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Performance Analysis of OTDM using PON in Direct and External Modulation

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Abstract: ***The steady increase in the demand for broadband services and the consequent increase in the volume of generated traffic in our communication networks have motivated the need to implement next generation networks. The vision of Fiber-to the- Home (FTTH) was developed to satisfy the perceived need for future consumer applications. Optical fiber would permit high bandwidth transport, remove "bottlenecks" as video-rich services are developed, enable upgrades, and permit passive multiplexing that would remove remote powering costs. In this project an optical time division multiplexing PON is simulated. In order to determine the maximum transmission performance the link has been designed at different data rates of 30 Gbps, 40 Gbps, 50 Gbps, for different number of users, and using direct and external modulation. The eye diagrams for different data rates, different number of users, direct and external modulation has been obtained and graphical analysis has been performed. The simulation is done using Optsim software.***

Keywords: Time Division Multiplexing (TDM), Optical Time Division Multiplexing (OTDM), Passive Optical Network (PON), Bit Error Rate (BER)

1. Introduction

Optical fibers, clearly the chosen technology for transmission media, are beginning to find their place in the subscriber's loop. Currently fiber costs are high as compared to copper but there is a trend towards decreasing costs of optical fiber cables and photonics employed. In addition the tremendous advantage in terms of information capacity of fiber, its small weight and size over copper cable are making it a very attractive technology to replace copper in subs loop when advanced broadband services need to be offered to the customer. To carry the same information as one fiber cable we would need hundreds of reels of twisted wire of Cu cables. In crowded city networks they can easily be accommodated in existing ducted systems. In addition of a new Internet services like Triple Play and increasing user demands grow the requirement for greater bandwidth. Internet traffic grows around 50-70% per year.

Copper wiring are close to their limits - both achievable distance and bandwidth, and optical fiber seems to be the best appropriate solution. Gradually, optical fibers spread from a core networks to access networks. Data transport in optical networks can be presented by Time Division Multiplexing (TDM) and Wavelength Division Multiplexing (WDM), where TDM can be realize electrically (ETDM) or optically (OTDM). New trends in optical access networks include Passive Optical Networks (PONs), which are more economical than Active Optical Networks (AONs). For further increasing the bandwidth of PONs, it can be realized by OTDM, which has no electronics limitations and so can be used for high-speed data generation.

2. Passive Optical Networks

2.1 PON architecture

A passive optical network (PON) is a point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32-128. Figure 1 shows the PON architecture. The key interface points of PON are in the central office equipment, called the optical line terminal (OLT), and in the optical network unit (ONU). OLT devices support management functions and manage maximum up to 128 downstream links. In practice, it is common for only 8 to 32 ports to be linked to a single OLT in the central office. Consequently, the ONT/ONU devices are much less expensive while the OLTs tend to be more capable and therefore more expensive.

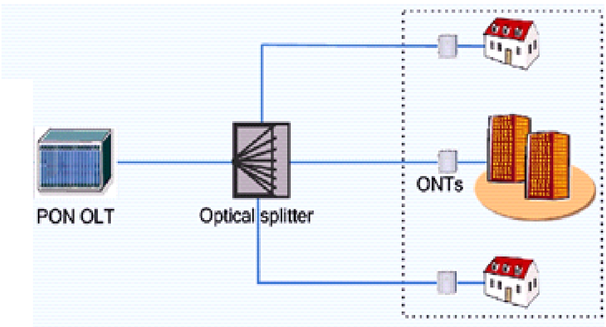

Figure 1: PON Architecture

2.2 PON Advantages

Passive Optical Networks (PON) provide high-speed, high-bandwidth and secure voice, video and data service delivery over a combined fiber network. Compared to active Ethernet, PON technology offers:

- Very high speed data up to 1 Gbit/s to home and businesses
- Maintenance cost reduction due to no electronics between CO and customers
- Low cost due to fiber and CO interface shared by several customers
- Constant data rate regardless of reach
- Multiple applications including data (IP), video and voice (triple play)

- 80% less power consumption and heat output
- 90% reduction in floor, rack and closet space

3. Optical Time Division Multiplexing

Optical Time Division Multiplexing (OTDM) is a scalable and powerful technique for investigating high-speed data transmission systems, associated signal processing and monitoring techniques at serial data rates far away from the bandwidth limitation of electronics. As compared to the Wavelength Division Multiplexing (WDM), only single wavelength (color) of light is used. An OTDM system includes a multiplexer at the transmission side and a demultiplexer at the receiving side. The multiplexer (MUX) brings together the bit stream with higher bit-rate from the base band streams, whereas the demultiplexer (DEMUX) rebuilds bit streams at the basic lower bit rate by bit separation in the multiplexed stream.

