Giga Passive Optical Network GPON Based upon Fiber to the Home FTTH: Design, Implementation and Evaluation

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Giga Passive Optical Network GPON Based upon Fiber to the Home FTTH: Design, Implementation and Evaluation

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***Abstract*—FTTH access network (Fiber to the Home), based on GPON: Giga Passive Optical Network technology is a technology that meets application performance requirements (high-speed access network, high bandwidth, Voice over Internet Protocol "VOIP, high-speed Internet"). In fact, telecom operators' networks use FTTH over GPON due to its reliability, flexibility and accuracy in handling advanced technologies. GPON is used to provide communication speeds of at least 1.2 Gbit/s. It handles 1.24 Gbps upstream and 2.44 Gbps downstream data transmission.**

GPON is the basis for promoting innovative and prestigious services, which are being researched for residential and business customers due to broadband capacity.This paper deals with the design and implementation of FTTH networks based on GPON technology and the evaluation of the proposed architecture for residential and commercial solutions.

Keywords*—*BPON:Broadband PON, FTTH:Fiber To The Home,GPON: Giga Passive Optical Network, ONT:Optical Network Terminal, PON: Passive optical Network; Splitter.

I. INTRODUCTION

To handle higher bandwidth requirements, especially for data traffic, optical communication systems have increased [1], especially for Internet traffic. Indeed, strong demand for the Internet includes cloud-based solutions and triple-play services that offer new business opportunities for telecom users. It provides additional services (Internet, video and voice) to subscribers. Various techniques and high technologies have been pursued to meet the demand for increased bandwidth. GPON: Gigabit Passive Optical Network deployed on FTTH networks: Fiber to the Home is considered to be the best solution to meet the increasing bandwidth demands [2]. Operators rely heavily on GPON for FTTH implementation. It is becoming an important measure for services that require increased bandwidth, such as triple play services and cloud computing. Triple play is the provision of requested services at double the bandwidth (faster, less bandwidth, calls over a single high-performance broadband connection).

Using a single fiber for downstream and upstream traffic is an important improvement [3]. "Passive optical network" comes from the connection of optical fibers to passive optical splitters.

APON: Most recently calledPON asynchronous.

BPON: Commercialized broadband PON.

EPON refers to Ethernet PON, which is a new alternative standardized by IEEE 802.3. EPON maintains similar wavelength architecture to GPON, but withdifferent protocols.

Tunisie Telecom has laid hundreds of kilometers of fiber optic cable.Our project focuses on our interest on the fiber optic architecture for FTTH via GPON in the municipality of ERRIADH;Tunisia. It Allows network simulations to demonstrate the performance of our implemented solutions. Optisystem is recognized as the first optical communication system dedicated to packet emulation for the design, optimization and testing of optical links within the physical layer of optical networks, especially for broad spectrum. It is widely integrated for powerful performance in triple-play solutions applied to GPON and BPON. The present work;first, examines the development of access networks. Second, presents evaluation designs for network WDM GPON and broadband access network technologies. Then discusses the design and implementation of FTTH network based on GPON technology. Finally, It evaluates the results and reviews of the proposed architecture for residential and commercial solutions.

II. RELATED WORKS

The technologies and interfaces developed allow new operators to enter the market with strict authority approval, stimulating original services. The development of the access network will benefit both the industry and customers [4].

The allowed bandwidth is sufficient for many Internet services; however, it is not enough to simply upload very large files, leaving only instant time for the video [5].

2.1 ISDN: Integrated Services for Digital Network

ISDN is considered the first point of contact needed by well-known telecommunication networks. All analogue services are converted into corresponding digital signals for transmission on ISDN. In general, ISDN is offered in addition to the copper cables available in the access network and is offered to operators in two structures [6]:

- Provides a basic average connection of two 64 kbit/s signaling channels, which can be shared by fundamental average connection to provide a rate of 128 kbit/s per channel;

- Primary rate service of thirty 64 kbit/s dominant signed channels with 2 Mbit/s correlations.

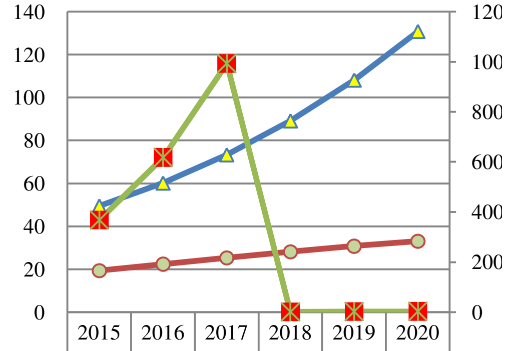
2.2 Wireless Local Loop and Leased lines

A leased line provides the user with a persistent connection to two endpoints, eg B. A connection between a local bank branch and the head office. Instead of copper or fiber optics, wireless can be used as the connection, connecting users to some or all of the previously connected or fixed-connected constrained switches. It is called a wireless local loop. Now it is used again and again for regular telephone or ISDN connections [7]. Compared to copper cables, WLL increases equipment cost, for example caused by limited spectrum and shadowing tall buildings [8]. 80% of the cable system is reserved for equipment and the rest is used to install the wireless system. For this reason; WLL is expected to be the best approach for network operators [9].

