Design and OAM&P aspects of a DWDM system equipped with a 40Gb/s PM-QPSK alien wavelength and adjacent 10Gb/s channels

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Abstract
We present theoretical and experimental investigations of the interaction, in terms of BER performance, between a 40Gb/s PM-QPSK alien wavelength and adjacent (50GHz spacing) 10Gb/s NRZ-OOK channels. Experiments were conducted on the Hamburg-Copenhagen section of the Amsterdam-Copenhagen CBF (Cross Border Fiber) connection between SURFnet and NORDUnet. Furthermore, we investigated the OAM&P (Operation, Administration, Maintenance and Provisioning) of an alien wavelength in CBF transmission systems.

1. Introduction
The continuous roll-out of hybrid networks initiated the demand for international CBF (Cross Border Fiber) DWDM links between NRENs. For example, SURFnet established CBFs to Münster and Aachen in Germany (DFN), to Hamburg (NORDUnet), and, most recently at the end of 2009, SURFnet deployed a CBF connection between Amsterdam and the open exchange in Geneva¹. Typically, at the transition between NRENs, the DWDM systems that are supplied by different equipment vendors are connected via transponders to provide a clear demarcation point and regenerate the received signal (i.e. remove distortion and noise and re-time) before it enters the next DWDM system. This may not be necessary from a transmission point of view and for this reason alien wavelengths in CBF systems are an appealing concept, since they eliminate the cost and (carbon) footprint of transponders at the transition between the DWDM systems from different NRENs. In an earlier report², SURFnet and NORDUnet conducted a joint 40Gb/s PM-QPSK (Polarization Multiplexed-Quadruple Phase Shift Keying) alien wavelength experiment on the CBF connection between Amsterdam and Copenhagen. In that experiment, a single 40Gb/s bi-directional wavelength traversed a CIENA CPL DWDM system between Amsterdam and Hamburg and an Alcatel-Lucent DWDM system between Hamburg and Copenhagen without regeneration. However, in that experiment a large guard band of 350GHz between the 40Gb/s alien wavelength and the other live-traffic was used to ensure minimal interaction. More traffic will be deployed on this CBF system and in order to efficiently utilize the available system capacity, large guard bands are not sustainable. In this paper we investigated the effects of the adjacent 10Gb/s channels on the performance of the 40Gb/s alien wavelength theoretically by numerical simulations and experimentally by measuring the pre-FEC BER rates of the 40Gb/s alien wavelength for different power levels of the adjacent 10Gb/s channels. Challenges arising from the lack of standardization for OAM&P related to alien wavelengths will be discussed in section 4.

2. System simulations
Figure 1 shows the system configuration of the CBF transmission system that we used for the 40Gb/s alien wavelength experiment. The transmission fiber was TWRS (True Wave Reduced Slope) fiber and the total transmission distance was equal to 1056km. The DWDM system between Amsterdam and Hamburg is equipped with four 40Gb/s channels, at the wavelengths of 1546.52nm, 1546.92nm, 1547.32nm and 1548.11nm. The four 40Gb/s channels used PM-QPSK transmitters and coherent receivers were capable of electronically compensating more than 40,000 ps/nm of chromatic dispersion. For this reason, this section was not equipped with optical in-line dispersion compensators. In Hamburg, the 40Gb/s wavelength of 1546.92nm is all-optically connected to the DWDM system between Hamburg and Copenhagen,
spaced at 50GHz from two adjacent 10Gb/s OOK test channels, and transported as alien wavelength to Copenhagen. The traffic in the other three 40Gb/s wavelengths is routed through a geographically separate Alcatel-Lucent transmission system towards Copenhagen. We modeled the BER performance of the 40Gb/s PM-QPSK alien wavelength by using the commercial software package VPI photonics. In this section, we describe the results of a theoretical study of the BER performance of the alien wavelength versus number of and the power level of the adjacent 10Gb/s OOK (On-Off Keying) channels in order to obtain more knowledge on the guidelines for the design of such transmission systems.

![Image of 40Gb/s alien wavelength transmission system setup]

Figure 1. 40Gb/s alien wavelength transmission system setup

3. Transmission experiments

This section summarizes the comparison of the theoretical investigation of the previous section and experimental data of BER performance for the case of two adjacent 10Gb/s channels, spaced at 50GHz from the 40Gb/s alien wavelength, and for different power levels of the 40Gb/s alien wavelength and the adjacent 10Gb/s channels.

4. OAM&P (Operation, Administration, Maintenance and Provisioning)

Lack of standardization prevents exchanging OAM&P information between DWDM systems from different vendors for monitoring alien wavelengths\(^{[3,4,5]}\). In this section we will provide an overview of standardization efforts for alien wavelengths at the ITU-T and a method that we used for monitoring the 40Gb/s alien wavelength between Amsterdam and Copenhagen. Finally, we compare the CAPEX (Capital Expenditures) and OPEX (Operating Expenditures) of the alien wavelength and native wavelength approaches.

5. Conclusions

We investigated theoretically and experimentally the all-optical transmission of a 40Gb/s PM-QPSK alien wavelength between Amsterdam and Copenhagen via concatenated native and third party DWDM systems. The total transmission distance was equal to 1056km. All transmission fiber was TWRS (TrueWave Reduced Slope). At TNC2011, we will present the results of a meticulous theoretical and experimental investigation of the optimum BER performance of the 40Gb/s alien wavelength for different power levels of the adjacent 10Gb/s channels between Hamburg and Copenhagen. Furthermore, we will present a status update of the standardization efforts for OAM&P at the ITU-T and work-arounds that can be implemented to monitor the performance of the alien wavelength.
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References


Biographies

Roeland Nuijts received the Ir. Degree in EE from the Eindhoven University of Technology (1993), and the PhD degree (with honours) in modeling of optical transmission systems from the ÉNST, Paris (1997). He conducted his Ph.D. research at AT&T Bell Labs in the USA. After graduation, he joined Lucent Technologies in the Netherlands and worked on integration of SDH and DWDM systems. From 1999, he supported the Asia-Pacific region technical marketing for Lucent based in Tokyo. In 2001, he joined OpNext in California, and subsequently AZNA in LA (acquired by Finisar). Roeland is currently a network services manager at SURFnet.

Lars Lange Bjørn is Optical Network Architect at NORDUnet and responsible for implementation, network planning and maintenance of NORDUnets DWDM network. During the last 10 years Lars has worked with SDH, DWDM and the associated management systems, holding different positions; operational engineer, system engineer, project manager and system administrator. He has worked at both green field operators as well as incumbents and holds a M.Sc in engineering from Department of Communications, Optics & Materials at the Technical University of Denmark.

Martin Nordal Petersen is a post-doctoral researcher at the Fotonik Institute at the Technical University of Denmark. He is in charge of teaching within optical networks courses as well as managing and working on various research projects. Born in Denmark 1976, he received his Master of Engineering degree in 2001 and successfully defended his PhD thesis titled “Optical Performance monitoring in Optical Networks” in 2005. Both degrees were obtained at the Technical University of Denmark. Having worked on several fields within optical communication his main research areas remains to be optical performance monitoring as well as radio over fiber networks.