FTTH network economics: Key parameters impacting technology decisions

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Different technology options are available to operators today for their Fiber-to-the-home (FTTH) network deployment strategy decisions. Gigabit-Passive Optical Network (GPON), Ethernet Passive Optical Network (EPON), Active Ethernet (AE) and Point-to-Point Ethernet (P2P) are the major competing technologies. There are a number of technical, economic and business drivers that impact the right choice for each specific network situation. When modeling network economics, it is important to consider a Total Cost of Ownership (TCO) model to enable operators to rightly evaluate these choices, instead of comparisons of only specific cost elements (e.g., port costs). On the other hand, in a network model with a large number of parameters it is often challenging to identify the key parameters that are critical to the decision-making. An operator runs the risk of picking an incorrect technology strategy if any of these key parameters are not identified and cost optimized.

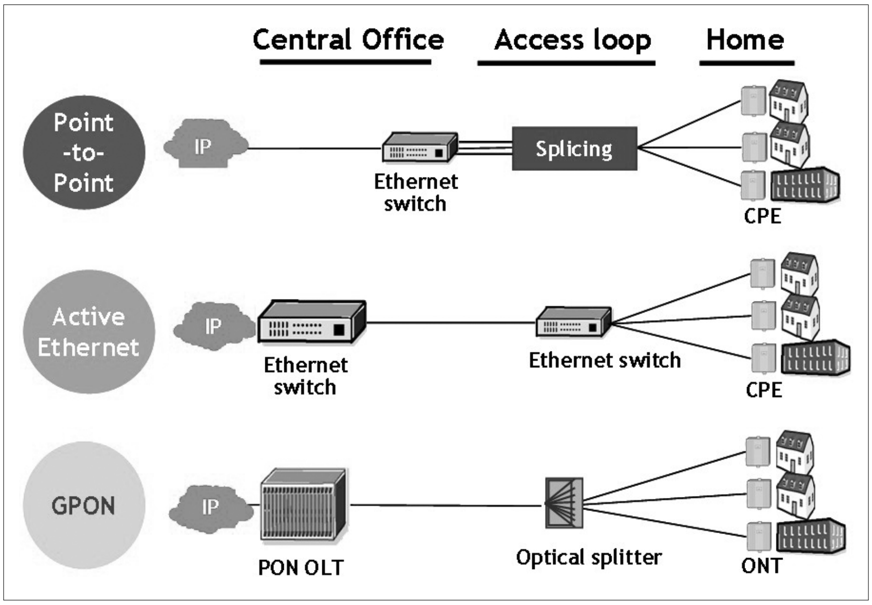
In this paper, we present the results obtained by modeling the capital investments and operations expenses incurred for some operator cases, and identify the key parameters that impact FTTH economics covering these major technologies. We show sensitivity analysis to identify the critical parameters. The methodology and results will enable operators quickly make the right FTTH technology deployment decisions.

1. Introduction

The number of households with fiber-optic network connections will grow by nearly 43% worldwide in 2008 and will continue to grow at rates above 30% a year through 2012, when the number of fiber-connected households will reach nearly 90 million globally according to a recent report by Heavy Reading [1]. Hence it is no surprise that almost all the network operators around the world are evaluating the different FTTH technology options today. Deploying a FTTH network requires significant upfront capital investments and it is absolutely critical for an operator to build a detailed network economic model and pick the right technology that optimizes their capital expenses, operations expenses and payback period. Service Provider network requirements and topologies vary considerably; hence network modeling and solutions need to be tailored to specific service provider situations.

Figure 1 shows the key FTTH technology options that exist today and are already being deployed by some of the major operators in the world. GPON [2] and EPON [3] optimize the outside plant (OSP) by using a passive splitter which provides bandwidth aggregation, requires less maintenance and doesn't have any power requirements like an active network element. The Active Ethernet solution achieves optimization in the OSP by using an Ethernet switch for aggregation, but requires hardened cabinets and remote power supply. The Point-to-point solution also uses Ethernet switching and aggregation, however all the Ethernet switches are deployed in the Central Office (CO). These COs, also known as Points-of-Presence (PoPs) tend to be closer to the subscriber.

Figure 1. Key FTTH technology options



In the next section, we discuss the details of a comprehensive and flexible network cost model that compares these FTTH technology options, and quantifies the savings through case studies. This model also includes a task-based operations analysis. Results of three case studies are presented, and sensitivity analyses of the results are applied to identify the key parameters.

2. Modeling framework

The network economic modeling framework includes capital investments (CAPEX) and operations expenses (OPEX) optimization for the technology options and across scenarios applicable to typical service provider networks. The services revenues supportable by these access options are assumed to be common and hence are not included in this model Also, the scope is related to cost-elements, and does not cover other aspects (such as performance, standards etc).

