Journal of Data Mining and Knowledge Discovery
ISSN: 2229–6662 & ISSN: 2229–6670, Volume 3, Issue 1, 2012, pp.-45-48.
Available online at http://www. bioinfo. in/contents. php?id=42

STUDY OF DEVELOPMENT OF 40 Gb/S DWDM SYSTEMS OVER EXISTING 10Gb/S DWDM SYSTEMS

KAPSE M.C.* AND SRIRAMWAR S.S.

Department of Electronics Engg., Priyadarshini College Of Engg., Nagpur, MS, India.
*Corresponding Author: Email- kapse.milind@gmail.com

Received: February 21, 2012; Accepted: March 15, 2012

Abstract- In fiber-optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e colours) of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. The extensive growth in data transmission is pushing carriers and service providers to deploy increasing optical backbone transmission capacity. An attractive alternative to deploying higher wave counts at 10 Gb/S(OC-192/STM-64) is the deployment of higher capacity 40 Gb/S(OC-768/STM-256) per wave. The40 Gb/SDWDM solution provides better spectral efficiency and results in lower overall cost for capacity, relative to existing 10 Gb/Ssystems. The paper aims at the study of developing solution for High OSNR, developing Solution for Chromatic Dispersion and developing Solution for High PMD.
Keywords- OSNR- optical signal-to-noise ratio, EFEC- enhance forward error correction, CD- Chromatic Dispersion, NRZ- non return to zero, PMD-Polarization Mode Dispersion.

Citation: Kapse M.C. and Sriramwar S.S. (2012) Study Of Development Of 40 Gb/S DWDM Systems Over Existing 10Gb/S DWDM Systems. Journal of Data Mining and Knowledge Discovery, ISSN: 2229–6662 & ISSN: 2229–6670, Volume 3, Issue 1, pp.-45-48.

Introduction

Typical 10Gb/Slink engineering rules are:

i) Polarization Mode Dispersion (PMD) tolerance of 10ps (mean);
ii) chromatic Dispersion (CD) tolerance of ±700ps/nm;
iii) Operation at 50GHz channel spacing, including transit through multiple cascaded [R]OADMs;

A typical EDFA supports approximately 80–90 wavelengths with 50 GHz spacing or 40–45 with 100-GHz spacing in the C-band (1530–1565 nm). This has allowed a single amplifier to replace per wavelength optoelectronic regenerators in today's DWDM systems thus significantly reducing cost.

A. OSNR Sensitivity

The tighter tolerances associated with driving a 40G pulse of light down a narrow fiber requires a different response than 10G. As the following pages explain, all technical challenges have been successfully met. 40G signals occupy four times the bandwidth of signals with 10G line rates. Therefore, an optical receiver suitable for 40G utilizes a four times larger pass band. The broader pass band collects four times the optical noise of a standard 10G receiver.

This explains why 40G receivers are inherently much more sensitive to optical noise and require a four times (or 6 dB) higher optical signal to noise ratio.

B. Enhanced forward error correction (EFEC)

Enhanced forward error correction (EFEC) filters out errors that occur during transmission and reduces the sensitivity to optical noise. Alternative modulation formats reduce the required optical bandwidth and therefore also the sensitivity to optical noise. Since the required optical signal to-noise ratio at the receiver is 6 dB higher at 40G compared to 10G.

C. Chromatic Dispersion

when moving from 10G signals to 40G signals, the sensitivity against chromatic dispersion increases by a factor of 16. This leads to issues with NRZ modulation, the standard for 10G DWDM. While 10G NRZ signals tolerate up to 1000 ps/nm chromatic dispersion with an acceptable penalty, 40G NRZ signals can tolerate only about 60 ps/nm. This is just too low for any practical use of 40 G.

D. Dispersion

Dispersion of the transmission fiber is another important effect that must be properly managed. At the data rate of 40 Gb/s, chromatic dispersion of the transmission fiber quickly leads to pulse broadening The dispersion tolerance at 40 Gb/Sis approximately ±50ps/nm, corresponding to 3 km of SSMF. Consequently, precise dispersion compensation techniques are required. (i.e. the wavelength dependency of the dispersion) of some types of transmission fiber (SSMF and TWRS), whereas the dispersion slope of some other fiber types (like LEAF and TW Classic) cannot be totally compensated with available DCM. The result of in adequate dispersion slope compensation is illustrated in Fig.1. Without sufficient compensation of the dispersion slope, excessive compensation on a per wavelength basis will be needed at the receiver in long haul systems.

