

POWERING PON WITH HFC, A HYBRID FOR A NEW GENERATION

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TECHNOLOGIES



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OVERVIEW

Hybrid fiber-coax (HFC) networks are the most widely deployed technology for delivering video, voice and data to consumers. Service providers have a huge investment in these HFC networks. HFC networks can be expanded and upgraded to meet customer needs and have been shown to have sufficient capacity for at least another 20 years.

In the past 10-15 years, fiber-to-the-premise (FTTP) networks have been deployed in many regions of the world. The most common type of FTTP network is a passive optical network (PON), with the most common types of PONs being Ethernet passive optical networks (EPON), gigabit-capable passive optical networks (GPON), and broadband passive optical networks (BPON). A less common type of PON network is radio frequency over glass (RFoG), which is specifically designed to be compatible with HFC networks by using exactly the same headend and customer premise equipment (CPE). Most of these PON technologies can be augmented by placing active equipment in the network in order to increase reach, increase coverage, increase capacity or add other features.

GPON and EPON networks have been widely deployed globally in the last 10 years as a technology to deliver Ethernet services to large populations of subscribers. Due to its point-to-multipoint nature, PON can be substantially more economical than point-to-point Ethernet for moderate to large populations. Furthermore, the baseband “on-off keying” PON media access control (MAC) layer avoids limitations such as optical beat interference (OBI) that are encountered in plain “DOCSIS over fiber” / RFoG implementations. PON also offers a compelling Fiber-to-the-Home (FTTH) solution when combined with radio frequency (RF) overlays. An RF overlay is essentially adding the downstream of an RFoG network to a PON network without using the RFoG upstream and, thus avoiding the potential for OBI issues that two-way RFoG can have.

This paper will give a brief overview of each technology along with a comparison of the deployment and operational costs of each and an analysis of how compatible each option is with a deployed HFC network. The best solutions for a cable operator use the existing operational support, provisioning and billing systems, share the trunk fibers with HFC and use existing CPE. The ideal solution will give an operator maximum flexibility for an xPON evolution and a transparent solution that will allow operators to deploy best in class technology for either EPON or GPON. This paper will compare the costs, throughput and equipment reuse of each option and will demonstrate how the HFC node can be used to reduce the cost of PON networks. By placing modules in the HFC node, operators can use dense wavelength division multiplexing (DWDM) optics on their trunk fibers between the headend and node and then use standardized PON

wavelengths from the node to each customer. This significantly reduces costs by conserving trunk fiber and by allowing the use of lower-powered optical modules in the CPE equipment than would have been required if there was not a module in the node.

This paper will compare the total end-to-end costs and throughput of the various architectures and will demonstrate how the HFC node can be used to enable cable operators to deliver HFC and FTTP services simultaneously from the same node.

OVERVIEW OF THE ARCHITECTURES

HFC

The HFC architecture, shown in Figure 1, is the most widely deployed network for the delivery of voice, video and data. All of the processing equipment is in the headend or hub and the outside plant consists only of equipment designed to transport RF signals, either over coax or AM modulated onto fiber. Key aspects of this network are the following:

Characteristic	HFC
Transport from hub to serving area	Analog fiber
Transport throughout serving area	RF over coax with amplification
Delivery to customer premise	RF over coax
Transparency to signal type	Will carry any RF-modulated signal
“Smart” or “Dumb” network	Dumb
Active or Passive network	Active

