White paper

Optimizing PON architectures maximizes electronics efficiencies

When deploying a passive optical network (PON), the FTTH architecture chosen directly affects the cost of active equipment. Placement of optical splitters in the architecture plays a particularly important role. The size of the customer base served from the last splitter point influences the utilization rate of the optical line terminal (OLT) equipment in the central office or POP house. Utilization rate is the percentage of active customers on the port per total number of customers that could potentially be served from that OLT port.

Why is this important? OLT ports are expensive. Not using equipment's maximum capacity drains CAPEX when take rates are low. Active equipment occupies expensive floor space and requires power and cooling even when not serving a revenue-generating customer. Finally, active ports become obsolete every three to five years. When migrating to the latest generation active equipment, unused capacity will be replaced with new unused capacity, further wasting CAPEX.

When deploying FTTH networks, operators pay attention to network take rates to define the breakeven point between network construction and revenue generated by the total number of customers paying for service. Take rate is calculated by dividing the number of active customers ("homes connected") on the FTTH network by the total number of potential customers ("homes passed").

TAKE RATE =

$$\frac{\text{number of homes connected}}{\text{number of homes passed}} \%$$

In general, FTTH network deployments with take rates between 25 and 40-percent are considered profitable. Many factors determine profitability, but it is mainly driven by the CAPEX spent to build the network, which in turn depends on factors such as:

- Population density
- SFU versus MDU
- Aerial versus buried infrastructure
- Distances from central office
- Ability to reuse existing infrastructure such as ducts and poles
- Required amount of new civil works and the related hourly labor rates
- Right of way costs
- Etcetera

When deploying a PON architecture, several active customers will be grouped on a single fiber that is in turn connected to a fiber coming from the central office. This happens by using passive splitters that separate traffic from the CO (downstream traffic) to individual connected customers and merge all upstream traffic from different customers into the single fiber leading back to the central office. All this traffic is managed through time domain multiplexing technology, whereby up and downstream time slots are dedicated to each customer.

In the central office/POP site an OLT manages the traffic to and from the customers connected to this OLT port. Typically these ports can manage data traffic to and from 64 customers. At the customer side, typically inside the premises, an ONT (Optical Network Terminal) receives the downstream traffic from and sends the upstream traffic to the OLT. With this in mind, let's consider a term much less defined in literature and architecture descriptions—the Utilization Rate (UR) of the transmission equipment. The utilization rate can be defined as the number of active customers per number of OLT ports multiplied by the OLT's capacity to serve different customers from a single port (typically 64).

UTILIZATION RATE =

$$\frac{\text{number of paying customers}}{\text{number of OLT ports x 64}} \%$$

In most cases, utilization rate and take rate are not the same and, as a percentage, can be very close or very remote. This has a significant impact on the network's total cost of ownership.

Currently, an OLT line card costs between $2000 and $3200 (USD), and serves 64 customers. The variation arises from the generation of transmission equipment (PON, GPON, XGPON) used, the class of laser integrated, the services integrated to run over the network, the competitive landscape of the market space, etc. If the utilization rate is 100-percent, i.e. all customers connected to an OLT port are active/paying customers, the investment runs at the highest possible rate of return. This means that the operator invested CAPEX for the equipment of $30 to $50 (USD) per customer (the port price / 64).

If the utilization rate is 10-percent, i.e. only 6 customers are active on an OLT port, the relative cost per customer will be eight times higher -- ranging between $240 and $400 (USD) per customer. This significantly impacts the total CAPEX spend per customer in a deployment. And for that reason should more often be a topic for optimization. Though rarely considered, the payback times of the network deployment can be substantially influenced by low utilization rates.

It is tempting to blame low utilization rates on lower take rates – but the outside plant architecture, and in particular the placement of splitters in that network, actually drives the utilization rate of the electronics in central offices and POP locations. To better understand this, let us examine two extreme examples.