2.3 Broadband Access Technologies: Evolution and Trends

Recently, the broadband access model has become extremely popular; it is involved in the lifestyle of many people [10]. This model may scale to full broadband capacity with more connections, minimal latency, and increased bandwidth to meet end-user demand. Internet and leased line bandwidth must continue to grow at a rate of 20% per year, fueled by the creation of cloud computing, increasing video streaming, social media, big data, and mobile phone data transfers [11]. The total number of authorized video communications traffic via landlines and systems in 2020 exceeds the 2,600 in 2010. In terms of mobile information data, full broadband users of mobile devices are growing at an annual rate of about 35%. It was 2.3 billion in the first quarter of 2014; however, in 2019, they were estimated at 7.6 billion. Growth is also accelerated by innovative types of communication services, such as B. Conscious services, including D2D:Device-to-device connectivity, in addition to M2M communication (machine-to-machine) [12], it allows direct connection between spectrum and wireless tools via the same interface [12]. In 2018, the global traffic IP of 1.6 zetta-bytes per month or per year will reach 131.6 exabytes, and the global IP has further increased by more than five times in the past five years [13].

Furthermore, by 2020, traffic videos will show about 80% of traffic IPs worldwide [14], as shown in Figure 1.



	2015	2016	2017	2018	2019	2020
Fixed Internet	49,494	60,16	73,3	89,102	108,102	130,758
Managed IP	19,342	22,378	25,303	28,155	30,75	33,052
Mobile data	3685	6180	9931	14,934	21,708	30,564

Fig. 1: Evolution of Traffic IP

IP Traffic-By Type:2015–2020(PB per Month)

III. A WDM GPON NETWORK: DESIGN AND EVALUATION

PON leads to design execution of a pure PON, not involving elements of active network [15].

3.1 Access networkGPON FTTH: Design

Access network FTTH is determined by its design, which can be challenging. Various factors including cost, scalability, and scale need to be agreed upon, and with reference to feasibility, there are no prototypes or typical models of FTTH access networks [15].Overall standards are usually not applicable since country posses its distinct subterranean factors. Freeze line or thermal line of ground has to be measured[16].

3.2 Network elements

A network FTTx design or connection requires the following parameters to be set and met:

- Connector and fiber type
- Maximum transmission range;
- Maximum reflection (reverse);
- Attenuation and splicing or combining;
- Optical attenuation balance for related systems;
- Mechanical lifetime range.

➢ *Optical fiber Types*

The perfect choice of optical fiber can be identified by various parameters. Limited scattering and optical attenuation are important criteria. SM fiber is commonly used for network FTTX.

➢ *Fibers numberper user*

System points are mainly based on using 2 fibers in each connection. The first fiber is dedicated upstream and the last one is dedicated downstream. Sales services can be divided into market segments of our mission:

- Public sector;
- Residential;
- Business:

a. Residential

Classic residential services include:

- Basic phone (integrated VOIP);
- Internet access;
- IPTV.

A package containing these three components is called a "triple play".

b. Business

Due to its high bandwidth, high security requirements and high reliability, well-known companies have turned to fiber optic networks earlier than in residential areas. In fact, large companies generally have indirect ties to private customers with similar infrastructure or equipment.

3.3 *Project description*

This approach is a prototype passive optical infrastructure designed for neutral users and operators who actually adapt their fiber optic networks to the various cable manipulators and operators available in the market. The proposed model includes extended WDM GPON start-up at local exchanges in different regions, and ultimately operators will benefit from all the services that only network fiber can bring. Our projects refer to the following information:

- Supply of all main components to provide a suitable passive optical network FTTx infrastructure, from OLT to ONT-: household optical socket.
- Selection of Design Architecture and Planning for FTTx Deployment Based on Networks WDM PON.

➢ *Challenge application*

Bandwidth requirements per application per user type. It is set to meet cost and quality of service (QoS). Estimated bandwidth calculations are shown in Tables 1, 2, and 3.

Table1: Residential: /30 Mbps for all types ofapplications

Application Type	**Bandwidth capacity**
THD Internet Access	10 Mb/s
HDTV	12 Mb/s
VOIP: IP Telephony	2 Mb/s
Games Online	2 Mb/s
Total	**26 Mb/**s

Table2: Business: /40 Mbpsfor all types of applications

Application/ Service	**Typical Bandwidth**
THD:Internet Access	10 Mb/s
VOIP :IP Telephony	2 Mb/s
Video Conference	7 Mb/s
Cloud	10 Mb/s
FTP	10 Mb/s
Total	**39Mb/**s

Table 3: Survey Result

Residence Type	**Number**	**Services**	**Bandwidth $Mbit/s**	**Max. Distance**	**Bandwidth Totality Mbit/s**
Residential	150	VoIP, IPTV Data,	30	1,4 km	4 500
Business	10	VoIP, Data, surveilla - ncevide o, cloud	40	1,4 km	400
Total					**4900**

The Solution 2 revealed in figure.3 can gratify all Operators inapplicationbackgroundhowever, security is seen as an issue. There are several solutions. The safety splitter uses 2 optical fibers. As far as the solution is concerned, the hoop design is considered a design. There the fee increased; we decided to split each user's type into a splitter. As shown in Figure 2, the solution provides security through a single splitter behind an uncompromised advanced FTTH-GPON design reserved for residential customers.