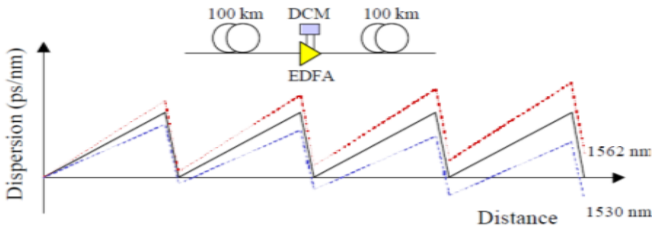

Fig. 1- Effect of inadequate dispersion slope compensation

Fiber non-linearities: Two categories of nonlinear effects can place limitations on system performance. The first category encompasses the nonlinear inelastic scattering processes. These are stimulated Raman Scattering (SRS) and stimulated Brillouin Scattering (SBS).The second category of nonlinear effects arises from intensity dependent variations in the refractive index in a silica fiber. These are often called Kerr nonlinear effects, and include four-wave mixing, self phase modulation and cross phase modulation. Note that the nonlinear effects are lower in fiber with high effective mode area, and using fiber with relative high dispersion can further reduce the impact of the non-linearities. In long haul 40G DWDM transmission systems with a standard ITU channel spacing of 100 GHz the main non-linear impairments are cross phase modulation (LEAF and TWRS fiber) and self phase modulation (SSMF,LEAF and TWRS fiber).

Modulation format

A. CS-RZ (Carrier Suppressed Return to Zero)

CS-RZ modulation utilizes a return to zero modulation. It also engineers the phase of the optical signal in a way that the average optical signal power is reduced by one half. Therefore, the 40G signal is much less sensitive to fiber nonlinear effects and provides higher robustness against transmission impairments. It further provides improved OSNR performance and slightly improved dispersion tolerance compared to NRZ. However, CS-RZ has a fundamental limitation: it can't operate on a 50 GHz grid necessary to support 80 channel DWDM systems. This limits its use to DWDM systems operating on a 100 GHz grid used to carry 40 channels.

B. Duo-binary

Duo-binary modulation (also called Phase Shaped Binary Transmission, or PSBT) also engineers the phase of the optical signal and reduces the average optical signal power by one half compared to standard NRZ signals.

C. DPSK and DQPSK

In contrast to amplitude modulation techniques such as NRZ and duo binary, DPSK (Differential Phase Shifted Keying) and DQPSK (Differential Quadruple Phase Shifted Keying) code the bit information directly into the phase of the optical light without touching the amplitude. Comparison of different modulation technique shown in Fig. 2.

Modulation Format Performance vs. NRZ	CS-RZ	Duobinary	DPSK	DQPSK	DPSK-RZ	DQPSK-RZ
OSNR Sensitivity	Slightly Better	Slightly Worse	Much Better	Slightly Better	Much Better	Better
CD Tolerance & Spectral Efficiency	Slightly Worse	Much Better	Slightly Better	Much Better	Slightly Worse	Much Better
PMD Tolerance	Better	Equivalent	Slightly Better	Much Better	Better	Much Better
Nonlinearity Tolerance	Better	Equivalent	Better	Equivalent	Much Better	Equivalent
Cost & Complexity	Slightly Worse	Equivalent	Slightly Worse	Much Worse	Worse	Much Worse

Fig. 2- Comparison of different modulation techniques

D. PMD

Polarization mode dispersion (PMD) is another factor that must be considered when transmitting 40G over long fiber distances. In fibers, PMD is caused by the refractive index not exhibiting perfect rotational symmetry about the fiber axis. As a result, the two possible polarization states of the fiber propagate with different speeds. In effect, the difference in propagation speed between the slow and fast fiber axis leads to a broadening of the transmitted bits. This is illustrated in Fig. 3.

