Camera ready version for

International Conference on Telecommunications

May 22-25, Acapulco, Mexico

Title: Permanent Quality of Transport Monitoring in Optical Transparent Paths of All-Optical WDM-Networks

Technical area

1st Choice : Network Operating & Management
2nd Choice: Optical Communications

Authors: Tim Welsch, Klaus Jobmann

Affiliation: IANT, University of Hannover
Appelstr. 9a, 30167 Hannover, Germany
Tel: ++49 / 511 / 762-2835
Fax: ++49 / 511 / 762-3030
e-Mail: welsch@ant.uni-hannover.de

Permanent Quality of Transport Monitoring in Optical Transparent Paths of All-Optical WDM-Networks

Tim Welsch, Klaus Jobmann

University of Hannover, IANT Institute for Communications
Appelstrasse 9A, 30167 Hannover, Germany
Tel: +49 511 762-2814, Fax: -3030, eMail: welsch@ant.uni-hannover.de

Abstract
Future all-optical networks are based on wavelangth division multiplex (WDM) technology with all-optical routing facilities within the network nodes. Providing transparent optical pathes on separate wavelengths through the network will lead to most flexible network usage. In many cases the supervision and protection of the WDM transportation service can not be managed by the used transport format itself. Either it does not support quality of service (QoS) mechanisms or it is not connected to the network management system.
A novel method for estimating the quality of all-optical transport services by monitoring essential physical path parameters is introduced. The method is based on direct sequence spread spectrum technology that leads to least interfering with the payload transport formant. The performance of the method, the modes of operation and first laboratory measurements are presented in this paper.

I. INTRODUCTION

The Wavelangth Division Multiplex (WDM) technology in all-optical networks enables the utilization of separate wavelengths in one fiber or separate optical pathes within fiber networks. The renting out of single transparent optical pathes becomes now interessting for network providers. The customers have the benefit of being independent from the provider in transport formats and data rates. They can use digital formats like SONET, SDH, PDH or Gigabit Ethernet to build up their own virtual network on the providers fibers. The provider can supply many customers using different broadband services with one single network infrastructure. But the customers are demanding a guarantee in quality of transport over the hired paths that usually is assessable by observing specific limits in the bit error rate (BER) of the digital transport signal. In most future cases the network provider neither knows the current transport format the customer uses nor he has reliably access to the BER measurements that are done by the customers transmission systems.

The BER for a specific transport format is determinded by the physical channel parameters attenuation, path noise and crosstalk from other pathes, dispersion and some further nonlinear effects with minor influence. In conjunction with the defined quantities for all typical transport formats (e.g. signal transmission output power, signal form) the knowledge of these parameters enables the provider to estimate the reachable BER within his path for all typical transport formats. Thus, the quality of transport can be guaranteed for all relevant transport formats without getting to know the current customer format by permanent supervision of that path parameters. In this way most network malfunctions like fiber cuts, filter shifts by temperature or damaged fiber switches routing the payload to wrong destinations can be detected by the network provider before the customer complains.
This paper introduces a method for permanent measuring of path attenuation, path scattering and reflection, signal to noise ratio (SNR), crosstalk and four wave interference for use in WDM pathes carring digital payload that has not to be interfered by the measurement.

II. MEASUREMENT PRINCIPLE

The measurement is based on the transmission and the afterwards valuation of a measurement symbol that is formed with the direct sequence spread spectrum technology (DSSS). For transmission the DSSS line code drives an LED or LD and the optical power is inserted into the transparent optical path in the forward direction of the payload by a power combiner as showed in figure 1.

