High Density FTTH Network Utilizing Asymmetric Data Transmission

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Abstract: A WDM-PON recycling incoming light to transmit upload stream has been proposed. Effect of Rayleigh scattering and uneven energy distribution are evaluated to achieve >60km bidirectional communication carrying 10Gb/s download and >300Mb/s upload data traffic.

OCIS Codes: 060.2330 Fiber optics communications, 060.2360 Fiber optics links and subsystems, 060.4510 Optical communications

1. Introduction

There have been many substantial research and development efforts placed on next generation optical access networks to provide low cost and broadband connectivity to multimedia and data communication users. WDM-PON is one of the most favorable approaches to provide large bandwidth [1-4]. However, it is expensive to use this approach because up-stream data communication requires a separate light source at each end user site. Since this requirement will increase the cost per user and require large backup inventory, alternative approaches has been sought. Recycling the incoming signal has been proposed to be a way of solving this problem. However, so far the proposed approaches either require time sharing of the source located in the central office [1,3,5] or complicated modulation and filtering schemes to generate clean signal for upload communication [1-4,6,7].

In this paper we propose and analyze a WDM-PON structure which recycles the incoming download data stream without any pre-processing and takes advantage of asymmetric nature of current data traffic. True PRBS nature of incoming data allows error free bidirectional communications with ~10x-100x asymmetry (10Gb/s download and 156 Mb/s-1 Gb/s upload). The system performance is impaired by the noise accumulation, Rayleigh backscattering and uneven energy distribution. By carefully adjusting the power levels in both directions, error free transmission up to 80 km can be achieved at 64x asymmetry. Increasing the upload data rates to over 1 Gb/s will result in 11 dB reduction in electrical Q values. However, despite the limitation of uneven energy distribution, 10 dB electrical Q values can be achieved over a >50 km communication link carrying 10 Gb/s download traffic and 625 Mb/s upload traffic.

2. Proposed System and Performance Analysis

The proposed network architecture is illustrated in Fig.1a. The central office generates 10 Gb/s broadcast signal and processes the upload data transmitted by the end user terminal. In this work we assume central office transmits 10 Gb/s 2^{18}-1 PRBS data with on-off ratio of 10 dB. Similarly, the end user terminal receives the broadcasted 10 Gb/s signal and splits into two. First part is sent to a receiver and the second half is recycled to transmit upstream data by using reflective semiconductor amplifiers (RSOA). After amplification in an EDFA with 6 dB noise figure, the transmitted signal passes through a ~10dB lumped loss element representing different loss elements such as splitters, an optical circulator separating upload and download data. The gain of the EDFA is adjusted accordingly to tune the power per channel launched into the fiber between 0.1mW and 10mW. At the user end, a small portion of the selected wavelength will be sent to a RSOA to generate upload data stream. The loss between the end of the transmission fiber and the amplifier is set to be 12 dB. We assume up to 20mW saturated output with 6 dB noise figure and ~30 dB small signal gain in the semiconductor amplifier is achievable. Figure 1b illustrates the modulation concept used in these simulations. Download data stream is generated by modulating a DFB laser at 10 Gb/s. The upload stream is directly encoded on top of the received signal, Fig. 1c. Here the envelope contains the information about the upload stream and 10 Gb/s modulation underneath the envelope needs to be discarded at the

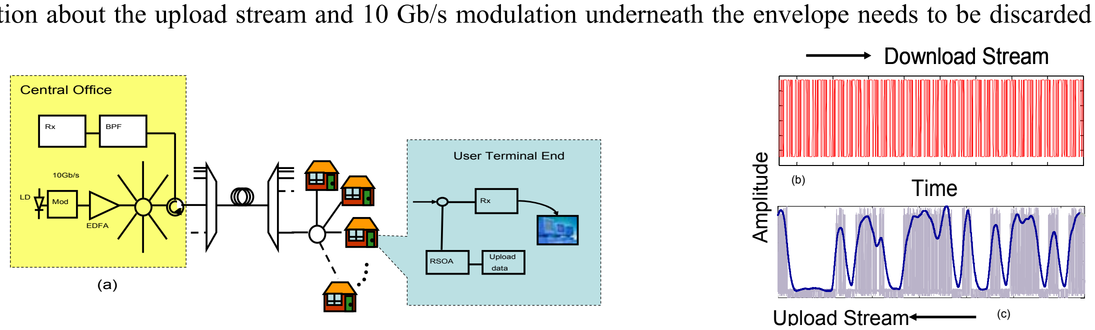

Fig. 1(a). Simulated network configuration. WDM PON is constructed to recycle download bit stream and facilitate bidirectional operation. Data encoding system for (b). Download data stream and for (c) Upload data stream.

receiver. This was achieved by using a low pass electrical filter at the receiver end at the central office, Fig 1c.