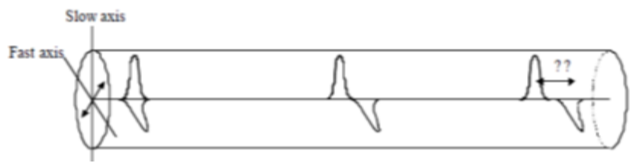

Fig. 3- Polarization Mode Dispersion

Countermeasures for resolving the above issues

A. High OSNR

The ratio of the signal to the signal-spontaneous beat noise in the receiver is conveniently quantified by the optical signal-to-noise ratio (OSNR), defined as the ratio of the optical signal power to the

ASE power in a specified optical bandwidth (usually taken to be 0.1 nm). The OSNR achieved in an amplified system with equal span losses can be estimated by OSNR (dB) = $58+P-L-\text{NF}-10\log N$ where P (in dBm units or decibel referenced to 1 mW) is the optical power per channel launched in the fiber, L is the span loss (in decibel), NF is the noise figure (in decibel), and N is the number of spans. Although in practice span losses are typically not equal, the above equation shows that the system OSNR can be increased decibel-for-decibel by increasing the power per channel (P),by decreasing the noise figure (NF), or by decreasing the span loss (L). Note that increasing the optical amplifier output power (or the number of spans) also increases nonlinear effects in the transmission system and, therefore, would require a higher target OSNR at the receiver, especially in systems with a large number of spans. Also, note that since the OSNR depends logarithmically on the number of spans, an increase in the number of spans by 26% only lowers the OSNR by 1 dB. Thus, small changes in the target OSNR launch power, span loss, and noise figure will have an enormous impact on the transparent optical reach that can be achieved. The required target OSNR can be significantly reduced through the use of forward error correction (FEC), which allows the receiver to operate at a much higher BER than the specified target BER for the system, and the choice of modulation method as shown in a subsequent section. The choice of optical amplification technology has a major impact on the noise figure and, thus, the OSNR that can be achieved. For high-gain EDFAs, the best noise figure achievable in theory is 3 dB but in practice a noise figure of 5–6 dB is typical. The use of distributed Raman amplification effectively reduces the loss of the fiber span and increases the signal power at the end of the span, resulting in a significant improvement of OSNR compared with the use of a discrete EDFA at the end of the span. This improvement is most easily understood by representing Raman amplification by the equivalent noise figure of a hypothetical EDFA in the above OSNR equation shown in Fig. 4. Equivalent noise figures with an improvement of more than 6 dB have been achieved. Such OSNR improvement can be used to significantly extend optical span length, increase the number of spans and/or reduce channel power to mitigate nonlinear impairments, or to accommodate an increase in target OSNR for operation at higher bit rate.

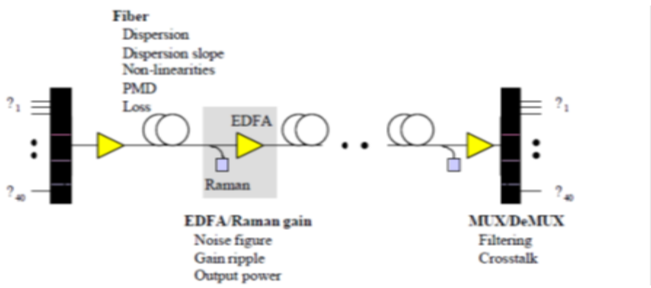

Fig. 4- Main Transmission Issues for 40 G Systems

B. Chromatic Dispersion

New modulation formats help to reduce the influence of dispersion and so make 40G transmission feasible. In addition the dispersion compensation scheme along the line can be optimized to facilitate robust transmission of 10G as well as 40G traffic. In addition, tunable dispersion compensation modules can adjust the chromatic dispersion at the receiver site. Usually expressed in ps/nm km, is caused by variations in the group velocity (propagation speed) with optical frequency. As a pulse travels through a fiber (with positive dispersion), the shorter wavelength components of the pulse travel faster than the longer wavelength components thus causing the pulse to broaden and this in turn results in intersymbol interference (ISI) at the receiver. The tolerance of a receiver to dispersion is dependent on receiver design, modulation format and is inversely proportional to the square of the bit rate. In traditional transmission systems, dispersion compensation modules (DCM's) are placed in the middle of two-stage optical in-line amplifiers. Today, DCM consists of a single -mode dispersion compensating fiber (DCF) with a dispersion that is of opposite sign of the transmission fiber. Current DCF can compensate both the dispersion and the dispersion slope.