Typical operator scenarios include:

- Type of subscriber:
  Single-family residential (SFR),
  Multi-Dwelling Unit (MDU) and Enterprises.
- Subscriber housing density:
  Loop lengths from the CO,
  number of houses per square-km;
- Network build type: Greenfield, Overbuild.
- Fiber cost type:
  Leased vs. own, one-time fee vs. recurring.
- Outside plant construction type:
  Aerial, Buried, Conduit, Sewer etc.
- Splitting levels:
  1-Tier centralized and/or 2-Tier distributed for PON.

Typical cost elements are:

- Hardware and software for Central Office (CO), OSP, and Customer Premises Equipment (CPE), active equipment and operating support systems. List prices are prorated based on experience curves (market averages and up to 10% annual cost reductions) and equipment discounts (0-50%) for sensitivity analysis.
- Cost of the OSP: feeder, distribution and drop fiber; civil works for the structures, trenches, installation and splicing; cabinets, splitters, fiber management points and patch-panels.
- Power and space/housing costs: Costs to setup active nodes, realtor fees, provisioning of AC, ongoing energy costs and floor space rental.
- Activation costs such as truck roll to OSP, customer service visit, service activation in CO.
- Other operations cost such as provisioning and maintenance activities.

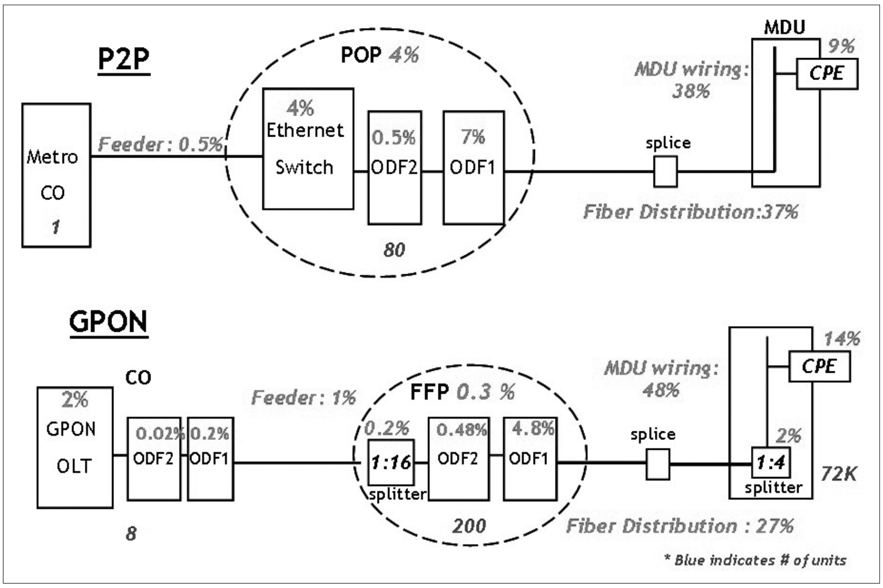


Figure 2. CAPEX Breakdown at 20% take-rate

3. Case Studies

In this section, we discuss and summarize results from three network modeling case studies as below. For all the three case studies, it can be assumed that the CAPEX/subscriber and OPEX/subscriber have been optimized for each technology solution by assuming a reasonable OSP model and based on the specific scenario and cost parameters. Then we use sensitivity analysis techniques to identify the key network cost parameters.

3.1 Case Study 1: GPON vs P2P for a dense urban city

This case study compares the costs of deploying GPON and P2P in a dense urban MDU subscriber base. There are close to a million households (HH) passed in an area of roughly 100 square kms. The average size of an MDU is assumed to be 16HH. A GPON operator has 8 CO locations to serve these HH and 200 Fiber Flexibility Points (FFPs) where splitters are located, whilst the P2P operator is deploying 80 new PoPs. The civil works is assumed to use existing structures such as the sewer in the city thereby eliminating most of the trenching and duct costs. In our modeling analysis the take-rate is varied from 0-100%.

Figure 2 shows the P2P and GPON 2-Tier architectures and the corresponding CAPEX cost components for a take-rate of 20%. The 2-Tier GPON architecture assumes a splitter in the basement of the building.

It is observed that the bulk of the CAPEX/sub is in the fiber distribution and MDU wiring. The CPE accounts for the next highest cost component followed by Ethernet switch cost and the GPON OLT. The remaining network elements do not contribute significantly to the overall cost.