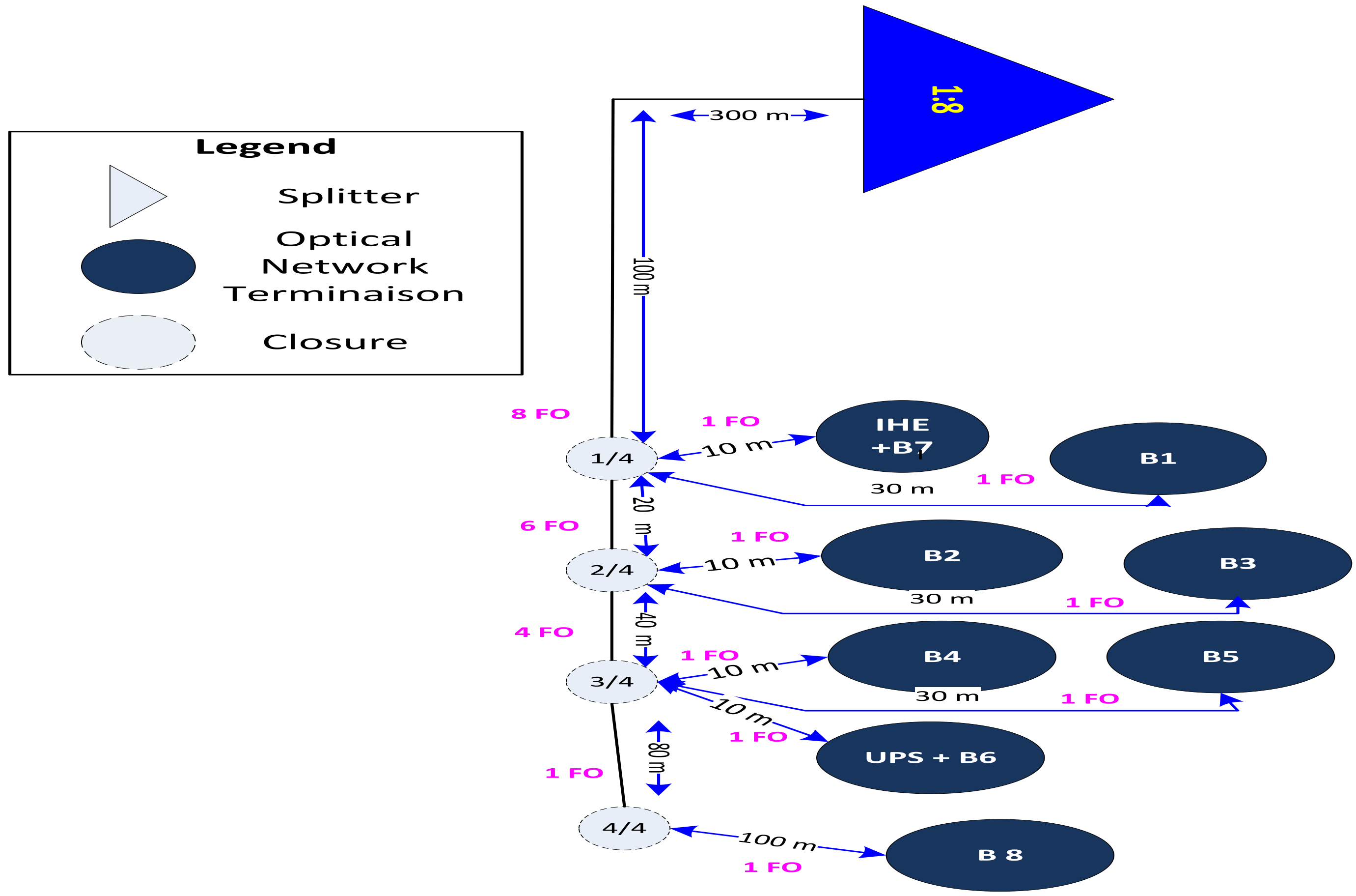


Fig. 2: Solution 1: FTTH GPON for residential users.

