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Gate Based Design of WDM PON to Dynamically Allocate Bandwidth for Extended Reach

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Abstract
Passive Optical Networks (PON) has been considered as a promising technique to support the high-speed services for data and video conference. In traditional PON the bandwidth is not efficiently utilized and also bandwidth requirement is variable from one user to another user. In this paper we have designed and proposed a system for Wavelength Division Multiplexing (WDM) PON using “Gates” to Dynamically Allocate Bandwidth (DBA) for Extended-reach Gigabit-capable Passive Optical Networks (GPONs). The performance of this system is investigated for different users and variable fibre distances and for gigabit data rates. DBA gives better performance and proves that the technology is a viable solution for the future. The simulation performance are investigated and analysed using BER, SNR and Q Factor parameters.

Keywords: Passive Optical Networks (PON), Wavelength Division Multiplexing (WDM), *Dynamically Allocate Bandwidth (DBA), Gigabit-capable Passive Optical Networks (GPONs),* Bit Error Rate (BER), Signal to Noise ratio (SNR), *Status Reporting (SR), Non Status Reporting (NSR).* Dense Wavelength Division Multiplexing (DWDM), Optical Line Terminal (OLT), Optical Networks Unit (ONU), PIN and Avalanche Photo detectors (APD).

Introduction

In today’s telecommunication world there is a increasing demand for data traffic. The demand is met by the use of Optical Networks. The Next Generation Optical Networks increases the coverage area of wireless access networks and reduces the system overall cost, because of the huge band width and low attenuation offered by the optical fiber. The recent state-of the-art research on the enabling technologies needed to realize future TDM-PON and WDM-PON systems, and discusses the future directions toward practical PON systems. The recent PON’s are categorized as ATM, Ethernet, and WDM.

The WDM PON are designed using only passive components. Since active components are not used power and heat issues are negligible. So WDM PON requires less components and cost is low for maintenance. Different Dynamic Bandwidth Allocation Algorithms and an idea of how to apply them in long-reach Gigabit-capable Passive Optical networks (GPONs) is been developed. WDM PON plays a crucial role for multiservice and multicasting.

A heterogeneous, optical/wireless dynamic bandwidth allocation framework is presented, exhibiting intelligent traffic queuing for practically controlling the quality-of-service (QoS) of mobile traffic, backhauled via orthogonal frequency division multiple access–PON (OFDMA-PON) networks[1]. In this work an XG-PON oriented dynamic bandwidth allocation (DBA) algorithm that distributes the available upstream bandwidth by taking into account delay limits and fairness considerations[2]. We examined CluLoR, which improves throughput-delay performance compared to a flat (unclustered) topology, only for an elementary dynamic bandwidth allocation (DBA) algorithm in the optical part of the FiWi network[3].

Dynamic bandwidth allocation algorithm has been proposed for high utilization which is used to utilize the unused bandwidth[4]. A simple and feasible dynamic bandwidth allocation (SFDBA) algorithm in order to utilize the unallocated bandwidth and to achieve the implementation feasibility. SFDBA is based on an immediate allocation with colorless grant (IACG) algorithm but SFDBA uses only a single available byte counter and a single down counter for multiple queues of a same service class[5]. A FTTx system using an active wavelength selective switch (WSS) incorporated with a dynamic wavelength and bandwidth allocation (DWBA) in order to improve the efficiency in bandwidth consumption of the FTTx based on wavelength division multiplexed passive optical network (WDM-PON)[6].

A dynamic bandwidth allocation algorithm called adaptive limited dynamic bandwidth allocation for multi-OLT PON (ALDBAM)[7]. Algorithm can effectively prevent excess distribution from bandwidth monopolization and over-allocation [8]. An immediate allocation with reallocation (IAR) algorithm for a dynamic bandwidth allocation of lO-gigabit-capable passive optical networks (XGPONs)[9]. A robust dynamic approach which periodically identifies bandwidth allocation to VNs to work reasonable well for a range of traffic patterns over a period of time, rather than certain traffic pattern instance[10]. Research an improved dynamic bandwidth allocation algorithm for difficult problems of QoS in Multi-service transmission, which is named Multi Sub-Cycle dynamic bandwidth allocation (MSC-DBA) algorithm. MSC-DBA algorithm divides a complete polling cycle into two sub-cycles, which are used for priority forwarding and conventional forwarding[11].