We also find that GPON provides a saving of about 20% compared to P2P at a take-rate of 20%, and the savings are positive over the entire range of take-rates up

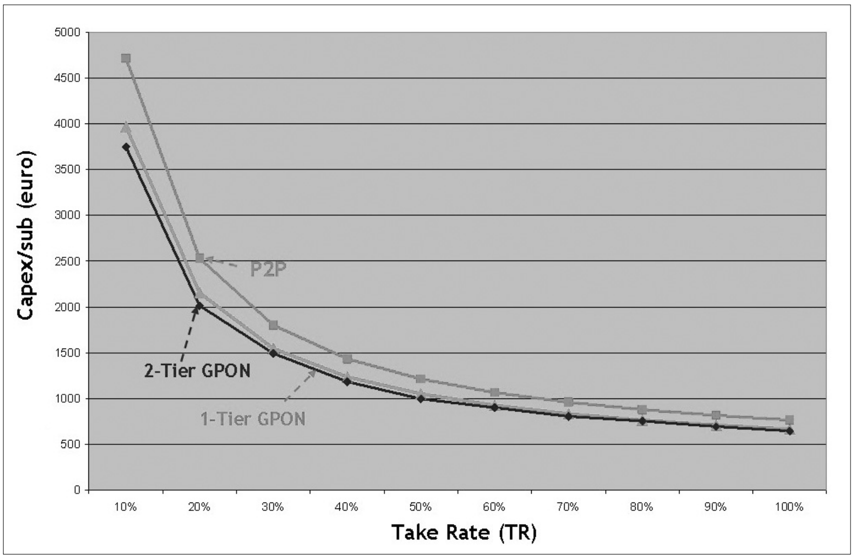


Figure 3. CAPEX/sub vs. Take-rate

to 100% *(Figure 3)*. Also 2- Tier GPON is cost-effective by 0-10% over 1-Tier GPON and the savings are higher at lower take-rates.

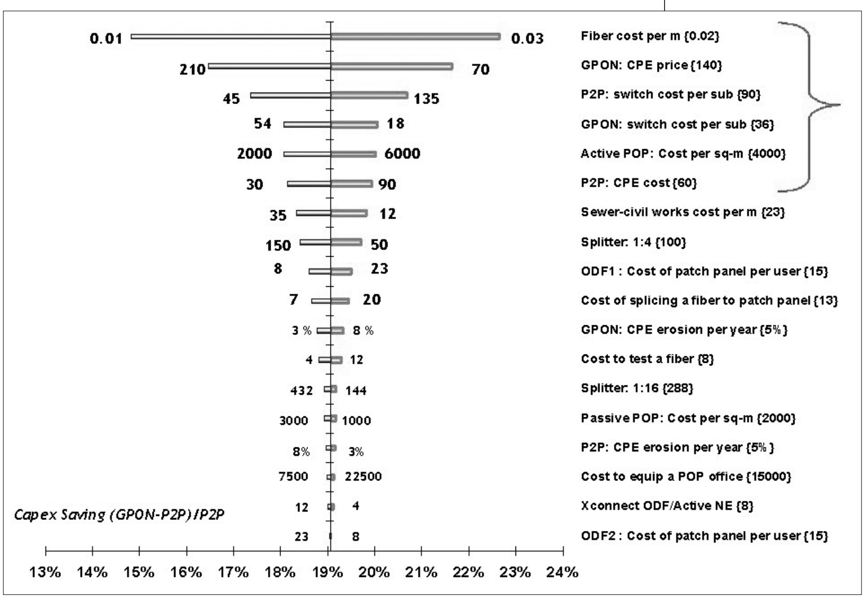
To identify the key cost parameters, we look at the results of a single parameter sensitivity analysis (Tornado analysis) as shown in *Figure 4.*

Sensitivity analysis shows, the Top-5 CAPEX parameters are:

– Fiber-cost per meter,
– GPON CPE cost,
– Ethernet switch cost,
– Real-estate cost for Ethernet switches deployed outside the CO,
– GPON OLT cost.

The remaining parameters have an impact on the overall CAPEX but do not swing the GPON vs. P2P decision as much.

Figure 4. CAPEX Tornado analysis



The tornado analysis does not capture the interaction between the parameters. Hence a 1000-iteration Monte-Carlo analysis was performed with a ±50% variation in the value of the cost parameters with all parameters varied randomly per iteration, and histogram of results plotted. The x-axis of *Figure 5* shows the percent savings of GPON over P2P. Even with this wide range of variation, GPON still provided a significant cost advantage over P2P making it the technology of choice.

