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Design of Wireless Passive Optical Communication Network Based On Fusion of Fibre to the Home Architecture

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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 in our territories. Optical Fibre cable is used as media to design long/short network and it supports high bandwidth in Gigabits per second speed. Earlier OFC is used to connect the long distance places and called Optical Transport Network and presently used even in local/Access network called Optical Access Network. In present environment data to be transmitted is so high due to growth in internet. Successful transmission of such a huge bandwidth is big challenging job for long distance network designer. All customers require the QOS and they are interested to make SLA for their service to be obtained from Service provider. ISP should design their network to support the customer requirement suitably otherwise ISP cannot survive in this competitive environment. This paper aims to explain the design and planning of a passive optical network based fiber to the home architecture. The main idea of this paper is to build a fabricated environment that allows us to analyse the depth on FTTx networks and decide which is the most preferable option for this environment. Finally, the simulation software that meets the design requirements will be chosen, the design of passive optical network will be made and the results justify that the network is more viable and can be implemented in a real time.

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1 Introduction

Fiber optics is simply strands of flexible glass as thin as human hair that is used for telecommunications. These strands carry digital signals with light. The glass cables are covered with a special protective coating called cladding. It is made from a material that reflects the light back into the core or centre of the cable. The final outer layer is a buffer coating to protect this special glass cable from damage and moisture. Fiber optics work using the total internal reflection principle. By using Fiber optics we are going to transmit signals over Long distances. Light travelling from one material to another changes its speed, which results in light changing its direction of travel. This deflection of light is called Refraction. As the angle of incidence increases, the angle of refraction approaches 90° to the normal. The angle of incidence that yields an angle of refraction of 90° is the critical angle. If the angle of incidence increases more than the critical angle, the light is totally reflected back into the first material so that it does not enter the second material. The angle of incidence and reflection are equal and it is called Total Internal Reflection. The optical Fiber has two concentric layers called the core and the cladding. The inner core is the light carrying part. Typical values for example are a core refractive index of 1.47 and a cladding index of 1.46. This buffer coating is a shock absorber. The specific characteristics of light propagation through a Fiber depends on many factors, including the size of the Fiber, the composition of the Fiber, the light injected into the Fibre [2]. The idea of light travelling through a Fiber. Light gets injected into the Fiber and strike the core to cladding interface at an angle greater than the critical angle, reflects back into core, since the angle of incidence and reflection are equal. The light will continue zigzagging down the length of the Fiber.

2 Related Work: DSL Technology

The range of DSL technologies is quite broad, and this breadth can be somewhat confusing to the uninitiated. This paper briefly describes the different types of DSL technology that have been developed or are currently under development. The existing digital subscriber line (DSL) provides internet access by transmitting digital data over the wires of a local telephone network [3–5]. On the customer premises, a filter on each outlet removes the high frequency interference, to enable simultaneous use of telephone and data. The data rate of consumer DSL services ranges from 256 kbps to 40 Mbps in the direction to the customer.

- *Symmetric* It uses one pair of copper wires, with a maximum range of 10,000 feet. It cannot coexist with the conventional voice service on the same pair as it takes over entire bandwidth. It supports the same data rates for upstream and downstream traffic.
- *Asymmetric* The basic telephone service channel is split off from the digital modem by splitter at the client site. It allows simultaneous access of the line by the telephone and the computer. In case of power failure, data transmission is lost but basic telephone

service will be operational. It provides 16–640 kbps upstream and 1.5–9 Mbps downstream. It can work up to a distance of 3.7–5.5 kms.

2.1 FTTH (Fibre to the Home)

FTTH (Fiber-To-The-Home), the future proof access technology incorporating voice, data and video in single connection, However, for providing multi-play services (voice, video, data etc.) and other futuristic services fiber in the local loop is must. The subscriber market for multi-play is large and growing and includes both residences and businesses. Businesses need more bandwidth and many of the advanced services that only fibre can deliver [1]. The customer on the FTTH will get more than 1.0 Gbps bandwidth which is a virtually unlimited bandwidth on today's scenario. The growing use of the Internet by businesses and general households in recent years, coupled with demands for increased capacity, the need for optical fiber cable for the last mile has increased. A primary consideration for providers is to decide whether to deploy an active (point-to-point) or passive (point-to-multipoint) fiber network.

3 Materials and Methods: Passive Optical Network

3.1 Elements

3.1.1 OLT

The OLT provides management functions for the subtended optical distribution network (ODN) and Optical Network Unit (ONU). It provides two main functions. To perform conversion between the electrical signals used by the service provider's equipment and the fiber optic signals used by Passive Optical Network. Between the conversion devices it will coordinate multiplexing on the other end of ONT/ONU.

3.1.2 ONU/ONT

A single subscriber device that terminates any one of the distributed end points of an ODN, implements a PON protocol, and adapts PON PDU to subscriber service interfaces. An ONT is a special case of an ONU. The ONT converts fiber optic light signals to electric signals.ONU is used for multiple users and ONT is used for single user.

3.1.3 SPLITTERS

Splitters are passive power dividers. It allows communication between the OLT and their respective ONT. Splitters not only multiplex or demultiplex signals, but also combine power. Splitters are bidirectional optical distribution devices with one input and multiple outputs. These are available in various options like 1:4, 1:8, 1:16, 1:32 and 1:64.

3.2 Network Management System

Management of the complete PON system shown in Fig. 1 from OLT.

- One OLT can serve multiple ONU/ONTs through PON

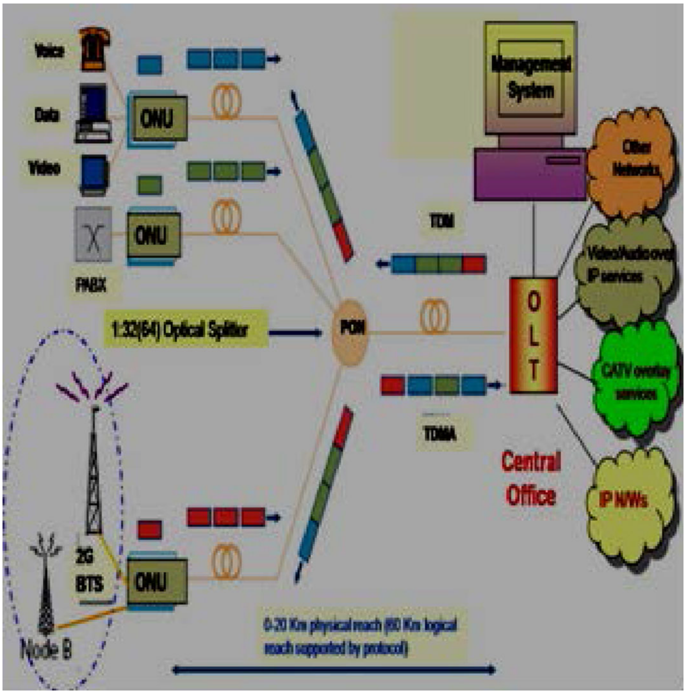

Fig. 1 Passive optical network architecture

- TDM/TDMA protocol is used between OLT and ONT
- Single Fiber/Dual Fiber is used for upstream and downstream
- Provision to support protection for taking care of fiber cuts, card failure etc.
- It can provide a maximum Split Ratio of 1:64
- The distance between OLT and ONT
- The Downstream transmission i.e. from OLT to ONU/ONT is generally TDM
- The Upstream traffic i.e. from ONU/ONT to OLT is usually TDMA