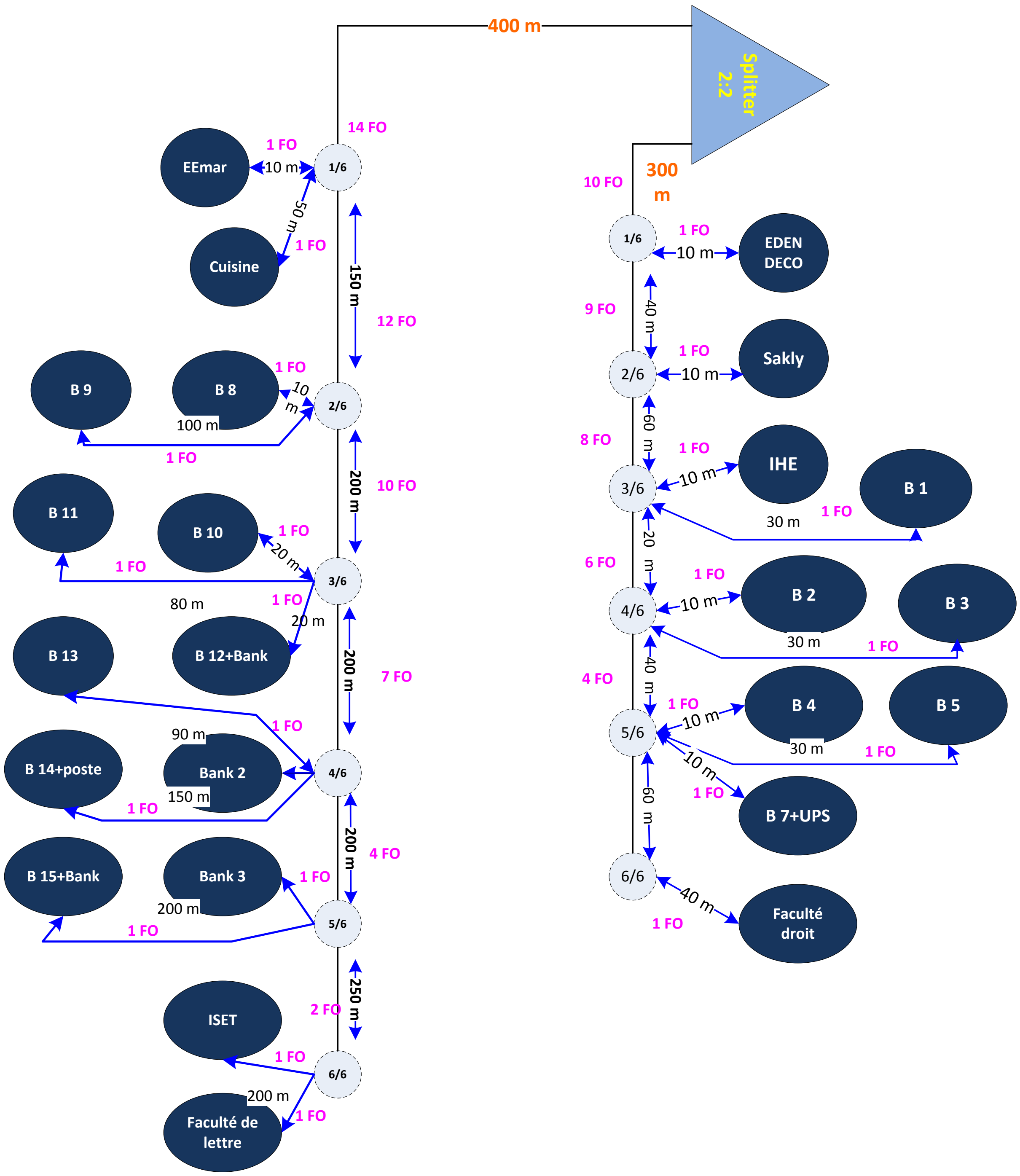


Fig.3: Solution 2: FTTH GPON

IV. Design validation

In order to evaluate the performance and feasibility of the proposed FTTH network design, the total optical power loss between the OLT GPON port and the ONT must also be considered to ensure sufficient performance for all network users. In the equation below, we generalize the loss.

loss = lcable+lconnector+ lsplitter + (1)

Table 4 presents the values and definitions for each parameter shown in Equationn°1.Then the power collected by the ONT at the receiving end of the building is:***Power received = Transmitted power - loss** (2)*

The transmit power is 3dB of the transmit power of the GPON interface on the OLT board. The equivalent power received by the ONT and various loss values are shown in Table 5. List the calculated losses according to the parameters shown in Table (4). The locations shown in Table (4) were chosen because they are mostly isolated in the access network and thus represent the worst case of network failure. The calculations in the table below show the worst case received power for an ONT sensitivity over -26dB.

Table 4: Parameters engendering to optical powerlossataccess networks GPON FTTH.

Parameter	Description	Value
P_{Cable}	Power lost of optical signal via fiber cable can be evaluated in dB / km. We use OTDR, to calculate correct value forpresent parameter	0.21dB/km
$P_{Splitter}$	According to the inclusion splitterloss, it varies referring to the rate of splitting. Values approvedin parameter are gathered frommatching splitterdata-sheets.	Level 1 of splitter: 8 dB Level 2of splitter:14dB for
P_{splice}	Denotes the loss which is introduced owing to splicing, it is measured withafusion splicingdevice. Value revealedintroduces the highest loss reached.	0.003dB
$P_{connector}$	Manifest losspresentedvia coupling connectors.	0.2dB

