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Hybrid wavelength division multiplexing/time domain multiplexed (WDM/TDM) using radio over fiber technique with 16QAM at 2.5 Gbps

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There is growing demand for higher bit rates in the access domain due to the emergence of bandwidth-hungry applications such as video-on-Demand and file sharing. Gigabit-capable passive optical network (GPON) is the most important PON. In a hybrid wave division multiplexing/time division multiplexing (WDM/TDM passive optical network (PON), Quadrature amplitude modulation (QAM) is proposed as a way to achieve the necessary high bit rates. In this paper, 2.5-Gb/s hybrid WDM/TDM downstream link is presented, using radio-over-fiber (RoF) techniques in the GPON network, where 16QAM is used at 2.4 GHz frequency. The result shows a good performance with a distance of 25 km for single mode fiber which serves up to 32 users. The analysis was made based on the performance of eye and constellation diagrams.

Key words: Hybrid wavelength division multiplexing / Time domain multiplexed -passive optical network (WDM/TDM-PON, radio-over-fiber (RoF), Quadrature amplitude modulation (QAM) modulation.

INTRODUCTION

The rapid growth in internet use has led to the requirement of much higher bit rates for home and office users and has increased the popularity of video-related services (Heron et al., 2008). Users have required at least 100 Mb/s bandwidth in recent years, and to provide this broadband service, several technologies such as digital subscriber and coaxial cable have been made available to subscribers. However, the bandwidth of copper wire is limited due to physical media constraints, and as a result optical access networks have been used to satisfy the required bandwidth. In the future, a wireless system will have a lot of base stations, and a passive optical network to share the infrastructure between the base stations and reduce network costs (Shamim et al., 2011).

Time domain multiplexed (TDM) PONs is a cost-efficient solution for providing high bandwidth to users, but the bandwidth is still limited. Combining wavelength division multiplexing (WDM) with (TDM) PONs is very scalable and flexible network architectures are possible(Grobe and Elbers, 2008; Zhu et al., 2009). Many researchers have demonstrated the effectiveness of the different architectures of WDM-PON and hybrid WDM/TDM-PONs. In Bock et al. (2005), the researchers proposed a shared tunable laser based hybrid WDM/TDM PON architecture. Each optical network unit (ONU) was assigned a wavelength for a particular time slot that connects to the optical line terminal (OLT), providing a comprehensive insight into the most relevant protection mechanisms for hybrid WDM/TDM PONs (Abhishek et al., 2012), where the architecture provided support to TDM-PONs only. In Shachaf et al. (2007), the authors proposed a hybrid WDM/TDM-PON that used tunable lasers in the OLT. A coarse array waveguide grating (AWG) was used to support multiple TDM and WDM-PONs by using a

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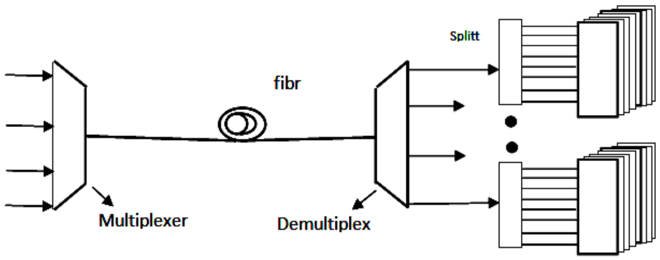

Figure 1. Hybrid WDM/TDM.

single OLT. We proposed a λ-tunable WDM/TDMPON system that flexibly operates using the distorted wave born approximation (DWBA) (Kimura, 2010). The main disadvantage of TDM PONs is that, since users share the available bandwidth, the total system bit rate is the sum of the bit rate guaranteed to each user. The increasing demand for higher user bit rates means that the system bit rate will need to be very high, requiring expensive electronics and optoelectronics at the Central office (CO) and the optical network unit (ONU). An interesting solution to this problem is the use of advanced multilevel modulation techniques. In order for the switch to multilevel modulation to be meaningful, the symbol rate should be at least four times lower than the bit rate (Sotiropoulos et al., 2010). Passive optical network (PON) architecture is capable of providing a low cost solution.

We categorize PONs into current generation and next generation PONs. TDM-PONs, such as Asynchronous transfer mode PON (A-PON), Broadband PON (B-PON), Gigabit capable PON (G-PON), and Ethernet PON (E-PON) are considered to be the current generation of PONs. The next generation of PONs is sub-categorized into short-term and long-term future generation PONs: 10GE-PON, XG-PON1, and XG-PON-2 as short-term future generation PONs, while WDM-PON and hybrid WDM/TDM-PONs are long-term future generation PONs.

