VIAVI Solutions

White Paper

Balanced vs. Unbalanced PON: Key Differences and Deployment Impact

Fiber broadband internet networks based on passive optical network (PON) and fiber-to-the-home (FTTH) technology are being deployed at a rapid pace in North America, as universal access to high-speed broadband internet has become a priority. In designing these networks, operators have two different network architectures from which to choose—balanced and unbalanced PON.

Balanced vs. Unbalanced PON

Standards for all passive optical networks (PONs) call for feeder fiber to be run from an optical line terminal (OLT) located in the operator's central/local office or headend/hub to a splitter, where optical signals from a single feeder fiber are split onto multiple distribution fibers that, in turn, connect to drop terminals located near customer premises.

In a balanced PON architecture, a single splitter or a cascade of 2 or 3 splitters divide (as shown in figure 1) the optical light from the OLT equally among all the distribution fibers. This is known as a single split or cascaded splitter PON architecture and utilizes balanced splitters. Typically, either a 1:32 or 1:64 split ratio is used, meaning that each feeder fiber serves either 32 or 64 customer locations.

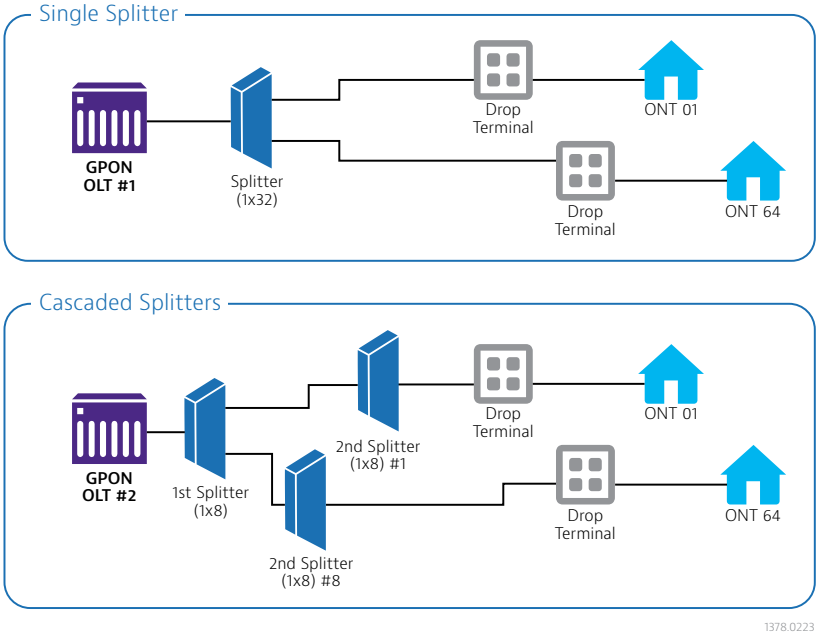

Fig. 1: Single vs. cascaded splitters

The balanced PON architecture is commonly used in metro areas, where individual customer locations are in close proximity to one another (urban density). In a typical deployment scenario, fiber and network equipment are installed from the local office/headend to the drop terminal for all locations that can be served from the splitter. Essentially the PON is built almost completely during the construction phase, meaning more up-front investment. Only when an individual customer signs up for service is a drop fiber installed from the drop terminal into the customers premises and an optical network terminal (ONT) installed.

The distance between each customer and the operator's central office or headend is typically no greater than 20 kilometers (between 12 and 12.5 miles).

In an unbalanced PON architecture, also known as a distributed tap approach, multiple optical taps are installed in a linear daisy-chain topology and the portion of the light from the OLT that is directed to a drop terminal varies from one tap to another. This architecture is often better suited for serving rural areas where homes are separated by greater distances (rural spread) than in metro areas.

In a typical unbalanced PON deployment scenario with an equivalent of 1:64 split ratio (shown below in figure 2), the first tap divides the optical light using a 90/10 split, meaning that 10% of the light is directed to a local drop terminal , while 90% of the light is directed to the next tap in the chain to serve homes that are located further from the central office or headend. As light from an OLT progresses down a chain of taps the optical split will change, 85/15 to 80/20 and so on, as the optical losses build up ensuring the same amount of light (optical power) is delivered to each drop terminal.

