TraceSpan communications

Access Network Analysis

White Paper

Successful Triple Play Service Delivery in FTTx Networks

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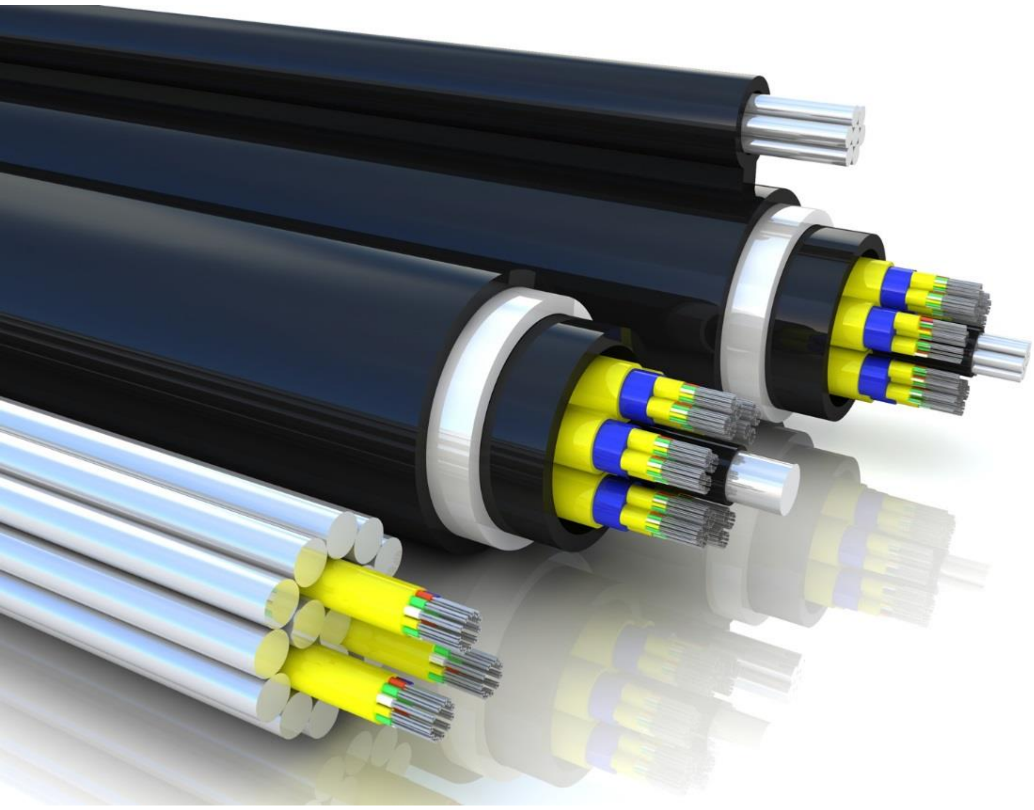


Successful Triple Play Service Delivery in FTTx Networks

Introduction

In today's competitive telecom market service providers are looking for new ways to address their customers' demands, thus improving their competitive position and increasing their revenues and margins. Advanced triple-play residential services and premium business services are becoming part of their offering, and more and more service providers are offering them today or planning to do so in the near future.

To enable these services providers are modifying their network architectures by deploying fiber deeper into their networks, either all the way to the customer or to a location closer to the customer, from which services are delivered over copper for a short distance.

In this document we will discuss some of the challenges that service providers typically run into when delivering their triple-play services over their fiber networks.

We will first explain the different network topologies that are used for the broadband service delivery and the different technologies that are used to enable them; then discuss considerations in the selection of equipment for these networks; and finally describe some typical customer complaints and propose methodologies and tools for troubleshooting them.

Network Topologies and Technologies

The traditional access network was based on copper twisted-pair lines, which were in use since the early days of telephony for connecting telephone subscribers to the local exchange. DSL technologies, which emerged in the late 1990s, utilize the same copper lines for delivering broadband services to the subscribers. Copper lines are still widely deployed in the access network, but they have some inherent limitations in the bandwidth that they can deliver. Their throughput decreases with the distance and their performance is further degraded by interference from external noise sources and by crosstalk from other lines in the same cable.

