Hybrid TDM-WDM 10G-PON for High Scalability Next Generation PON

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***Abstract*— Current passive optical networks (PONs) (Gigabit PON (GPON) and Ethernet PON (EPON)) will run out of bandwidth sooner or later due to the ever increasing bandwidth demand. These standards and the new next generation (NG-PON) standards (10 Gigabit-PON (XG-PON) and 10 Gigabit Ethernet-PON (10G-EPON)) are based on time division multiplexing (TDM-PON) which also has its limitations. In this paper hybrid TDM-WDM PON architecture is proposed to meet the requirements of NG-PON. The proposed TDM-WDM PON architecture has longer reach than 10G TDM-PON and has high scalability. System architecture and system performance characterization will be presented considering long-reach PON.**

Keywords—component; PON; WDM; hybrid TDM-WDM; next generation PON; bandwidth demand.

I. INTRODUCTION

Research activities are focusing on possible extensions of NG-PON1 since these systems may suffer bandwidth limitations in the future, and they do not make use of the full optical bandwidth [1]. There are two 10 Gb/s PON systems recently standardized to extend current PONs and to satisfy the requirements of NG-PON1. These standards, defined by both IEEE and ITU-T, allow backward compatibility and co-existence with the current generation PONs (GPON and EPON), enabling progressive upgrades with minimal financial investment on the ODN (Optical Distribution Network) and minimal operational impact on existing users [2]. The IEEE and the ITU-T with the Full Services Access Network (FSAN) group, have defined their respective 10 Gb/s solution, namely 10 GE-PON [3] and ITU-T XG-PON [4].

All these standards are based on TDM-PON which has its limitations. Using one wavelength for downstream and one for upstream data limits the average bandwidth per user and the available bandwidth of a single fiber is wasted. Also, it limits the system reach due to the high required splitting ratio (32, 64 or 128). For example, for a 32 split and a 28 dB link budget, this will typically limit the system reach to about 20 km. Therefore, mixing the TDM-PON with WDM capabilities can overcome these problems.

Pure WDM-PON, OCDMA (Optical Code Division Multiple Access) PON, or OFDM (Orthogonal Frequency Division Multiplexing) PON technologies are not nearly as matured as TDM PON today[5]. Furthermore, other WDM hybrid schemes (based on added SCMA (Subcarrier Multiple Access) or CDMA) from today's perspective do not seem to offer advantages over the WDM/TDMA hybrid PON [6].

In this paper hybrid architecture that combines TDM and WDM technologies is proposed. The performance in terms of the highest possible reach and data rate (without any form of amplification) is evaluated and compared with traditional TDM-PON.

II. ARCHITECTURE OF THE PROPOSED SYSTEM

The proposed architecture uses four wavelengths in each direction to increase the network capacity as can be seen from Figure 1. It employs coarse-wavelength division multiplexing (CWDM) technology in the upstream because they are cheaper than dense-wavelength division multiplexing (DWDM) transmitters with a channel spacing of 0.8 nm used in the downstream (optical line terminal (OLT) side). DWDM is used in the downstream because of the narrow frequency band that is defined by GPON standard.

In hybrid TDM-WDM PON each group of users share one wavelength in the time domain. In the case of four wavelengths for 32 users, each group will comprise of 8 users.

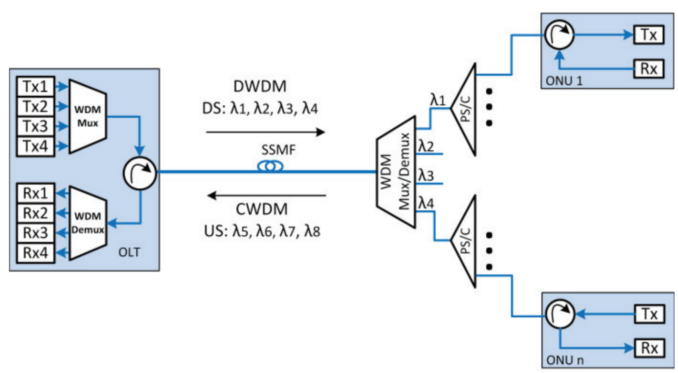

Fig. 1. Architecture of the proposed system.

The system transceivers capability is 2.5 Gbps, taking advantage of the existing GPON transceivers. Typically the input power is between 0 dBm to 5 dBm and the receiver sensitivity is -30 dBm. Table 1 shows the operating wavelengths for this architecture as specified for GPON downstream and upstream. OptiSystem 11.0 software tool is used to simulate the proposed system.

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TABLE I. HYBRID TDM-WDM PON WAVELENGTHS ALLOCATION

Downstream Wavelengths	Upstream Wavelengths
1496.0 nm	1271 nm
1496.8 nm	1291 nm
1497.6 nm	1311 nm
1498.4 nm	1331 nm

III. RESULT AND ANALYSIS

The performance analysis is based on the Q Factor. The reason why the results are presented in Q-Factor instead of BER (Bit Error Rate), because in high Q-Factor (more than 40) the BER will be zero, so we will not have an exact performance indicator. However, the BER and the Q Factor are used interchangeably. Our target Q-Factor in this paper is 7 which is equivalent to BER=10^-12 (reference BER for XG-PON [4]). The Q-Factor was computed when the fiber length is varied from 20 to 100 Km to different number of users (32, 64 and 128). For comparison, 10G TDM-PON architecture was simulated with one wavelength for each direction.

