Comparison of 10 Gbit/s PON vs WDM-PON

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Abstract *For next generation PONs, the main effort is currently on increasing the line rate with 10GPON while WDM-PON is increasingly being discussed. These approaches are compared based on performance, cost and power consumption.*

Introduction

With an ever increasing demand for bandwidth driven by media consumption such as file-sharing, high-definition video, gaming etc. the need for more and more capacity both for end user access and transport networks is a reality. In addition, the explosion of mobile broadband, primarily serving Internet users, also requires high capacity backhaul links to serve radio base stations such as future LTE.
Increasingly, operators world-wide are deploying Gigabit-capable Passive Optical Networks (GPON[1]) to meet these demands.
As there are no signs of the demand for bandwidth slowing down in the future, next generation PON (NG-PON) technologies offering higher bandwidth than GPON are being investigated.

Introduction and Standardization

Much effort on NG-PON is currently being done in pre-standardization and standardization bodies such as FSAN/ITU-T for 10GPON and IEEE P802.3av task force for 10G EPON. This paper will focus on the FSAN track.
In FSAN, NG-PON is divided into two types: NG-PON1 for higher speed GPON, i.e. using time-division multiplexing (TDM) in the downstream (DS, towards the end-used) and time-division multiple access (TDMA) in the upstream (US) and NG-PON2 where the technology is open.
NG-PON1 is required to work over existing GPON fiber plants and come in two speeds: XG-PON1 with 10G/2.5G DS/US and XG-PON2 with 10/10G.
An interesting candidate technology for NG-PON2 being much discussed and researched is wavelength division multiplexing PON (WDM-PON), which normally refers to the case where each subscriber is connected with its own wavelength. This is unlike GPON where the same wavelength is shared by all subscribers (one wavelength for DS and one for US). The rest of this paper will compare 10GPON and WDM-PON with respect to technical performance, cost and power consumption.

Key components

The key components for 10GPON is the 10G optics: In case of XG-PON1, the transmitter, Tx, at the optical line terminal, OLT, side and receiver, Rx, at the optical network termination, ONT, side. In case of XG-PON2 also the OLT Rx and ONT Tx. Especially the burst-mode OLT Rx is technically challenging. The GPON power splitter needs to have a low uniform insertion loss across the whole single-mode band (1260 -1625 nm). For WDM-PON is the wavelength splitter (typically arrayed waveguide grating, AWG) critical, especially in 1-fiber applications where so called cyclic AWG are needed to carry both DS and US wavelengths on each port. The most critical WDM-PON component is the colour-less ONT transmitter (i.e. wavelength adaptive transmitter) since only one type of ONT is desirable. Two main types can be identified, seeded reflective semiconductor optical amplifiers (RSOA) and tuneable lasers.

Technical performance

Table 1 summarizes the technical performance of 10GPON and WDM-PON. The line rate for 10GPON is as stated above 10G in the DS and 2.5G or 10G in the US. Although both 100M and 10G are possible for WDM-PON, the main-stream is currently towards 1G (or actually 1.25G with 8B/10B line coding of 1 Gigabit Ethernet). When it comes to the split ratio (N, i.e. number of subscribers per feeder fibre), 10GPON is designed to co-exist with GPON where typical split ratios are 32, 64 and 128. For WDM-PON the split ratio equals the number of wavelengths: a typical value of 100 GHz ITU-T spacing makes 32 split possible but also 64 splits are being discussed[5]. The bandwidth (BW) available per subscriber is more difficult to place a number on: for 10GPON just dividing the line rate with the split could be a valid number for the US (e.g. 78 Mbps for 2.5G US and 32 split) while the subscriber BW in the DS depends on

Tab. 1: Technical comparison: 10GPON and WDM-PON

Item	10GPON	WDM-PON
DS line rate	10G	1G
US line rate	2.5G	1G
Sub/feeder fiber (split)	N= up to128	N= up to 64
BW/sub DS	10G/N	1G
BW/Sub US	2.5G/N	1G
Reach w/o RE	20 km	50 km
Reach w RE	60 km	100 km
GPON co-existence	Yes	Maybe

the relation between broadcast and unicast traffic. In the extreme case of all subscribers just consuming broadcast (e.g. IPTV), all would have 10G capacity! In the other extreme with all subscribers just having unicast, the BW would be 10G/N (e.g. 312 Mbps for 32 split). In a triple-play scenario, the DS BW would be something between these values depending on the service mix. For WDM-PON, the subscriber BW is simply the line rate, i.e. 1G. It should however be

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pointed out that for both 10GPON and especially WDM-PON, the uplink capacity from the first active equipment in the central office (i.e. OLT) in relation to the access side capacity, sometimes referred to as oversubscription or aggregation factor, will put a limit to the available subscriber bandwidth. For example for a WDM-PON OLT with 32 1G port and 10G uplink, the subscriber BW is the same as for a 10GPON with 32 split. The advantage for WDM-PON in this case is however that the subscriber BW can be upgraded by increasing the OLT uplink. For unlimited uplink, the WDM-PON used would have 1G capacity, which would allow just a 10 split on a 10GPON to reach the same capacity.

The system reach is in the 10GPON case determined by the split. For example for a 32 split (~18 dB insertion loss) and a 28 dB link budget, 10 dB is left for connectors, margin and fibre attenuation, typically equating to about 20 km. For WDM-PON, reach is one of the strong points since the AWG has much lower loss that a power splitter. It is typically stated that WDM-PON with tuneable laser ONTs reach longer than RSOA-based; 50 km looks achievable[2].

Both 10GPON and WDM-PON can be adapted to long-reach scenarios by introducing mid-span reach extenders. For 10GPON either opto-electric-optic (OEO) or SOA extenders can be used to reach up to 60 km (limited by GPON protocol) whereas WDM-PON in C/L-band using erbium-doped amplifiers could reach up to 100 km.

Finally, in the case GPON is already deployed on a particular fibre and the operator wish to place the NG-PON as an overlay, a co-existence band plan is needed. For XG-PON, FSAN has placed much effort in assuring co-existence while it for WDM-PON still is an open question if this is achievable.

Cost

Estimating the cost of NG-PON is very difficult since it assumes the use of components in future high volume which today only exists in much lower volume high-end applications. Recent calculations[3] indicate that compared to current GPON, XG-PON1 cost will be ~x1.5-2 per line, XG-PON2 x2-3 per line and WDM-PON more than x3. Future advances in photonic integration is however likely to drive the cost down.

Power consumption

With its shared OLT port, 10GPON has and advantage when it comes to power consumption compared to WDM-PON which needs one dedicated OLT port per subscriber. The main part of the power consumption is however typically found on the ONT side where 10GPON gains from not needing cooled lasers while WDM-PON can make use of lower speed components. The ONT consumptions difference is therefore minor.

Conclusions

An overview of the differences of 10GPON and WDM-PON has been presented: 10GPON has a slight advantage in terms of standardization/maturity, cost and power consumption while WDM-PON can offer higher bandwidth and reach. Additionally, although the standardization towards 10GPON is planning considerably improvements in security compared to GPON, WDM-PON with its dedicated wavelength channel per subscriber is often considered to be more secure.

For these reasons, and following the operator plans[4], the trend is that 10PGON is envisioned for residential applications while WDM-PON is investigated for business or bandwidth intensive backhaul.

Thus, the conclusion on the best choice between 10GPON or WDM-PON may end up in both being used, albeit for different applications.

References

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