High Speed TWDM PON - A Review

Sonakshi
PG Research Scholar
Electronics and Communication Engineering Dept.
PEC University of technology, Chandigarh
sonakshi.tulsi@gmail.com

Divya Dhawan
Assistant Professor
Electronics and Communication Engineering Dept.
PEC University of technology, Chandigarh
divyadhawan@pec.ac.in

Abstract- The invention of Internet and its growth has provided a well-defined means of development of society. It has aided the people with a lot of convenience and entertainment. With the advancements in the new application, such as online audio, video conferencing, HD tv, online games etc. the bandwidth requirement of each user is rising exponentially over the years. The optical communications industry is developing rapidly to meet the increasing demand of bandwidth. Optical access network (OAN) is able to provide high bandwidth at a lower cost, following the replacement of the copper access.It has now become the primary access method. In this paper the comparative study of legacy PON is presented and the further development of NG-PON2 is analysed.

*****

I. INTRODUCTION

Broadband access networks are one of the important infrastructures for the development of modern society, where Internet users including consumers and business organisations are sending, receiving and storing more data than ever before. These networks are used to connect users or consumers to the central office, where their traffic is accumulated and transmitted to the next level of the telecommunication network. The state of art in this field is fibre to-the-x (FTTx), where x -curb, cabinet, home or building. In this technology optical fibre is used as the transmission medium to a point close to the subscriber[1]. For such an application the requirement is a network which has a point-to-multipoint topology . The point-to-point systems (PtP) and passive optical networks (PONs) are most popular competitors. In the implementation of FTTH majority of these networksare realized in a PON technology.

Passive optical networks are used in telecommunications where datais transmitted over an optical fibre medium. It is termed as passive because the splitters which are used to route the data are not powered .PON has evolved continuously owing to increase in the demand of more and more data rate. The evolution of PON technology in terms of data rate is as shown in table Table 1

Evolution of PON in terms of bitrate.

TYPES OF PON	Downstream line rates	Upstream line rate
BPON	155.52, 622.08 and 1244.16 Mbit/s,	155.52 and 622.08 Mbit/sec.
EPON	2.5/1.25Gbit/sec	
GPON	2.4 Gbit/sec 2.4 Gbit/sec	1.2 Gbit/sec 2.4 Gbit/sec
XG-PON1	10 Gbit/sec	2.5 Gbit/sec
XG-PON2:	10 Gbit/sec	10 Gbit/sec

The latest addition in passive optical network is NG-PON2. Owing to increase in demand of data rate the aggregated downstream rate of at least 40 Gbit/secandupstream data rate of a 10 Gbps, 20 Km of passive reach and a split ratio of at least 1:64 is required. NG-PON2 completes the requirement criteria and the specifications are listed below.

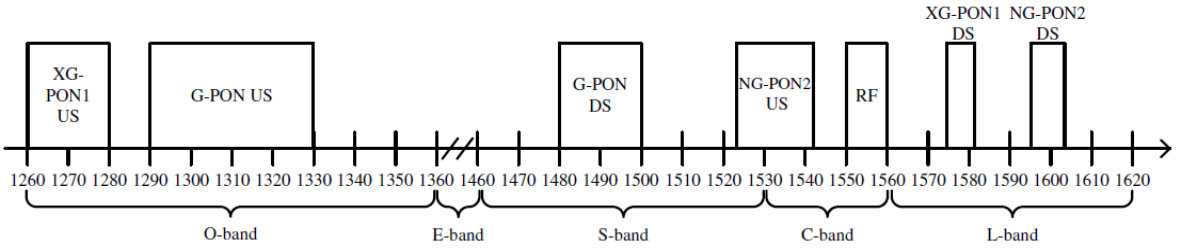

Fig.1. wavelength plan for ng-pon2 [2]