Gigabit-capable passive optical network (GPON) is flexible in the information transfer of different bit rates and formats because bit rate and data format are transmitted over a different wavelength. The upstream bit rate can be up to 1.244 Gbps, while the downstream bit rate can be up to 2.44 Gbps in a single optical fiber. According to recommendations of ITU-T, G.652 also has high (92%) efficiency compared to other GPON types. Architecture which is discussed in the Gigabit-PON (GPON) is a preferred type of PON network to send high data rates with high frequencies which has been standardized under the ITU-T G.984 recommendation (ITU-T Recommendation G.984, 2008).

Hybrid structure

Figure 1 shows the hybrid WDM/TDM-system as modeled typically consists of three parts: transmitter, optical line terminal (OLT), fiber optic link (single mode fiber), receiver (Bras and Moignard, 2006; Talli and Townsend, 2006). The signal goes from the transmitter with multi wavelengths to the receiver, and these wavelengths are distributed among end users by using time slot splitter devices.

In OLT the radio frequency (RF) signal is modulated by a 16QAM sequence generator combined with a CW laser at wavelengths ranging from 193.1 THz to 193.4 THz by Mach Zehnder Modulator (MZM) to form the optical signal which is sent through the 25 km optical fiber to the receiver. The frequency spacing is 100 GHZ which defines the type of elements employed in the network and the cost associated with them (Chang et al., 2009). Here, all wavelengths are separated and fed to the power splitter so that signals can be further distributed to eight end users. At the receiver, photodiode detects the signal and passes it to the 16QAM decoder.

MATERIALS AND METHODS

Simulation design

This section briefly describes the simulation setup using OptiSystem *TM* software. Figure 2 shows the hybrid WDM/TDM-PON scheme. In the central office (CO), downlink 16QAM signals are generated. Channels are multiplexed and demultiplexed by 1x4/4x1 MUX/DEMUX, respectively. Each demultiplexed wavelength is connected to the splitter with a ratio of 1: 8 such that each splitter is connected to eight BSs. The electrical data signal is generated by a pseudo-random bit sequence generator (PRBS) with a 2.5 Gbps bit rate.

The data is modulated by a quadrature amplitude modulation (16QAM) sequence generator and an M-ary pulse generator producing M-ary signal. The M-ary signal is fed into a quadrature modulator (QM) at 2.4 GHz combined with a CW laser diode (LD) at frequency 193.1 THz for the first wavelength by Mach Zehnder modulator (MZM) to convert the electrical signal to an optical signal for transport through a 25 Km SMF.

The signal is detected by a photodiode in the receiver at the ONU, and fed to clock recovery in order to recover the data stream before it is passed to a quadrature demodulator. In order for the signal to be discovered by a 16QAM sequence decoder and pulsed by return-to-zero (RZ) pulse generator to obtain the binary signal, the QM is connected to an M-ary threshold detector to quantize the signal based on a suitable value of threshold amplitudes, and the constellation of signals is displayed by a constellation visualizer.

Eye diagram tools are added to plot the M-ary signal at the quadrature modulator output of the receiver, which consists of PRBS generator, RZ generator and eye diagram analyzer. The simulation was conducted using a total of 32768 samples with 128 samples/bit and sequence length of 256 bits.

RESULTS AND DISCUSSION

Figure 3 shows an eye diagram of one of the received signals at the 16QAM receiver. The clear opening eye indicates an error free performance of the system. Similar performances were observed at all receivers 32 BSs.

Figure 4(a) and (b) show the constellation diagram of

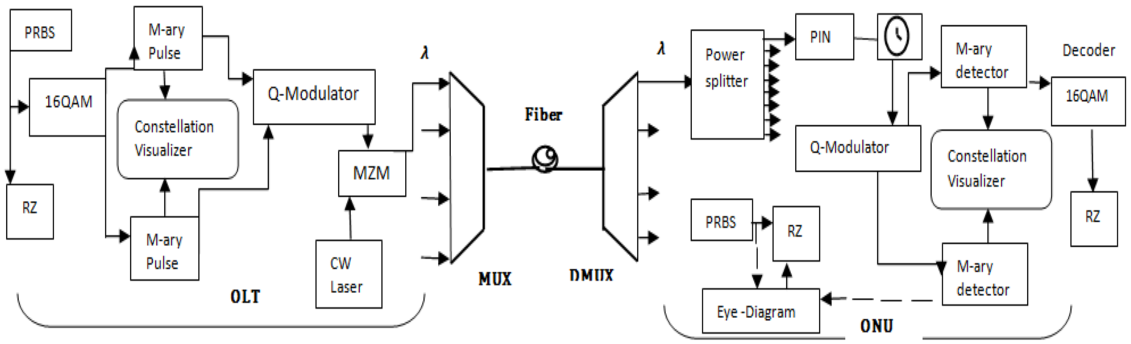

Figure 2. Downlink Hybrid WDM/TDM Schematic Diagram.

