Techno-economic study of high–splitting ratio PONs and comparison with conventional FTTH-PONs/FTTH-P2P/ FTTB and FTTC deployments

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Abstract: We present a techno-economic study on the outside plant costs comparison between the standard FTTH-PON deployments with future high-splitting ratio PONs. The high-splitting ratio PONs are also compared with other FTTx deployments.

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1. Introduction

The point-to-multi-point (P2MP) Fiber to the Home (FTTH) Passive Optical Networks (FTTH-PON) solution seams to be appealing to many network operators (especially incumbent ones), due to its CAPEX and OPEX saving attributes. In addition compared to FTTH point-to-point (FTTH-P2P) and Fiber to the Building/Curb (FTTB/FTTC) architectures (based on active Ethernet and VDSL technologies respectively) it offers a more "green" solution due to smaller power consumption.

The increase of high bandwidth applications, coupled with the need for decrease of the investment levels for next generation networks deployments, has led on one hand the main players of the broadband market to adopt the already standardized ITU G.984 GPON technology (for current deployments primarily in Europe and North America), while on the other hand the research community to focus on innovations that will result in PON enhancements related with increased reach and number of customers served per PON tree (i.e. an increase of the splitting ratio). According to the current 2.5Gb/s GPON standard, the maximum reach is limited to 20km and the most typical configuration to achieve a bandwidth of approximately 150Mb/s per household requires the use of a relatively low splitting ratio 1:16 [1]. Efforts to increase the achievable PON reach to 100km (i.e. long-reach PONs) and the splitting ratio, while maintaining a high access bandwidth per user (i.e. as in the case of 10Gb/s GPON) are many years underway, while even more advanced PON technologies (e.g. WDM-TDMA hybrid PONs or OFDMA PONs) promise to support an increased splitting ratio and/or longer distances. Assuming that the technologies to achieve high-splitting ratio PONs will be available, we need to understand what are the expected savings in terms of outside plant (OSP) costs due to the higher splitting ratio and associated bandwidth/resources sharing.

In our current work we have performed a thorough techno-economic study to investigate the projected OSP costs shavings when high splitting PONs (with splitting ratios up to 1:512; irrespective of the underlying supporting technology to achieve this) will be introduced in the marketplace. It is shown that the increase of the splitting ratio leads to a cost improvement due to the smaller number of fibers used but this is not so significant as the ducts and trenches sizes that are used in current FTTH deployments do not allow for the maximum benefit to be achieved. Another important finding of our study is that the costs shavings are not increasing linenarly with the splitting ratio as compared to legacy PONs. However, the results for 1:512 splitting ratio suggest that more than 25% OSP cost savings are to be expected compared to PONs with a splitting ratio of 1:16.

2. OSP cost comparison of various FTTx next generation optical access network architectures

Several implementations of FTTx next generation optical access network architectures and technologies have been suggested. Each choice serves different needs and covers different deployment area requirements. Both active and passive network technologies can be implemented in point-to-point (P2P) or P2MP / Star architectures [2]. However the associated deployment costs for the OSP as well as those for the active equipment vary quite significantly depending on the architecture/technology choice and the density of households at the deployment area.

In the home-run FTTH-P2P architecture, each fiber is dedicated to each end-user which is being translated into high OSP cost (due to more required fibers as well as due to the requirement from more/larger ducts and larger trenches). The cost benefit from the FTTH-P2MP architectures stems from the fact that the feeder fiber is shared among many end-users (depending on the splitting ratio). The cost-benefit obviously will depend on the amount of sharing implemented at the feeder fiber cable (i.e. which depends on the splitting ratio). High splitting ratio PONs might lead to reduced OSP costs and make this architecture/technology option comparable in terms of OSP costs to current deployment options, such as the Fiber to the Building-FTTB and the Fiber to the Curb-FTTC (although of course these architecture options cannot achieve performance in terms of down-load/up-load speeds comparable to those achieved by FTTH architecture).