Table 2 Specification of NG-pon2

SPECIFICATION	VALUE	
TWDM architecture	4-8 TWDM channel pairs	
line rates per channel:	SYMMETRICAL	
	Downstream	Upstream
	10 Gbit/sec	10 Gbit/sec
	2.5 Gbit/sec	2.5 Gbit/sec
	ASSYMETRICAL	
	Downstream	upstream
	10 Gbit/sec	2.5 Gbit/sec
split ratio	≥ 1:256	
Length of Passive fibre	≥ 40 km	
maximum differential fibre distance	40 km	
Services	Residential user, business users, mobile backhaul, etc.	
Concurrence	All legacy PONs (RF Video included)	

The NG-PON2 architecture is such that it coexists with the other passive optical networks. It therefore results in upgrading the existing system without even replacing them.

As shown in Fig. 2, the system is mainly composed of (OLT) optical line terminal which is connected to central office, an optical distribution network, colourless optical network units (ONUs) which is close to the subscribers and co-existence element is needed to support the existing PON system in NG-PON2 .[2] WM is wavelength multiplexer.

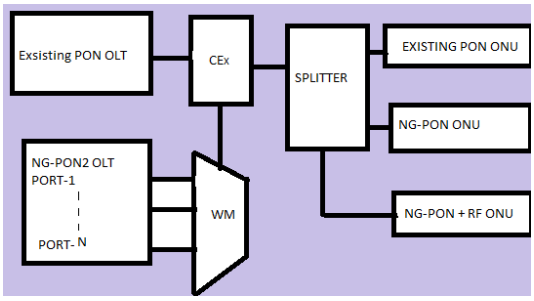

Fig.2. Interdependence of NG-PON2 with existing PON

II. ESSENTIAL REQUIREMENT FOR NG-PON2

A. MULTIPLEXING SCHEME

TWDM is selected as primary multiplexing scheme for NG-PON2 owing to its backward compatibility and other advantages sited in table 3.

B. LINE CODING SCHEME.

NRZ coding is a binary code in which there are two levels, Positive voltage and negative voltage. positive voltage is used to represent the one, while zeros are usually represented by a negative voltage. There are no other neutral or rest condition. The NRZ coding for 101101 is as shown below.

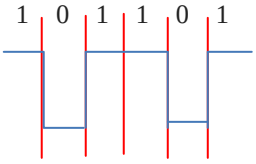

Fig.3. NRZ coding example

Table 3 Advantages and disadvantages of various PON techniques.

TECHNOLOGY	ADVANTAGES	DISADVANTAGES
TDM-PON	1.Simple 2.Less costly components	1.Bandwidth per user is less. 2.Lacks security
WDM-PON	1.Secure 2.Point to point communication 3.Efficient use of bandwidth 4.Can support long coverage	1.expensive 2.non-linear effects,limitsthe performance.
OFDM-PON	1.Support huge data rate 2.spectral efficiency is high 3.Immune to ISI	1.Complex receiver
TWDM-PON	1. Compatible to existing technology. 2.Technical maturity	1.Less scalability

Delay modulationit is also called Miller code.In this coding scheme at least two and at most four consecutive like symbols may occur in the transmitted sequence.[6]It is therefore called run length limited coding scheme. In this scheme bit 1 is shown by change in state at the mid of the bit period and no change in state for bit 0.However for repeating zeros there is a transition at the end of the first bit0.[6]The example is shown below.

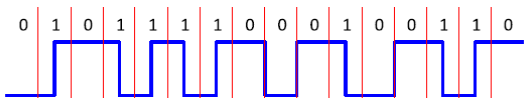

Fig.4. DM coding example[6]

This code provide good timing content and relatively small bandwidth.[6]

The power spectral density of DM at low frequencies are low when compared to NRZ coding;so DM can also remove the crosstalk onto the coexisting RF video signal.[6]

The specific encoding scheme and relatively narrow bandwidth can reduce the fibre dispersion.[6]

III. PERFORMANCE PARAMTER

CCR: It is carrier to crosstalk ratio. This parameter is useful in determining the effect of SRS induced cross talk on signal.