4 Simulation and Implementation

This paper is simulated and implemented the proposed method using using OPTISIM and implemented in BSNL office, Chennai. In this section the parameters and scenarios of simulation are described and simulation work is done using OptSim software. The purpose is to show the behavior of links of optical fiber when the signal goes through all the elements such as optical fiber, splitters, multiplexers and the goal is to find a good quality of signal in all receivers. The final goal pursued with this paper is to evaluate the performance of the whole system. The parameters used to evaluate this behavior are the BER and the Eye Diagram. The first condition used to assess the performance of the link is generally BER (Bit Error Rate) at the receiver. Simulations are done trying to approach at the receiver with a minimum BER. Any simulation with a BER $< 10^{-4}$ results in inconsistent and unreliable link. The FEC techniques are used for correcting errors and bringing the BER from 10^{-4} to 10^{-13}. The techniques can be for example Reed–Solomon (255,239) defined at the standard ITU G.709. The second condition corresponds to the eye diagram. The eye diagram describes the quality of the received signal. In the presence of ISI, when the pulse does not satisfy the Nyquist criterion, the diagram tends to close vertically. For error-free transmission in the absence of noise, the eye must be kept some vertical opening, or otherwise there exist interference between symbols that would cause errors [10, 13]. When the eye is not fully closed, the interference between symbols reduces the value of allowable additive noise. Therefore, the higher vertical opening the greater immunity to noise. In this chapter the various network has been described and the most important parameters are also analyzed. The comprehensive description of the entire network, and the detailed analysis of each of the different areas that compose the design is described in the following sections. Finally the results of each ONU is obtained, which means that the network is viable and therefore its practical implementation would work.

4.1 WDM PON: Complete Design

The complete design of WDM-PON is shown in Fig. 2. The Steps in evaluation of network deployment planning has been studied. To facilitate understanding, the design from the OLT to the different ONT's for downstream, and from the ONTs of the different areas to the OLT for upstream is described. On the left side of the design you can see the OLT which transmits information to different users and also receives information from the ONT's. All this information is transmitted multiplexed at different wavelengths through a single optical fiber, and then demultiplexed to spread to different areas in downstream, and multiplexed from different areas in upstream [6]. As explained in previous sections, the simulation also has been divided into five areas.

4.2 WDM PON in Downstream

In downstream, the optical signal is transmitted from the OLT to the end users (ONT's). Returning to Fig. 2, the first network element is the optical transmitter located at the OLT. This laser broadcast's five different wavelengths from 1450 to 1530 nm with a frequency spacing of 20 nm. The transmission power is set to 0 dBm and NRZ modulation is used. The next element is an optical multiplexer, which multiplexes these five wavelengths to transmit on a single fiber. This multiplexer 1:5 (which actually correspond to a multiplexer 1:8) has an insertion loss of 2 dB. Since the residential area has many users the signal suffers in that area so EDFA amplifier of about 5 dB of gain is placed in front of OLT to ensure good quality signal in the case of major losses. In addition, the OLT has to handle both the downstream and upstream traffic, so an optical circulator with insertion losses of 3 dB and return losses of 65 dB has been inserted [8]. Being described the elements of the OLT, the optical signal is then inserted in the optical fiber which reaches the multiplexer located at 5 km from the central office. The fiber, the SPLITTER contains a multiplexer and demultiplexer (splitters). Each is used in one direction of traffic. For downstream traffic, the signal from optical fiber is demultiplexed into 5 different branches with each of them carries a different wavelength [7]. This 1:5 splitter has a starting frequency of 1450 nm and a frequency spacing of 20 nm. As explained in the previous multiplexer, the splitter is also implemented in reality as 1:8 splitter, therefore it has insertion losses of 2 dB.The first branch of the splitter is directed to the block corresponding to the hospital area, the second to the business area and so on until the fifth that gets directed to the BUILDINGS area, third to residential area, Fourth to the school mall and fifth to the building block. The Fig. 3 shown is hospital block. The hospital block consist of one ONU.

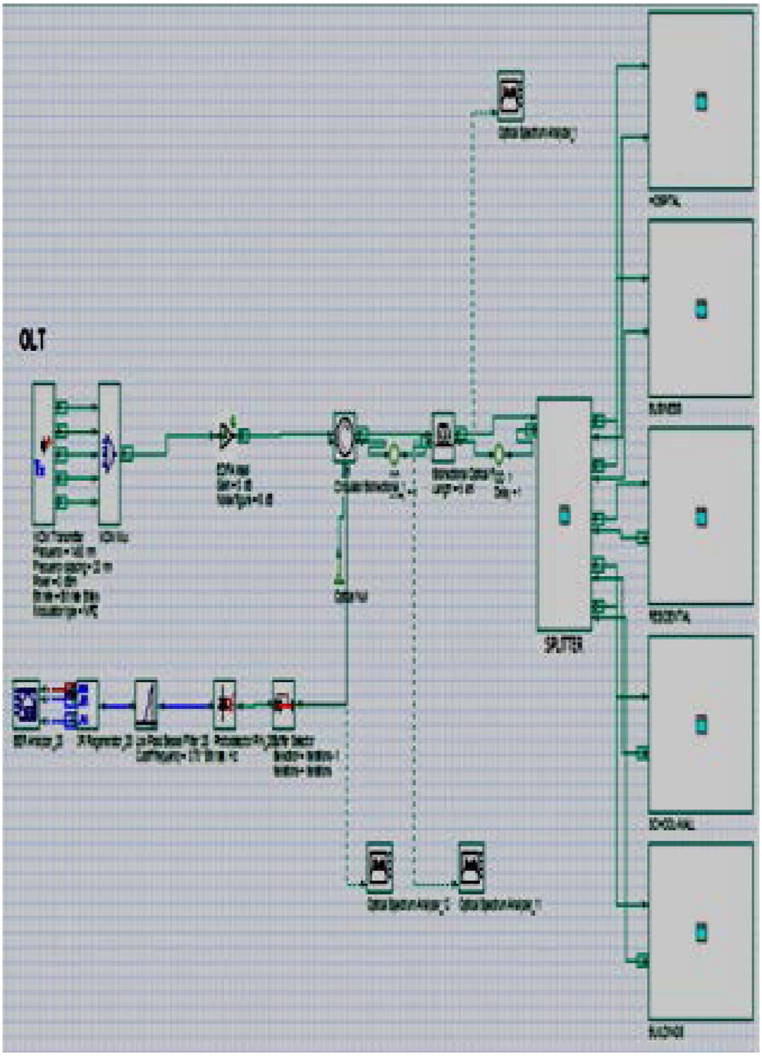

Fig. 2 Design of PON

The school mall block,business and building block consist of two ONU's but wavelength differs for each block. The residential block consist of multiple ONU's performance of all the blocks have to be checked. For understanding purpose only the hospital block is taken which is shown in Fig. 3. The downstream spectrum for all the blocks are shown in (Figs. 4, 5, 6, 7).