Optical fibers have some inherent advantages over the copper wires, including significantly higher bandwidth capacity, lower power loss, higher reliability and immunity to interference. Thanks to this they are becoming more and more widely used as a communications media for the access network. In an ideal world services providers would replace all their copper infrastructure to fiber and create an access network with almost no limitations, but there are two main factors that are holding them from taking such a step:

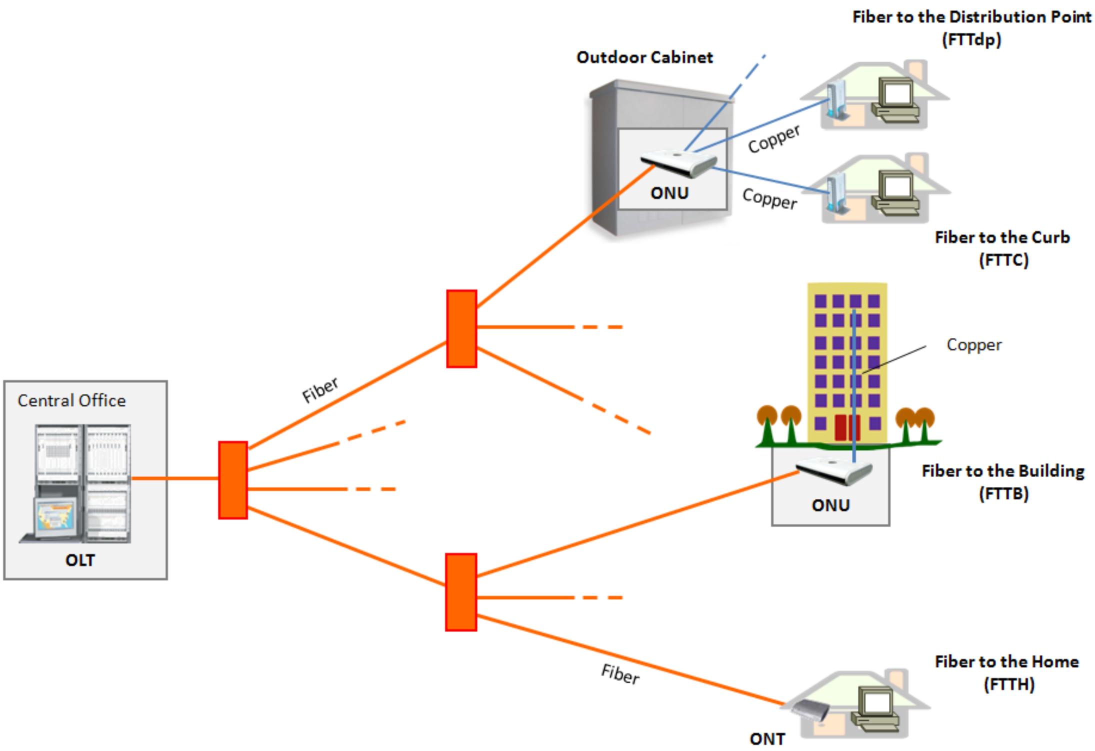
1. Cost – replacing the copper to every subscriber home requires a big capital investment with a long ROI.
2. Logistics – installing the fiber in the customer's home requires dispatching a person to every home and coordinating the operation with the customer, which adds an additional level of complexity.

In new areas optical fibers are indeed becoming the main communications media today, but in existing neighborhoods and highly-populated areas, such as city centers, service providers are often taking a different approach of "shortening" their copper loops from several kilometers to hundreds of meters. This is done by deploying fiber-fed outdoor cabinets and delivering the services from these cabinets. This has made room for the VDSL2 technology, which can deliver up to 100 Mbit/s symmetrical over these shorter loops by utilizing the spectrum up to 30 MHz. The new G.Fast technology is aimed at breaking new throughput records by delivering up to 1 Gbit/s over copper loops of up to 100 meters.

This results in different deployment topologies, which may live side-by-side in the same network:

- Fiber to the Home (FTTH): In this topology the fiber goes all the way to the customer's home, in which his or her modem is connected directly to the fiber access network. FTTH is typically used in new neighborhoods or in locations where replacement of the infrastructure is feasible and cost-effective.
- Fiber to the Building (FTTB): The fiber goes to a building, where it feeds a DSLAM or a switch, which in turn connects to the customers. The customer's modem is connected to a copper line that runs xDSL, or in some cases to a CAT-5 with Ethernet. FTTB is typically used in apartment or office buildings (also known as MDU/MTU).
- Fiber to the Curb (FTTC): The fiber goes to an outdoor cabinet, which is typically located in the proximity of several tens or several hundreds of homes. A DSLAM is installed in the cabinet and delivers services to the homes over copper lines running xDSL, with a typical copper loop length of several hundreds of meters. FTTC is typically used in residential areas, where it isn't feasible or isn't cost-effective to replace the copper infrastructure to the customer homes.
- Fiber to the Distribution Point (FTTdp) may be seen as a flavor of FTTB or FTTC. This term is used when copper loops are shorter than 200 meters and can thus provide the customers with higher data rates. There are also some additional characteristics of the DPU (distribution point unit), which are beyond the scope of this document.