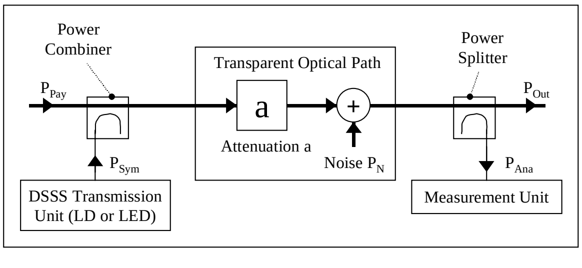

Figure 1 – Optical Path Measurement

At any section of the path a power splitter can feed a measurement unit to measure the energy of the symbol. The symbol itself may consist of one single logical “1” which is modulated with a pseudo random noise (PRN) spreadcode. Depending on the desired response time for network alarms a very low symbol rate of less than one symbol per second can be programmed.
Using a cheap broadband LD or LED a WDM suitable filter can be used to feed optical symbol energy into one single wavelength channel only. On the one hand broadband transmitters only can emit low power in the order of –20dBm into a small bandwidth like a WDM channel but on the other hand the low power is suitable to do not degrade the payload. Moreover the optical receiver for the measurement symbols can be designed for low frequencies less than 10 MHz. This leads to higher sensitivity.
Several advantages of the DSSS application for signalling purposes within WDM channels are mentioned in [1] and [2]. The measurement unit consists of a matched filter that uses the same spreading sequence to despread the symbol linecode. We adjusted the DSSS to fit the special measurement requrements by using the principal advatages:

- Using the same wavelength channel the measurement symbol linecode is effected in the same manner as the payload, in particular by attenuation, amplifiing, scattering, crosstalk, noise insertion and other nonlinear phenomenons.
- The measurement symbol is routed to the same destination as the payload. This enables a supervision of the network routing function.
- The symbol can be transferred with very low power and can be detected reliably because of the very long symbol duration.
- The high process gain of the used DSSS method allows low power symbol transmission with very low influence on payload, in particular it is not degrading the payloads BER.
- The different payload formats and power have no measureable influence on the symbol detection.
- Insertion of different spreading codes at different path sections provides more detailed information about network status and the location of network malfunctions.

To calculate reliable path parameters, it is not enough just to detect a symbol with a usual probability that fits for error corrected signalling purposes, rather we need a dimension to assess the symbol energy accuracy that may be affected by different types of payload signal. Therefore our measurement unit calculates the correlation of the input signal with seven deviant PRN spreadcodes. The ratio of the symbol energy to the seven test values is used to guarantee the accuracy. Our first laboratory measurements are not based on an optical WDM system with SDH carriers but on an electrical substitution carrying a 32Mbit/s PDH signal with a NRZ linecode. The NRZ linecode is used at most electro-optical nodes. For symbol detection in the component signal a 12bit Analog-to-Digital converter is used with 10 kSamples per second. Figure 2 shows the measured symbol accurancy for a set of different symbol codelengths and different power levels on which the symbol linecode is inserted into the payload.

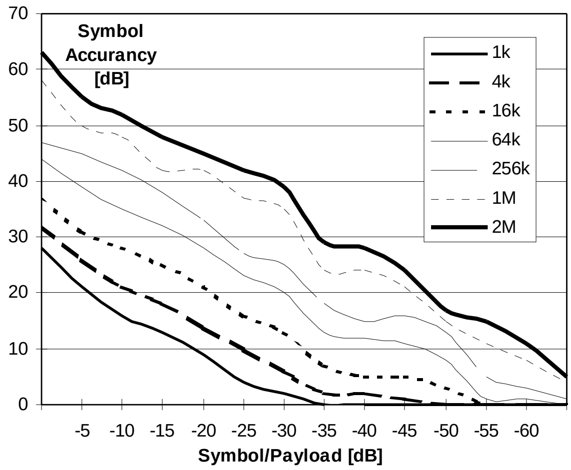

Figure 2 - Symbol accurancy over insertion level at different codelength [chips]

The symbol accuracy is calculated on the ration of the symbol energy to the correlations of the received signal to the seven deviant PRN spreadcodes that builds a noise level. For a fixed DSSS design one part of the symbol accurancy amount can be seen as a safety margin for statistical fault probability in symbol measurement and the other part represents the useable dynamic range of the measured values.

III. NETWORK APPLICATION

A scenario for the application of this method within optical networks is shown in figure 4. The symbol energy is measured at the input path of the section under supervision and at the output path of the section. The attenuation of the path A within the section can be derived out of the measured symbol power as a = 10 x log10 (POutput / PInput). The resulting absolute error between adjusted attenuation at the path model and the calculated value is small (figure 3). Shifts of the optical filters increasing the attenuation, long term aging of erbium doped fiber amplifiers (EDFA) and other effects can be supervised in this way.