The next section consists on the business block (Fig. 1). In it two ONU's transmits at a wavelength of 1290 nm. The parameters of these ONU's are same: 0 dBm of optical power, NRZ modulation and bit rate per default.

In this case as shown in Fig. 4, it has more than one transmitter operating on the same wavelength, it must take into account the time division multiple access (TDMA). Therefore it uses a Dynamic Select Y which allows to pass the signal only at a determined time

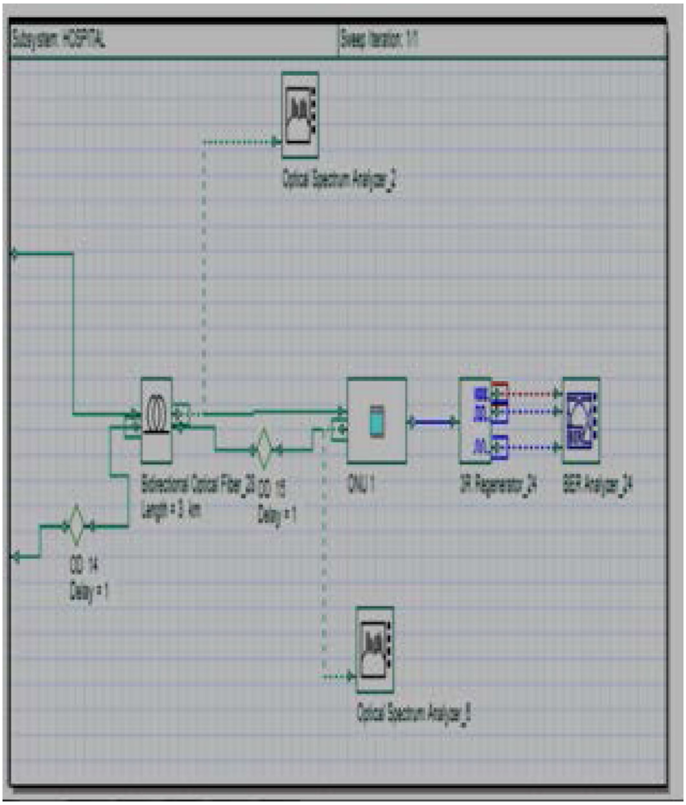

Fig. 3 Hospital block

instant and the rest is set to zero. Since only two ONU's is there, The formula to define the time interval of each one is given by Eq. (1):

$$TS * \frac{1}{BR} * \frac{SL}{2} \bigstar \frac{TW}{2} \tag{1}$$

TS = Timeslot, BR = Bit rate, SL = Sequence length, TW = Time window.

Where Timeslot is set to 0 in the first ONU and 1 in the second. The Fig. 2 shows the signal transmitted by the two ONU's in the time domain and therefore it proves that the signals transmitted by the various ONU's do not overlap in time.

Next the residential block is taken for consideration. Here twenty ONU's corresponding to the twenty homes and it can transmits the data with a default bit rate and a wavelength of 1310 nm. These ONU's transmits with a power of 0 dBm and NRZ modulation [9]. However, to adjust the interval of time that has to transmit each ONU, the Dynamic Select Y by the following Eq. (2).

$$(\mathrm{TS} \times 1/\mathrm{BR} \times \mathrm{SL}/20 + \mathrm{TW}/20) \tag{2}$$

TS = Timeslot, BR = Bit rate, SL = Sequence length, TW = Time window.

Where Time Slot is set to 0 for the first ONU, 1 for the second, and so on until the twentieth ONU with value 19.

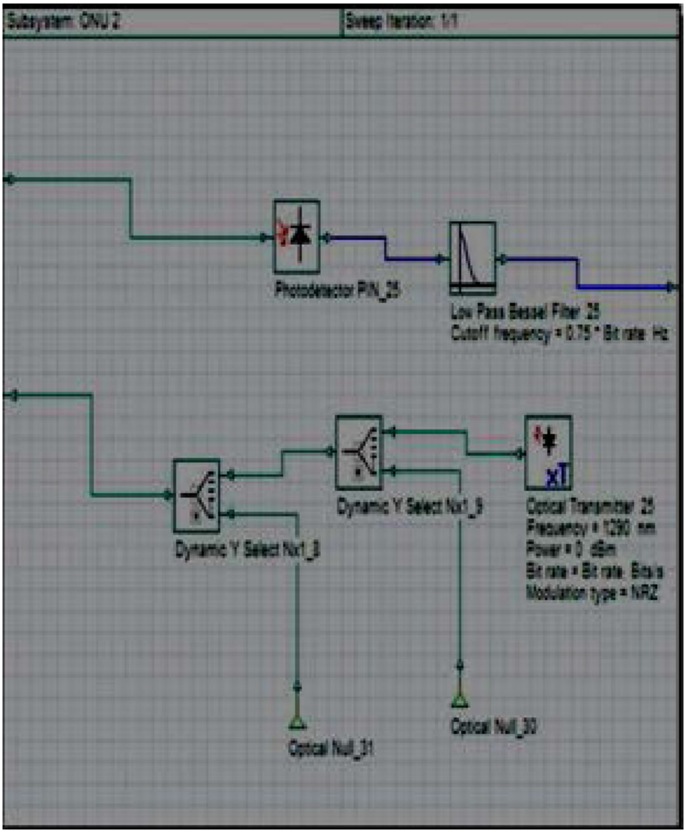

Fig. 4 WDM PON—business, residential, school-mall and buildings ONU block

As expected, the peak is centered in 1450 nm as shown in Fig. 4.

Visualizing the Optical Spectrum Analyzer the carrier centered in 1470 nm as shown in Fig. 5.

Visualizing the Optical Spectrum Analyzer the carrier centered in 1490 nm as shown in Fig. 7.