3.1 Principle of OTDM

The basic principle of time-division multiplexing and demultiplexing involves allocation of a series of time slots to all the baseband data streams on the multiplexed channel, this is shown in Figure 2. With the ever-increasing demand for higher speeds and larger capacity brought about by rapid data growth on the Internet, interest in optical time division multiplexing has been growing rapidly in recent years. OTDM also has the ability to overcome the electronic bottleneck offered by todays electronic components. In contrast to WDM, where multiplexing occurs in the frequency domain, OTDM transmits multiple data channels in the form of ultra-short duration optical pulses which are interleaved into a single high-speed data stream by accurate control of their relative delay in the time domain.

At the receiving end, an optical gate is used to extract one base rate tributary from the aggregate data stream for subsequent processing. Although such systems can potentially operate at speed much higher (>100Gb/s) than that limited by electronic components, several technologies are required to realize high-speed OTDM systems. These include high repetition rate ultra-short pulse sources, high speed demultiplexing and clock recovery. Some of these technologies are still at the research stage. OTDM is an effective way to increase the transmission capacity of a fibre system.

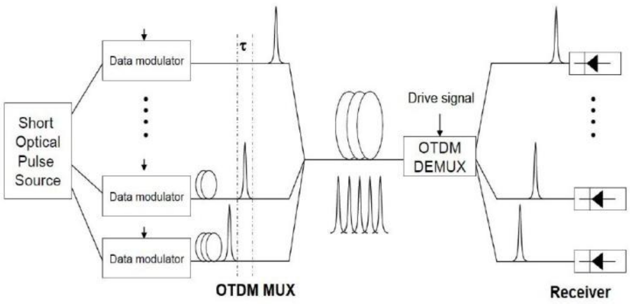

Figure 2: Principle of OTDM

3.2 OTDM Advantages

Compared to conventional WDM transmission systems, OTDM offers several advantages:

- In terms of transmission performance, since only one wavelength is used in a pure OTDM system, the gain tilt problem and dispersion tilt problem associated with wide-band WDM transmission can be eliminated. Also, the major limiting nonlinear effects for WDM systems, such as Four Wave Mixing (FWM) and Stimulated Raman Scattering (SRS) can be avoided.
- OTDM is not incompatible with WDM. For point-to-point applications, OTDM can be used to increase the data rate of WDM channels to reduce the overall complexity of the system. This is also a potential approach for enhancing the spectral efficiency for WDM system.
- By manipulating data in the electrical domain, a carefully organized OTDM transmission system may provide a truly high-speed low-latency data link with maximum parallelism. This may have important applications in both the distributed computing industry and scientific data acquisition.

4. OTDM Passive Optical Network

For increasing available distance and bandwidth of PONs, OTDM can be employed. The present bandwidth limit of PONs is about 40 Gbps. The TDM PON is a point to multipoint architecture. The packets are broadcasted by the Optical Line Terminal in the downstream direction. It is passed through a 1: N optical splitter and it is extracted by the designated Optical Network Unit. The data is sent in the form of packets and each user transmits after a definite time delay. The same time delay is utilized at the destination ONU to distinguish the packets meant for it. Using Optical Time Domain Multiplexing (OTDM) with the clock signal can be way for high speed PON in next future. There are two types of OTDM PON. In the first type, the transmitted signal is split into 1:N by optical splitter and each output branch of PON will demultiplex all OTDM channels. After demultiplexing, each Optical Network Unit (ONU) takes its own data and drops data of other units. Disadvantage of this design option is demultiplexing all OTDM channels in each output branch and also lower security because of channel sharing. Next type is similar to the first type, but each branch of split network demultiplex only its own OTDM channel. Figure 3 shows the diagram of an OTDM Passive Optical Network.

