Power Optimization for Datacenter Optical Transmitters

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Abstract: Power allocation is investigated for a non-repeated/non-amplified datacenter network scenario. A mathematical model is constructed for the optical eye amplitude in a power constrained case, and the effectiveness of the model is demonstrated experimentally. © 2019 The Author(s)

1. Introduction

Mega datacenters are fundamental for an increasing number of services. These include cloud-based data storage, high performance computing, video streaming etc. Thus resulting in a relevant energy footprint, with an estimated energy consumption in the United States of 70 billion kWh in 2014, approximately 1.8% of the total national electricity consumption [1], estimated to reach 13% of the world energy consumption by 2030 [2]. Of those, approximately 15% (more than 10 billion kWh in 2014) consumed by the network equipment [3]. Many efforts, are directed to lower the power requirement of the physical level network components [4]. Most studies, however, focuses on the efficiency of the overall network architecture, or at improving individual optical components.

Here beginning with the assumption of limited total available power, we analyze how different power allocation strategies affect the performance of an externally modulated intensity modulated direct detection (IM-DD) link. We first define the mathematical transmitter model and estimate the link performance. We then compare the analytical results with the experimental bit error rate (BER) measurements. The optimal power allocation is found to be of 2/3 of the power to the laser source and 1/3 to the electrical data signal.

2. Model and measurements

Fig.1(a) sketches the network scenario. The transmitter, is composed of a laser source externally modulated by a Mach-Zehnder modulator (MZM), connected through a passive optical link to the receiver. The power dissipated by the link equals the electrical power dissipated by the laser plus the power required to drive the modulator. A laser wall-plug efficiency of η=20% is assumed, the MZM half-wave voltage (V_π), insertion loss (IL), and input impedance (Z) are 5V, 6dB, and 30Ω, respectively. The amplitude ΔP of the optical modulated signal (see Fig. 1(a)), defined as the power difference between the logic zero (P_0) and one (P_1), can be calculated, neglecting noise contributions as in Eq. 1, where P_laser is the wall plug power dissipated by the laser, V_0 and V_1 are, respectively, the digital zero and one electrical amplitudes, assumed bipolar (i.e. V_0=−V_1), and V_b is the modulator bias voltage.

\[ ΔP = P_1 - P_0 = 10^{δ/10} η P_{laser} \left[ \cos \left( \frac{2πV_1 + V_b}{V_π} \right) - \cos \left( \frac{2πV_0 + V_b}{V_π} \right) \right] \]

(1)

The bias voltage, which maximizes the MZM electro-optical conversion, is found by maximizing the derivative of the MZM transfer function with respect to V_b. The point of maximum slope corresponds to the MZM quadrature point (V_b=V_π/2). Using the small signal approximation, and defining V_s=|V_1−V_0|/V_π, Eq. 1 can be written as:

\[ ΔP = k P_{laser} \left[ \cos \left( \frac{2πV_s}{V_π} \right) \right] \]

(2)

where \( k=10^{δ/10} \). \( P_{tot}=P_{laser}+P_s \) is the total available power, and \( P_s=V_s^2/Z \). From Eq. 2, the ΔP is linearly proportional both to the laser power and the electrical signal amplitude. Therefore, to double ΔP, it is possible either to double P_laser, or V_s, leading in the second case to a four-fold increase in the signal power required. Maximizing
4. References

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6. References