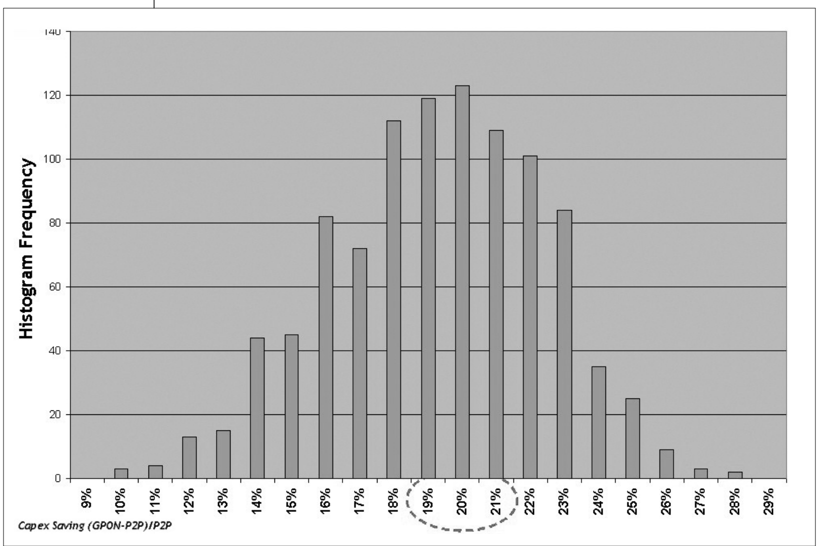
Operations Cost Modeling Results

The following operations cost elements are considered in this model.

• Unplanned Maintenance:

Repair activity based on equipment quantities and FIT data. Operation tasks include: testing, fault isolation and equipment repair (Truck roll).

Figure 5. CAPEX Monte-Carlo analysis



• Planned Maintenance:

Calculated based on equipment quantity, maintenance interval and effort, equipment clustering and location density. Fiber maintenance based on total length of cables and yearly per meter. Operation tasks include: battery replacement, fan filter replacement, drive time and paperwork to document preventative maintenance, fiber inspection/cleaning and debris removal.

• Centralized NOC Staffing:

Surveillance staff estimated based on total number of active devices. Operation tasks include: 24x7 fault monitoring, remote diagnostics and trouble ticket creation.

• Differences in Customer Provisioning and Disconnect Scenarios:

Cost of connecting/disconnecting a customer based on equipment locations and utilization. Operation Tasks include: CPE installation, in-building fiber connection, PoP/FFP connections, testing and inventory updates.

• Customer Care:

Estimated based on failure incidence (calculated for unplanned maintenance) and number of customer impacts/incidents. Operation Tasks include: customer care call handling.

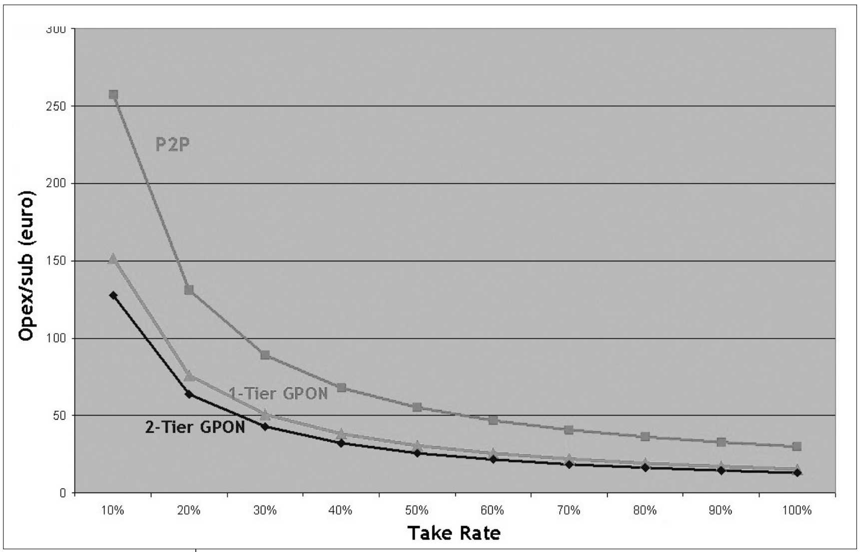


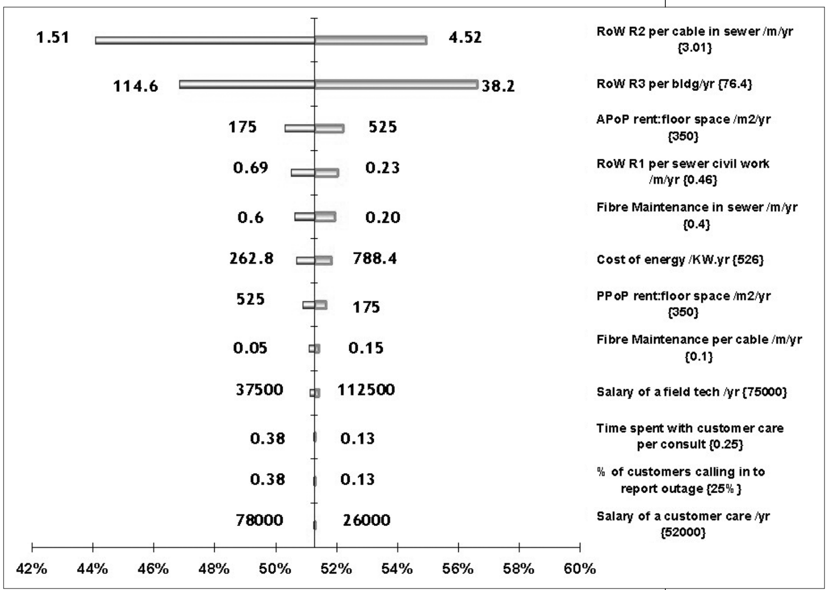
Figure 6. OPEX per sub vs. Take-rate

The OPEX modeling results show a saving of 55-60% for GPON compared to P2P over a wide range of take-rates *(Figure 6)*. These savings are mainly due to the higher Right-of-Way (RoW) expenses for P2P given the large amount of fiber infrastructure deployed on Day 1.

