Transponder Impact on Power and Spectral Efficiencies in WDM Links Based on 10-40-100 Gbps Mixed-Line Rates

Peteris Gavars, Vjaceslavs Bobrovs, and Aleksejs Udalcovs
Institute of Telecommunications, Riga Technical University, Riga, Latvia

Abstract – It has been proved that optical networks which architecture is based on the Mixed-Line Rate (MLR) could in a cost-efficient manner scope with heterogeneity of constantly increasing traffic demands comparing to the Single-Line Rate (SLR) solutions. In the same time, the total power consumption required to ensure the transmission of 1 bps over a Wavelength Division Multiplexing (WDM) transport system depends on the number factors such as *(i)* number of wavelengths operating with the particular bitrate and modulation format; *(ii)* energy efficiency of transponder; *(iii)* spectral efficiency which will define the transparent optical reach and, hence, the number of 3R (re-timing, re-shaping, re-amplification) regenerations; *(iv)* distance between two network nodes between whom an end-to-end connection should be provisioned; and *(v)* signal quality need to be guaranteed at the receiving node.

In this paper we focus on MLR solution which employs three different bitrates – 10, 40 and 100 Gbps. Commonly used optical signal modulation format for the 10 Gbps wavelengths is the non-return-to-zero (NRZ) on-off keying (OOK), for the 100 Gbps – dual polarization quadrature phase-shift keying (DP-QPSK). Although several options are considered for the 40 Gbps such as the NRZ differential phase-shift keying (NRZ-DPSK), the optical duobinary (ODB) format or even the differential QPSK (DQPSK), the NRZ-DPSK is selected due to its very simple realization and lower OSNR (optical signal-to-noise ratio) requirements.

Hence, this papers aims at exploring the power efficient 10 Gbps, 40 Gbps and 100 Gbps wavelength assignment approach as well as the minimum optical bandwidth required to allocate these wavelengths in an end-to-end WDM link where the signal quality ($Q \geq 6$) is mainly limited by a linear crosstalk. In addition, in this paper we *(i)* report about power consumption values for different transponder and 3R types; *(ii)* explores the minimum allowable frequency intervals between collocated wavelengths to fulfill the signal quality requirements; *(iii)* compare the power efficiency of proposed MLR solution with the SLR ones; and *(iv)* analyze the gained transponder load as a function of average aggregated traffic.

While evaluating the power consumption of WDM transport system, we made these assumptions: *(i)* signal quality at the receiving node should be higher than Q=6 (corresponds BER=10^{-9}); *(ii)* spectral efficiency is fixed to the maximum value that is mainly defined by the linear crosstalk; *(iii)* frequency intervals used to separate neighboring channels is selected using ITU-T Recommendation G.694.1 while using finer granularity – 6.25 GHz. *(iv)* transparent optical reach is fixed to the one sector of transmission line consisted from the booster amplifier, 40 km of standard single mode fiber (SSMF) based on ITU-T Recommendation G.652.D and 8 km of dispersion compensating fiber (DCF). For the further transmission, 3R operations need to be done to secure the defined signal quality. And, finally, *(v)* connection is provisioned over end-to-end link without crossing any optical crossconnect (OXC) .

It is revealed that the lowest overall transponder power consumption is secured when not more than there 10 Gbps wavelengths are used to transmit the data and not more than one 40 Gbps wavelength is used regardless to the total capacity need to be transmitted, while the number of 100 Gbps wavelength should be increased as average aggregated traffic grows. This is explained with the highest energy efficiency of 100 Gbps transponders comparing to the 10 Gbps and 40 Gbps. If the number of each wavelength is selected using this proposed algorithm then the total power consumption required to ensure data transmission over one section of transmission line is: *(i)* the same as it would be for the 10 Gbps SLR solution and the capacity less than 30 Gbps; *(ii)* the lowest one for the traffic between 30 and 60 Gbps; *(iii)* not higher as it would be for 100 Gbps SLR solution.