The system performance is evaluated based on the estimated Q value of the received signal at the central office. Here, we ignore the system performance of the download traffic and focus only on the upload traffic. The Rayleigh scattering, amplifier noise and uneven energy distribution of the received bits are identified to be three critical parameters affecting the system performance. In Fig. 2a, the system performance for different download stream power is estimated for 2 mW maximum upload stream power values. As estimated results indicate, error free communication is achievable up to 60 km if the Rayleigh scattering is low for low download power. As the download stream power increases to 10 mW, system performance decreases due to increased Rayleigh scattering. At very low power values (0.1 mW), the system performance is, as expected, noise limited. However, the maximum reach can be increased if the power levels at both ends are optimized, Fig. 2b. The results indicate that the increasing of the upload stream power will overcome the Rayleigh limitation and facilitate error free communication over 80 km. Practically, the saturated output power and small signal gain of RSOAs will limit the maximum reach.

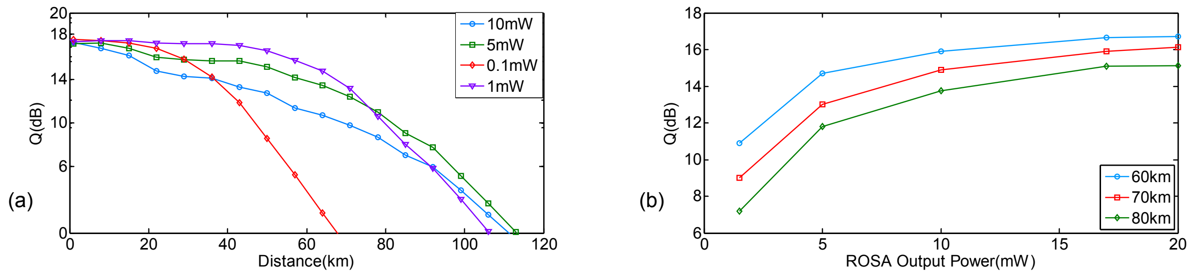

Fig. 2(a). Q value versus distance with four different power. (b). Q value versus RSOA output power with three different distance.

In addition to Rayleigh scattering, uneven energy distribution of received upload data will reduce the system performance. Ideally, a CW light source is desired to encode upload data for error free operation. If the random bit stream is recycled for upload data stream, different upload bits will have different energies due to the fact that each bit will contain different pattern underneath it. Probability of having long consecutive zeros in download data will raise the standard deviation of level "1" and level "0" which, in turn, will diminish the Q values. This problem is also related to randomness of the download data and asymmetry factor. As the upload bitrates increase, the variation in energy levels will increase. As Fig. 3 illustrates, the Q values decrease more than 11 dB if the asymmetry factor reduces to 10 to transmit 1 Gb/s upload data stream due to uneven energy distribution. However, >60km bidirectional communication is feasible at 312 Mb/s with ~14 dB Q values.

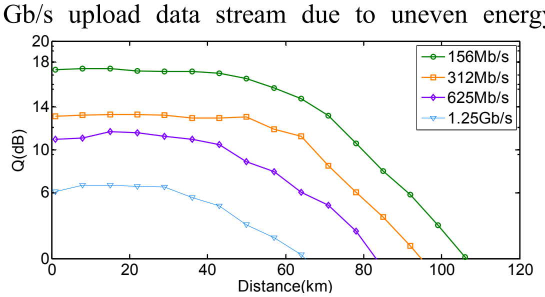

Fig. 3. Q value versus distance with four different upload bitrates

3. Conclusion

In summary, we propose and evaluate a PON structure which eliminates the laser source requirement at the end user terminal. Theoretical estimates show that bidirectional communication up to 80km is achievable with >14dB Q values. Rayleigh scattering, which requires strict power control, and uneven energy distribution, which limit the asymmetry factor and upload speed, are identified as two parameters affecting the system performance.

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