The carrier centered at 1510 nm which reaches the area as shown in Fig. 8.

The optical spectrum analyzer shows the optical carrier that it was expected and it is centered on 1530 nm as shown in Fig. 9. The optical spectrum analyzer shows the optical carrier of downstream of WDM PON of building block and it is centered on 1530 nm as shown in Fig. 10.

4.3 WDM PON in Upstream

In upstream direction, the optical signal travel's from each of the end user (ONT's) to the OLT. Therefore, the various blocks that define the five areas are reviewed and also the OLT as the receiver is considered. Note that the signal in upstream passes through the same elements and therefore they has the same characteristics [11, 12]. It is also important to note that each area operates in a different wavelength. Therefore, TDMA is implemented in

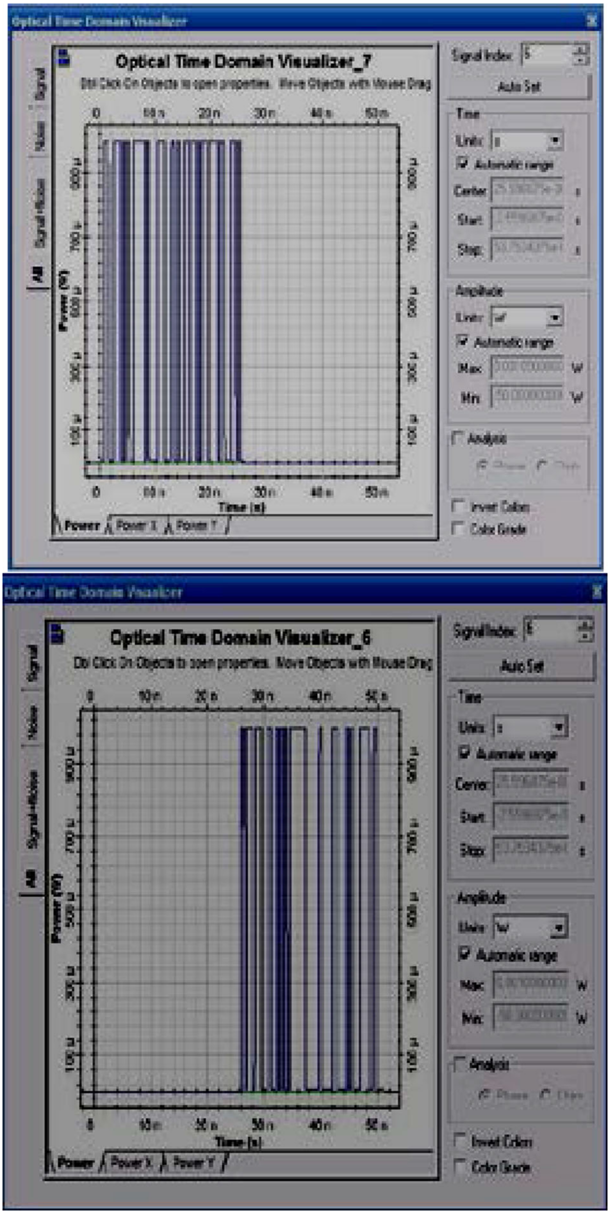

Fig. 5 WDM PON—optical time domain visualizer in business block

each of the areas for each user to transmits in a determined instant of time. This action avoids the collision of two users when they wish to transmit information at the same time [13, 15]. Referring the Fig. 5.1, the first block to be analyzed is the hospital block. The ONU that in this case transmits at 1270 nm with a power of 0 dBm, NRZ modulation and 2.5 Gbps bit rate. The transmitter of the hospital ONU is shown in Fig. 5.5. The optical signal crosses the same elements of the block (as that for downstream), but this time in

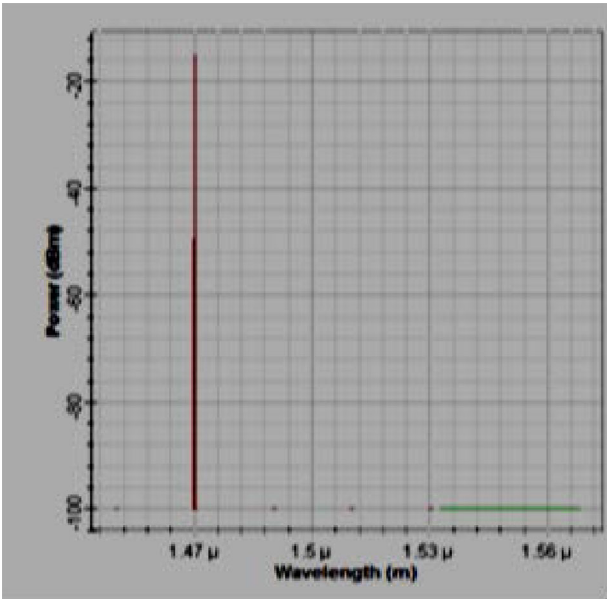

Fig. 6 WDM PON—downstream spectrum into hospital block

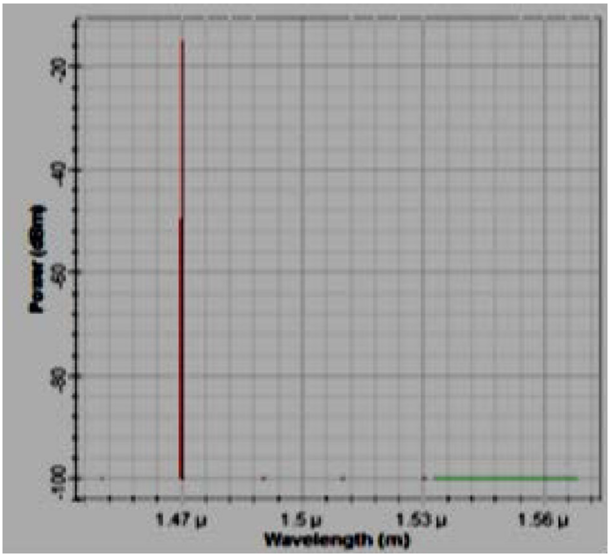

Fig. 7 Carrier centered in 1470 nm

upstream. The next consists on the Business, Residential, School-Mall and Buildings ONU block as shown in Fig. 11.