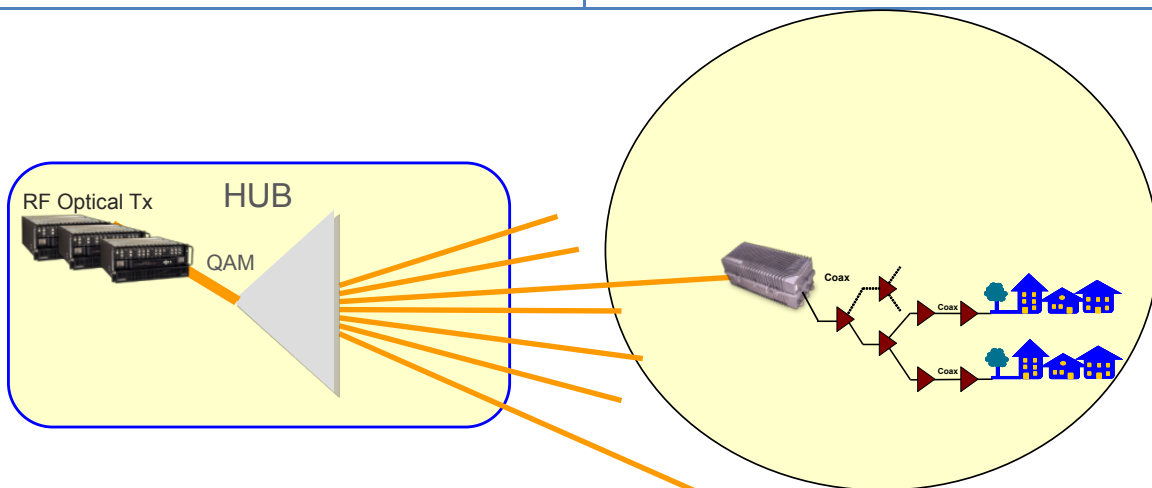


Figure 1 HFC Network

HFC networks are extremely flexible, due to the fact that they can carry any signal that can be modulated onto an RF carrier. When Data over Cable System Interface

Specification (DOCSIS) 1.1 was enhanced by the new Advanced Time Division Multiple Access (ATDMA) and Synchronous Code Division Multiple Access (SCDMA) modulation schemes in DOCSIS 2.0, no changes needed to be made to the HFC network to accommodate the new signals. Similarly, when channel bonding was added to DOCSIS 3.0, the existing HFC networks were able to handle the new technology without any changes.

EPON and GPON

A typical EPON or GPON network is shown in Figure 2. Although there are technical differences between the two types of PONs, both carry information over fiber through a passive optical network all the way from the hub to the customer premise. Additionally, both use baseband digital signaling over the fiber to carry packetized information. Key aspects of this network are the following:

Characteristic	EPON and GPON
Transport from hub to serving area	Digital fiber
Transport throughout serving area	Digital fiber
Delivery to customer premise	Digital fiber
Transparency to signal type	Will carry any packetized data at the designed data rate
“Smart” or “Dumb” network	Dumb
Active or Passive network	Passive

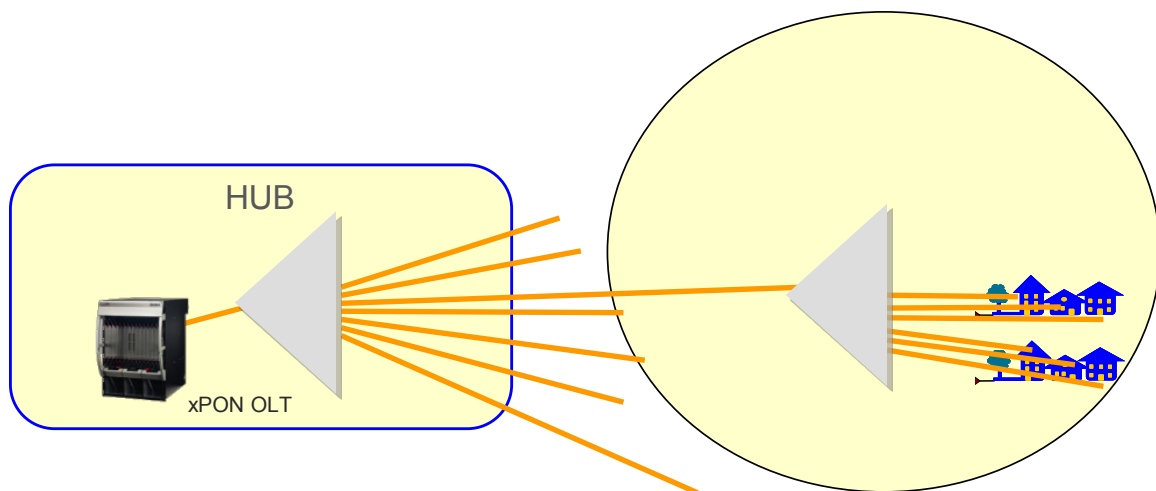


Figure 2 EPON or GPON Network

PON networks are very attractive because they are passive in the outside network, increasing reliability and lowering operational and maintenance costs. Since the fiber