The following diagram describes these different deployment topologies.



Access Network Fiber Technologies

As we mentioned previously, optical fibers are becoming more and more widely used as a communications media for the access network. All the FTTx topologies described above use fiber up to some point in the access network.

Fiber itself has two main deployment technologies, which are typically used in the access network – point-to-point and PON. In point-to-point deployment a dedicated fiber goes from the service provider's location to every customer. This ensures that there are no bottlenecks in the fiber network, but compared to PON it requires more fibers and consumes more energy. In some countries it is used for business services only and in some it isn't used at all. There are even some countries that have point-to-point as the only fiber topology, but these are a minority.

In the majority of countries PON is the prevalent fiber deployment topology, especially for residential services, mainly thanks to its cost-effective architecture and its low energy consumption. PON uses tree topology, in which the fiber is split one or more times between the service provider's central office or other point of presence and the subscriber homes.

GPON is the most common PON technology today and the fastest growing one. It was first standardized in 2004 but went through some major modifications since then. Its throughput is 2.5 Gbit/s downstream and 1.25 Gbit/s upstream and is capable of supporting up to 128 subscriber end points, commonly called ONUs or ONTs, over a single PON, with distances of up to 20 km.

As PON topology is becoming more popular the need for higher bandwidth grows, new PON technologies are developed to address this need. The XG-PON1, also known as NG-PON1, provides 10 Gbit/s downstream and 2.5 Gbit/s upstream and can support up to 256 ONUs/ONTs. NG-PON2 expands the bandwidth over the PON to 40 Gbit/s in both directions and is still in the standardization process, with first products expected in 2015.

Network Equipment Selection - Considerations

In the early days of GPON service providers cared primarily about getting the service to work, and the easiest way to ensure this was to purchase an end-to-end GPON solution from a single vendor, who was responsible to make it work. Providers that used multiple vendors in their network divided their service area into different regions, and within each region used the same vendor for the OLT and the ONUs or ONTs.

In today's competitive environment providers are looking for ways to speed up the service bring-up for new customers and reduce the costs associated with capital investment, installation and continuous operations. Cost-competitive ONUs, including the emerging small-footprint-ONUs from new vendors, are aimed to enable self installation by the end customer.

On paper if both ends comply with the relevant GPON standards, the service provider should be able to connect any ONU with any OLT and deliver your service, just like you can buy a mouse from one brand and plug it into the USB port of a PC from another brand. But in reality, if you buy the ONU and OLT from different brands, they often don’t work together.

There may be various reasons for this, and some service providers rely on their vendors with their internal debugging logs to figure out where the failure occurs, but this requires resource investment from the vendors' side, which will often not be their highest priority. Other providers have adopted a more proactive approach of using a GPON analyzer for viewing the message exchange on the PON at the different layers and pointing out conflicts and errors. This puts them in a much stronger position to demand their vendors to resolve the issues, prevents finger pointing between vendors and significantly speeds up the process of getting the OLT and ONU ends to work together.

Typical Customer Complaints and Underlying Causes

When the network infrastructure is ready and equipment has been selected and approved, service providers can proceed with the delivery of their triple-play services and get revenue from their customers.

However, with the opportunities of the triple-play service delivery come new challenges. Each type of service goes through a long path from the server that delivers it to the customer, and when something goes wrong, troubleshooting it might become a time and resource consuming task. Customer satisfaction is always one of the targets of a service provider, but with today's competition it becomes increasingly important. Pinpointing the source of an issue and resolving it quickly at the first attempt is a key factor for keeping your customers satisfied.

In this section we will describe some service-related issues which are typically reported by the providers, analyze their potential causes and discuss methodologies and tools to handle them. For the sake of the discussion we will assume that the fiber technology is GPON, which will indeed be the case in the majority of the scenarios.