In this case, as it has more than one transmitter operating on the same wavelength, it must take into account the time division multiple access (TDMA). Therefore uses a Dynamic Select Y which it will allow to pass the signal only at a determined time instant

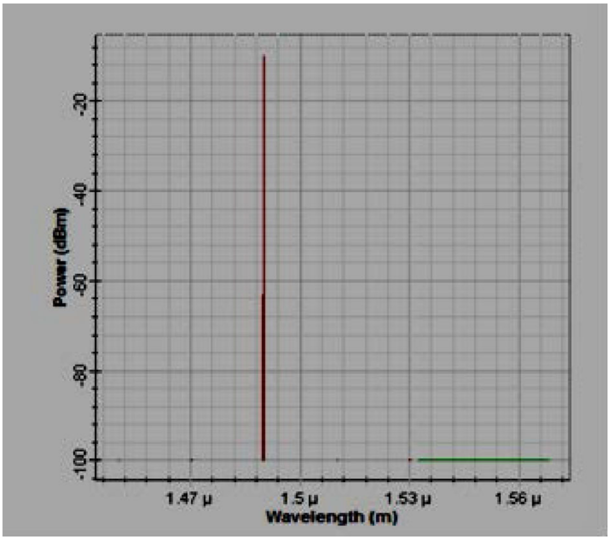

Fig. 8 WDM PON—downstream spectrum into residential block

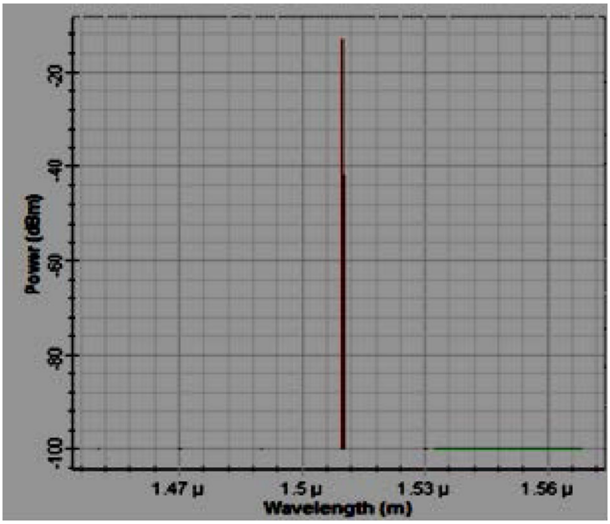

Fig. 9 WDM PON—downstream spectrum into school-mall block

and the rest is set to be zero [14]. WDM PON—Upstream spectrum into the OLT receiver is shown in Fig. 12.

The first element of the receiver is the Buffer Selector, which is used to select only the latest iteration of the simulation, which is the one with the correct results. After this element, the signal is passed through the PIN Photo detector where it get converted to electrical domain and as in other cases it is filtered through a Low Pass Bessel Filter with a cutoff frequency of 0.75 × Bit Rate. To end, this signal is regenerated in order to be displayed on the BER Analyzer. Let's see first downstream results and later upstream

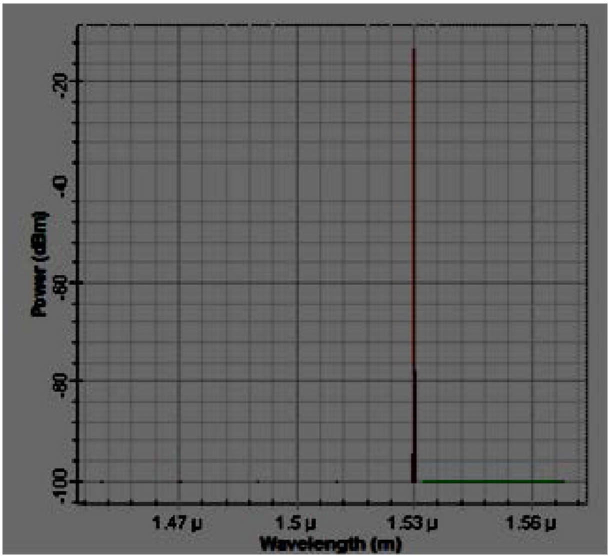

Fig. 10 WDM PON—downstream spectrum into buildings block

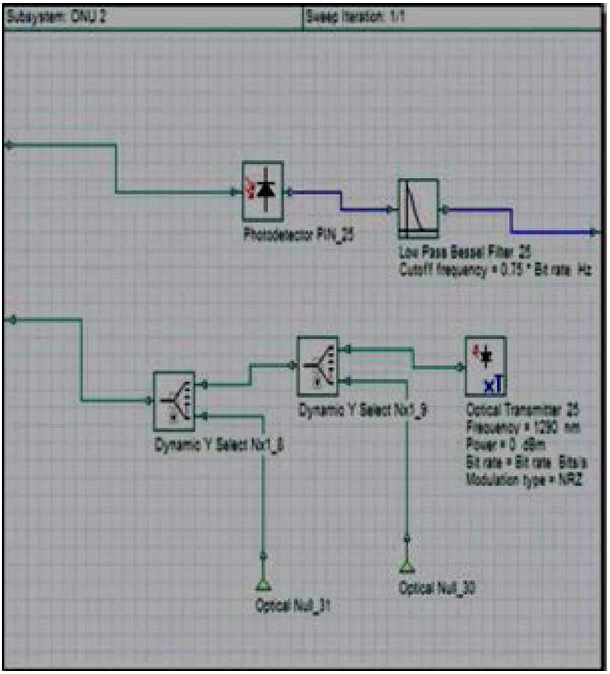

Fig. 11 WDM PON—business, residential, school-mall and buildings ONU block

results. In the case of the ONU located in the hospital block as shown in Fig. 12, it has been obtained the following results.

