applications, video-on-demand, interactive games/ conferencing etc. As a result, network operators are interested in approaches for evolution from today's TDMA-PON [1,2] systems to next generation PON systems with higher bandwidth. Next generation PON architectures can be categorized into three approaches: 1. Increasing the speed of TDMA (e.g. 10 Gb/s line rate), 2. Providing a wavelength to each user (WDM-PON) [3], and 3. Combining TDMA and WDM. In the short term, designing and manufacturing of 10 Gb/s burst mode transceivers at low cost is a challenge. The second approach of allocating a wavelength to each user entails higher cost due to the need for colorless ONUs based on technologies such as spectrum slicing, reflective SOA etc. The third approach of combining TDMA and WDM relies on off-the-shelf components and technologies to share the fiber infrastructure using simple system configuration at lower cost. The recently proposed novel PON architecture based on the combination of TDMA and WDM, called Wavelength Shared-Hybrid PON (WS-HPON), satisfies future bandwidth demand as well as mitigates the impairment of analog video due to Raman crosstalk [4,5]. In this paper, we discuss the transmission convergence protocol and characterize the performance of analog video overlay in WS-HPONs.

## 2 Wavelength Shared Hybrid PON Architecture

The WS-HPON architecture shown in Figure 1 uses either CWDM or DWDM wavelengths for digital data transmission in the downstream direction, while in the upstream direction a single wavelength at 1310nm (same as standard PON systems) is used. Each downstream wavelength is shared by a group of ONUs, thereby lowering the cost but increasing the downstream bandwidth N-fold, where N is the number of downstream wavelengths. Since the upstream wavelength is same as TDMA-PON, the existing TDMA-PON ONUs can be made WS-HPON ready for future upgrade. This WS-HPON architecture provides flexible bandwidth upgrade at lower cost and complexity compared to WDM-PON.

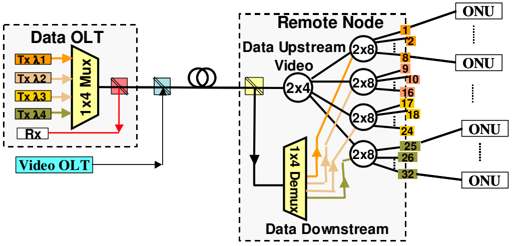

Figure 1. Wavelength Shared Hybrid PON architecture

In this architecture, the different downstream wavelength signals at the OLT are combined using a wavelength multiplexer and launched into the feeder fiber. The remote node for WS-HPON architecture shown in Figure 1 has two paths. The feeder fiber from the OLT is terminated with a 3-port WDM filter at the junction of the two paths. This filter separates out the downstream wavelengths of the digital signals and sends them to the lower path. The upper path is used for broadcasting the video overlay signal downstream at 1550nm to all ONUs and also for combining upstream 1310nm signal from all of the ONUs. The lower path consists of wavelength routing (filtering) component to direct each downstream wavelength to a different group of ONUs. The two paths are combined using couplers/splitters. Figure 1 shows an example configuration with 4 downstream wavelengths for digital data serving four groups of 8 ONUs each. One of the main advantages of this next generation PON architecture is that the optical loss for downstream data signals is lower than that of the overlay broadcast video signal and also to the typical downstream loss of a power splitter based PON (e.g. TDMA-PON, stacked PON), which allows the transmitter power at OLT to be 5.5 dB lower per wavelength. This lower transmitted power results in reduction of Raman crosstalk in

WS-HPON architecture compared to standard PON or stacked PON architectures.

## 3 Transmission Convergence Protocol for WS-HPON

The logical topology of WS-HPON is shown in Figure 2. The downstream traffic is sent to ONUs via multiple wavelength transmitters, while a single receiver at the OLT receives the upstream traffic. Each group of ONUs associated with a downstream wavelength can be viewed as a virtual PON. So the discovery phase (including serial number acquisition and ranging [1,2]), can be done sequentially for each downstream wavelength transmitter. This requires no changes to existing transmission convergence layer protocol [1, 2]. The reachability table associating the wavelength transmitter with the corresponding ONUs is established at the OLT during this discovery phase.