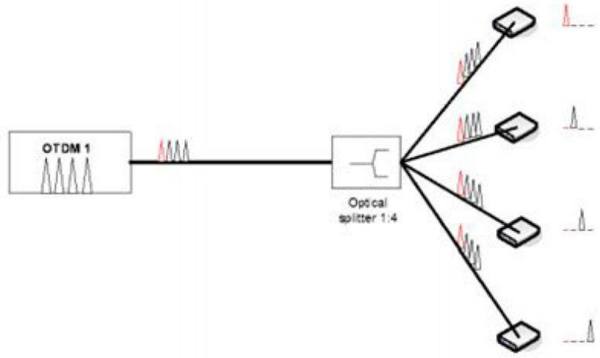

Figure 3: OTDM PON

5. Block Diagram of OTDM PON

5.1 Transmitter Section

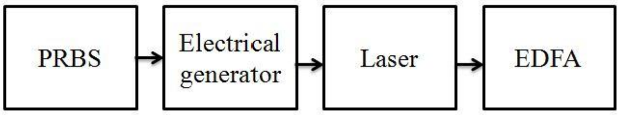

Figure 4: Transmitter section of OTDM PON

The block diagram of data transmitter section in an OTDM PON is shown in Figure 4. In the case of data transmitter, the PRBS generator produces a bit stream which is directly fed to the NRZ electrical driver, the output of the electrical driver goes to the modulator for producing optical signal. The modulator can be a direct or an external modulator. The output of which is fed to an EDFA for amplification.

5.2 OTDM Passive Optical Network

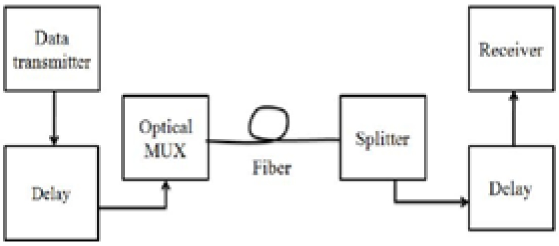

Figure 5: OTDM PON

The block diagram of an OTDM PON is shown in Figure 5. The outputs of the amplifier is fed to multiplexer, where the data is combined and passed through the optical fiber. Now at the end of the receiver side, every ONU has a particular receiver. Before the reception, a splitter is used to differentiate the particular user. The optical signal from central office travels through fiber and arrives at optical network termination. Block diagram of an OTDM PON unit. At the subscriber, the optical signal is demultiplexed and is fed to the corresponding detectors.

6. System Design

The simulation layout for the analysis of an OTDM link is shown in Figure 6 and Figure 7 using Direct and External modulation respectively. It mainly consists of three parts, the transmitter, channel and receiver. Transmitter consists of PRBS generator, mode locked laser, electrical generator, time shifting blocks, optical multiplexer and an optical normalizer. Multiple channels from the laser are modulated with PRBS patterns and hence generate multiple output patterns, with every one dissimilar from the other one and at the same bit rate. It is designed for ten channels operating on the same wavelength 1550 nm and with dissimilar pseudo random bit sequence (PRBS) modulated with NRZ and RZ modulation.

After the modulation process, every channel is delayed, multiplexed transmitted through the fiber and send to the splitter. The slitter is used to differentiate the users. Each branch of split network demultiplexes only its own OTDM channel. In order to determine the maximum transmission performance the link has been designed at different data rates of 30 Gbps, 40 Gbps, 50 Gbps, for different number of users, and using direct and external modulation.

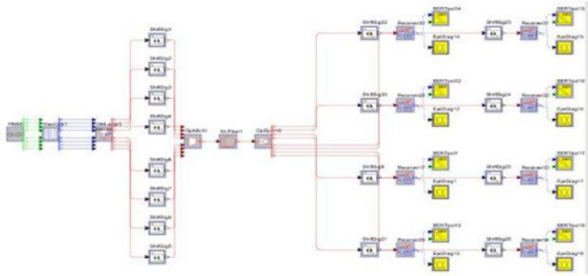

Figure 6: Simulation diagram of an OTDM PON using direct modulation

The modulation process can be done either by direct modulation or external modulation. In direct modulation, light is emitted from a semiconductor laser only when a 1 bit is transmitted. Ideally, no light should be emitted when a 0 bit is transmitted.