Example 1:

In this architecture, the operator chose to optimize the cost of the network build by reducing the amount of fiber deployed in the access network and reducing the number of splices. An eight-port terminal (secondary splitter point) was situated close to a grouping of eight houses. To minimize the number of splices, the operator integrated a 1:8 splitter in this last terminal. This terminal was connected to a node (primary splitter point) which grouped eight similar terminals. This node contained the primary 1:8 splitter. The overall split ratio is 1:64 and the node required only nine splices to link 64 homes. This architecture greatly reduced the cost of splice labor (assuming a rate of $10 USD per splice).

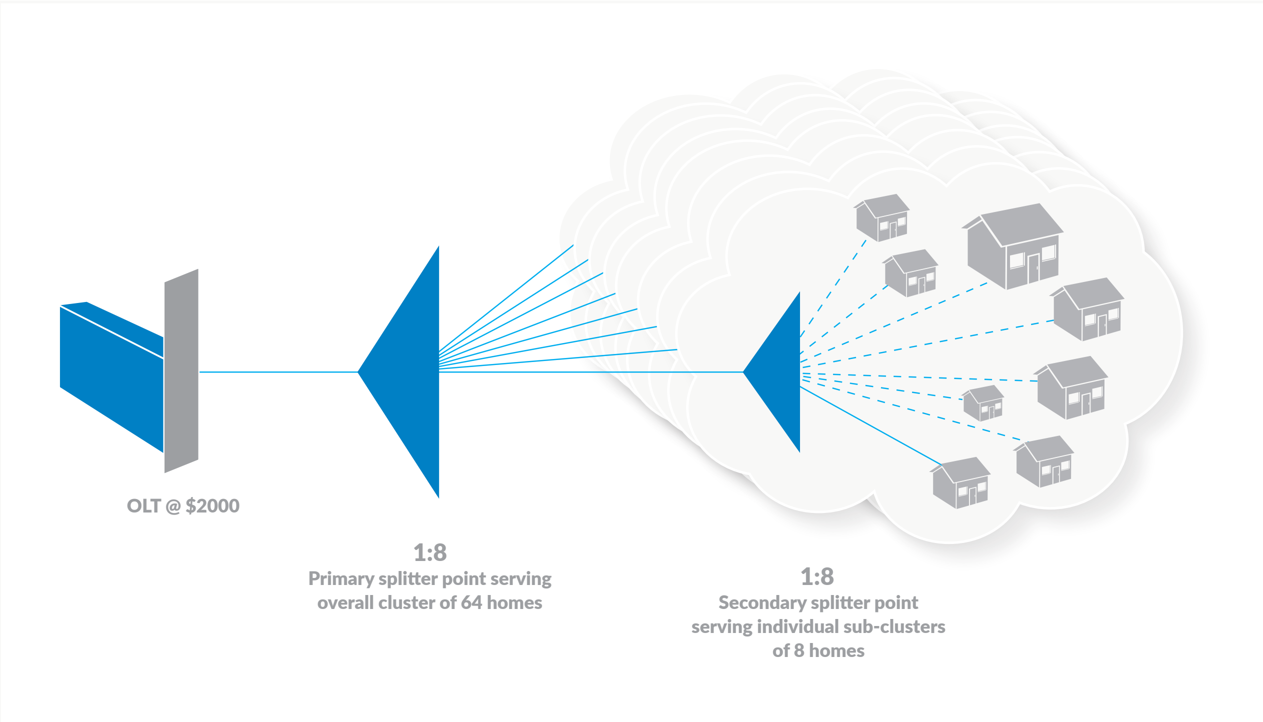
The utilization rate achieved by this architecture and take rate is shown below.

