Analysis of the threshold between GPON and EP2P

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Abstract— **New services like Video on demand, Television (IPTV), high speed Internet access and Voice over IP on top the same link are called Triple Play services. These services demand very high bandwidth to customers. ADSL and ADLS2+ aren't enough for supporting the new bandwidth requirement. One suitable solution for high bandwidth demand with a long reach is to use optical cable to customers (FTTX). Nowadays there are two technologies GPON (Gigabit passive optical network) and EP2P (Ethernet point-to-point) fighting for to be implemented in network access. This paper makes an evaluation between both solutions and it tries to answer the next question: What is the best solution for supporting requirement of Triple Play applications?**

Keywords-component; GPON, EP2P, QoS, FTTX, OPNET, TriplePlay

I. INTRODUCTION

Currently, the most used access network technologies are ADSL and ADSL2+ over copper wire. With the arrival of new multimedia applications like voice IP (VoIP), video on demand (VoD) or IP television (IPTV), more capacity and QoS guaranties are needed. New FTTH (Fiber to the Home) technologies replace link copper by optical fiber. There are many alternatives for this network topology but there are two options that have more opportunities to be elected for being implemented in the access networks by telecommunications operators.

These alternatives are: GPON (Gigabit Passive Optical Network) and EP2P (Ethernet Point to Point). This paper presents a comparison of both technologies and tries to answer the next question: *What is the best alternative to bear Triple Play services with the Quality of Service required nowadays?*

To answer this question we analyze the main characteristics and requirements of the users and we simulate the behaviour of the GPON technology using the OPNET Modeller software.

This paper provides an economic and technical study comparing both solutions. The results allow choosing the technology that is more reliable, simple and cheaper to support voice IP, Internet and high definition television.

If we consider 30 Mbps per user as bandwidth objective [15], we only are going to simulate the behaviour of GPON networks since they are shared networks and the results must indicate the boundary in terms of bandwidth and number of users with EP2P. Anyway simulation it's not necessary in unshared networks as EP2P with enough bandwidth per user.

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II. GIGABIT PASSIVE OPTICAL NETWORK (GPON) TECHNOLOGY

Passive Optical Network (PON) appears in the mid 90s. GPON is a variety of PON architecture and it is defined by ITU-T recommendations series G.984. [1][2][3][4]

A. Features

GPON standard defines different line transmission rates for downstream and upstream direction. All combinations are possible (except downstream 1.2 Gbps and upstream 2.4 Gbps). The combination which has been chosen to be implemented in this study is 2.4 Gbps for downstream and 1.2 Gbps for upstream direction in the same link.

The operating wavelength range is 1480-1500 nm for the downstream and 1260-1360 for upstream. The distance that can be supported from the central office to the user is around 20 km, although the standards are ready to support 60 Km. GPON can work with ATM protocol and GEM protocol (GPON Encapsulation method), being GEM a method to encapsulate data over GPON. GEM supports voice traffic, video traffic and data traffic without any extra level of encapsulation. [6]

B. Network architecture

Network equipment in GPON consists on:

- *OLT*: Optical Line Termination presents the native service interface to the user. It's in operator central
- *ONU*: Optical Network Unit provides connection to the network to users. It's in the home of user
- *Splitter*: It divides optical power into N separate paths to the subscribers. It's between central and users. Figure 1.

There are different logical network architectures called FTTX options, depending on the optical link ends. [8]

- FTTH: Fiber to the home, the installation of optical fiber goes directly into the subscriber's home.
- FTTB: Fiber to the building, the optical fiber terminates before reaching the home living space or business office space, with the path extended from that point up to the user's space over a copper links.
- FTTC: Fiber to the Curb or Fiber to the Cabinet, there are two solutions where the optical fiber stay more far

that the other solutions. These latest solutions need additional cooper links to connect the users.

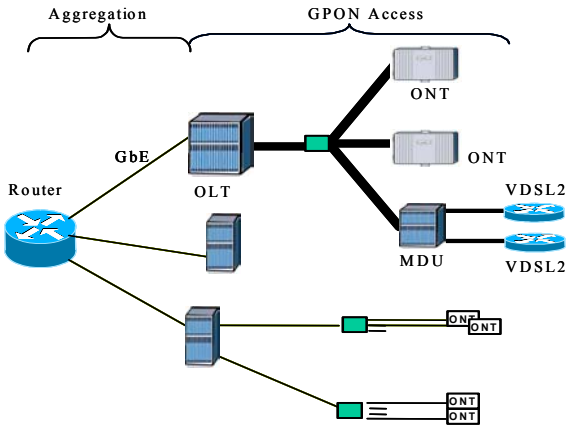

Figure 1. GPON architecture

The topology that has been used in this study is FTTH since offers more bandwidth [7].