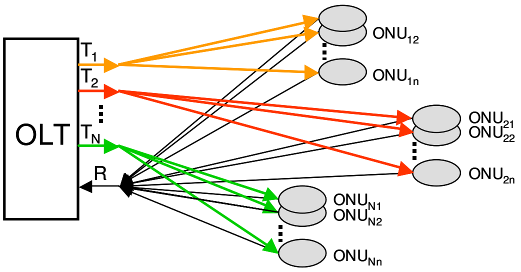

Figure 2. Logical topology of WS-HPON

## 4 Experiment

The experimental setup used an analog video transmitter operating at 1554nm and amplified by an EDFA to 20 dBm. The RF video input to the transmitter is a combination of four un-modulated carriers (channel 2 @ 55.25MHz, channel 3 @ 61.25 MHz, channel 4 @ 67.25 MHz and channel 5 @ 77.25 MHz). The CWDM OLT transmitter used four SFPs operating at CWDM wavelengths of 1430 nm, 1450 nm, 1470 nm and 1490 nm. These SFPs were driven with a $2^7$ PRBS pattern. These signals were combined with analog video signal and launched into different feeder fiber lengths. At the end of the fiber, the video signal was separated and attenuated independently to 0 dBm at the input of the triplexer. Table 1 shows the experimental results of carrier-to-spur ratio measurements for various optical power levels launched into the feeder fiber of 10 km. Initially measurements were done for each CWDM downstream wavelength. The amount of Raman crosstalk (carrier-to-spur) is dependent on the wavelength. The 1450nm wavelength with a separation of ~100nm (at the peak of Raman gain spectrum) from the video signal has the highest crosstalk, while the 1430nm wavelength has the lowest since the separation is ~120nm (other side of the Raman gain spectrum peak). The acceptable carrier-to-spur is < -60 dB according to the CATV standard. In the experiment, the transmitter power levels for GPON/stacked PON and WS-HPON are set at 1.5 dBm and –4 dBm (due to 5.5 dB lower loss) respectively. The standard GPON downstream wavelength of 1490nm shows unacceptable carrier-to-spur even at the minimum launch power of 1.5 dBm. In the case of WS-HPON architecture, the launch power of –4 dBm results in acceptable carrier-to-spur of –66.5 dB. For 4λ CWDM case, we estimate the carrier-to-spur for stacked PON architecture and WS-HPON architecture is around –49 dB and –60 dB respectively, a reduction of 11 dB in crosstalk. These measurements can be viewed as worst-case crosstalk since all wavelength channels are driven by the same traffic pattern. In actual network deployment each wavelength channel is driven by GPON formatted signals with different content, the crosstalk levels are expected to be lower.

| | **Wavelength (nm)** | | | | **4λ CWDM** |
|---|---|---|---|---|---|
| | **1430** | **1450** | **1470** | **1490** | |
| **GPON/ Stacked PON** | -60.5 | -52 | -54 | -56 | -49 |
| **WS-HPON** | -71 | -63 | -65 | -66.5 | -60 |

Table 1. Experimental results showing carrier-to-spur (in dB) of video signal

## 5 Conclusion

Wavelength shared hybrid PON architecture delivers at least 4-fold increase of bandwidth to each user compared to standard PON architectures. We have shown that existing standard GPON protocol can be used without any changes in WS-HPON. This allows bandwidth upgrade without replacement of existing ONUs in the field. In addition, WS-HPON reduces the effect of Raman crosstalk on video overlay signal by more than 10 dB compared to stacked PON architecture.

## 6 References

[1] ITU-T G.984, “Gigabit-capable Passive Optical Networks (GPON)”, 2004

[2] IEEE 802.3ah, “Media access control parameters, physical layers and management parameters for subscriber access networks”, 2004

[3] F. Effenberger et.al., “An introduction to PON technologies”, IEEE Comm. Mag., pp. S17-S25, Mar 2007

[4] M. Bouda et.al., “Cost-Effective Optical Access Upgrades using Wavelength Shared Hybrid Passive Optical Network Architecture,” Paper NThD5, NFOEC 2007

[5] P. Palacharla et.al., “Video overlay in next generation PON”, Paper OWS5, OFC 2007.