Proposes a multi OLT-PON system that allows multiple vendors to provide services to users in parallel through a single network. The Guaranteed Limited Dynamic Bandwidth Allocation (GLDBA) scheme is proposed for downstream transmission in the system[12]. Two techniques for reducing the buffer size and computational complexity of an aggregation layer-2 switch (L2SW) in access systems by using buffer observation and multilevel dynamic bandwidth allocation (DBA)[13]. Vehicular social network (VSNs) proposed in this paper needs to consider both social aspects (such as social ties through common interests) and physical network operational mechanisms to design a system that is effective to its users and efficient to network resources[14].

The paper reviews the static and dynamic models for WDM PON and as an extension it has also provided models for WDM/TDM PON[15]. The Dynamic Bandwidth Allocation algorithm which enables to overlap the idle time slots in each packet transmission cycle with a virtual polling cycle to increase the effective transmission bandwidth. The new scheme has exhibited significant improvement in channel throughput, mean packet delay, and packet loss rate in the presence of class-of-service and service-level differentiation.[16]

The paper proposes and demonstrates a novel Wavelength-Division-Multiplexed PON (WDM-PON) architecture to simultaneously provide wired services. The optical line terminal (OLT) uses two cascaded Mach–Zehnder modulators (MZMs) on each wavelength channel to generate an optical carrier, and produce the wireless and the downstream traffic using the orthogonal modulation technique.[17]

A well-defined DBA algorithm significantly improve network performance, provide a means of flexibly tailoring network responsiveness and enable a service provider to generate more revenue from their FTTH networks without boosting raw bandwidth by increasing the percentage of acceptable oversubscription.[18]. This article compares currently available Bandwidth Allocation methods and their impact on the service provided to the subscriber. By simulating a real-life TCP download scenario, it shows that Status Reporting (SR) DBA is a superior tool to provide a high level of quality of service. [19]

In this paper [6], WDM EPON architecture is presented along with a novel algorithm for wavelength and bandwidth allocation with full QoS support. Besides theoretical analysis, simulation results are presented and they confirm a good performance of presented solution. Paper[20] proposes a λ-tunable WDM/TDMPON system that flexibly operates using the DWBA. It is believed that this system will have a great impact on the development of future flexible optical access networks. A WDM/TDM-PON system employing a dynamic wavelength and bandwidth-allocation technique is proposed for future flexible optical-access networks.

An intense research work has been carried out in WDM PON for DBA applying different algorithm. The deployment of several architecture have raised the data carrying capability and system reach. The research work is carried and examined using gate logic. The rest of the paper is organised as section 2 describes proposed methodology carried out, section 3 says about the simulation and performance analysis, section 4 gives a brief about results and discussions, section 5 says about conclusions and last the references.

Proposed Method

Gate Based DBA WDM PON Design

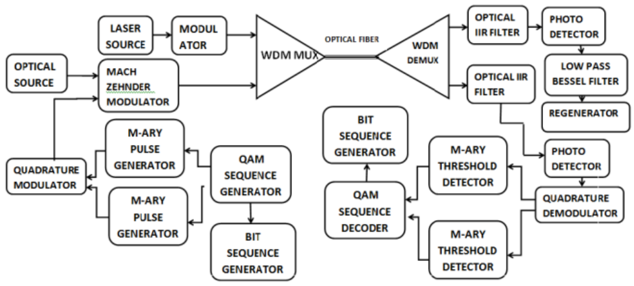

Fig1 Block diagram of WDM DBA PON

Transmitter Design

The layout of the data transmitter and receiver using gates is shown in fig1. Data transmission is done by Pseudo Random Bit Sequence Generator is used to approximate the characteristics of random data. The bit sequence generated is given to an NRZ Pulse to convert the bit sequence into a series of pulses. Low frequency messages pluses is modulated by a high frequency signal of Continuous Wave Laser. The electrical signal is modulated to light beam by Mach Zehnder Modulator.

Video transmission is done by PRBS, the bit sequence generated is given to QAM sequence generator. QAM restores the two independent DSBSC signal, is given to M-ary pulse generator. In the QAM modulator the messages varies the amplitude of each of the DSBSC signals. In quadrature modulator, QPSK modulator is used, but with binary messages in both the I and Q channels. Each message has only two levels, ±V volt. For a non-band limited message this does not vary the amplitude of the output DSBSC. As the message changes polarity this is interpreted as a 180^0 phase shift, given to the DSBSC.