C. *Transmission*

The procedure for data transmission in GPON networks depends on the direction of the communications. We TDM (Time Division Multiplexing) for downstream and full data rate are transmitted to all ONUs. In that case each ONU filters the received data and only accepts its own traffic. The upstream channel uses TDMA (Time Division Multiple Access) where OLT controls the upward capacity assigning bandwidth for all users. Each ONU transmits in slot time windows, for avoiding collisions. [9] [14]

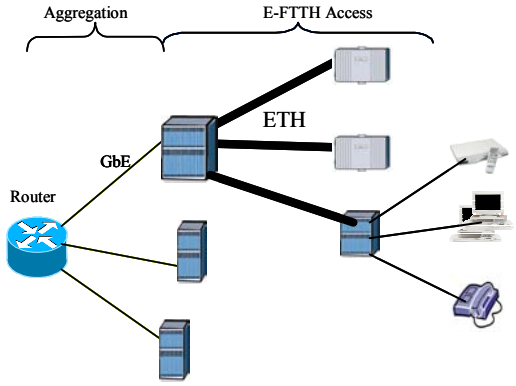

Figure 2. EP2P topology

III. ETHERNET POINT TO POINT (EP2P) TECHNOLOGY

EP2P (Ethernet Point to Point) is a solution that use Ethernet transport protocol over optical fiber. This solution offers more bandwidth and more bit rate benefits than copper. Ethernet is defined by IEEE 802.3ah recommendations. [5]

A. *Features*

Ethernet supports different line transmission rates depending on the fiber link used . The speed goes since 100Mbps up to 1000Mbps. Ethernet supports both directions of transmission in the same link, splitting the capacity of the link. The system uses Ethernet protocol transport for carrier data.

B. *Network architecture*

Network equipment in EP2P is composed by two nodes. OLT (Optical Line Termination) and ONU (Optical Network Unit), both of them realize the same functions described in GPON. The distance that can be supported from the central office to the user is around 100 Km. In that case the splitter disappears between central and user (figure 2). Network uses one link dedicated fiber for every user. The fiber arrives directly at home of users and l the full infrastructure is optical fiber.

IV. TRIPLE PLAY SERVICES

Triple Play service allows providing voice, video and data in a single access subscription. The most common applications are Telephony, TV and high-speed internet access [11].

The proposed bandwidths which have been used for the different applications in this work are:

- VoIP: For voice over IP is needed 15Kbps with G.723 voice codec.
- TV: For television we use 8Mbps for high definition channel and 1,5Mbps for standard definition channel with MPEG4 compression.
- Internet Access: we use from 6Mbps up to 10Mbps for downstream and 1Mbps for upstream.

V. GPON SIMULATION

The objective of this chapter is to design a simulation environment for checking GPON network access. We are specifically interested to probe bandwidth allocation for downstream and upstream when the number of users connected is changed.

For this goal the packet simulation software OPNET Modeler 14.0 has been used [12]. OPNET proposes hierarchical structure of pattern for creating new simulation scenarios. We define tree levels:

- Network model: It's the first level of design. It's the most abstract and generic level. The goals will be to define network topology, to define network nodes and to define the communication between each node.
- Node model: In this second level, goals are to concrete the functionalities for every node that has been used in the network topology. For all nodes we build a scheme for designing internal functions with the module that offers OPNET, and to create the specific modules required.
- Process model: The Last level. In this level is defined a graph for modules used in the second level and implemented with C++ code. The graphs specify the

jobs executed by the module with the info which will be processed.

A. *Network construction*

To create the simulation scenario, we have used the tree levels proposed by OPNET. We have decided to use FTTH topology (no FTTC or others) because the optical fiber arrives directly at user's home and it is the solution who offers more bandwidth capacity.

The network nodes that we have designed are OLT, ONU and Optical splitter. The communications between central and customers has been implemented with two packet types called "report" and "gate".

The "report" packet goes from ONU to OLT and carrier information about upstream bandwidth request. The "gate" packet goes from OLT to ONU and carrier information about upstream and downstream bandwidth assignment.