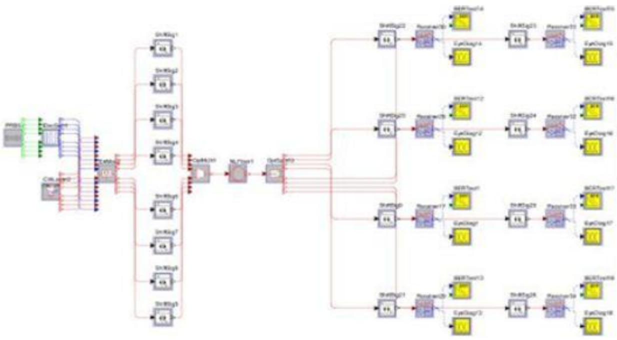

Figure 7: Simulation diagram of an OTDM PON using external modulation

In external modulation, a Continuous Wave (CW) laser is used to emit light whose power is constant with time. A second component, known as modulator, is used as a switch to pass the light whenever the data corresponds to a 1 bit and to block it whenever the signal is a 0 bit.

7. Results and Discussion

In order to determine the maximum transmission performance the link has been designed at different data rates of 30 Gbps, 40 Gbps, 50 Gbps, for different number of users, and using direct and external modulation. The eye diagrams for different data rates, different number of users, direct and external modulation has been obtained and the performance has been analysed. The effect of input signal power on BER has also been analysed.

7.1 Eye Diagram Analysis of OTDM PON

The eye diagram analysis of an OTDM PON is done at a distance of 2 Km, using ITU G.653 fiber standard at different data rates of 30 Gbps, 40 Gbps and 50 Gbps. The eye diagrams obtained for different data rates and different number of users are shown below:

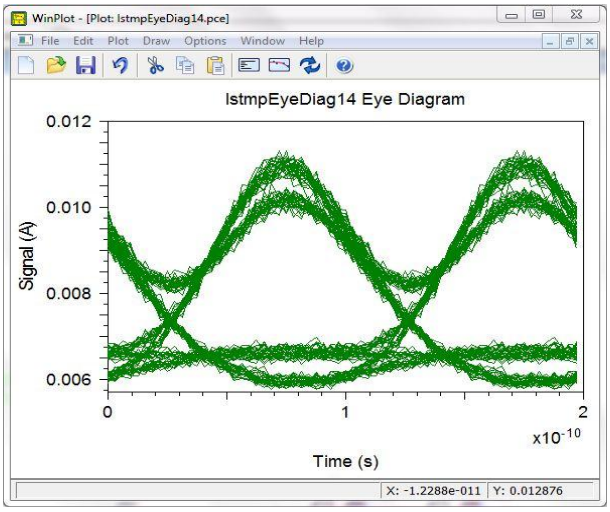

Figure 8: Eye diagram for direct modulation with 1 user

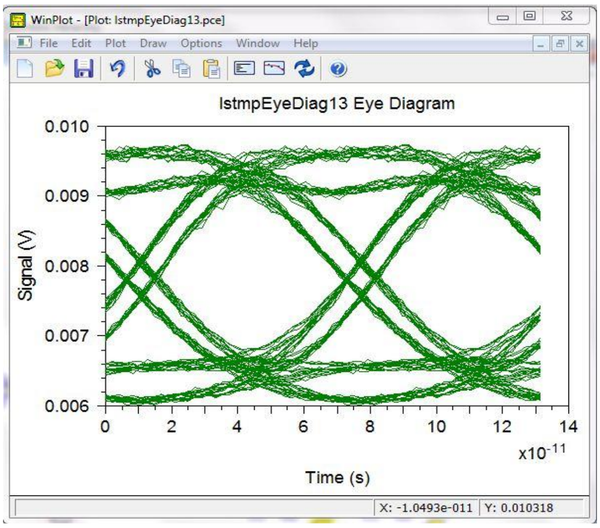

Figure 9: Eye diagram for direct modulation with 8 users

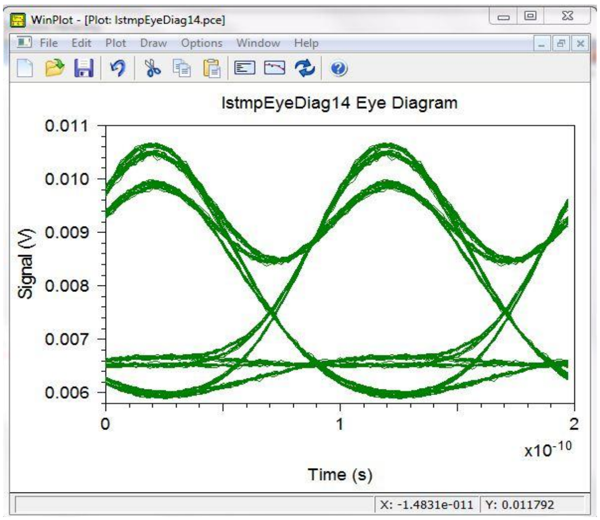

Figure 10: Eye diagram for external modulation with 1 user

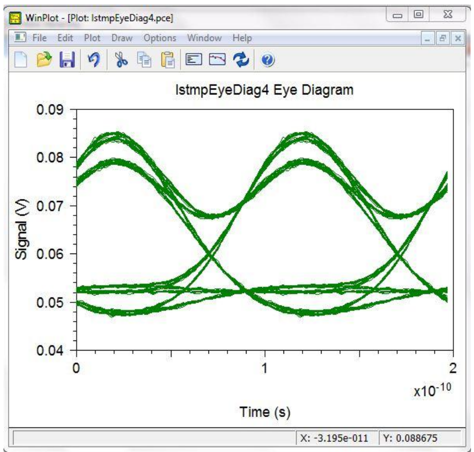

Figure 11: Eye diagram for external modulation with 8 users

Figure 8, 9, 10 and 11 shows the eye diagrams obtained for direct and external modulation with different number of users. From the above eye diagram analysis of an OTDM PON it is clear that the maximum eye opening i.e maximum transmission performance is obtained while using direct modulation with 1 user.

7.2 Graphical Analysis of OTDM PON

In the transmitter section of an OTDM PON, the data signals are modulated directly and externally. The effect of different modulation techniques on BER is given below.

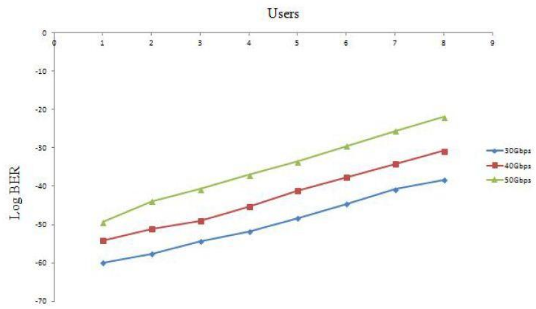

Figure 12: Log BER Vs. no. of users for Direct Modulation

The effect of direct modulation, no. of users and data rate on BER is shown in Figure 12. As the no.of users and the data rate increases the BER also increases. From the graph it is clear that the BER is minimum for a single user and at a data rate of 30 Gbps.

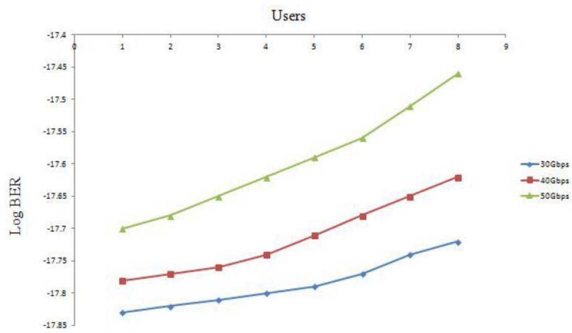

Figure 13 Log BER Vs. no. of users for External Modulation

The effect of external modulation, no. of users and data rate on BER is shown in Figure 13. As the no.of users and the data rate increases the BER also increases. From the graph it is clear that the BER is minimum for a single user and at a data rate of 30 Gbps.

In direct modulation the BER ranges from -60 to -50, whereas in external modulation the BER ranges from -17.82 to -17.7. This is because direct modulation occurs when the electrical information stream varies the laser current directly to produce a different optical power. The main limitation of direct modulation is the broadening in the line width of the laser because of the laser on and off process. This results from the electrical signal that drives the laser source. The broadening of the line width is called chirp, and it will lead to degradation in the system performance.

Whereas in external modulation, the laser source emits a constant amplitude signal that enters the external modulator such as a Mach-Zehnder Modulator (MZM). The electrical signal then enters the external modulator to change the optical power level alone, it does not change the amplitude of the light. The constant amplitude signal from the laser source helps to avoid the chirp of the pulses which reduces the dispersion and makes this process more effective.

8. Conclusion

Optical Time Division Multiplexing (OTDM) provides a strategy for increasing the bit rate of digital optical fiber system beyond the bandwidth capabilities of the drive electronics. Further increase in bandwidth is provided by OTDM PON. An OTDM PON using both external and direct modulation has been analysed for different number of users. Graphical analysis and eye diagram analysis has been performed. From the graphical analysis of the OTDM PON it has been found that external modulation is better than direct modulation. It has also been found that the transmission performance is better for less number of users.

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