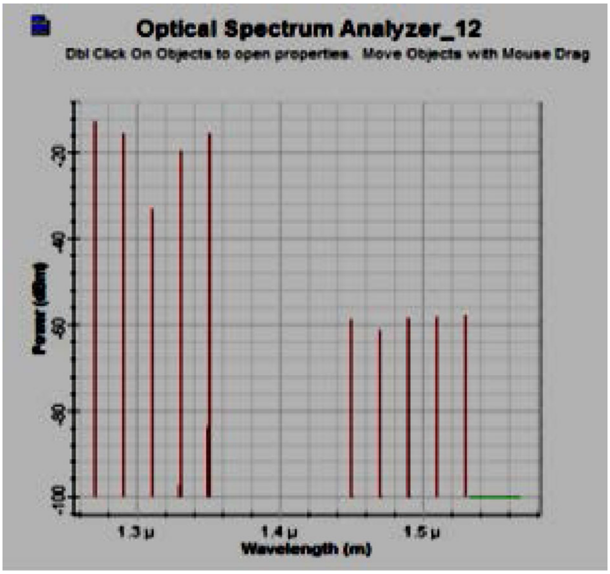

Fig. 12 WDM PON—Upstream spectrum into the OLT receiver

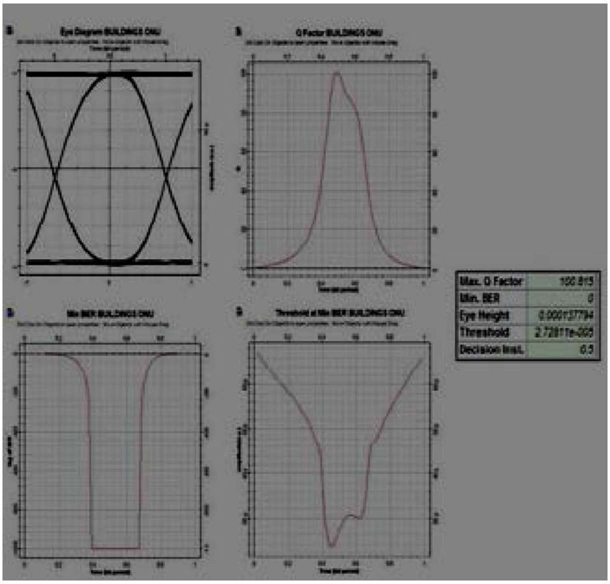

Fig. 13 WDM PON—business ONU result

In the business block as shown in Fig. 13, the path that the signal covers to two ONU's is exactly the same since the last fiber has the same dimensions. So the results are identical.

The residential block has 20 ONU's. As expose the results of the 20 ONU's is required. The results of the closest ONU as shown in Fig. 14 (located at 50 m from the splitter) and the farthest ONU as shown in Fig. 15 (situated at 185 m from the splitter).

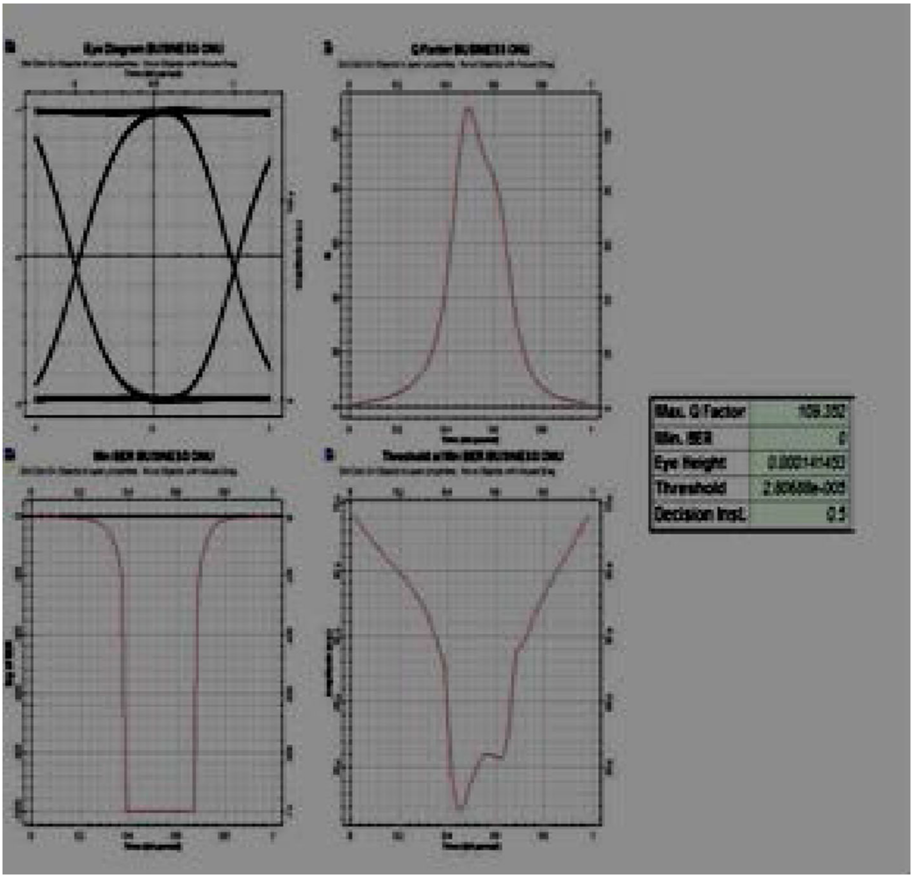

Fig. 14 WDM PON—residential ONU1 results

The results are very similar, although as it expected, the results of the ONU placed on the shortest fiber results of the ONU is better than the longest fiber. Turning now to the school-mall block, the results for the two ONU's as shown in Fig. 16.

The last block in downstream is buildings Block. As in the case of the business block, the paths that the signal covers are identical, so both ONU's offers the same results in Fig. 17.

As for the uplink, the results obtained in the OLT as shown in Fig. 18. The results obtained in the OLT as shown in Fig. 19 for WDM PON OLT ONU of residential block considered for the wavelength of 1310 nm.

Residential Tables 1 and 2 shows the upstream and downstream parameters (wavelength and splitting ratio) which vary for each blocks.

In Fig. 20 the design of PON parameters are designed for 8162 samples and 64 samples per bit. The global bit rate used for the design is set to 2.5 Gbps. This bit rate is used throughout the design if the network work for this bit rate it would work for all other bit rates because they will be lower than this. Other important parameters are the sequence length (128 bits) and the samples per bit (64). The parameters make a total of 8192 samples and are important because it needs a large enough sequences for simulate the network at