We consider only this type of control packets in our simulation and we don't consider others features related to delays or protocols since the objectives of our analysis need only results about bandwidth consumption due to medium access control procedures.

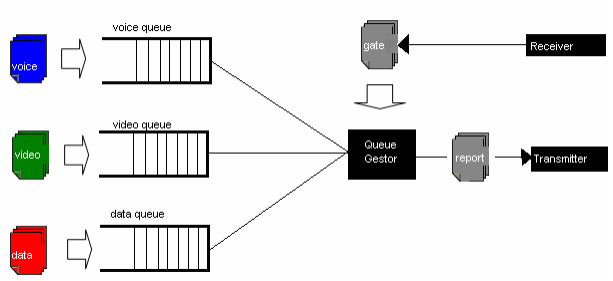

Figure 3. ONU functional schema

B. *ONU design*

Optical Network Unit is the device situated at customer's home. It allows connecting the user with the rest off the telecommunication network. Their jobs are received downstream traffic and request upstream traffic according to their needs (figure 4).

It has three traffic packet queues, one for every type of traffic (voice, video, and data) and in that queues are the packets that wait to be sent. Furthermore the module receives the "gate packet" with upstream bandwidth allocation. With this information, the module called *Gestor_de_colas* give up the queues and also it creates the "report packet" with information about upstream bandwidth requested after analysing the queues status.

The ONU design model in OPNET Modeler has two different parts, one for downstream and other for upstream, to simplify simulation management.

Firstly for upstream (figure 5) it has two sections: reception and transmission.

- Reception has tree modules: *Receptor*: Get incoming packets from the link; *Filtro*: Filter incoming packets owner; *Gestor_GATE*: Extract upstream bandwidth info allocation from the packet received.
- Transmission has the next modules: *Generadores*: Create packet voice, packet data and packet video, for sending; *Gestor_colas_trafico*: Classify packet types, send packets and control upstream bandwidth allocation; *Emisor:* Send packets to OLT.

Secondly for downstream (figure 6) it has the same parts of upstream and the design is very similar. In this way, in the reception part, "*Gestor_GATE"* disappears, because the traffic received comes in directly at "*Gestor_consumo"* who distributes it to the "Consumidores" modules.

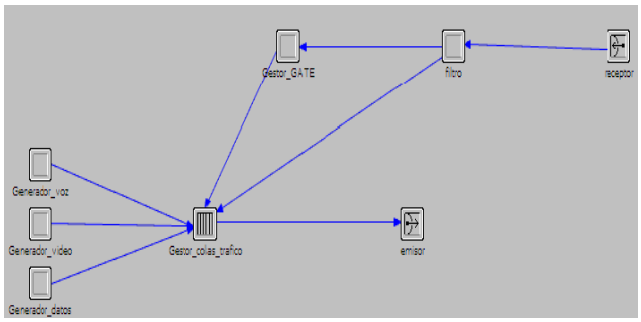

Figure 4. ONU upstream

The transmission part has the next modules: "Gestor_consumo": It distributes incoming traffic to "Consumidores" and note the new downstream bandwidth request; "Consumidores": It consumes downstream traffic; "Emisor": Send packets to OLT.

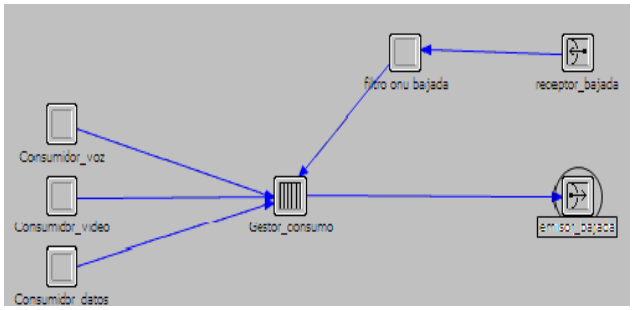

Figure 5. ONU downstream

C. *OLT design*

Optical Line Termination is the device situated in the operator switch central. It provides the different services to all customers. Their job is calculated and assigns upstream and downstream bandwidth according to the bandwidth requested (figure 7).