A. The Proposed System as Long-Reach PON

From figure 2 it is clear that the maximum distance for the hybrid architecture is 100 km for a Q Factor = 7 when the number of users was 32. Since we have in this model eight wavelengths (four for the downstream and four for the upstream), the limited factor for the maximum transmission distance is the wavelength that has the worst performance. Table 2 shows the maximum distance for different number of users for the hybrid architecture and conventional TDM-PON.

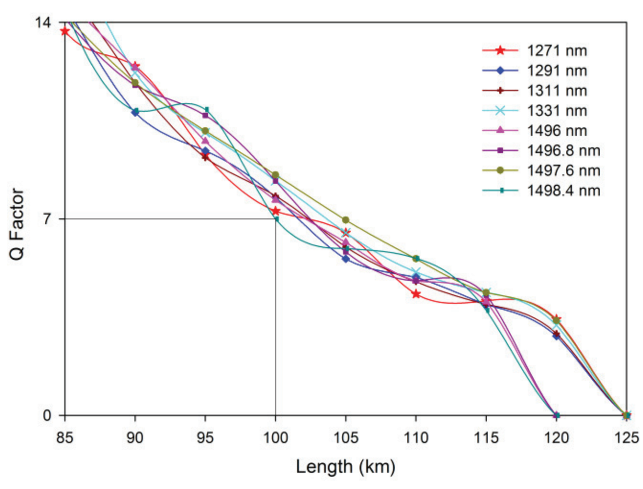

Fig. 2. Q Factor performance of varied fiber length for 32 users.

It is clear that the hybrid architecture has great power budget capability due to reduction in the splitting ratio by four times. Consequently, this architecture can be used as a Long-Reach PON without using any amplifier or reach extender, which can reach up to 100 Km for 32 users.

TABLE II. MAXIMUM DISTANCE FOR HYBRID TDM-WDM AND TDM-PON COMPARISON

Number of Users	Maximum Distance	
	Hybrid TDM-WDM	*TDM-PON*
32	100 km	65 km
64	85 km	55 km
128	70 km	40 km

B. The Proposed System Scalability

The Hybrid TDM-WDM PON architecture, beside its high power budget capability also has more future proofing than 10G TDM-PON. Figure 3 shows the Q Factor performance for the hybrid and TDM-PON architectures for data rate from 10 Gb/s to 75 Gb/s (32 Users, 20 Km). The Hybrid TDM-WDM PON architecture gives good performance at data rate up to 70 Gb/s, while 10G TDM-PON architecture performance will not meet the reference Q Factor when the data rate goes beyond 18 Gb/s. This is due to distributing the impact of chromatic dispersion over four wavelengths instead of one wavelength when increasing the data rate. In addition, the hybrid architecture divides the ONUs to four groups which allows any group to operate at different data rate which gives more flexibility and pay as you grow option.

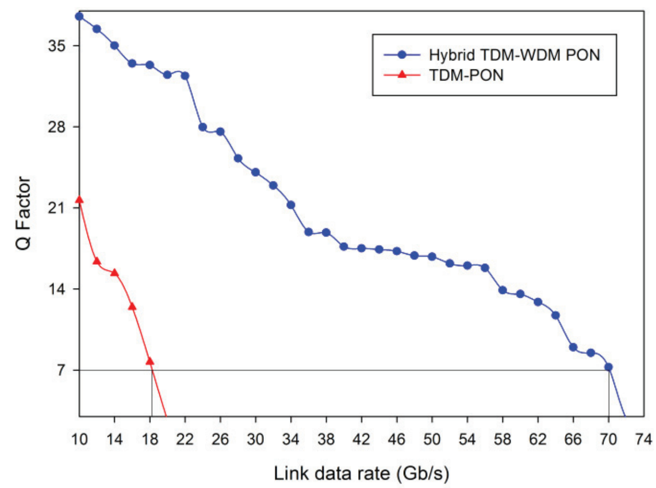

Fig. 3. Q Factor performance for varied data link rate for the two architectures.

With ODN capable of supporting up to 70 Gb/s, this makes the hybrid architecture a good candidate not just for NG-PON1 but also for NG-PON2 which requires data to be 40 Gb/s [7]. The drawback of the proposed system is having to make some modifications in the previous standards ODN (adding a WDM component in the remote node is needed), which will decrease the maximum reuse of the existing ODN.

IV. CONCLUSIONS

In this paper, the performance of proposed hybrid TDM-WDM PON was presented and compared with 10G TDM-PON. The main advantages of the hybrid architecture are its flexibility in future scaling of bandwidth and reach. Therefore, the hybrid architecture has great performance compared to the 10G TDM-PON and is suitable architecture for NG-PON. Some studies are needed in order for the hybrid architectures to be compatible with the existing ODN.

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