Example 1: Low Throughput

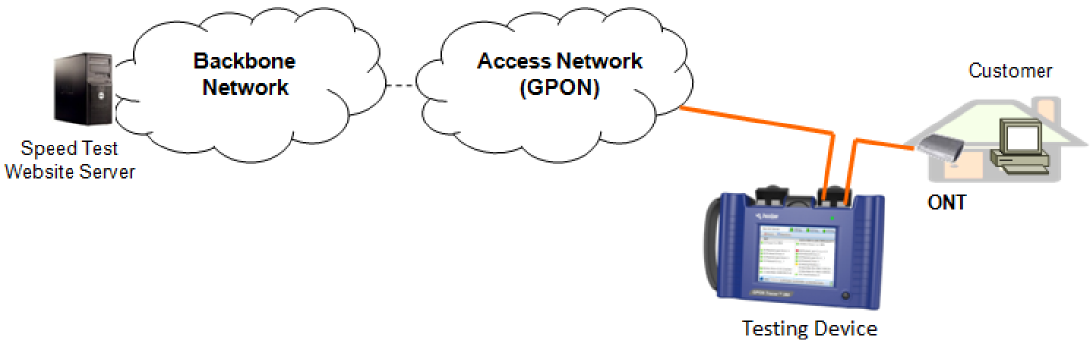
The first example, low data rate or low throughput, will have an immediate effect on the customer's Internet browsing experience, but is likely to also affect other applications, including gaming and file upload and download.

The source for such an issue may be in different parts of the network, including in the customer's PC, his or her modem or gateway, the access network, the backbone network or even the servers in the network. Furthermore, it may appear only in some hours during the day and completely disappear or become less severe in others.

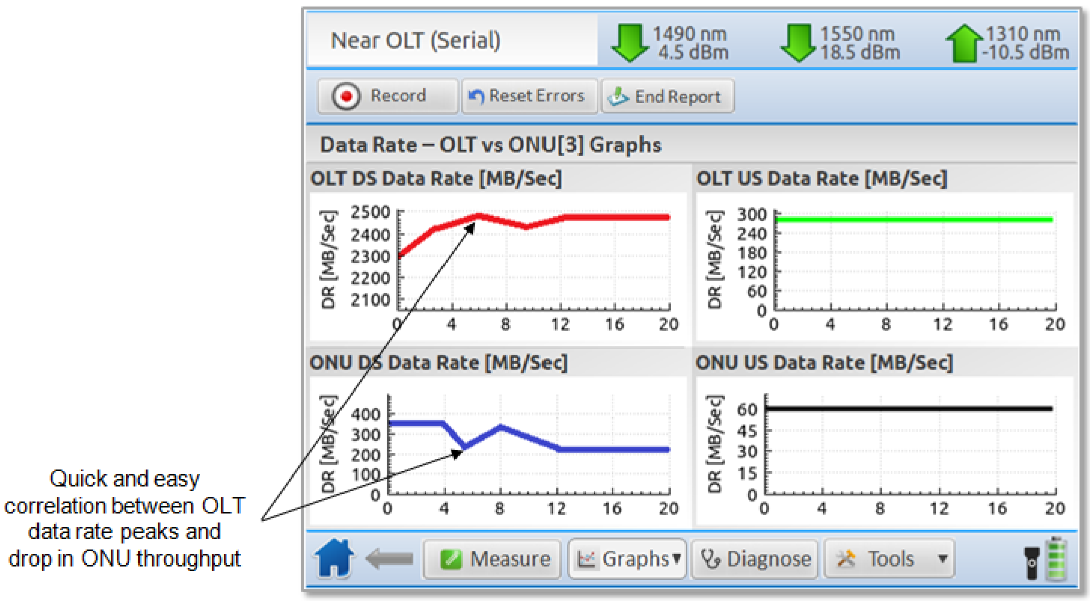
When the customer calls the service provider, he or she will usually be instructed to connect to a speed test website and run a speed test, which will test the actual downstream and upstream throughput of his or her line in ideal conditions. If indeed the throughput is less than the customer's package in either direction or in both, then the service provider will have to troubleshoot it as quickly and effectively as possible.

As mentioned above, the source of such a problem may be in different sections of the network, and the first challenge is to locate the right section to allow solving of the problem from its source. In the example of FTTH topology, typical causes may be:

1. A problem in the customer's PC or its configuration – as an example, its Ethernet port has throughput limitation, or is configured to be half-duplex.
2. The customer's CPE, the ONT or ONU in case of GPON, discards some of the downstream packets due to a failure or a configuration error.
3. A congested PON – a bottleneck in the PON's throughput capacity, resulting from other subscribers using the available bandwidth that is shared among them all.
4. A bottleneck in the backbone network.