Table 5: Design validation: Optical power budget calculations

ONU	Distance of Splitter ONU (m)	Splitter-OLT distance(m)	Distance of OLT -ONU (m)	FO loss (dB)	Connector Coupling-Loss (dB)	Loss of Splitter(dB)	Loss of Splicing (dB)	# of closures	Loss of splicing closure (dB)	Power of laser (dB)	Power Received (dB)
Eden Deco	310	3000	3310	0,6951	1	8	0,12	4	0,012	-7	-16,8271
Sakly	350	3000	3350	0,7035	1	8	0,12	4	0,012	-7	-16,8355
Eemar	410	3000	3410	0,7161	1	8	0,12	4	0,012	-7	-16,8481
Kitchen	450	3000	3450	0,7245	1	8	0,12	4	0,012	-7	-16,8565
Post	1030	3000	4030	0,8463	1	8	0,12	4	0,012	-7	-16,9783

Calculation of optical powerbudget is suitable for the requested solution. The reception performance of the network is excellent; all user signals are fully received

V. RESULTS AND DISCUSSION

5.1 Evaluation solution

Fiber optic communication models are based on current system-level simulators whose performance can be correlated with user equipment interface libraries. It can be disseminated as a widely used tool [14].This section presents an OptiSystem simulation where the required parameters are strongly anchored in normalized GPON.attributes.

Figure 5 shows the initial FTTH evaluation of a GPON network. In this approach, a receiver and a transmitter are integrated into an OLT, which are then distributed to eight ONUs through 1x8 bi-directional passive optical splitters. Integrated optical circulators separate signals from upstream and downstream, while optical delays aim to establish different rectification timings for the circulation [17].Fig.4 shows block diagrams of the transmitter. In order tostudy the signal performanceinto both upstream as well as downstream directions,network constructionis exposedin the figuresbelow:

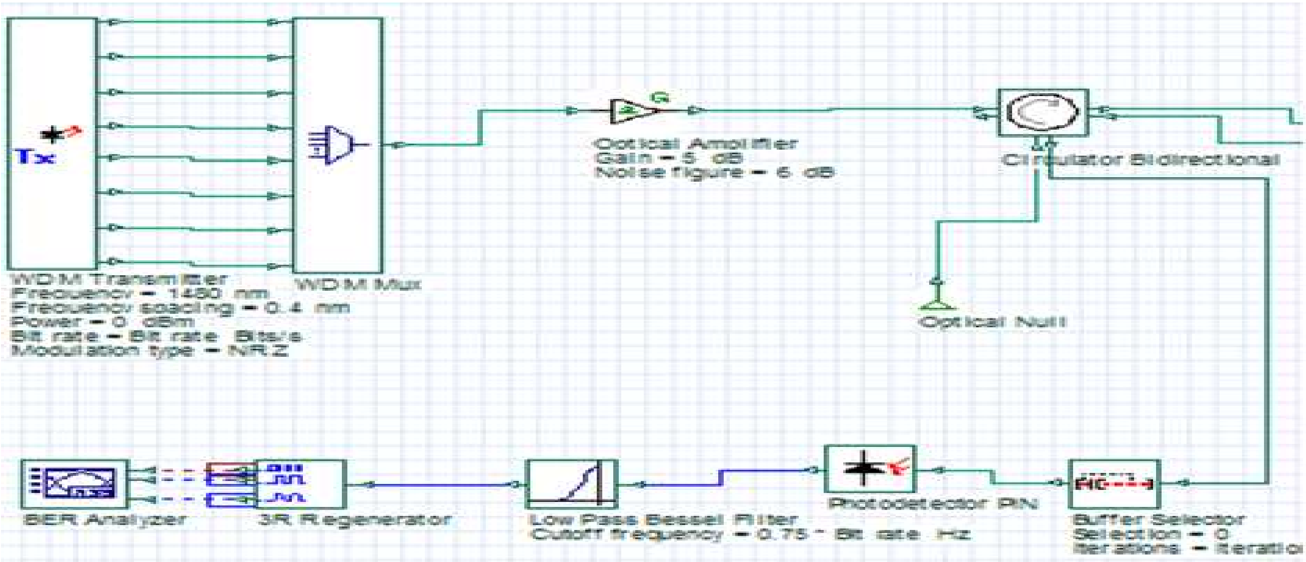


Fig.4: Transmitter

Simulation | Signals | Spatial effects | Noise | Signal tracing

Name	Value	Units	Mode
Simulation window	Set bit rate		Normal
Reference bit rate	☑		Normal
Bit rate	2500000000	Bits/s	Normal
Time window	1.024e-007	s	Normal
Sample rate	80000000000	Hz	Normal
Sequence length	256	Bits	Normal
Samples per bit	32		Normal
Number of samples	8192		Normal