LOSS BUDGET: During transmission of signal over fibre,data is lost due to dispersion, scattering, cabling losses etc. hence the power at transmitter has to be increased so that the signal is detected at the receiver. Loss budget is defined as total loss that a cable can have. Launch power and receiver sensitivity are the two important parameters that define loss budget.

IV. IMPAIREMENTS PRESENT IN NG-PON2

A. NON-LINEARITY

The non-linear effects present in the fibre causes severe signal distortion. The variation in the refractive index of medium due to power of modulated signal travelling through it causes phase modulation of the same signal travellingor other signals travelling through the medium, this effect is termed as self-phase modulation (SPM) or cross phase modulation (CPM) respectively. Other non-linearity occur due to stimulated brillouinscattering(SBS) and stimulated raman scattering (SRS) . In these mechanism inelastic collision results in transfer of optical power from photon to acoustic phonon in case of SBS and to optical phonon for SRS .These non-linearityeffects the sensitivity of receiver and the launch power.

B. CROSSTALK

TWDM PONs should support the existing PON systems such as GPON/EPON, XGPONand RF video in the same optical distribution network (ODN). Due to this concurrence severe cross talk is induced between TWDM PON signal and RF video signal due to the phenomenon of Raman scattering.As a result of stimulated Raman scattering the optical power of the radio frequency video signal is partially transferred to the TWDM PON signals, and the energy transferred varies with the variation in power of TWDM PON. This results in noise like crosstalk.

C. LASER SELF-HEATING

The laser current which is required for direct modulation is only partially converted into light[1]. The non-radiative portion of the laser current heats up the laser junction parasitically. This heating up of laser junction causes the drift of signal out of its wavelength channel.[1]

Various methods used to mitigate laser self-heating are

Subthreshold Heating

If the laser is not completely switched off before the onset of the burst and a bias currentis allowed to flowbelow the laser threshold then the self-heating is reduced to some extent

Laser Current Reduction

The self-heating of laser is a function of laser current. So one method to get rid of wavelength is by reducing the laser current. But by reducing laser current, output power also reduces.One way to reduce the laser current and still having sufficient optical output power is by operating the laser at lower temperature, hence making the laser more efficient.[1]

Burst Length Reduction

wavelength continuously shifts during burst[1]. So transmission of a shorter burst would mean less wavelength drift. Using this property the drift in wavelength can be reduced by transmitting shorter burst instead of longer burst.

V. REVIEW OF TWDM based NG- PON2

In NGPON2 to achieve high loss budget, proper selection of components are important. Directly modulated laser and chirped managed laser are one of the promising candidates in PON. CML is robust to the high launch power. DMl is carrier less and hence tolerant to SBS. It is also a low cost laser making it more economical.[3] If transmitting and receiving components are tunable, then speed for different users like residential, business etc. can be met on same fibre installation hence reducing cost.[4]With the selection of components the non-linearity issue such as crosstalk ,dispersion should also be checked. Different coding scheme like delay modulation or non-return to zero coding can be usedto improve the system performance by improving crosstalk, reducing dispersion etc.[6] The papers related to NGPON2 have been studied and the inferences drawn from the paper are given below.