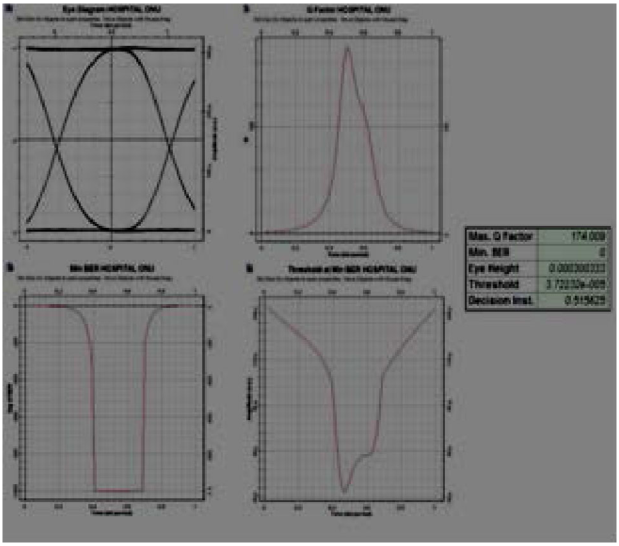

Fig. 15 WDM PON—hospital ONU

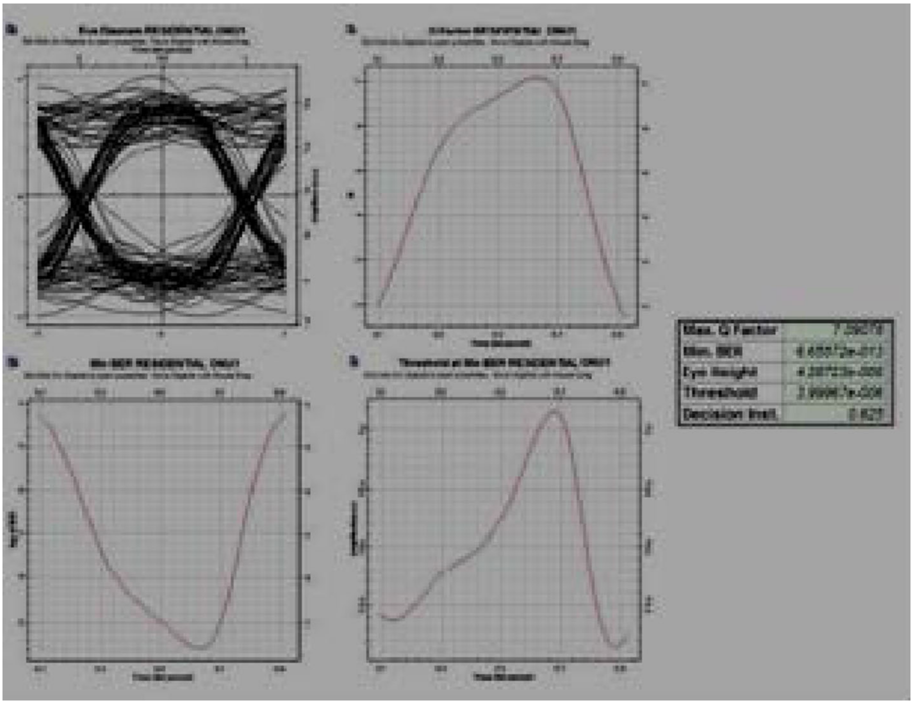

Fig. 16 WDM PON—residential ONU2 results

these high bit rates. The optical delays are required in some devices when they do not have all signals in the input ports. From the Table 3, the existing and proposed technologies has

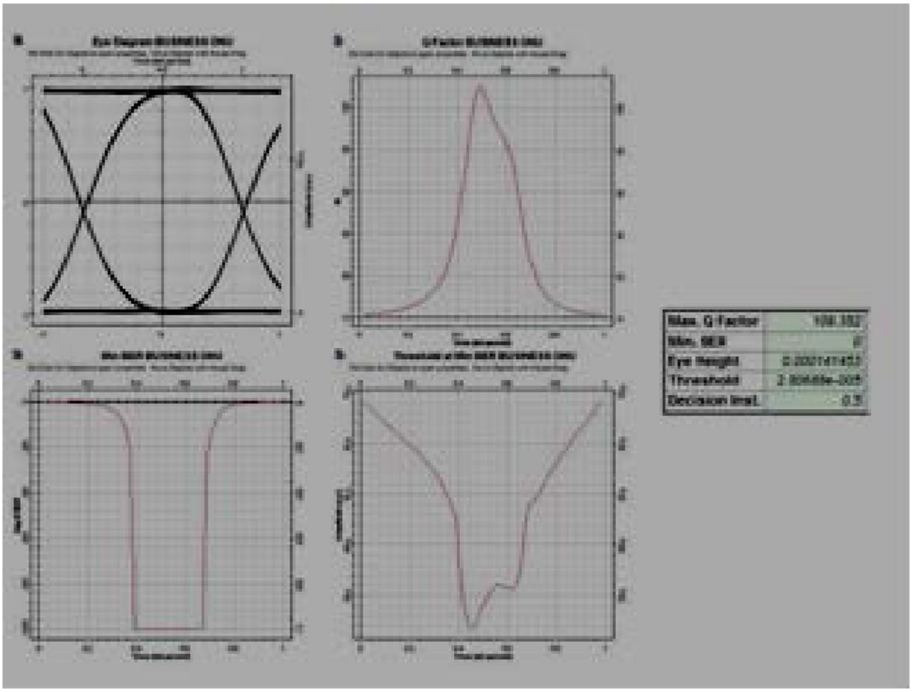

Fig. 17 WDM PON—school-mall ONU1 result

been compared and the results show's that the DSL and PON technologies gives BER (bit error rate) of 10^{-4} this makes the link of the network inconsistent and unreliable so by using forward error correction techniques in the proposed system of WDM-PON the bit error rate has been improved to 10^{-13}, thus it makes the network reliable and improve its performance. Throughout the paper a number of general guidelines for the development had been undertaken and had resulted in a thorough understanding of a passive optical network. They basically are: Theoretical detail and physical basis of the operation of optical networks, Planning and design of a PON [15]. Simulation and results obtained by the designed network. The detailed work of optical networks is considered essential for correct understanding of FTTx networks, as well as necessary to perform a particular design of passive optical network on which such networks are built. The images show what has the design been and an explanation of all the important elements and parameters that have taken into account to make it work. To make more understandable of the design, it has been separated into two parts, downstream and upstream, the work has been divided in five areas that define the entire design.

5 Conclusion and Future Work

This paper concludes that the designed network be the lines that can be followed for future network improvement. When making any design, it is essential to know the technology that depends on the needs that arise and also the topology of each network type. The operating principles of a network for both the uplink and downlink and also all the elements of the