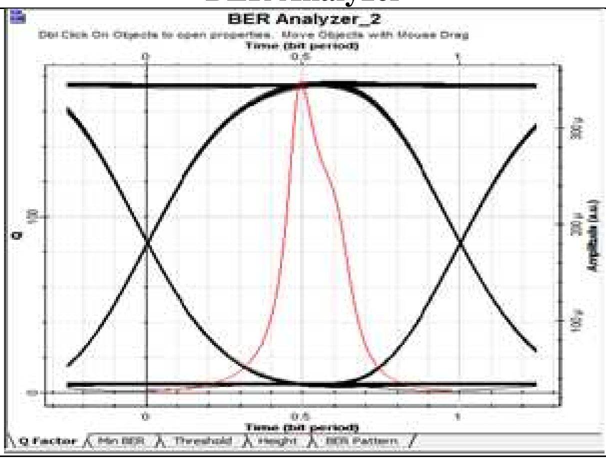
Fig.5: Fiber properties

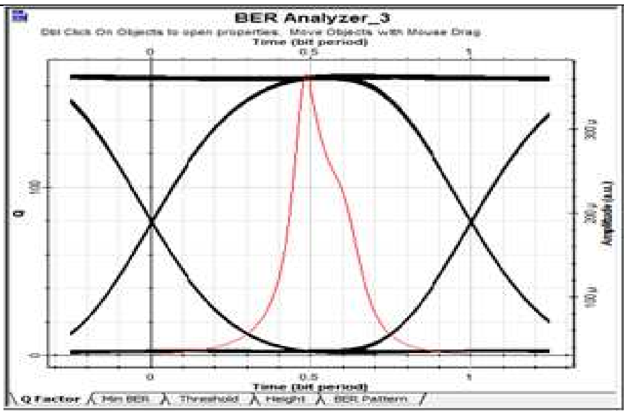
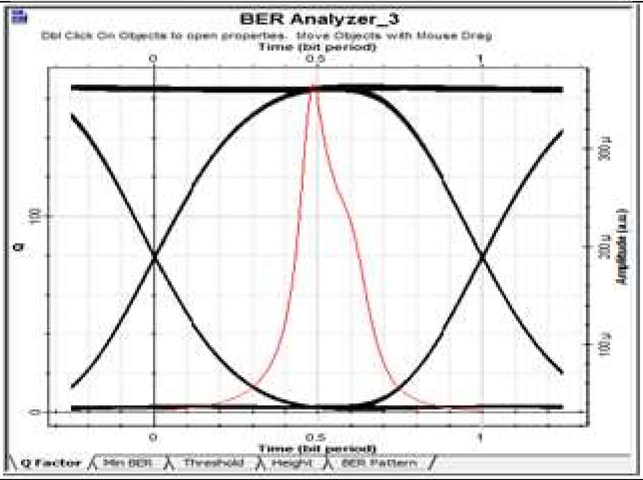
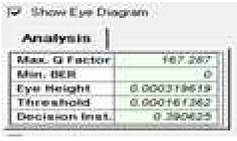
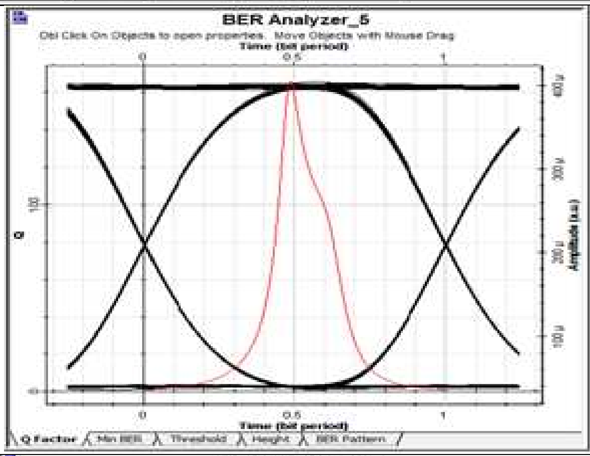
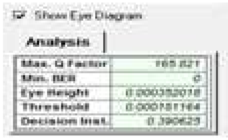
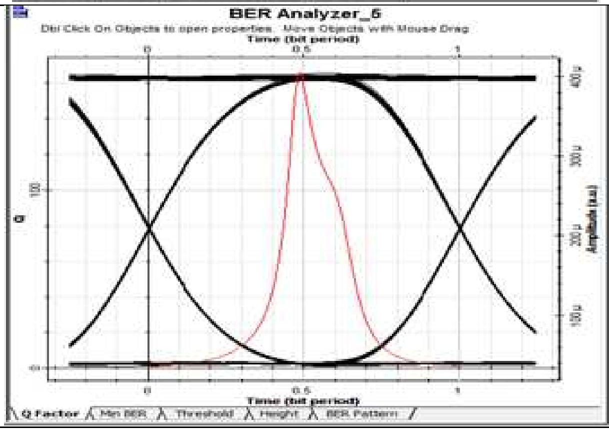
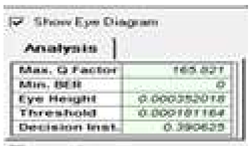
The transmitter generates a series of numbers that make up the signal data. NRZ: A non-return-to-zero pulse generator generates a series of NRZ pulses encoded with a digital input signal. And CW: The continuous wave of the laser produces the optical signal CW. The laser continuously emits and pumps light.