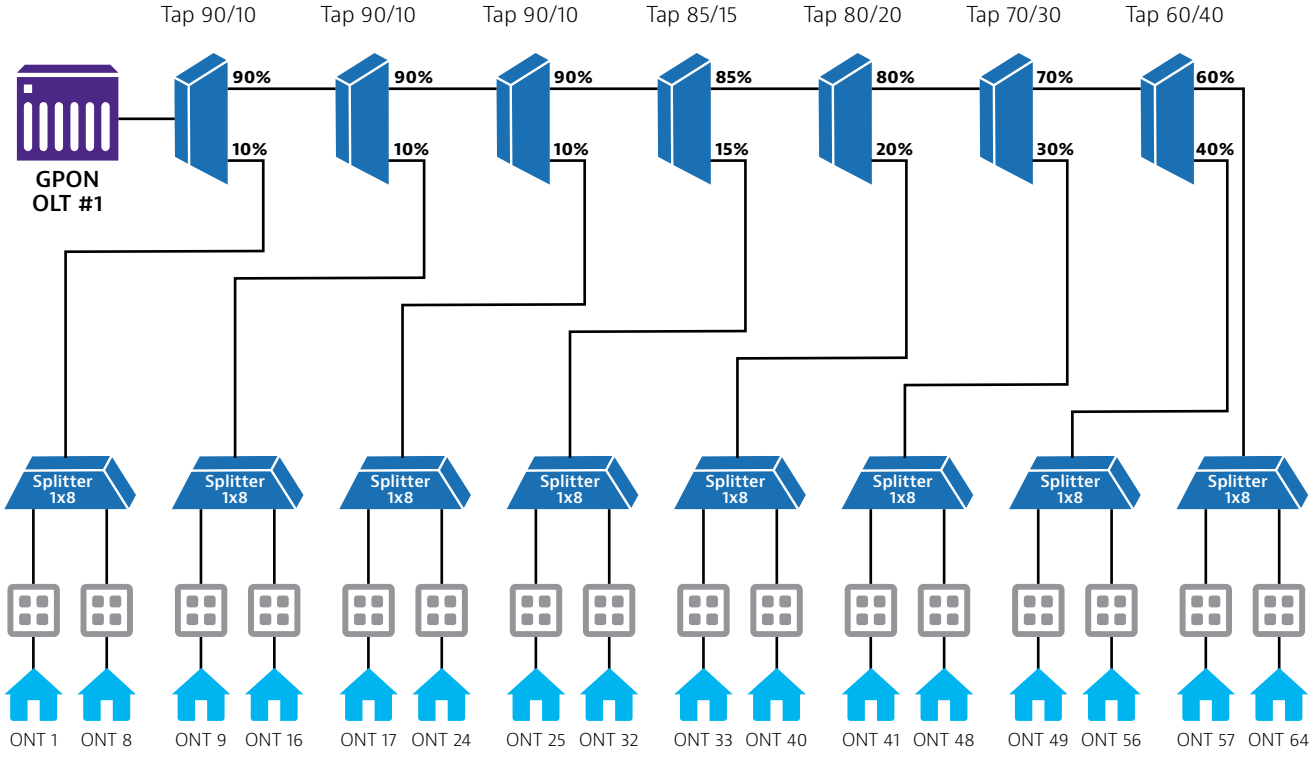

Fig. 2: Typical unbalanced PON deployment scenario

An optical tap may also integrate a balanced splitter (typically 1:2, 1:4, 1:8) in the same enclosure in order to serve a number of homes in the same local area.

Using an unbalanced PON architecture can extend the maximum distance between a customer location and the operator's central office or headend. That extra distance will depend on the number of drop ports supplied by each tap and the optical budget available.

Optical taps are available to support a wide range of split ratios.

It is also possible to design a network to use a mixture of unbalanced and balanced splitters as shown in figure 3 below.