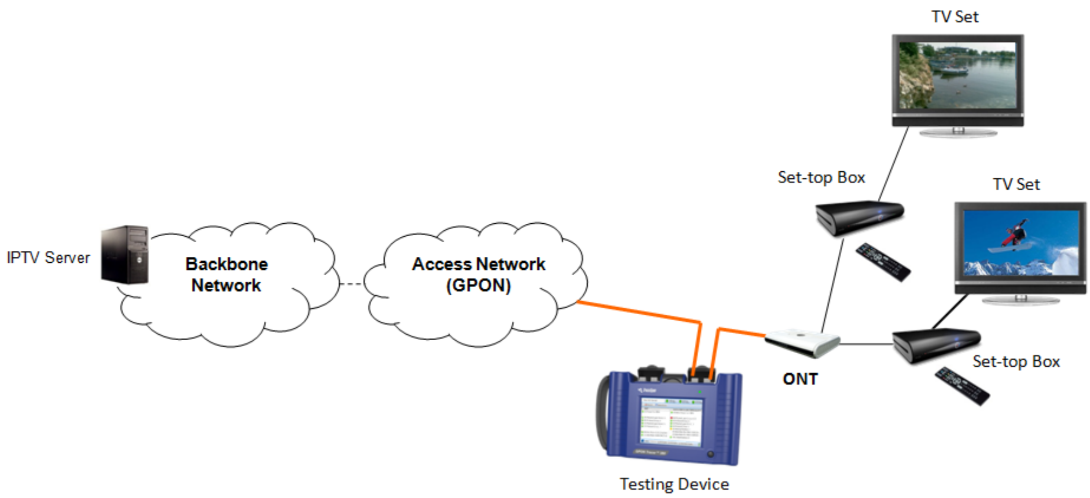


The service provider typically has some testing or monitoring tools in different sections of the network between the speed test server and the customer, and these can help isolate where the problem is. The fiber segment of the access network is typically the most difficult to troubleshoot, especially when it is GPON, which is a shared media. A testing device that connects to the fiber and tests the throughput and data directly on the PON can provide visibility into this "blind spot" and significantly ease the isolation of the problem, as an example by comparing the data rate in a specific customer's ONU with that of the whole PON, thus indication congestion and pinpointing the location of the problem. The following diagram describes an example of how this information can be presented by such a testing device.



Example 2: IPTV Service Issues

There are several typical problems that a customer may experience with IPTV, but the most common ones are screen pixelization and a picture freeze. In a typical scenario the customer's Internet browsing will work satisfactorily while he or she is experiencing the IPTV issues.

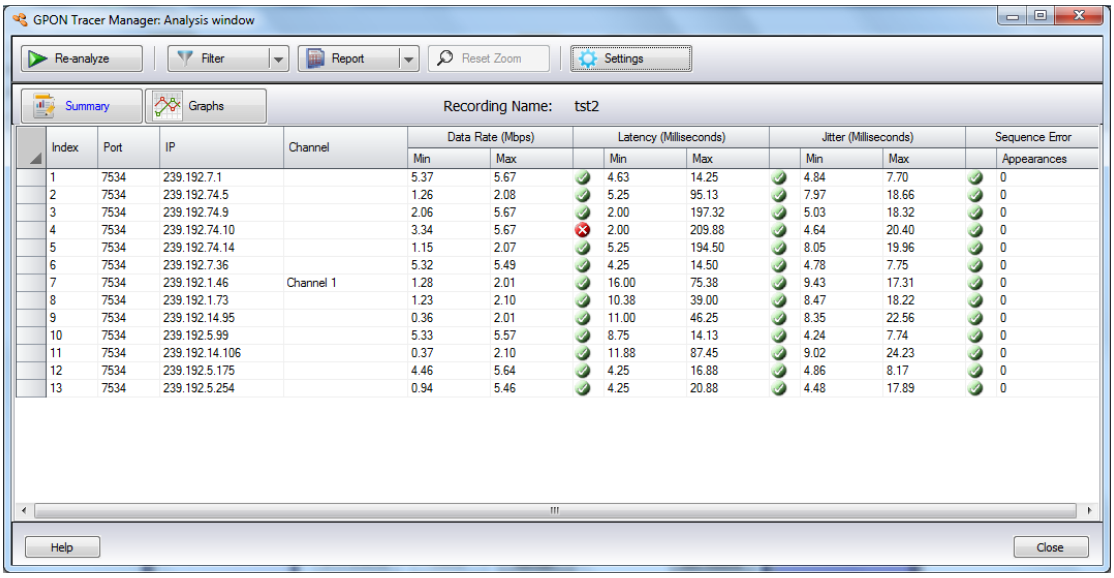


Common causes for the pixelization and picture freeze are lost packets of the video stream, either occasionally or constantly, and jitter in the video stream.