Inferences drawn from LITERATURE REVIEW of TWDM BASED NG-PON2

REFERENCE NO	TECHNIQUE	PARAMETERS	FINDINGS
[3]	SYMMETRIC TWDM-PON with DM-DD .	1. fibre length-100Km 2. The operating wavelength of DS DIRECTION ~1605 nm. 3. for the upstream link, 1542 nm . 4. launch power -10 dBm 5. total no of users1024	1) performanceof various lasers like EML,DML,CML, AND MZM are compared .CML isselected for downstream link and DML for the upstream link. 2) −35.2-dBm Sensitivity can be achieved. 3) sensitivitycan be increased from−15.5 to −25.5dBm by increasing the Extinction Ratio. 4) The loss budget 53.2 dB 5) cross phase modulation effect different channels and hence limits loss budget .
[4]	in-service tuning technique	Parameter for tunable transmitter are: 1. C-band channel spacing - 100Ghz 2. line rate -2.5 or 10 Gbps 3. burst-mode operation. The expected parameter for tunable receivers are 1. 4-channel tunability 2. L band channel spacing-100GHz 3. line rate - 2.5 or 10 Gb/s	1. DFB-LD with integrated heater. EML with thermo electric cooler. Heater-integrated TFF + PD These tunable components could be used for broadband services 2. Distributed bragg reflector-LD with short cavity. selector SW +4channel EML array DEMUX + selector SW + 4ch APD array DEMUX + PD +SOA gates These tunable components would be suitable for business users.
[6]	Delay Modulation for a TWDM PON	1. Power budget: 37.7 and 25.7 dB 2. Line rate-2.5 Gbps 10 Gbps 3. Transmissionlength- 20 km . 4. fibre-SSMF	1. DM is more effective in reduction of crosstalkdue to SRS, than NRZ. 2. CCR is improved by 10 dB . 3. eye diagram distorts due to dispersion after 20 km
[2]	Directly modulated laser and electronic dispersion compensation	1. Passive Reach-40 Km 2. Minimum sensitivityfor Rx−28dBm in onu. 3. Minimum OLT Rx sensitivity (dBm) without optical amplifier.	1. upstream transmission of 10 Gbps would not be possible without EDC for a length of 40Km. 2. the sensitivity of receiver without EDC is 2 dB worse compared to that with EDC.
[1]	wavelength drift effect		1. the burst induced wavelength shift can be measured using optical spectrum analyser . 2. Different methods to remove/reduce the self-heating induced wavelength drift are accelerated self heating, subthreshold heating, laser current reduction, use of flat top AWG, etc.

VI. CONCLUSION

NGPON-2 has opened door to new speed making the world more connected .After studying the following papers the chirped modulated laser and directly modulated laser are the possible choices for laser in downstream and upstream in NG-PON2 architecture owing to robustness to high launch power and dispersion. The costs of these lasers is economical. Delay modulation is more suitable mode of modulation to eliminate crosstalk which is induced due to interference of video signal with downstream, as legacy PON coexist with the NG-PON2.various components necessary for tuning are studied which can suit the services required for business and residential user.

VII. REFERENCES

[1] W. Poehlmann, D. Van Veen, R. Farah, T. Pfeiffer, and P. Vetter, "Wavelength Drift of Burst-Mode DML for TWDM-PON [Invited]," vol. 7, no. 1, pp. 44–51, 2015.

[2] Y. Guo, S. Zhu, G. Kuang, Y. Yin, D. Zhang, and X. Liu, "Demonstration of a Symmetric 40 Gbit/s TWDM-PON Over 40 km Passive Reach Using 10 G Burst-Mode DML and EDC for Upstream Transmission [Invited]," *J. Opt. Commun. Netw.*, vol. 7, no. 3, p. A363, 2015.

[3] T. L. Budget *et al.*, "Symmetric 40-Gb / s , 100-km Passive Reach," vol. 32, no. 21, pp. 3991–3998, 2014.

[4] K. Asaka, "Consideration of tunable components for next-generation passive optical network stage 2," *J. Light. Technol.*, vol. 33, no. 5, pp. 1072–1076, 2015.

[5] ITU-T, "ITU-T Recommendation G.989.1 40-Gigabit-capable passive optical networks (NG-PON2): General requirements," *Itu-T G-Series Recomm.*, pp. 1–26, 2013.

[6] N. Cheng, M. Zhou, and F. J. Effenberger, "10 Gbit / s Delay Modulation Using a Directly Modulated DFB Laser for a TWDM PON With Converged Services [Invited]," vol. 7, no. 1, 2015.