To evaluate the actual cost benefits, we performed a detailed techno-economic analysis. For the estimation of the OSP CAPEX per user, for each FTTx network architecture, we have considered the actual deployment methods of a fiber network and the components needed to create the infrastructure as described in the methodology/model outlined in Ref. [3]. We assume that the FTTx network forms part of an existing access network, connecting a large number of end users to a central point, the Central Office (CO) or Access Node. The CO contains the required active transmission equipment used to provide the applications and services over optical fiber to the subscriber. The FTTx OSP infrastructure elements considered are namely: the feeder cabling, the primary fiber concentration points, the distribution cabling, the secondary fiber concentration point and the drop cabling [4]. The handholes or manholes that house the splitters are considered as the primary fiber concentration points and the secondary concentration points are the Y-branches that help disjoin the drop cables. The most prevailing installation method for underground fiber cables involves the creation of a duct network to enable subsequent installation of cables by pulling, blowing or floatation techniques. This network comprises of a combination of large main ducts that contain smaller subducts for individual cable installation and furthermore microducts for the installation of a single cable for the drop part of the network. Finally the cables installation for the needs of the techno-economic study has been considered to take place with the blowing technique. The cost estimations were based on individual components and civil work costs, as shown in Table 1, and were provided by a construction and a telecom company. The potential deployment area considered is one with a mixture of multi-dwelling units and single dwelling units and with a varying density of households (HH) per km^2. The deployment considered is based on the geographic model already used in previous investigations [3, 5]. The feeder part of the network is deployed in big trenches with a capacity of 56 high fiber count cables, inside sub-ducts for easy installation and replacement. The distribution part of the network is parceled according to the density of the area into smaller ducts varying from 144 low fiber count cables capacity to 48 low fiber count cables. These are used between the splitter and the Y-branches. The drop part is implemented within a pavement trench with higher cost, by microducts containing 1, 2, 8 or 12 fiber cables. For the estimation of CAPEX per user and as far as the OSP is concerned, we consider the total length of the different types of trenches, ducts, subducts and fiber cables, the total number of handholes/manholes, splitters and Y-branches needed, their total cost and the cost of their installation.

The application of the techno-economic model/methodology for the various cases of FTTx architectures revealed the results presented in Fig.1 in terms of the OSP costs. It is shown (see table as inset of Fig. 1) that there is a significant cost benefit of the FTTH-PON architecture (using 1:16 splitting ratio) compared to the FTTH-P2P one. However, legacy FTTH-PON is still more costly than typical FTTH and FTTC deployments.

Table 1

OUTSIDE PLANT MATERIAL & INSTALLATION COST

Description	Unit	$
HDPE duct – (24 micro tubes)	m	2.25
HDPE duct – (7 micro tubes)	m	2.2
HDPE duct – (2 micro tubes)	m	0.75
Manhole	each	500
Handhole	each	400
96 - fiber cable	m	2.8
72 - fiber cable	m	2.1
12 - fiber cable	m	1.1
8 - fiber cable	m	1.1
Microcable- 1f	m	0.3
Y-Branch unit	each	35
Trench I	m	25
Trench II	m	20
Microtrench I	m	16
Microtrench II	m	14
Pavement trench	m	35
HDPE duct in trench	m	0.55
Cable in subduct	m	0.45
Splicing	each	5