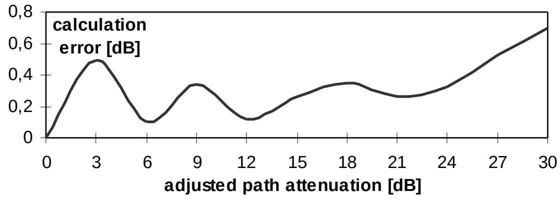

Figure 3 – Attenuation Offset Error

A set of very important parameters can be derived in addition if a power meter for the total optical power is added to the measurement units: The noise power that is added to the path by the EDFAs. This power amount may also contain little noise from neighbour channels crosstalk, four-wave-mixing and self- and cross-phase-modulation. The noise power can be used to calculate the real SNR penalty to the payload or to predict the BER to the typical, known transport formats.

Moreover the measurement units can seek for symbol power in pathes where that special symbol has not to occur. The detected power level gives information on the mechanism that spread the symbol in the wrong channel: High power levels can only occur due to optical switch malfunction, low power levels occur by filter shifts or serveral nonlinear effects due to exceeding maximum power limits for the payload transponders. Placing a further detector in reverse direction the scattering and reflection of optical energy can be supervised. Reverse power interferes the transponders laser and degrades signal quality.

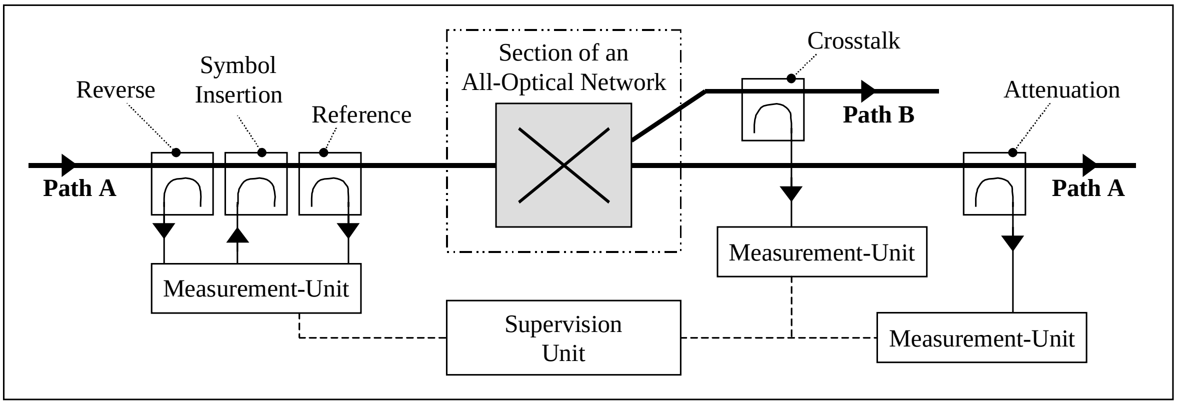

Figure 4 – Network Measurement Principle

IV. FUTURE WORK

Next trials will be run on optical WDM pathes with PDH, SDH and Gigabit Ethernet payload. We will use measurement units with improved accuracy.

The syncronisation of the measurement units may get difficult using very long spreading codes. To avoid locked synchronisation the application of a FIR filter with 4-times oversampling is proposed in [2]. We evaluate this for our next design.

V. CONCLUSION

A novel method for estimating the quality of optical transport services has been introduced. The first trials confirmed that method to be suitable for monitoring most of the relevant path parameters. The current design allows the valuation of measurement symbols at a power level of less than 50dB below the payload and is about to be improved. Network malfunctions are recognized within seconds and slow degrading of path quality can be supervised without interferring the optical payload. This method represents an important value added service for network providers. Due to the use of broadband optical transmitters and low frequency electrical components only, the realization of this system at very low cost is possible.

VI. REFERENCES

[1] A.A.Grau, C.G.Schäffer, J.C.Thiedke. Spread Spectrum In-Band Signalling Channel. *Proceedings of the ECOC 1999*, Nice, France 1999.
[2] L.Giehmann, A.Gladisch, J.Rudolph. Field Trail of OAM-Signal Transport Capabilities. *Proceedings of the OFC 1999.*
[3] J.G.Proakis. Digital Communications. McGraw Hill, New York, 2nd Edition 1989
[4] S.Haykin. Adaptive Filter Theory. Prentice Hall, 1991, 2nd Edition 1991
[5] United States Patent US5867289
[6] United States Patent US5790293
[7] German Patent DE4129543
[8] German Patent DE4427973