runs all the way to the consumer premise, PON networks provide the potential for virtually unlimited bandwidth to the premise. The disadvantage of a PON network is that signal types on the fiber cannot be easily changed. For instance, a BPON network cannot be upgraded to a GPON network without changing all the equipment on both sides of the fiber. If the upgrade path is known, then a new technology can be added, such as adding 10G to a 1G network by utilizing different wavelengths. But, this is only possible if the original 1G equipment is designed to tolerate or reject the new 10G signal when it is added.

EPON or GPON with Video Overlay

A variation of the EPON or GPON network is to add a downstream analog RF signal to the PON signals on the fiber. This is shown in Figure 3 and has the advantages of EPON or GPON with the additional advantage of having an RF pipe to carry other signals that can be RF modulated. The xPON network carries packetized digital data, while the RF network can carry any signal, analog or digital, as long as it is RF modulated. The disadvantage of this network is that the RF signals require a more stringent optical link budget design, making the network more expensive. This hybrid network has the following characteristics:

Characteristic	EPON and GPON with RF Overlay
Transport from hub to serving area	Digital and analog fiber
Transport throughout serving area	Digital and analog fiber
Delivery to customer premise	Digital and analog fiber
Transparency to signal type	Will carry any packetized data at the designed data rate and any RF modulated signal
“Smart” or “Dumb” network	Dumb
Active or Passive network	Passive

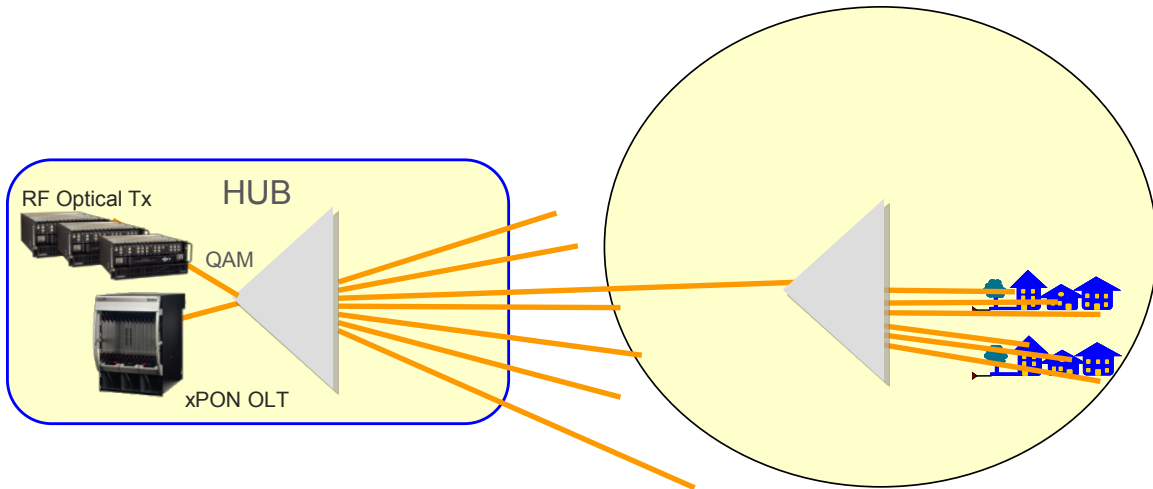


Figure 3 EPON or GPON Network with RF Overlay

RFoG

RFoG networks were created to carry HFC signals to the home without using coax or RF amplifiers. The system is designed so that all the headend, hub and CPE equipment is exactly the same as is used in an HFC network, while the outside plant is all fiber. The RFoG network is shown in Figure 4, and consists of the same fiber network as a PON, but with the same hub as HFC. Key aspects of this network are the following:

Characteristic	RFoG
Transport from hub to serving area	Analog fiber
Transport throughout serving area	Analog fiber
Delivery to customer premise	Analog fiber
Transparency to signal type	Will carry any RF-modulated signal
“Smart” or “Dumb” network	Dumb
Active or Passive network	Passive

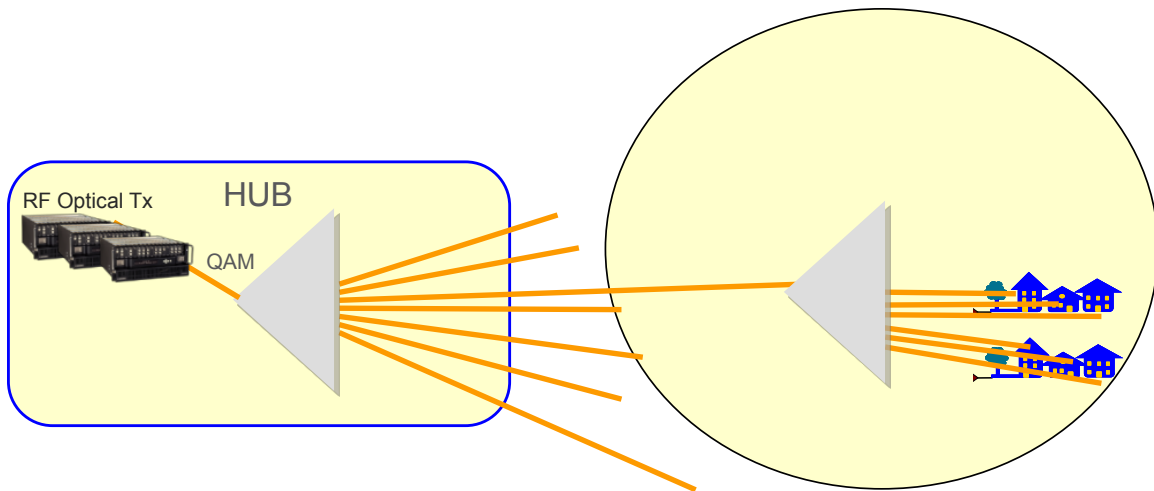


Figure 4 RFoG

CURRENT STATUS OF EXISTING HFC NETWORKS

Limited Fiber

Most of today's HFC networks evolved from old tree and branch networks in the 1990's, as fiber was pulled from headends and hubs out into the plant. At first the trunk amps were segmented by pulling a few fibers deep into the network. Eventually, as fiber optic equipment became more cost-effective, most tree and branch networks were upgraded into HFC networks in which the concept of trunk levels, designed to go long distances, was eliminated. When those networks were converted to HFC in the 1990's, fiber was still relatively expensive, so operators decided to only pull a modest amount of fiber to each node. Some operators decided to pull six fibers to each node to enable future expansion, while others only pulled two fibers.

As consumers desire ever-increasing amounts of bandwidth, the HFC networks have been split into smaller pieces. Every time a node is split additional fiber or additional wavelengths are required. Service providers have been offering high speed connections to the businesses in their footprint, and have often used available dark fiber for those connections. Since residential and commercial bandwidth continues to increase, most operators have lit up all their trunk fibers and often have several, if not many, wavelengths operating on each one. As a result it is becoming increasingly difficult to add more services.

Another limitation on trunk fibers is due to that fact that the standardized EPON and GPON networks are required to operate at specific wavelengths. For instance, the first generation of these PONs uses 1490 nm in the downstream and 1310 in the upstream.

Similarly, the 10G versions of these networks use 1577 nm in the downstream and 1270 nm in the upstream. Therefore, it is not possible to operate more than one service group of a PON on the same trunk fiber at the same time. This significantly limits the utilization of the fiber.

Long Distances

In addition to the limited amount of fiber deployed, many of those fiber connections from the hubs to the nodes are a very long distance. Some operators were careful to deploy enough hubs to assure that the vast majority of the fiber distances were 20 km or less. Other operators in more rural areas allowed much longer fiber distances to be used. The long fiber distances in these networks eats into the available performance budget and makes it difficult to serve many homes in the serving area.