Thus the signal in each arm is said to be undergoing a 180^0 phase shift, or phase shift keying-or PSK. Because there are two PSK signals combined, in quadrature, the two-channel modulator gives rise to a quadrature phase shift keyed-QPSK-signal. The M-PAM Modulator Baseband block modulates using M-ary pulse amplitude modulation. The output is a baseband representation of the modulated signal. The **M-ary number** parameter, M, is the number of points in the signal constellation. It must be an even integer

The signal from the transmitter is converted to electrical signal to perform the logical gate operations. So an optical to electrical converter is used where photo detector converts the

signal to electrical. There are two optical to electrical converters, one for the data signal transmitted at the frequency of 193.1 THz (TX_1) and the other for the video signal transmitted at the frequency of 193.2 THz (TX_2).
If the trigger is set ON, meaning the user is asking for more bandwidth, then the Optical Switch will switch the path of the signal to the Mux offering more bandwidth (MUX_60GHz). If there is no request then the signal will be sent along the original
path (MUX_10GHz). The signals from both the Muxes are then added together and sent along the optical fiber. Theoretically the output from the Mux which is not being used should be zero. Hence the result of the optical adder is the signal which is sent through the active Mux. forwarded to the AND_2 gate which is directly connected to MUX_60GHz. Logical operator decides whether the signal is to be sent to MUX_10GHz or to MUX_60GHz. Here, the trigger signal is the determining factor as to which mux must be chosen. When the trigger is OFF (i.e. no request has been sent), the main signal is forwarded to the AND_1 gate which is directly connected to MUX_10GHz. When the trigger is ON (i.e. a request has been sent), the main signal is forwarded to the AND_2 gate which is directly connected to MUX_60GHz.

Gate Logical Operations.
Considering the following cases:

- TRIGGER is OFF ("0"): The gate AND_1 will be active while AND_2 will not. This is due to the NOT gate which is connected in between the Trigger Signal and the gate AND_1. The signal is forwarded to MUX_10 GHz.
- TRIGGER is ON ("1"): The gate AND_2 will be active while AND_1 will not. This is because there is no NOT gate connected in between the Trigger Signal and the gate AND_2. The signal is forwarded to MUX_60 GHz.

This logic enables the system to function dynamically.

Electrical to Optical Converter
To transmit the signal through the optical fiber, it must be converted again to an optical signal. Hence an optical to electrical converter is used. The signal is then forwarded to the appropriate mux. The problem encountered due to these conversions is that noise is added from the CW Laser. This is because irrespective of the state of the Trigger only one Laser and Modulator will be used. The other Laser will inadvertently add noise to the system. The optical signals from the EO conversion is sent to data wdm mux and video wdm mux and finally the optical signals are added together and these signals are send to the optical fiber.

Receiver Design
After traversing the length of the fiber the signals are then passed through both the DEMUX (Demux_10GHz and Demux_60GHz). The reason behind sending the signals through both the demuxes is that while the signal is travelling through the fiber, converting it to an electrical signal.
Sconverted to electrical signals using an Optical to Electrical Converter. Fig 4. Shows the schematic of the receiver end using gates.

Considering the following cases:

- TRIGGER is OFF ("0"): From the schematic, it can be seen that only gates Electrical AND_1 and Electrical AND_2 will produce an output. This is because of the
- NOT gates connected in between the trigger and the AND gates 1 and 2.
- TRIGGER is ON ("1"): It can be seen that only gates Electrical AND_3 and Electrical AND_4 will produce an output. This is because of the absence of the NOT gates connected in between the trigger and the AND gates 3 and 4.

The Electrical OR gate performs a function similar to that of the Optical adder.

Considering the following cases:

- TRIGGER is OFF ("0"): The inputs to the Electrical OR_1 are the outputs of the gates Electrical AND_1 and Electrical AND_3. As mentioned above, for this condition, only AND_1 will produce an output whereas AND_3 will not. So the output of Electrical OR_1 will be the output of AND_1. Similarly the output of Electrical OR_2 will be the output of AND_2.
- TRIGGER is ON ("1"): The inputs to the Electrical OR_1 are the outputs of the gates Electrical AND_1 and Electrical AND_3. As mentioned above, for this condition, only AND_3 will produce an output whereas AND_1 will not. So the output of Electrical OR_1 will be the output of AND_3. Similarly the output of Electrical OR_2 will be the output of AND_4.

After performing this sequence of logical operations the signals are once again converted to optical signals and finally transmitted to the end user. The above procedure shows that even though both the demux are used only one of them provides output to the end user thus showing that the bandwidth has been allocated as per the requirements of the user.Table 1 shows the parameters used for the simulation of both PON network.