The Right-of-Way is a yearly recurring expense that the operator in this case would need to pay to the governing entity to use the civil works infrastructure while laying out fiber cables.

Typical components of RoW are a fixed cost to access the civil works in the OSP and in the building, and a variable cost as a function of the number of cables run. Furthermore, the cost of maintenance and management is higher in P2P compared to GPON because of the higher number of fiber-pairs deployed.

Figure 7. OPEX Sensitivity Analysis



The sensitivity analysis *(Figure 7)* shows that the Top-3 OPEX impacting parameters are:

– Right-of-Way charges,

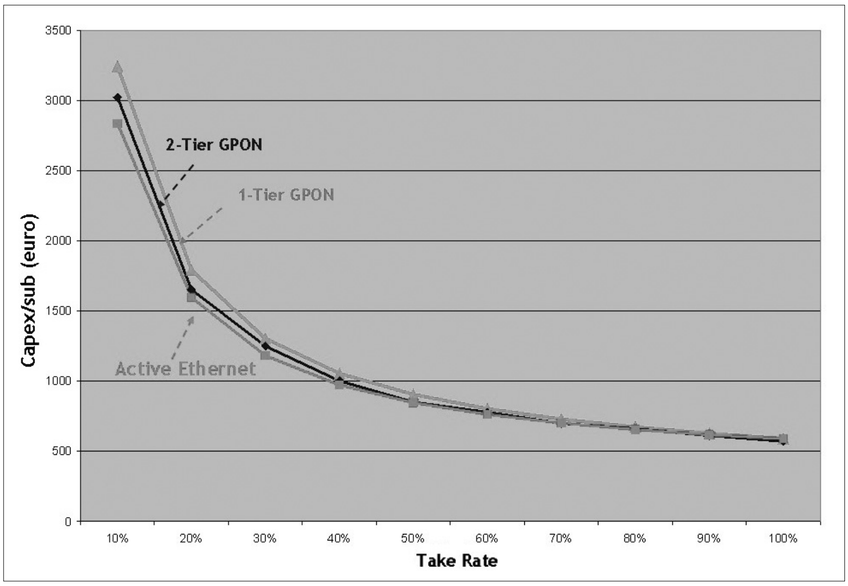
– cost of energy (KW/hr),

– fiber maintenance costs.

A Monte-Carlo analysis was also performed that confirmed the results that GPON provides significant OPEX savings compared to P2P, and details are not presented here for brevity.

Also, although this case study looked at a dense urban MDU deployment, it has been found that the same trend in terms of the key parameters and GPON savings are applicable to a single family residential urban and sub-urban model with reasonable population densities and operator deployment scenarios.

Figure 8. GPON, AE CAPEX vs. Take-rate



3.2 Case Study 2: GPON vs. Active Ethernet for a dense urban city

An operator that has deployed DSLAMs to provide ADSL/VDSL broadband access to some end users may consider this scenario when they decide to migrate to a FTTH last mile, by provisioning fiber loops to the cabinet. Also, technology exists today to install Ethernet cards in an existing (DSLAM) street cabinet. We compare the CAPEX/sub and OPEX/sub for this operator to an operator deploying only GPON to serve the fiber subscribers.

The same dense urban MDU subscriber model as in Case Study 1 is used here. We assume for the Active Ethernet model, buried fiber civil work is needed in the distribution network only (cabinet to sub) since fiber already exists to the cabinet to backhaul the DSLAM traffic Assuming typical serving areas of 250-300 per cabinet, about 4500 cabinets are needed.

Figure 8 shows that Active Ethernet has a saving of about 5% compared to GPON 2-Tier and the savings diminish with increased take-rate. Given the range of savings (<5%), it is argued that neither technology is the clear winner in terms of CAPEX/sub.

Figure 9 shows the breakdown of CAPEX/sub at 20% take-rate. The AE solution has zero housing cost for the PoP since the OSP cabinets are re-used (unlike in Case Study 1), and remaining costs balance out. Therefore CAPEX is not a key differentiator in this case.

Now considering the OPEX/sub as shown in *Figure 10,* we find that GPON provides large savings compared to P2P. The OPEX savings for 2-Tier GPON increase with higher take-rates and are in the range of 5-58% savings annually. Therefore, if the operator plans to target for a 30% or higher subscriber take-rate, then GPON should be the technology of choice.