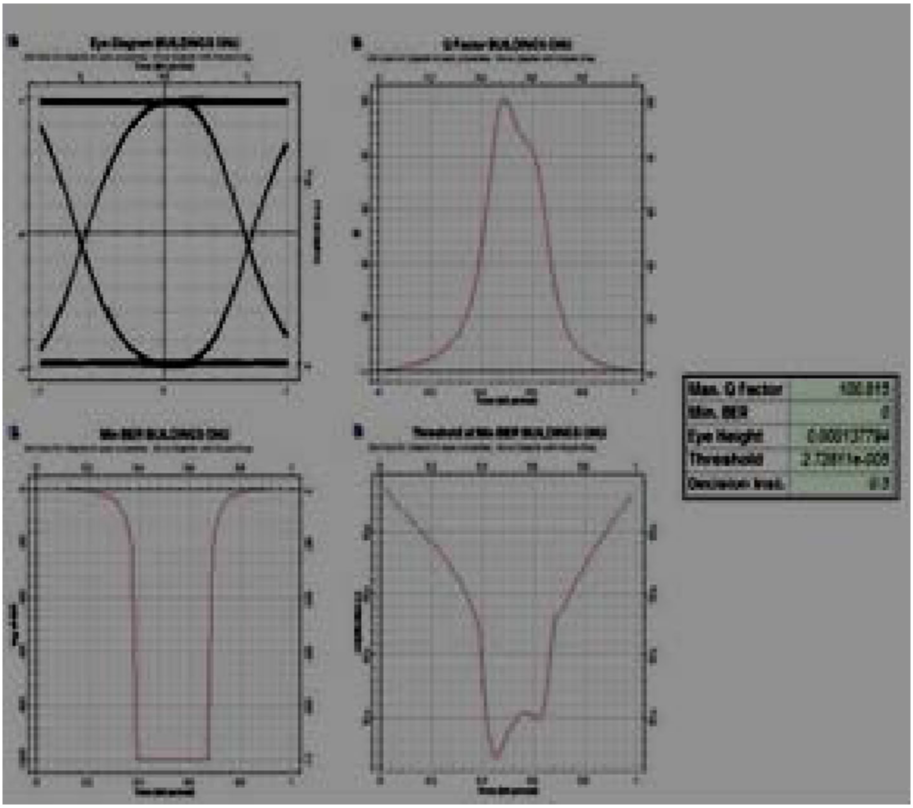

Fig. 18 WDM PON—buildings ONU results

passive network which uses tree topology has been taken into account. A comparison is made with point to point/multipoint networks and active optical networks (AON), concluding PON design optimal for its exploit of bandwidth and its lower implementation costs. Having defined the PON as the best option, advantages and disadvantages of these types of networks has been mentioned and all the standards that exist today have also been considered [16]. Finally a comparison between these technologies is done, choosing WDM-PON as the best option because of its greater speed, reach and number of users supported. The simulation results show that the network works. Finally, the obtained results in each of the ONT's have been attached, being these the eye diagram and the BER decision threshold for the minimum BER. These results have showed a BER of about 10^{-13} for the worst case for the farthest house in the residential area. This shows the high reliability in each of its points on this network. The choice of optical fiber as transmission medium allows guaranteeing longevity of the network during the coming years [17]. In addition, the specified equipment will be valid for migration to future standards as 10GPON and other technologies that improve the performance of optical fiber and provide the best possible performance. Other features of the design is the high degree of availability and network capacity, the ability to integrate multiple systems and services and the possibility of interconnecting these networks with other wide area networks and adding local networks by creating LAN.

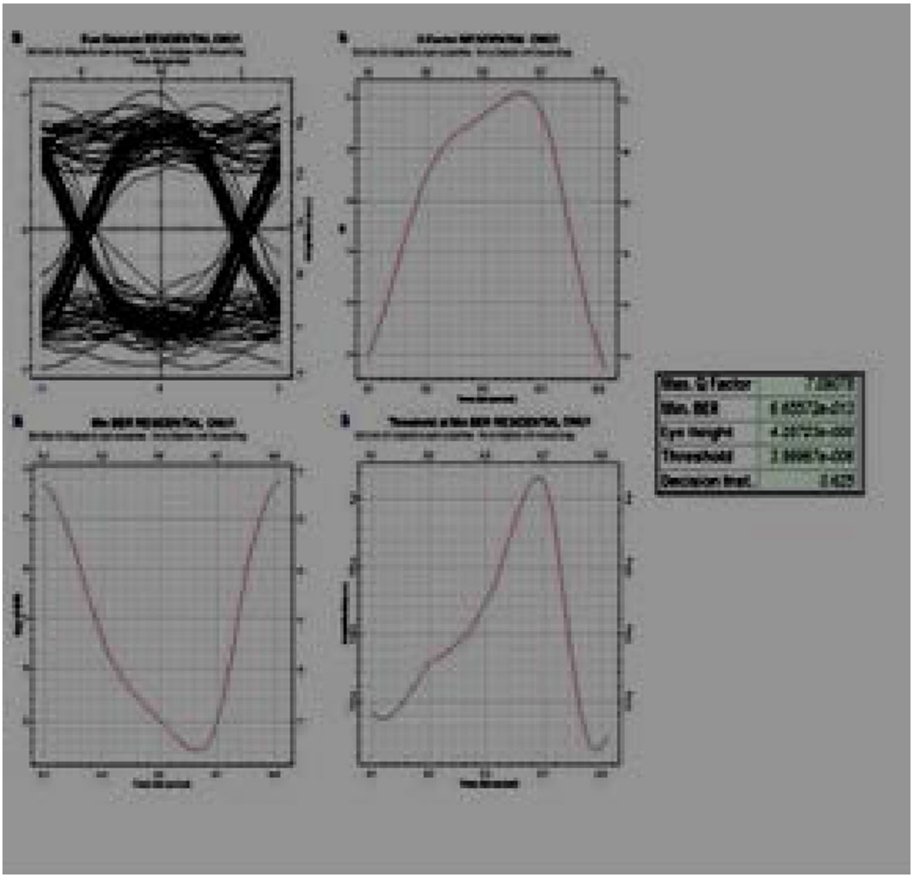

Fig. 19 WDM PON—OLT ONU results

Table 1 Downstream parameters

Blocks	Wavelength (nm)	Splitter ratio
Hospital	1270	1:1
Business	1290	1:2
Residential	1310	1:20
School mall	1330	1:2
Building	1350	1:2

Table 2 Upstream parameters

Blocks	Wavelength (nm)	Splitter ratio
Hospital	1450	1:1
Business	1470	1:2
Residential	1490	1:20
School mall	1510	1:2
Building	1530	1:2

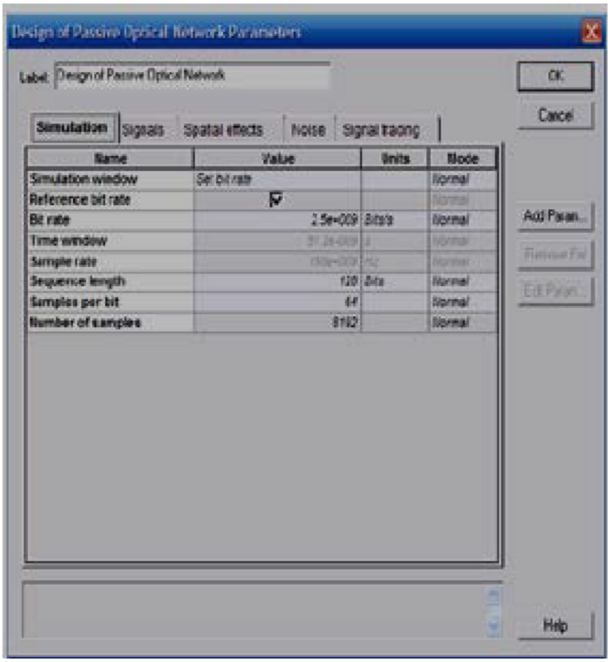

Fig. 20 Design of PON—input parameters

Table 3 Comparing existing and proposed technologies

Technologies		Bit error rate	Performance
Existing	DSL and PON	10^{-4}	The network shows that the link is not consistent and reliable
Proposed	WDM-PON	10^{-13}	Reliable and efficient performance

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