This device receive all the "report" packets from ONUs, with the information about the requested bandwidth and with the historic information about all the bandwidth requested, then "*Gesto ancho banda"* module calculates and assigns upstream

and downstream bandwidth. For this it prepares and sends "gate" packets (figure 8)

The design in OPNET has three different parts every one with their specific functions:

- *Reception:* It has three modules. "Receptor" and "Filtro" get incoming packets and identifying the ONU id that the packet sends. "Gestor_Report" extracts the bandwidth allocation and saves this information.
- *Transmission:* This module only sends the generated packets for the node. The modules are "emisor" and "emisor_bajada".
- *Management:* This is the most important module in the design. "Planificador" realizes the calculation for establishing the bandwidth allocations for every ONU.

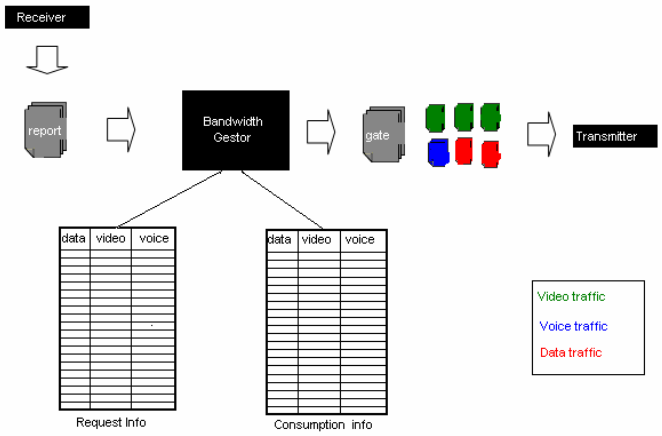

Figure 6. OLT Functional schema

D. Optical Splitter design

Optical splitter is the node who stays between OLT and ONUs. It has two different functions according to the communication direction. In the way from OLT to ONUs, it replicates incoming packets and sends it to all ONUs. In the way from ONUs to OLT it aggregates traffic and send it to OLT. The main goal is to route the traffic between OLT and ONUs.

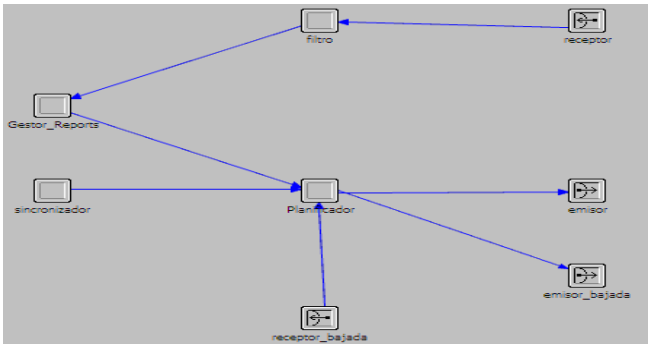

Figure 7. OLT Opnet design

VI. Simulation Scenario

The simulations pretend to answer the next questions:

- *¿How affect the number off customers connected to the bandwidth allocation?*
- *¿What is the maximum upstream and downstream bandwidth for every scenario?*
- *¿How many customers do the network support for having 30Mbps for downstream?*

The simulation parameters are:

Downstream payload 2,5Gbps and Upstream payload 1,2Gbps; The traffic generated and simulated use Poisson distribution; The real time simulated is 2 hours; Network is in congestion when the load is higher than 80% of total capacity; The number of ONU devices connected are 3, 8, 16, 32, 64, 70 and 72.

A. Results

We present two tables for results. The first table shows the maximum bandwidth consumed for upstream and downstream for all scenarios simulated. For example, in the scenario with 32 ONU, the maximum bandwidth for downstream is 68,16 Mbps, and for upstream is 32,92 Mbps. With the information of this table can answer the first and the second questions raised. If increase the number of ONU connected then decrease the maximum bandwidth supported in both ways. The maximum values supported for every scenario are in the table I.

TABLE I. Maximum Bandwidth Supported

ONU	Downstream	Upstream
3	724,48	348,91
8	284,6	144,33
16	146,89	76,04
32	68,16	32,92
64	34,03	16,8
70	32,62	16,48
72	30,1	15,19

Table II shows the number of ONU supported to achieve 30Mbps for every user.

With the 100% of ONU connected the network supports 72 users with 30Mbps for everyone. For 60% of ONU actives the number of users supported is 120. If decrease the percentage of ONU connected, increase the number of users supported.