As in the previous example, any section of the network – from the IPTV server, through the backbone, the access network, and all the way to the customer's modem and then the set-top box – may be the cause for such problems.

And again, the challenge is to locate the right section and handle its source. Proper isolation of the issue requires testing in different sections of the network and finding out where the source of the fault resides. The logical methodology of handling such a problem is to start testing is at the customer premises – which is where the problem was experienced, and then move back through the access network, and if needed through the backbone network all the way to the IPTV server.

When testing at the customer premises or in the access network there is a need for a testing device that can test some IPTV quality metrics and graphs along with error indications on the access network and help point to the source of the problem. The output of such a device should include a summary table, as shown in the following diagram, along with some graphs describing the quality metrics of each IPTV channel over time.



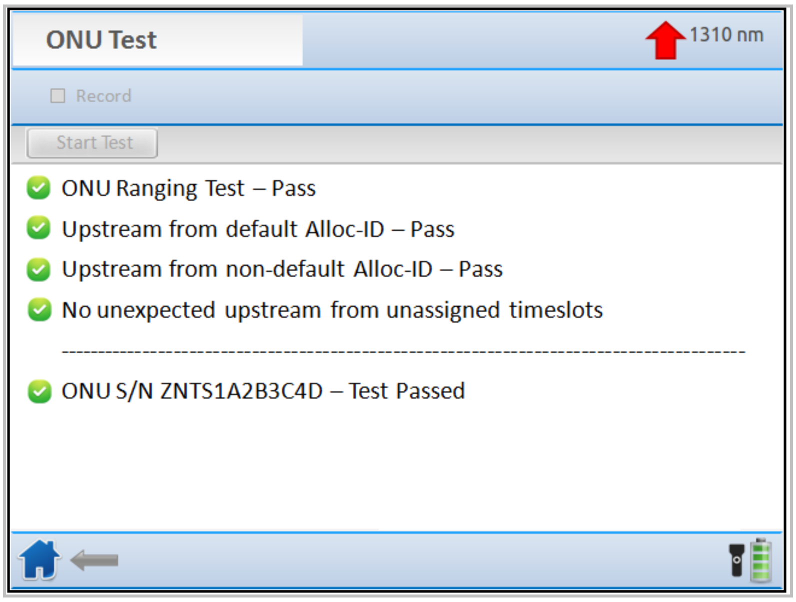
Index	Port	IP	Channel	Data Rate (Mbps)			Latency (Milliseconds)			Jitter (Milliseconds)		Sequence Error
				Min	Max		Min	Max		Min	Max		Appearances
1	7534	239.192.7.1		5.37	5.67		4.63	14.25		4.84	7.70		0
2	7534	239.192.74.5		1.26	2.08		5.25	95.13		7.97	18.66		0
3	7534	239.192.74.9		2.06	5.67		2.00	197.32		5.03	18.32		0
4	7534	239.192.74.10		3.34	5.67		2.00	209.88		4.64	20.40		0
5	7534	239.192.74.14		1.15	2.07		5.25	194.50		8.05	19.96		0
6	7534	239.192.7.36		5.32	5.49		4.25	14.50		4.78	7.75		0
7	7534	239.192.1.46	Channel 1	1.28	2.01		16.00	75.38		9.43	17.31		0
8	7534	239.192.1.73		1.23	2.10		10.38	39.00		8.47	18.22		0
9	7534	239.192.14.95		0.36	2.01		11.00	46.25		8.35	22.56		0
10	7534	239.192.5.99		5.33	5.57		8.75	14.13		4.24	7.74		0
11	7534	239.192.14.106		0.37	2.10		11.88	87.45		9.02	24.23		0
12	7534	239.192.5.175		4.46	5.64		4.25	16.88		4.86	8.17		0
13	7534	239.192.5.254		0.94	5.46		4.25	20.88		4.48	17.89		0

Example 3: Service Disconnections and Interruptions

The previous two examples described problems affecting a specific service – Internet browsing in the first one, and IPTV in the second one. In this third example the customer occasionally experiences total disconnection of the traffic, which affects all of his or her services.