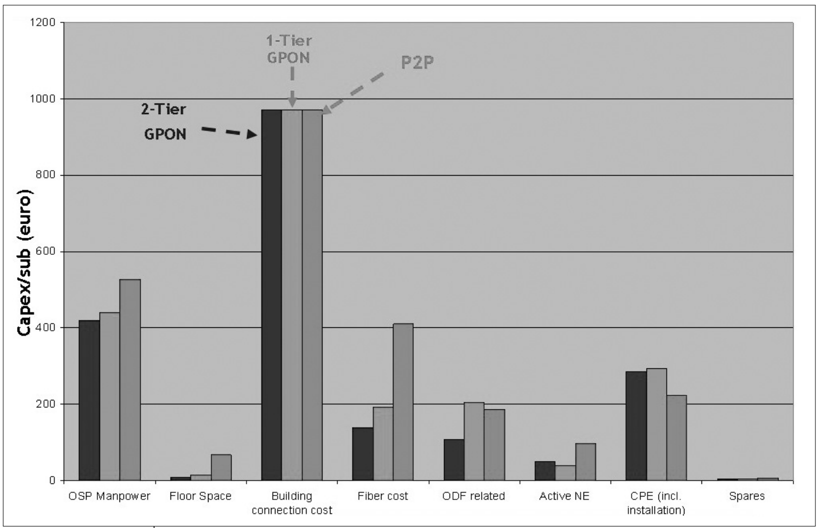


Figure 9. GPON vs. AE CAPEX (20% TR)