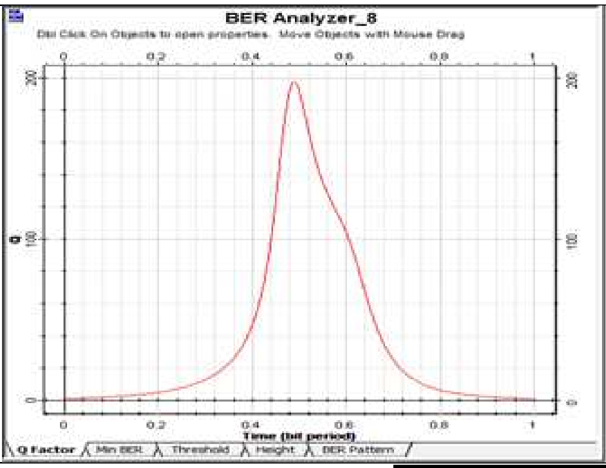
5.2 Residential solution

In the overall eye diagram shown in Table 6, Eyes are open. Noise is weak, resulting in user satisfaction and improved transmission. In any case at least BER 0, no transmission errors. An optical amplifier with 5dB amplification provides a good solution [17]. The distance between the OLT and the splitter is 20 km, so there is no attenuation. The distance between ONU and Splitter is less than 2 kilometers.

Table 6: Results of simulation

ONU	BER Analyzer	Q factor
B1		

B2	 	
B3	 	
B4	 	
B5	 	

B8		

5.3 Business solution

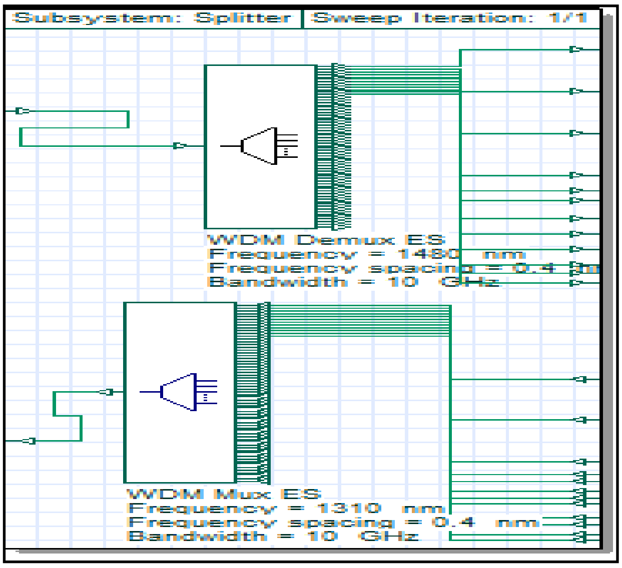


Fig.6: Splitter

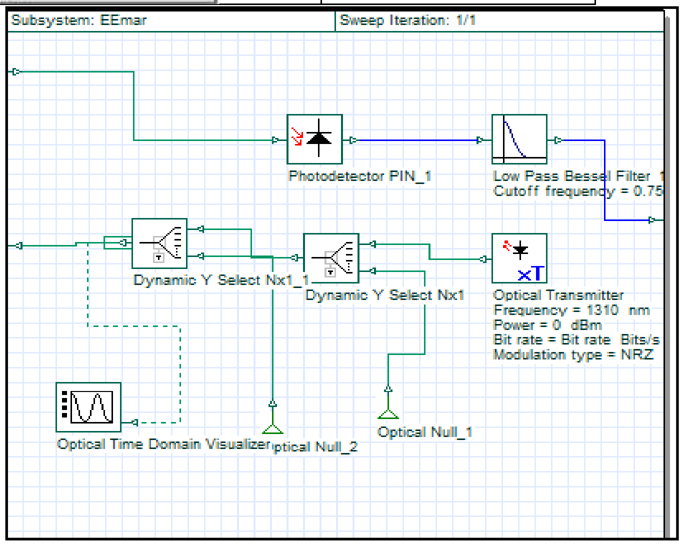
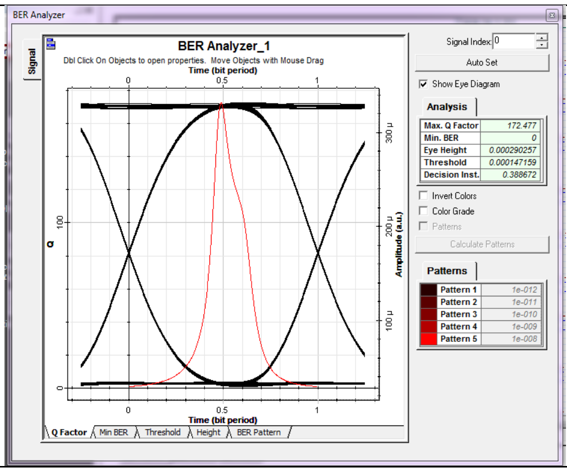
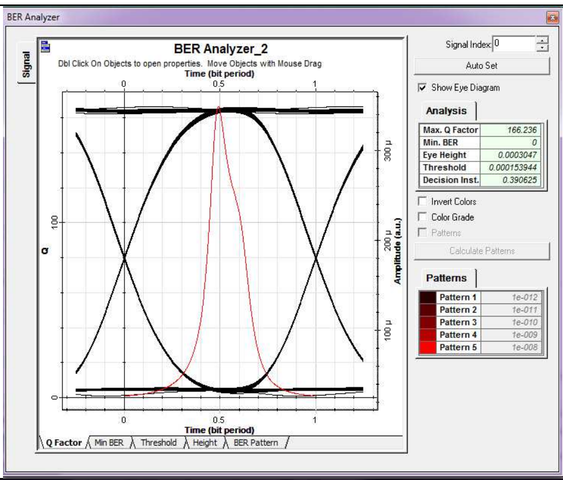