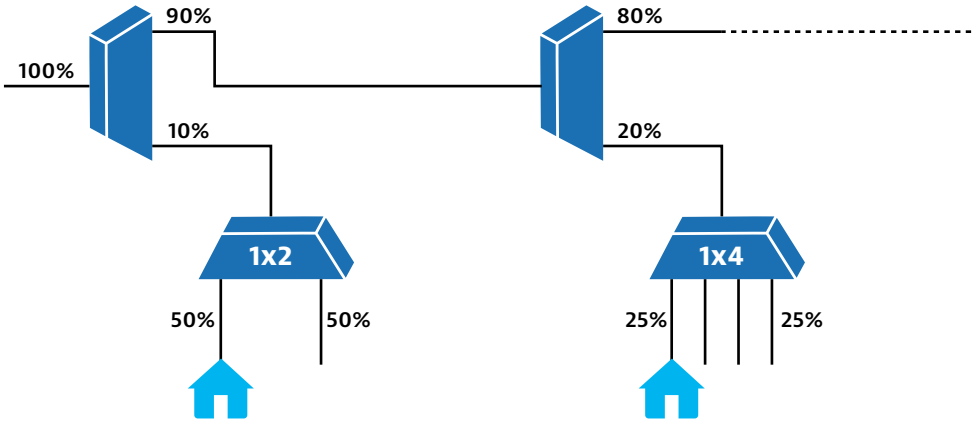

Fig. 3: Balanced splitter plus unbalanced splitter

In addition to being better suited for some rural deployment scenarios, an unbalanced PON architecture has another benefit as well. It can more easily be built in phases, with the network operator initially investing only in the equipment (fiber and taps) needed to serve customers located closest to their local office or headend/hub, with additional taps serving more distant customers added at a future date once there is demand for service, rather than the 'built it and they will come' approach for balanced PON in metro areas.

Fiber Indexing

One of the challenges of an unbalanced PON approach is that the network designer must carefully choose the right tap value sequence from a wide selection of options and must be mindful of optical budget constraints.

Some fiber manufacturers have created products designed to minimize those challenges when deploying PON. For example, Commscope makes a product line of pre-connectorized and indexed fiber that does not have to be fusion spliced and is designed specifically for distributed network architectures.

The basic building blocks are standardized terminal boxes with pre-connected 12-fiber cable inputs and fixed/standard feeder cable lengths. Internally there is a built-in balanced splitter and externally there are drop port connectors plus a 12-fiber output port. The 12-fiber cable entering the terminal box has one fiber routed to the internal splitter for servicing local customers and the remaining fibers route to the output port ready for connection to the next feeder cable and terminal box.

Indexing (as shown in figure 4 below) means that the second fiber entering the terminal box will exit as the first fiber to enter the next terminal and so on. Unlike with traditional cascaded architectures, a standardized configuration is used throughout the network, avoiding the complex planning required for these types of traditional balanced splitter and unbalanced splitter PON architectures.