C. DPQSK Modulation

DQPSK, due to the fact that it reduces the line rate by 50% while keeping the full data rate, provides significantly enhanced tolerance against chromatic dispersion and PMD. In contrast to DPSK, DQPSK can operate over a 50 GHz spacing, which is mandatory for DWDM backbones.

D. PMD

Today, transmission fiber can be fabricated with very low PMD, and most recently deployed fiber has sufficiently low PMD to allow 40G to be transmitted over distances in excess of 1000 km without PMD compensation. The accelerating pace of low-PMD fiber deployment will result in the vast majority of "fiber-in-the-ground" soon supporting ultra-long haul 40G transmission without PMD problems. Optical components like amplifiers, optical multiplexers and DCM's might also introduce PMD.It varies as the square of distance and thus is specified as a maximum anticipated value in units of **ps/√km.** High PMD (possibly > 0.5ps/km1/2) must be assumed for fiber manufactured before 1995. Older fiber was produced with more significant imperfections than today, and was also laid in the ground and routed around corners with more stress than is now acceptable. In addition, splices connecting fibers were of a lower quality standard. For these reasons, fiber installed prior to 1995 is generally considered to be of an unknown quantity for PMD, and not suitable for 40G transmission. For modern fibers (manufactured since 1995), PMD is usually within acceptable limits (< 0.2ps/km1/2) for 40G transmission. Some level of PMD can be expected in 10-20% of these newer fibers, with longer transmission lengths more likely to be affected. The loss of optical phase information with direct detection receivers however limits the performance of post-detection compensation techniques. The use of electronic pre-compensation at the transmitter allows the optical phase and amplitude of the transmitted signal to be controlled and has been successfully demonstrated [52, 53]. With electronic pre-compensation the channel is distorted at the transmitter with the inverse channel transfer function so that the effects of dispersion are canceled by the time the signal propagates through the fiber to the receiver.

Conclusion

40 Gb/SDWDM transport is the next logical step in the progression of optical backbone technology. 40G solutions provide better

spectral efficiency and results in lower overall cost for capacity compared to existing 10 Gb/Ssystems. The higher line rates also provide better terminal densities, which result in smaller terminals for a given capacity. These benefits combined with recent advances in optic and electronic technologies will drive 40 Gb/Ssystems from research laboratories to production ready systems that can be manufactured in large volumes in the near future.

References

[1] Zyskind J.L., Nigel J.A. and Kidorf H.D. (1997) *Optical Fiber Telecommunications*, 13-68.

[2] Mikkelsen B., Mamyshev P., Rasmussen C., Ketchian C., Miller J.L., Edward Dr Friedman and Ed Friedman (1996) *Photonics Rules of Thumb: Optics, Electro -Optics, Fiber Optics, and Lasers*.

[3] Gao Yan, Zhang Ruixia, Du Weifeng and Cui Xiaorong *Point-to-Point DWDM System Design and Simulation*, DWDM Systems Migration Towards 40Gb/s.

[4] Zyskind J.L., Nigel J.A. and Kidorf H.D. (1997) *Optical Fiber Telecommunications*, 13-68.

[5] Payne D.N., Mears R.J., Reeky L. and Jauncy I.M. (1987) *Electron. Lett.*, 23, 1026-1028.

[6] Li T. (1993) *IEEE*, 81(11), 1568-1579.

[7] Agrawal G.P. (2001) *Nonlinear Fiber Optics*.

[8] Cotter D. and Hill A.M. (1984) *Electron. Lett.*, 20, 185.

[9] Nelson L.E. (2005) *Proc. ECOC,* 1, 67-68.

[10] Chen D., Xia T.J., Wellbrock G., Petersen D., Park S.Y., Thoen E., Burton C., Zyskynd J., Penticost S.J. and Mamyshev P. (2005) *Proc. ECOC*, 1, 15-16.

[11] Hoffman P., Basch E.B., Gringeri S., Egorov R., Fishman D. and Thompson W. (2005) *DWDM long haul network deployment for the Verizon nationwide network*.

[12] Fishman D., Correra D.L., Goode E.H., Downs T.L., Sinha B.P., Ho A., Hale A., Hofmann P., Basch E.B. and Gringeri S. (2006) *Opt. Netw.*, 11(2).

[13] Desurvire E. (1994) *Erbium-Doped Fiber Amplifiers*, 98-114.