Fig.7:ONU

In all eye diagrams shown in Table 7, the eye diagrams are open. In fact, the noise is low, which improves user satisfaction and transmission performance. For all cases, we had a minimum BER of 0 and no transmission errors. An optical amplifier with 5 dB gain provides a good solution [17].The distance between the splitter and the OLT is 20 km, resulting in insufficient attenuation. The distance between the ONU and the splitter should not exceed 2 km as shown in Table 7

Table 7: Simulation resultsof business solution

EEMAR		No noise Jitter is nearby 0 Min. BER =0 Diagram of eye is wide open ->well transmission

<table>
<tr>
<td>KITCHEN</td>
<td>
</td>
<td>No noise
Jitter is nearby 0
Min. BER =0
Diagram of eyeis wide open ->well transmission</td>
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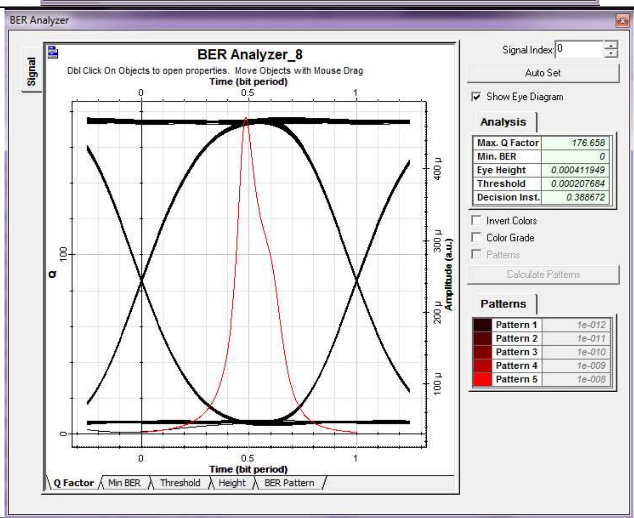
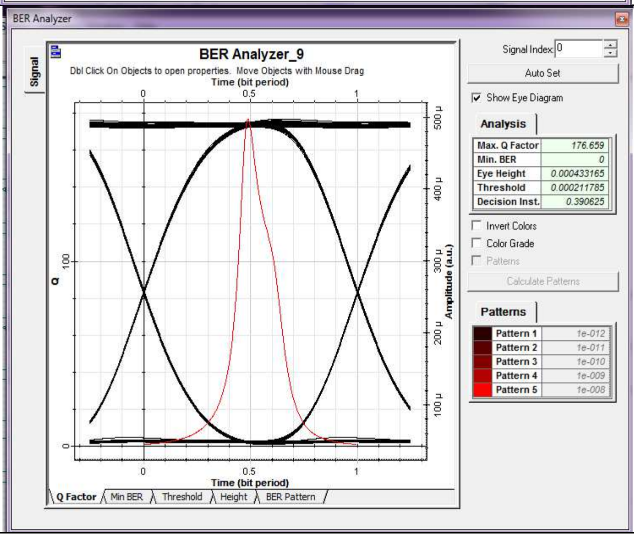
<tr>
<td>EDEN DECO</td>
<td>
</td>
<td>No noise
Jitter is nearby 0
Min. BER =0
Diagram of eyeis wide open ->well transmission</td>
</tr>
<tr>
<td>SAKLY</td>
<td>
</td>
<td>No noise
Jitter is nearby 0
Min. BER =0
Diagram of eyeis wide open ->well transmission</td>
</tr>
</table>

GPON provides a good solution for operators. Implementation and design can reduce maintenance prices and provide pristine service. With Quality of Service (QoS), the proposed solution can provide bandwidth to more operators than copper wire networks. The distance between OLT and splitter is 60km better than network copper wire; moreover, it can satisfy 128 users.

VI. Conclusions and Perspectives

GPON is used in the telecom sector to reduce costs. Strengths of the studied technology include its ability to support data, video, voice or "triple play" on a single network infrastructure. In fact, triple play can be easily implemented with GPON technology due to its reliable Quality of Service (QoS) support, high bandwidth and low latency.This study demonstrates the performance and reliability of the network's GPON downlink transmission in the studied cities. Various customers who access the PON share the cost of the OLT. Due to its increased bandwidth, GPON is considered the perfect technology for broadband FTTH applications where multiple terminal operators are always demanding ever-evolving bandwidth. Also, GPON is the most cost-effective solution in areas where commercial and residential customers use it. In the deployment scenario provided by the current network GPON, all parameters and specifications are analyzed for a range of business and home users. Standard GPON allows an OLT PON card to transport up to 128 ONTs, making GPON solutions 4 to 8 times more profitable.

10G-GPON is considered an innovative protocol to meet the demand, providing 25Gbps bandwidth to satisfy users. In fact, the upcoming network is an application of higher speed ahead of development.This research can be extended to multi-channel PON and NG-PON2 systems. This can not only increase the fiber capacity ((4 times)), but also extend the durability of customer ONU support, bringing unprecedented returns to users and operators.

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