If we again take GPON as an example, occasional service disconnections may be caused by a variety of factors, including a faulty ONU, a faulty PON port at the OLT, or high fiber network attenuation resulting from a faulty fiber or connector or marginal power budget planning. Here too, the challenge is to isolate and handle the source of the problem.

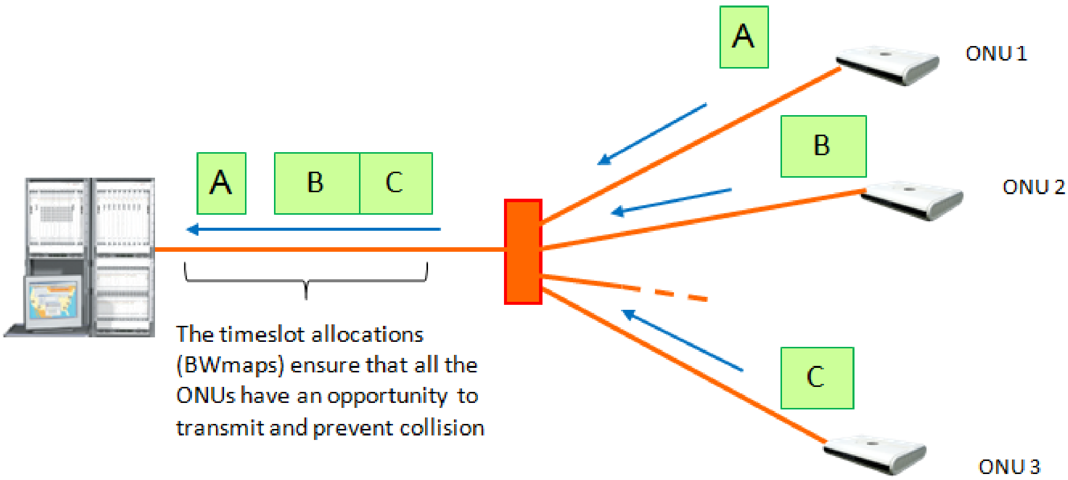
An ideal testing device for this scenario is one that can connect to the PON and tests its downstream and upstream power levels for every one of the ONUs, and also has the capability of testing the customer's ONU stand-alone and verifying its proper operation, with tests results in a format such as the one shown below.



But only one customer experiencing the problem is an easy example, so let's make things more complicated and assume that the problem affects several customers at once. A typical cause for such a problem is a 'rogue ONU', which refers to an ONU or an ONT which not only fails to deliver proper service – but also degrades or totally disables the service of other customers on the same fiber network!

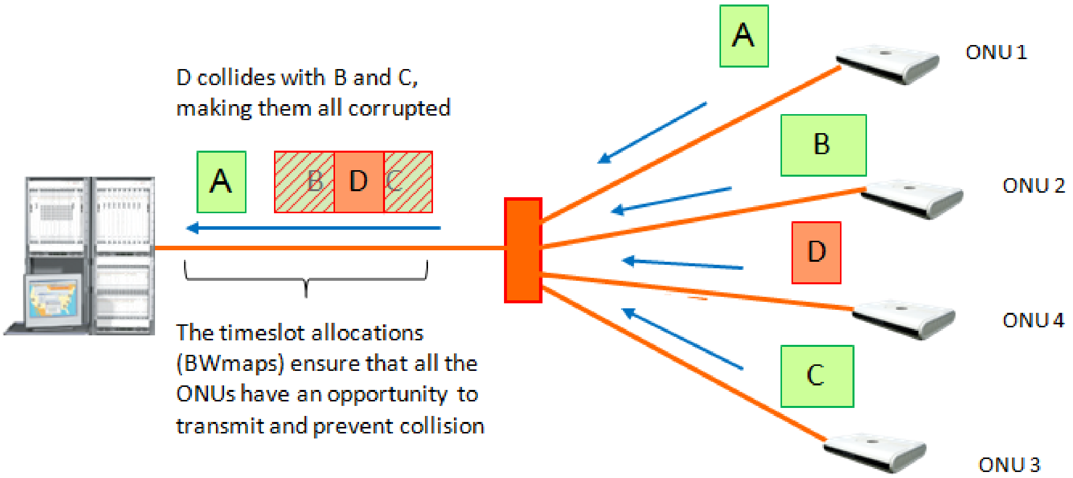
To understand how this happens, let's recall the principles of GPON transmission. For the sake of simplicity we will use the term 'ONU' to represent an ONU or an ONT.