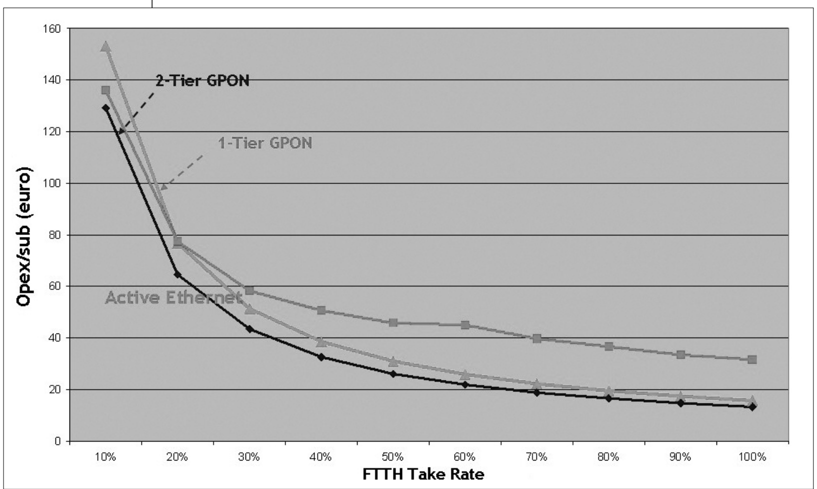


Figure 10. GPON, AE OPEX/sub vs. Take-rate

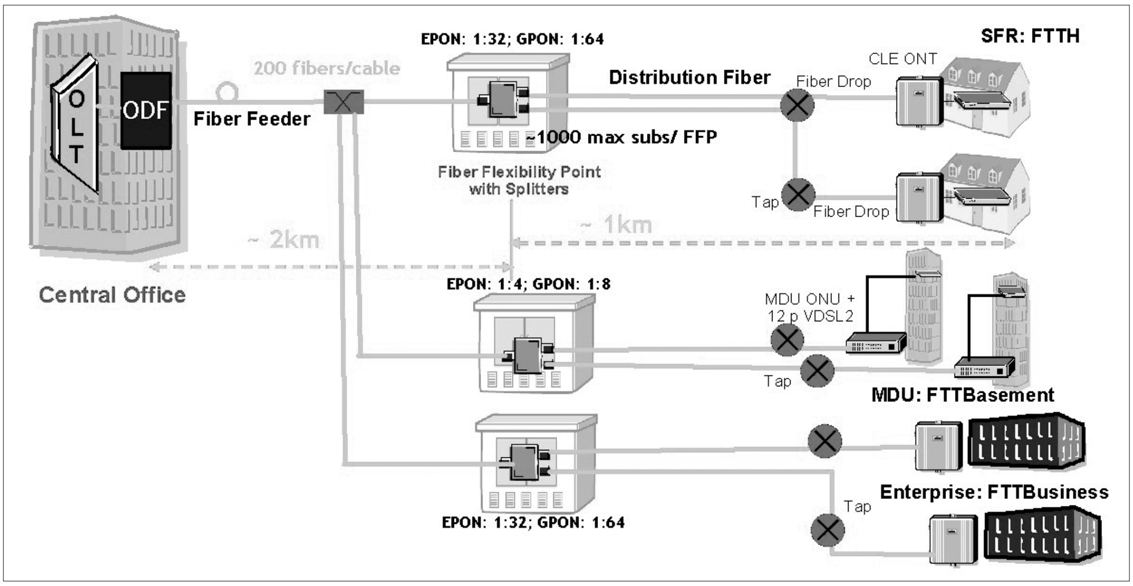


Figure 11. GPON vs. EPON network model

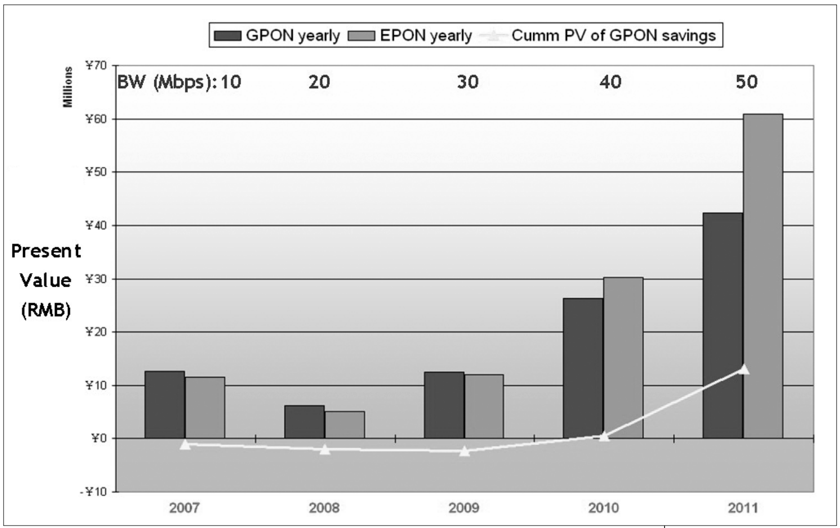


Figure 12. CAPEX for SFR (year-over-year)

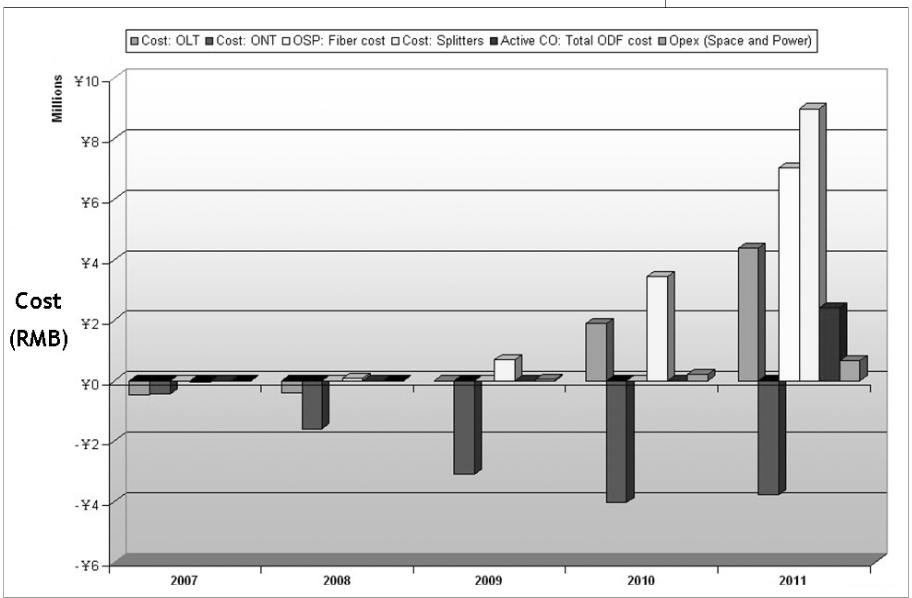


Figure 13. SFR CAPEX Delta (EPON-GPON)

We note that this case is really a special case of Case Study 1 with the assumption that the Ethernet switch is deployed in the OSP using a hardened cabinet instead of a PoP. The relevant key parameters identified through sensitivity analysis in Case Study 1 apply here as well.

3.3 GPON vs. EPON

This case study is for an operator deciding between GPON and EPON. We model an operator deploying a network in an urban city. The model assumes a deployment period of five years (2007-2011). *Figure 11* shows the architectures for the SFR model which is FTTH, MDU model which assumes Fiber-to-the-Building and VDSL2 inside the building, and enterprises served by fiber (Fiber-to-the-Business).

Each type is modeled independently. The MDU case assumes copper loops inside the building are used instead of fiber all the way. Services bandwidth is assumed to grow from 10 Mbps/year starting with 10 Mbps in 2007 to 50 Mbps in 2011.

Cost items modeled include: active NE (CO switch, CPE), passive components (splitter, ODF, fiber) and OPEX (space, power). It can be noted that both technologies use the same OSP infrastructure (civil works etc.) and that cost is ignored in this model.