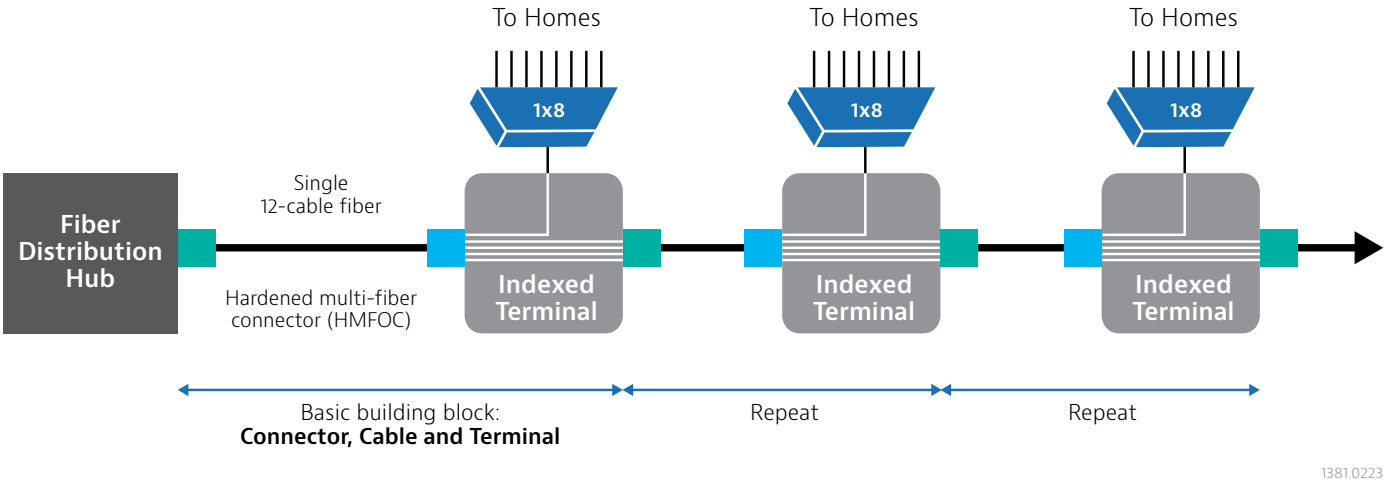

Fig. 4: Indexing example (content provided by Commscope)

Deployment Considerations

Regardless of whether a network operator is using a balanced or unbalanced PON architecture or a mixture of the two, different portions of the network may be built by different work crews. One crew may install the feeder fiber between the OLT and the first splitter, while another crew may install the distribution fiber and a third crew may install the drop fiber to an individual customer.

The network operator will want to ensure that each crew has done its work properly and deployed fiber that will support specifications and perform as needed. In addition, it will be critical to ensure that the end-to-end connection from the drop terminal or customer location to the OLT meets specifications.

When an unbalanced PON architecture is used, these issues are complicated by the fact that the network may be built over an extended time period. The final fiber link in a distributed tap architecture could be installed years after the first optical tap was deployed. This only underscores the need to test as a PON can degrade over time just like any access nerwork exposed to the elements. The best way to validate a PON end to end and verify all fiber sections and splitter/tap components is to test with an Optical Time Domain Reflectometer (OTDR).

Network operators deploying unbalanced PON should also take care to use OTDRs that can recognize the unique signatures generated by unbalanced splitters and taps used in an unbalanced PON approach. An OTDR not designed for that purpose may fail to pass an installation that should have passed, potentially causing technicians to waste time attempting to diagnose and troubleshoot a non-existent problem.

And considering that an operator may use an unbalanced PON approach in some areas and a balanced PON approach in others, the test equipment should be able to recognize network architectures and element/component signatures associated with both types of deployments in order to be universally useful.

Summary

Service providers deploying passive optical networks can use either a balanced or unbalanced splitter/tap approaches. With a balanced approach, a single split or a cascade of 2 or 3 splitters divides the optical signal from the OLT equally among all the distribution fibers. In an unbalanced approach, also known as a distributed tap approach, multiple taps are installed in a daisy chain topology and the portion of the light from the OLT that is directed to a drop terminal varies from one tap the next as you progress down the chain.

While a balanced PON approach is most often used in densely populated metro areas, an unbalanced PON approach may be more appropriate for rural areas because it extends the distance that optical signals can travel and gives the network operator the ability to serve small clusters of homes, separated by longer distances, more easily. Variations on these two basic approaches include mixing the two in the same deployment or using indexed fiber, which is designed for a distributed approach but uses a single terminal design throughout.

In making the decision about whether to deploy balanced or unbalanced PON, service providers should make sure that they use test equipment that can recognize the distinct optical signatures (tap element vs balanced splitter element) of whatever PON architecture or architectures they plan to use.

About VIAVI

VIAVI (NASDAQ: VIAV) is a global provider of network test, monitoring and assurance solutions for communications service providers, hyperscalers, equipment manufacturers, enterprises, government and avionics. VIAVI is also a leader in light management technologies for 3D sensing, anti-counterfeiting, consumer electronics, industrial, automotive, government and aerospace applications.

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