THE PARAMETERS FOR PON NETWORK

TABLE 1 THE PARAMETERS FOR PON NETWORK

Components	Parameters	
	Type	Value
PRBS generator	Bit Rate	1-5 GBPS
Light source	Wavelength	1552-1527 nm
Modulator	Modulation format	MANCHESTER
WDM MUX	Insertion loss	0dB

	Filter type	Bessel
	Filter order	2
Optical fiber	Fiber length	20-100km
Photodetector	Responsivity	1A/W
	Dark current	10 nA
Layout parameters	Sequence length	128 bits

4. PERFORMANCE OF WDM-PON AND DBA-WDM PON

Quality of service of DBA WDM-PON are recorded and the results are compared to check the performance level to show that DBA WDM-PON is better than the WDM PON. The DBA WDM PON model was studied extensively for 4, 8, 16, 32 users. It was also extensively studied for varying fibre lengths of 25km, 50km and 100km.Parameters used are Bit Rate 10 Gbits, Transmitter Signal Power 10dBm.

WDM Passive Optical Network

BER Plot:

Fig 2. Shows the BER Plot of the WDM PON. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The BER for 32 ONU's is optimum when compared with others.

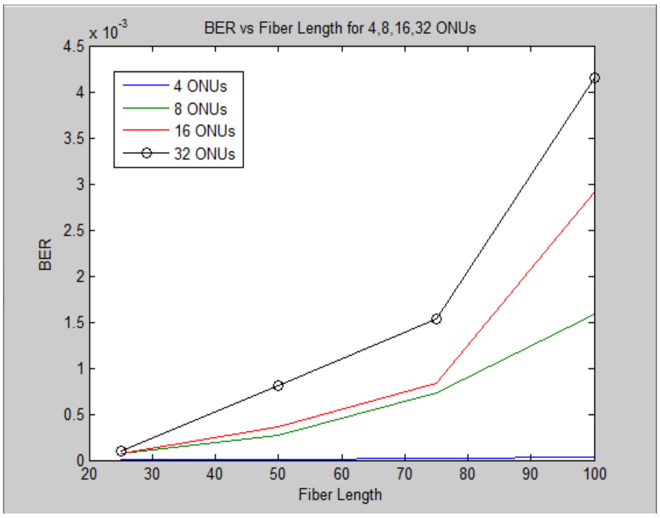

Fig 2. BER of the WDM PON system for different users and different lengths

Q Factor Plot:

Fig 3. Shows the Q factor Plot of the WDM PON. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The Q factor for 32 ONU's is optimum when compared with others. It also shows that Q factor decreases as length of the fiber increases.

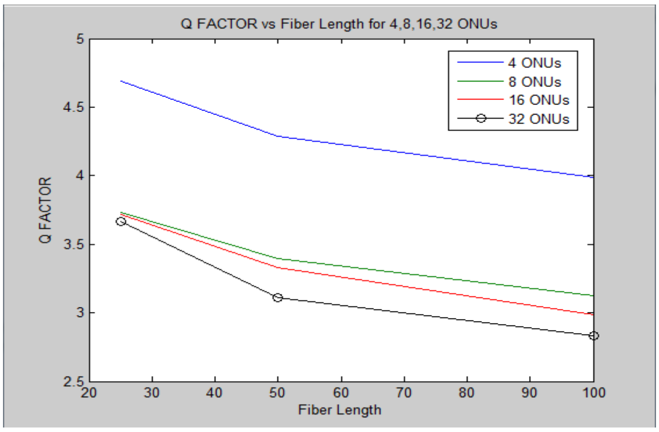

Fig 3. Q Factor of the system for different users and different lengths. SNR Plot:

Fig 4. Shows the SNR Plot of the WDM PON. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The SNR decreases as length increases. It also shows that noise increases and signal decreases.