Comparing the CAPEX/sub *(Figure 12)* shows that EPON provides a lower start-up cost in the initial years, but requires significant investment in future years.

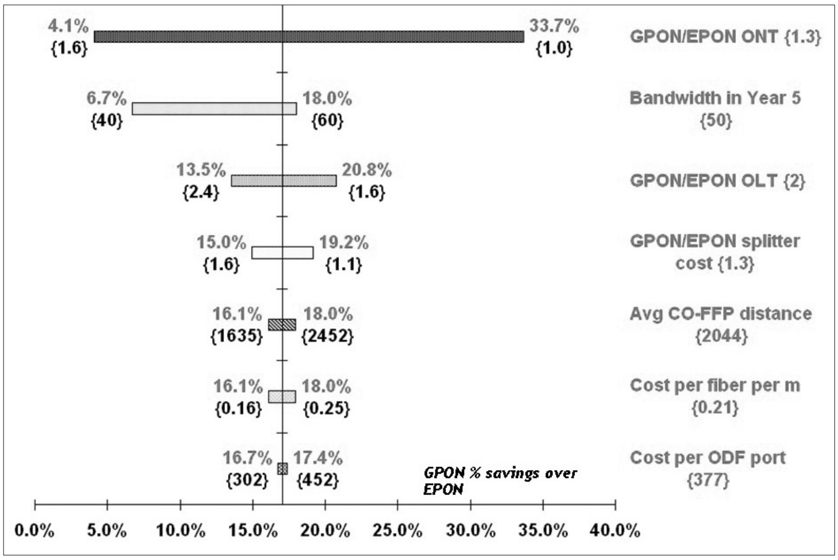
- Present Value of Savings of GPON over EPON = 17% (SFR), 19% (MDU) and 30% (Enterprise)

Figure 13 provides a breakdown of the key cost elements for the SFR case. When the bandwidth is low (<20 Mbps until 2008), EPON saves on all cost components. With increased bandwidth however, GPON scales better costwise whereas EPON needs more OLT ports, splitters, fibers etc.

This is because of the lower overheads and higher payload bit-rates in the GPON technology today compared to EPON.

Sensitivity analysis in *(Figure 14)* shows the key parameters impacting the economics.

Figure 14. GPON vs. EPON sensitivity analysis



The Top-2 critical parameters are:
- user bandwidth: if BW is below 30 Mbps, GPON doesn't save compared to EPON,
- GPON/EPON price ratios for the ONT and ONU.

Evaluating these key parameters correctly will enable the operator make the right technology decisions moving forward.

4. Conclusions

A detailed analysis of FTTH economics across a range of different scenarios and parameters was developed comparing GPON, EPON, P2P and Active Ethernet. Results for three real-world customer modeling case studies were presented with sensitivity analyses.

They are summarized as follows:

Case Study 1: (GPON vs. P2P network)

Over a wide range of take rates and parameters, GPON provides lower CAPEX/sub and OPEX/sub compared to P2P. This is primarily due to the significant OSP fiber investment needed on Day 1 for P2P.

- Average savings: CAPEX = 20% and OPEX = 55-60%
- 2-Tier GPON is more cost effective than 1-Tier (for MDU) by 0-10%.
- The specific results above apply to an example case of an overbuild FTTH network deployment in MDU; our studies show GPON savings apply to an urban/sub-urban SFR deployment case as well.

Sensitivity analysis shows that the Top-5 parameters impacting CAPEX are:
- fiber cost per meter,
- GPON CPE cost,
- Ethernet switch cost,
- real-estate/housing cost for Ethernet switches deployed outside the CO,
- GPON OLT cost.

Sensitivity analysis indicates that the Top-3 OPEX parameters are:
- Right-of-Way
- cost of energy
- fiber maintenance.

Case Study 2: (GPON vs. AE network)

Here an operator may consider serving FTTH subscribers directly from the DSLAM chassis. In such situations, the economics of Active Ethernet and GPON will change considerably.

- An Ethernet card in the DSLAM is expected to provide a cost effective solution for FTTH in low or medium fiber deployment situations (take-rates ~10-20%).
- The CAPEX/sub difference between GPON and AE are small (<5%), but OPEX/sub is a big differentiator. GPON provides OPEX savings from 5-58% with higher savings for increasing take-rates.
- In areas where no DSLAMs are deployed, GPON is expected to be more cost effective in general because of the additional cost of building the OSP cabinets for AE and significant OPEX savings from a passive outside plant.

Case Study 3: (GPON vs. EPON)

EPON provides a lower start-up cost, but requires significant investment in future years as demonstrated for all cases. A savings of 17% over EPON was obtained for the urban SFR model, 19% for MDU and 30% for the Enterprise model. Sensitivity analysis indicated that the two key parameters impacting the economics are:
- GPON/EPON ONT and ONU cost ratios,
- end year subscriber bandwidth.

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