Cluster Size = 8 1x8 splitter per cluster TR = 12,5% → UR = TR = 12,5%

- Splitters close to customer reduce the UR
- Splitters close to the customer optimize fiber utilization (includes effects of digging distance, amount of splices,...)
- OLT port investment is a regularly recurring cost (replaced every 2 to 5 years)
- Take rate 10-15% (PON)
- Splitters placed close to the customer resulting in:
  - Minimized splicing and fiber requirements
  - Decreased utilization rate of active OLT ports in CO and poor utilization of power, cooling and real estate

This network had a 10 to 15-percent take rate (TR). If for this example we assume a fixed TR of 12.5-percent; for every eight-port terminal, one customer is taking and paying for service. The seven other ports remain unused. When the first customer in this cluster of eight takes service, all the fibers back to the CO are connected and both the primary and secondary splitters are in place. This locks the OLT capacity in the central office and as a consequence, in this example, the take rate equals the utilization rate (12.5-percent). This means that 77.5-percent of the active equipment is switched on but not serving active customers.

When the network's take rate and utilization rate are the same, the effective OLT cost per customer is eight times higher than if the utilization rate would equal 100-percent. In this example, then, with a low take rate (and limited revenues), the cost invested in OLTs must be written off ($240 to 400 USD per customer).



Example 2:

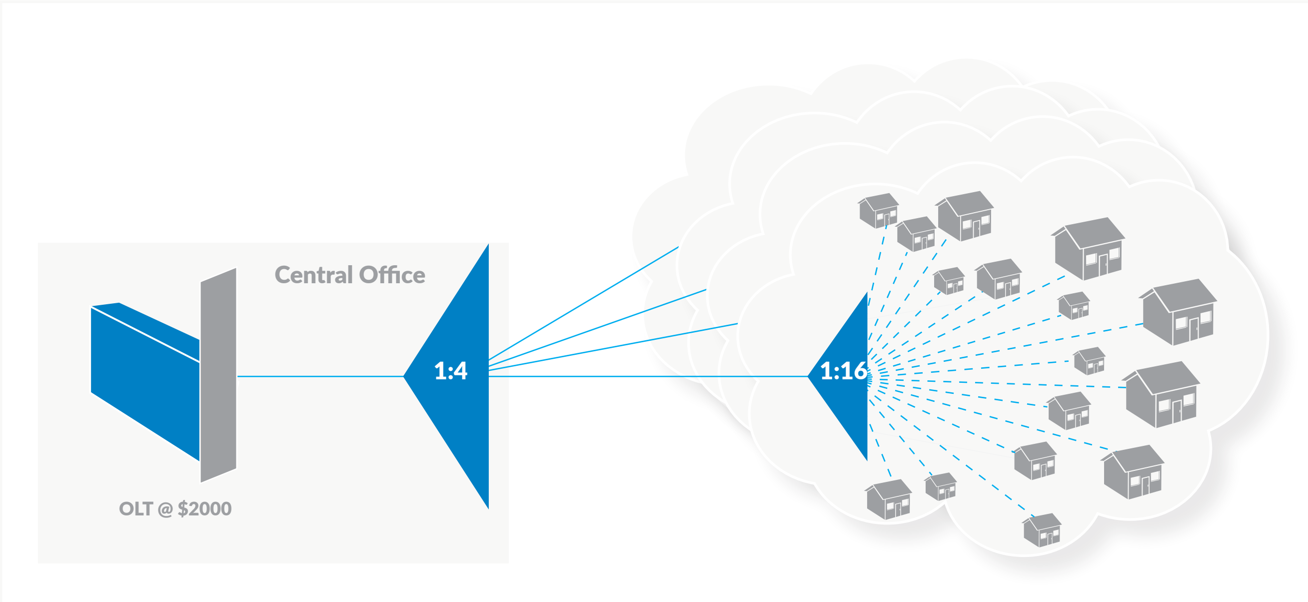
Taking the same network cluster size and take rate as in Example 1, let's examine the results of changing splitter location in the architecture. In this new example, a 1:4 splitter is placed in the central office close to the OLT, and a primary 1:16 splitter resides in place of the primary 1:8 splitter in Example 1. The 1:16 splitter serves eight terminals, each supporting a cluster of eight homes. The overall split ratio is 1:64, and no additional splitter is required in the terminal serving the cluster of eight homes. With a 12.5-percent take rate, eight customers taking service are connected through the single 1:16 splitter back to the 1:4 splitter in the central office, and thus to the OLT.