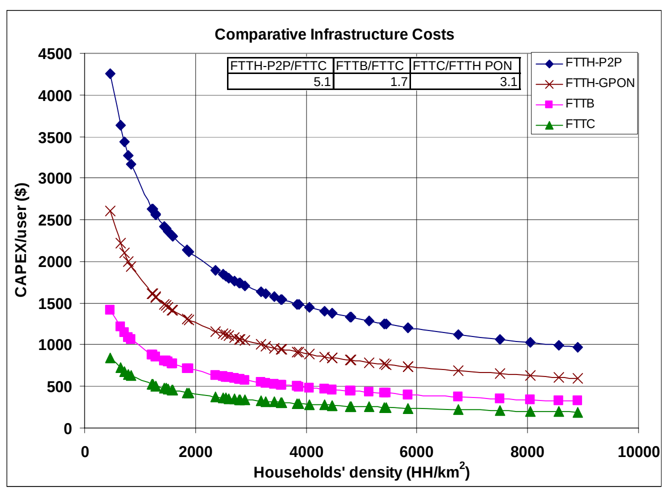
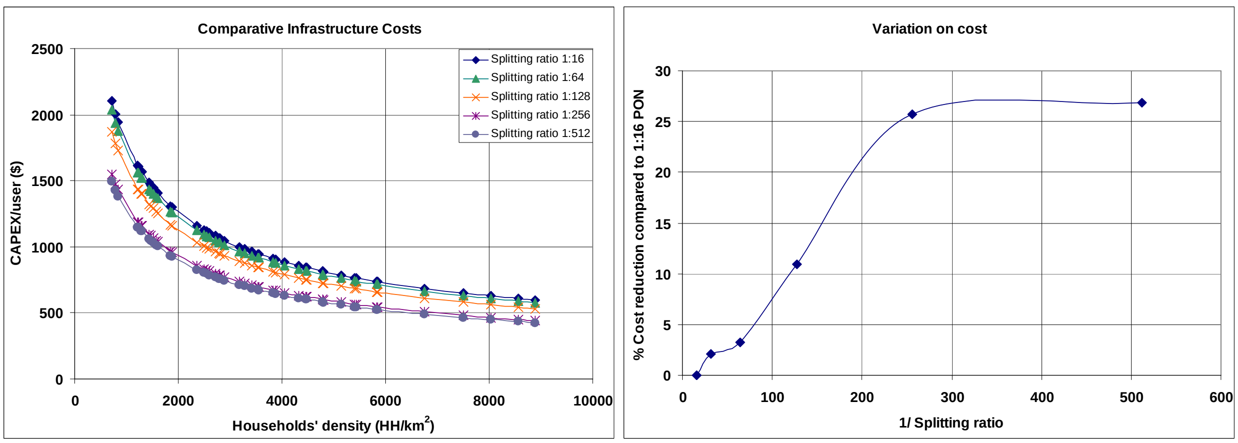


Fig. 1. OSP cost comparison of active/passive network deployments

3. Results for increased splitting ratio PONs

When considering future green-field FTTH-PON deployments, one should turn its attention towards newly emerging PONs technologies that can support with one feeder fiber up to 256 or even 512 end users (i.e. high-splitting ratio PONs). Therefore a techno-economic investigation has been also performed for PONs with increasing value of the splitting ratios. The fact that the trenches, ducts and sub-ducts, are by default quantized, in other words they have some restrictions in their size and capacity, has some impacts on the final cost of the network as well as on the variation of the total OSP CAPEX (thus the CAPEX/user) with regard to the cases of increasing splitting ratio. This effect was capture in our calculations and the results are presented in Fig. 2(a). It is shown that the increase of the splitting ratio leads to a cost improvement due to the smaller number of fibers used but it is not as significant as the ducts and trenches sizes that are used in current FTTH deployments do not allow for the maximum benefit to be achieved. Another important finding of our study is that an increase of the splitting ratio is not increasing linearly the costs shavings compared to legacy PONs. The results show that a PON with splitting ratios of 1:256 and 1:512 can be almost as cost effective as a typical FTTB deployment and not much more expensive than an FTTC deployment.



(a) (b)

Fig. 2. (a) OSP cost comparison of PONs with varying splitting ratios and (b) Percentage of cost reduction as a function of the splitting ratio compared to current PONs with a splitting ratio of 1:16

However, the particular "quantization" of available trenches and ducts sizes in terms of fiber capacity provides for a non-linear reduction of OSP costs as a function of the splitting ratio. This can be seen more clearly in Fig. 2(b), where we have plotted the percentage of cost reduction as a function of the splitting ratio compared to current PONs with a splitting ratio of 1:16. The reason for the "non-linear" increase in the cost reduction for higher splitting ratios is due to the fact that the size of the feeder and distribution part of the FTTH network, in terms of capacity, can decrease in the point that would offer subsequently an efficient cost decrease. At this figure is also shown that splitting ratios of 1:256 and 1:512 achieve more than 25% OSP cost shavings compared to PONs with a splitting ratio of 1:16; and that a ratio of 1:512 is not offering significant improvements over PONs with 1:256 splitting ratio.

5. Conclusions

We presented a techno-economic study on the OSP costs comparison between various FTTx architectures. For the first time to our knowledge we present results on the cost reductions to be expected with future high-splitting ratio PONs compared to the current FTTH-PON deployments. More flexible deployments (in terms of trenches' and ducts' sizes) are expected to further improve the cost savings and increase the estimation for 25% cost reduction.

6. References

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