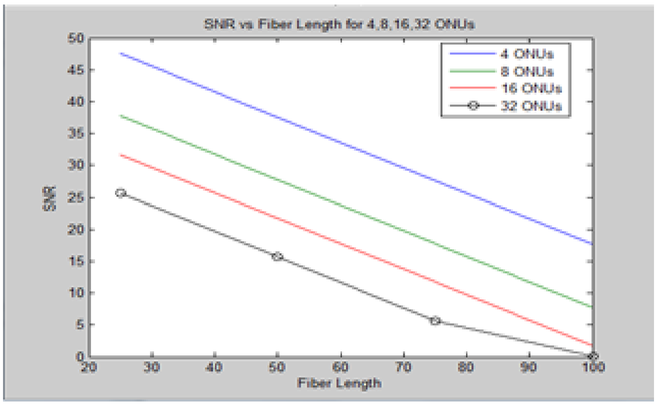

Fig 4. SNR of the system for different users and different lengths

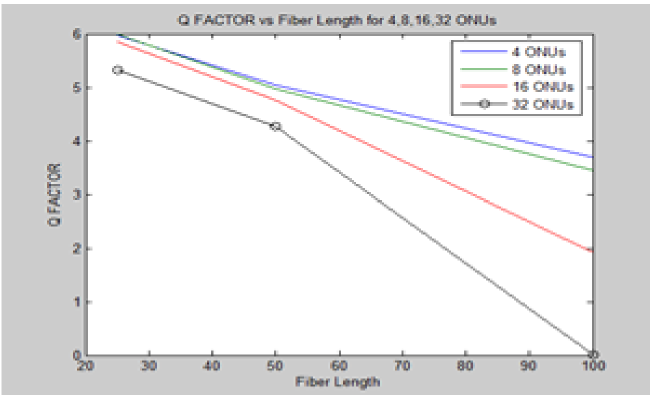

Fig 6.Q Factor of the DBA WDM PON system for different users and different lengths

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DBA WDM Passive Optical Network.

BER Plot:

Fig 5 shows the BER of the system for different users and different lengths under the influence of DBA. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The BER decreases as length increases.

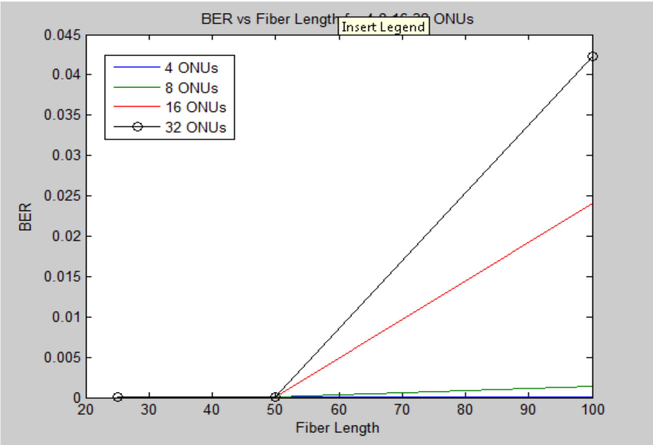

Fig 5. BER of the DBA WDM PON system for different users and different lengths.

Q Factor Plot:

Fig 6 shows the Q Factor of the system for different users and different lengths under the influence of DBA. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The Q factor decreases as length increases.

SNR Plot:

Fig 7 shows the SNR of the system for different users and different lengths under the influence of DBA. It was analyzed and studied form 4 users to 32 users and also for various length of optical fiber from 20 km to 100 km. The SNR value decreases as length increases.

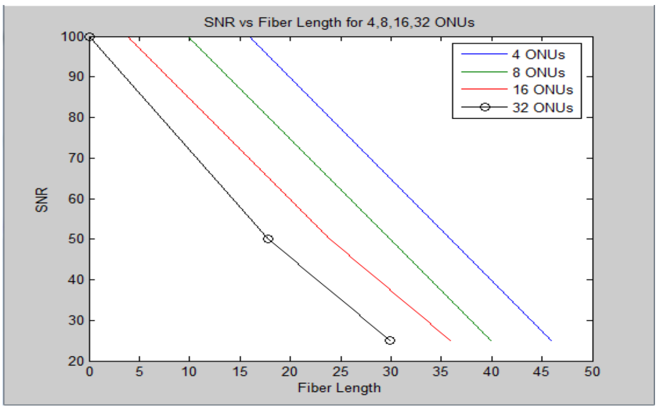

Fig 7.SNR of the DBA WDM PON system for different users and different lengths.

Spread Spectrum illustrating Bandwidth Spread at 10 GHz for Data.

Fig 8. Shows the spread spectrum at 10 GHz. It proves that the data send in this frequency is wide spread, so that it is experimentally proved that band width is allocated dynamically using gates in this region.