The utilization rate achieved by this architecture and take rate is shown below.

The utilization rate in Example 2 shows an increase over that of Example 1:

UR = 50% = 4x TR [with TR = 12.5%]

Compared to Example 1, the utilization of active equipment improves by a factor of four (400-percent). Therefore, the real cost of electronics per customer drops from $240 to $400 USD, to $60 to $100 USD. Of course, in this architecture, more splice work is required and balances the savings on the active equipment. However, even assuming a total splicing cost of between $30 and $63 (USD, per line/per customer), the savings for the electronics is still significant.



Overall cluster size = 64 1:16 splitter per sub-cluster
TR = 12,5% → UR = 50%

- Splitters closer to CO increases the UR
- Splitters closer to CO decreases fiber utilization (includes effects of digging distance, amount of splices,...)
- Improves OLT port investment as a regularly recurring cost (replaced every 2 to 5 years)

Splitters moved backwards towards the CO resulting in:

- Increased number of fibers (cables) and splices
- Greatly increased utilization rate of active OLT ports in CO

These examples clearly demonstrate that the OSP architecture significantly influences central office costs and in the initial planning phases of PON deployments, operators should balance both costs carefully. Obviously the take rate is critical in the overall business case of a network deployment as this will determine the overall revenue stream generated, but optimizing the utilization rate will reduce CAPEX and improve payback time.

Optimizing the utilization rate means optimizing the location of the splitters in a defined cluster size. Take rate targets are important for an overall business case, but market success, indicated by take rate, should not be fixed in a physical architecture. The architecture must be flexible enough to readily adapt to new technologies, new services and customer churn. We recommend a fully loaded OLT port at a take rate of 10- to 20-percent only. When the take rate grows above this level, a second group of OLTs and secondary splitters are introduced to serve the next group of active customers.

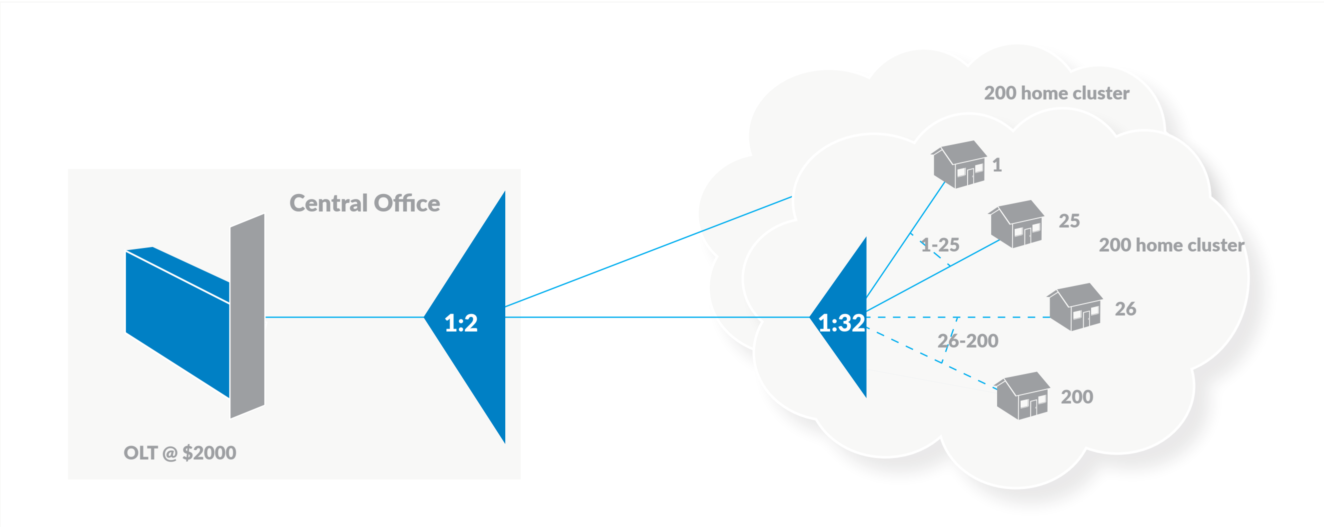
In the United States, network architects recommend a centralized splitter topology. Unlike the decentralized architectures examined in examples 1 and 2, the main area of focus in a centralized architecture is the overall cluster size, rather than that of the sub-clusters. In the US, a centralized splitter cabinet serves on average 200 homes passed and contains mainly 1:32 splitters (with a 1:2 splitter in the CO or POP). In this scenario, at a take rate of 12.5-percent as in examples 1 and 2, this would mean 25 active customers in a cluster of 200 households. These 25 active lines are served through the 1x32 splitter. In this example, we assume a second 1x32 splitter in a different cabinet and also serving 25 active lines in a second cluster of 200. Both 1:32 splitters link back through the 1:2 splitter in the CO or POP to the OLT card. This OLT port is then loaded at a level of 78-percent (25 active customers/ 32 ports). This example shows the optimization of the UR based on this choice of architecture.