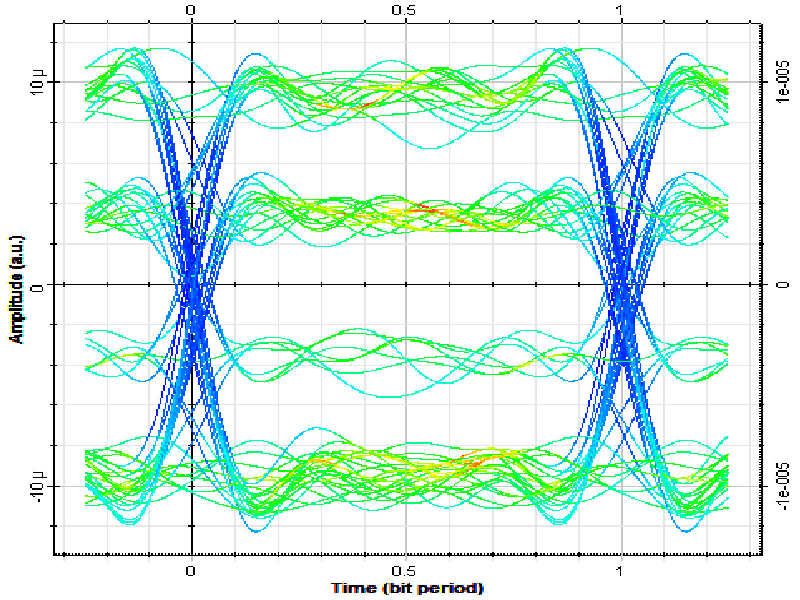

Figure 3. Eye diagram.

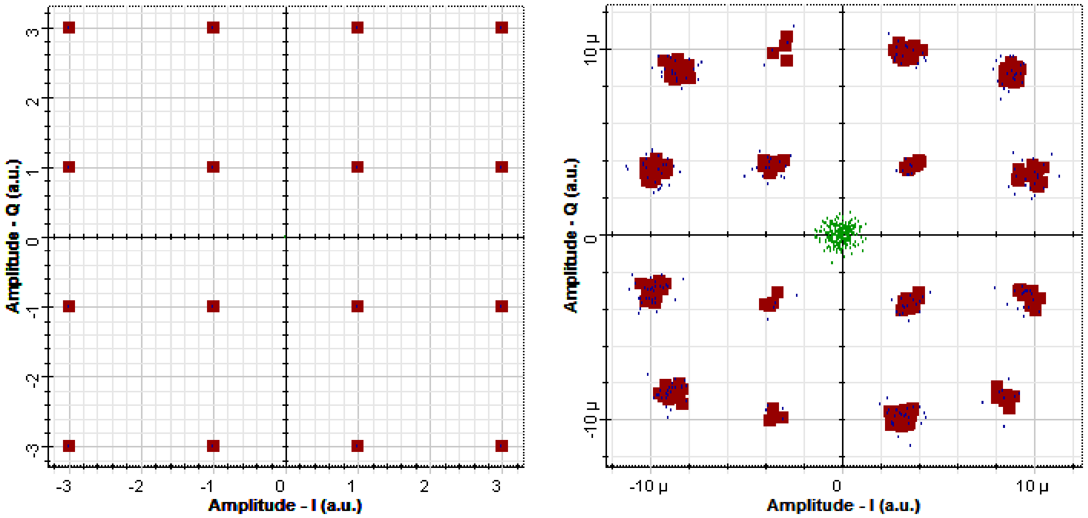

Figure 4. The constellation of the electrical signal at the (a) Transmitter and (b) receiver.

the outputs of the 16QAM transmitter and receiver, respectively. While the ideal scenario is depicted in Figure 4(a), the effects of noise and other distortion can be seen in Figure 4(b).

Conclusion

In this paper, the 2.5-Gb/s hybrid WDM/TDM GPON is based on 16 QAM modulation format, simulation results showed good performance of the proposed system for 16 to 32 users. Therefore, we believe that hybrid WDM/TDM GPON is a promising solution for today's communication to support the continuous demand for bandwidth among wireless users.

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