TABLE II. PERCENTAGE ONU SUPPORTED WITH 30 MBPS

Percentage actives ONU	Users supported
100	72
80	90
60	120
40	180
30	240
20	360

VII. CONFRONTATION

A. *Technical*

For technical evaluation we have took a commercial pack service. This pack has allowed having a point of reference for comparing both technologies. The pack has two options of services, both of them offers 30 Mbps for downstream and for upstream changes between 1 Mbps and 3 Mbps [17]. Bandwidth capacities for the different services included in Triple Play are: Voice IP uses 15Kbps with G.723 codec; Television IP requires 8Mbps for high definition channel and 1,5Mbps for standard channel and Internet access between 6Mbps and 10Mbps for downstream and 1Mbps for upstream.

Once both technologies have been analyzed and compared the main conclusions are [13]:

- EP2P solution have the network architecture more simple than GPON, because haven't any device between central office and customers.
- The management of EP2P network is more easy that GPON, because dynamic bandwidth allocation is not necessary in EP2P.
- The costumers in GPON topology are restricted, because the functionalities and capacity network depends on the number of users connected.
- GPON has more exploitation of infrastructure than EP2P, because the optical fiber link is shared for the users.
- EP2P present more expansion capacity and have more bandwidth capacity than GPON.

B. *Economical*

For Economical confrontation we have used two financial terms. One is CAPEX, capital expenditure is funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment. This type of outlay is made by companies to maintain or increase the scope of their operations. These expenditures can include everything from repairing a roof to building a brand new factory.

There are not important differences between GPON and EP2P in terms of CAPEX [10]. Connecting one home by GPON cost is €1.500 for user, and connecting one home by EP2P cost is €1.600 for user (these costs are calculated in urban context and without any existing infrastructure).

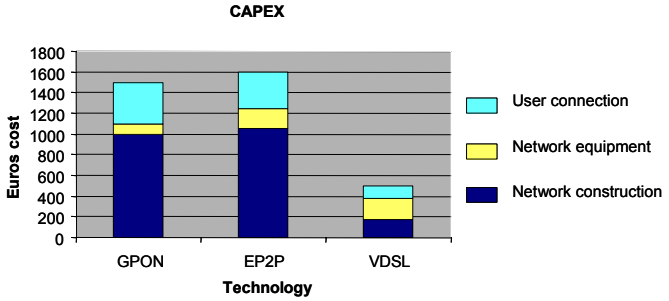

Figure 8. CAPEX cost

As we can see in figure 11, the real differences in CAPEX are in the network equipment where EP2P spends more than GPON.

The other term is OPEX or operational cost, and the index reflects the costs associated with the operation and maintenance and concretely are the cost associated with electricity and physic space in the office central. Analyzing OPEX costs are important difference between both technologies. [16]

For one central office to service 16.000 customers, Alcatel-Lucent says that GPON technology only one rack and 1.500 optical fiber links would be required, while to serve the same users by EP2P technology 24 fiber racks in central office and 16.000 optical fiber links would be required.

Summarizing, EP2P use 80% more energy and 92% more floor space in central office than GPON environment. EP2P OPEX, according to Alcatel-Lucent, works out at €35 more per year per subscriber compared to a GPON.

VIII. CONCLUSIONS

The study is real and tries the actual problem of bandwidth capacity in the network access. This problem appears with the new multimedia applications like video on demand, television over IP and fast access Internet, which requires more bandwidth capacity.

EP2P don't have bandwidth problems due network topology and optical fiber capacity, but that solution at this time is not adequate from economic point of view.

According the simulations results, GPON technology supports 72 users to offer 30Mbps with 100% of actives ONU and it supports 240 users to offer 30Mbps with 30% of actives ONU. If we suppose that 30% is a percentage acceptable of active users so GPON is a good solution for networks topology fewer than 240 users and this value becomes the threshold between GPON and EP2P. With the same manner we can calculate the threshold between GPON and EP2P depending on the percentage of active users required. That consideration is very important in FTTB (GPON + VDSL) access networks due the number of users available usually about 200 [18].

EP2P technology offers more bandwidth capacity than GPON, and the management network is easier, but with the current requirements of services is enough to use GPON.

If only analyse economical environment the best solutions is GPON technology because it has CAPEX and OPEX fewer than EP2P. If only analyse technical environment the best solution is EP2P technology because offers more bandwidth and more scalability than GPON.

Analysing both environment, technical and economical, with the actual requirements and users, the best solutions is GPON depending on the user number, although if analyse futures requirements and potential users the best alternative is EP2P.

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