As demonstrated, the FTTH OSP architecture has a significant influence on the utilization rate and drives the amount of electronics in the CO/POP. Costs in the CO/POP are driven by more than the initial price of the equipment

- Transmission equipment has an average life time of 2.5 to 5 years before it needs replacement and should be regarded as a recurring cost. The lower the utilization rate, the less that equipment is used – and the lower the return on the initial investment. By improving the network architecture and increasing the take rate by perhaps 4 times, the operator can save as much as 400-percent at each active equipment upgrade. As a result of careful architecture planning at the start, the savings made Day 1 will be recurring savings in the future.

- Central office and POP space is expensive. Typically, the cost of floor space for each rack is around $1000 (USD) (depending, of course, on the location). By maximizing the use of active equipment, operators can reduce the amount of space required for passive equipment racks used to connect active ports to outside plant ports. This reduces the cost and complexity of these interconnection sites.

- Less active equipment results in lower power and cooling requirements. Relatively speaking, equipment running at medium load consumes more energy than equipment running at full load. As power costs continuously increase, additional cost are avoided. There is also the green aspect of power consumption and the related CO2 emissions. For example, all data centers in the US consume energy of thirty-four 500-megawatt power plants – and that number is growing rapidly (to 51 by 2020). While today's fiber networks' power consumption represents a small fraction of the total power consumption, seen as part of the same food chain, the communications industry as a whole comes under increasingly negative attention as "data centers are the new polluters."[1] It appears that about one third of the equipment in the data center does not even add value in the network. As explained in the examples above, a similar low rate of efficiency is seen in many FTTH network deployments today - with a resulting low return on investment and recurring wasted energy costs.



However this increased utilization rate must be considered along with the larger investment required in civil works and cable installation. The cluster sizes are larger and the distance between splitting point and end customer greater in centralized splitter architectures.

In Europe, deployment of centralized splitters in (often obtrusive) cabinets is rarely allowed in large cities. Network architects, therefore, must design around the issue using the distributed architectures described in examples 1 and 2. If well planned, distributed splitter architectures deliver utilization rates as well as centralized architectures. In planning any network deployment, the network architect must carefully examine the particular circumstances for each section and neighborhood, weighing multiple factors, not least of which are the overall business objectives, and the acceptable expenditures to meet those objectives.

1 Patrick Thibodeau, "Data centers are the new polluters." Computer World, 26 August 2014

The outside plant fiber network architecture has an important impact on the total cost of the deployment. This paper focused on the impact on the central office and POP sites. Utilizing transmission equipment efficiently lowers initial capital investment and minimizes operational expenses that keep the network operational. Further, it reduces upgrade costs. Communications networks grow dynamically through increasing take rates. Careful initial planning of the architecture, anticipating that future growth, will provide a competitive advantage and bring better long-term profitability.

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