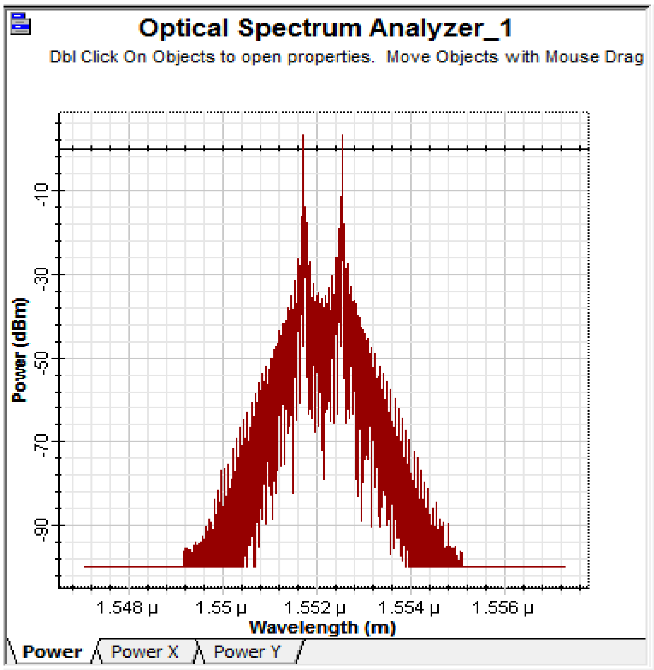

Fig. 9. Bandwidth spread at 10 GHz.

Spread Spectrum illustrating Bandwidth Spread at 10 GHz for Data.

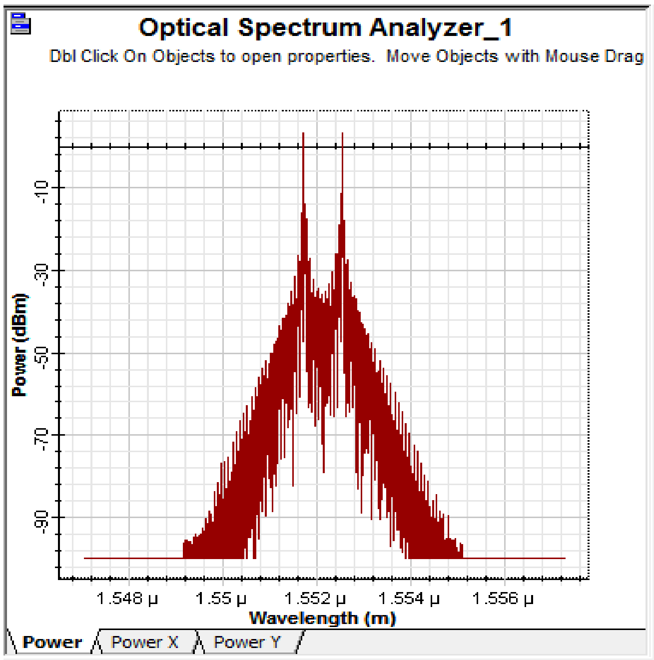

Fig. 9. Bandwidth spread at 60 GHz.

Spread Spectrum illustrating Bandwidth Spread at 60 GHz for Video

Fig 9. Shows the spread spectrum at 60GHz. It proves that the video send in this frequency is wide spread, so that it is experimentally proved that band width is allocated dynamically using gates in this region.

Tabulation of DBA WDM PON using Gates.

Table 2. shows the tabulation of DBA WDM PON using gates. It compares the BER, Q factor and SNR values for different fiber length.

Table 2. Readings of DBA WDM PON using Gates.

Parameter/ Fiber Length (km)	25	50	100
BER	$4.24577e^{-9}$	$5.79781e^{-6}$	$2.53845e^{-4}$
Q Factor	5.6813	3.69071	3.40385
SNR	32.533	31.76	19.308

Results and Discussions.

In this paper a WDM PON is designed and simulated and their performance is studied using BER, Q factor, and SNR which is shown all above. It shows that the bandwidth is fixed, so their performance is low. So we designed a system and analyzed using gates how to improve the performance for dynamically allocating bandwidth for WDM PON. It proved that DBA WDM PON gives better BER, Q factor and SNR when compared with WDM PON.

Conclusions and Future Scope.

The simple WDM PON and DBA WDM PON systems were successfully designed using OPTISYSTEM software. The results conclusively show that out of the two systems the DBA WDM PON system offered the best performance. The gates also have some disadvantages when encountered in the design are noise gets added to the system before the signal entered the optical fiber. The number of components required to design the system was high. Complexity of the system. These difficulties were overcome while designing the system using Optical Switches. Thus, in conclusion, it can be stated that a WDM PON system under the influence of Dynamic Bandwidth Allocation can offer superior performance if it is designed using Optical Switches.

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