The GPON network topology is a tree, where the fiber going from the OLT to the first optical splitter is shared among all the ONUs on the PON. To allow every ONU to transmit its data on one hand and avoid collisions on the other hand, the OLT assigns timeslots for the upstream transmission of each ONU. These timeslot allocations are called bandwidth maps or BWmaps in short. Each ONU **must** obey these BWmap allocations and transmit in, and only in, these timeslots.



A rogue ONU is one that transmits outside of its allocated BWmaps, potentially causing two main issues:

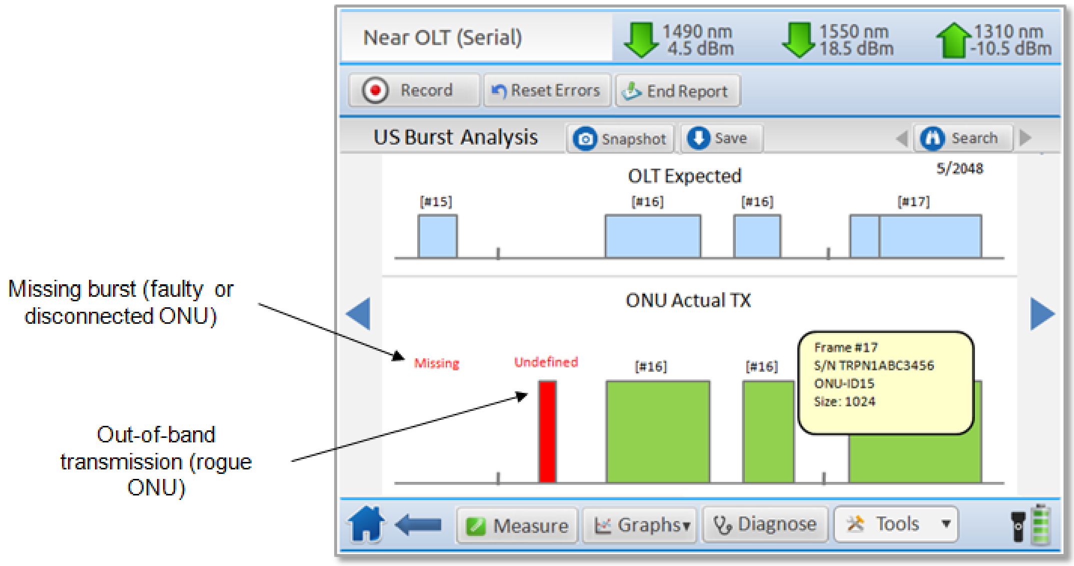
- This ONU's transmission isn't received by the OLT in the expected timeslots, and thus the OLT may regard it as invalid data.
- Its transmission may collide with valid transmissions of one or more "good" ONUs, making all these transmissions corrupted.



The GPON shared-network architecture makes the task of analyzing and pinpointing a rogue ONU challenging and extremely consuming in time and resources. The most common way to handle it is by turning off all the ONUs, and then turning them back on one-by-one until the faulty one is found. On top of being time-consuming, this process requires disconnection of traffic to every one of the customers on the PON. Needless to say, this is something that any service provider would like to avoid.

Some OLTs have built-in mechanisms for identifying and disabling a rogue ONU, but from the evidence of some service providers, these mechanisms have the risk of misidentifying good ONUs as rogue ones, thus causing the service provider to spend more time and money on resolving the problem and frustrating the customers even more.

A more productive approach is the use of an independent testing device, which can passively monitor and display the transmissions of the different ONUs in comparison with the OLT's timeslot allocation and can thus detect and identify a rogue ONU, usually without having to disconnect or disable any other ONU in the PON. The following screen is an example of how such a device can present its information and how it identifies and presents a rogue ONU.



Summary

As we learned in this document, triple play services are a big opportunity for service providers, but along with them come the challenges of customer complaints that are complicated to troubleshoot and resolve. With the examples of typical customer issues we showed how the right troubleshooting methodologies, along with the correct testing devices, allow the service providers handle these challenges, thus improving their competitive position and increasing their revenues and margins while maintaining customer satisfaction.