PON EXTENDERS

Characteristics of an Optimal PON Solution

As explained in the previous sections, operators are faced with the following difficulties when deploying PONs in their networks:

- There is a limited number of trunk fibers
- Only one PON can run on any one fiber
- Many nodes are far from the hub

Fortunately, the HFC infrastructure can be used to solve these problems. Before exploring the possible solutions, the characteristics of an optimal PON solution should be defined. Some elements of an ideal solution are:

- Low cost
- High reliability
- Low complexity
- Transparent to type of PON
- Interoperates with all vendors' Optical Line Terminal (OLT) and Optical Network Unit (ONU)
- Low power consumption

The HFC infrastructure can reduce the cost of PON deployments by providing the following benefits:

- Leverage the existing node locations
- Share trunk fibers
- Reach long distances

- Enable low power, low cost optics in ONUs

By placing the proper equipment in the HFC node, the existing trunk fibers can be used to carry multiple PONs to the node serving area, even over long distances.

Overview of PON Extenders

In order to accommodate the long distances and limited numbers of fibers, many operators are interested in deploying PON extenders. The PON extender is an active device in the node that can use Course Wavelength Division Multiplexing (CWDM) or Dense Wavelength Division Multiplexing (DWDM) optics on the trunk fiber at whatever wavelength is desired. It can also regenerate the electrical signals so that they can be retransmitted to the local serving area with high fidelity, eliminating the penalty of long link budgets between hubs and nodes. When properly designed, a PON extender will have the following benefits:

- CWDM or DWDM Ethernet optics or PON optics in the fiber backhaul trunk
- Reach long distances without performance penalty
- Enable low power, low cost optics in ONUs

The two primary types of PON extenders being considered for this application are remote OLTs and PON repeaters.

To understand how PON extenders can be used in a network, refer to Figures 5 and 6. Figure 5 shows a typical PON deployment in which the total distance served is limited to approximately 20 km. Each PON serving area is connected to the OLT with a unique fiber. There is only one PON on any fiber.

Direct PON (Customers within 10-20 km of Hub)

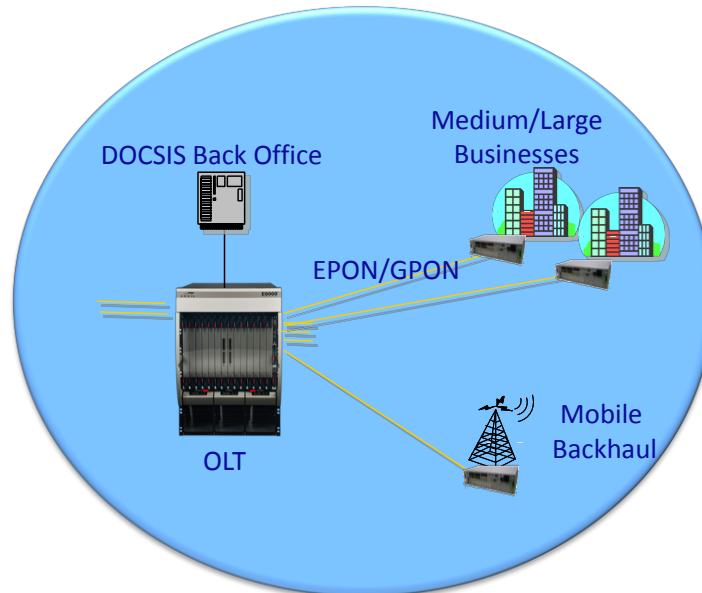


Figure 5 Typical PON Serving Area

A PON extender is shown in Figure 6. The direct serving area on the left is the same as shown in Figure 5, but additional remote areas are served by passing the signals through the PON extender in the HFC node. Since the PON extender module can convert wavelengths, it is possible to select wavelengths for use in the trunk fiber that will not interfere with existing HFC or Ethernet services already running on that fiber. Additionally, since the PON extender receives and retransmits data, the distance served by the trunk fiber can be much further than would be possible without the use of a PON extender.

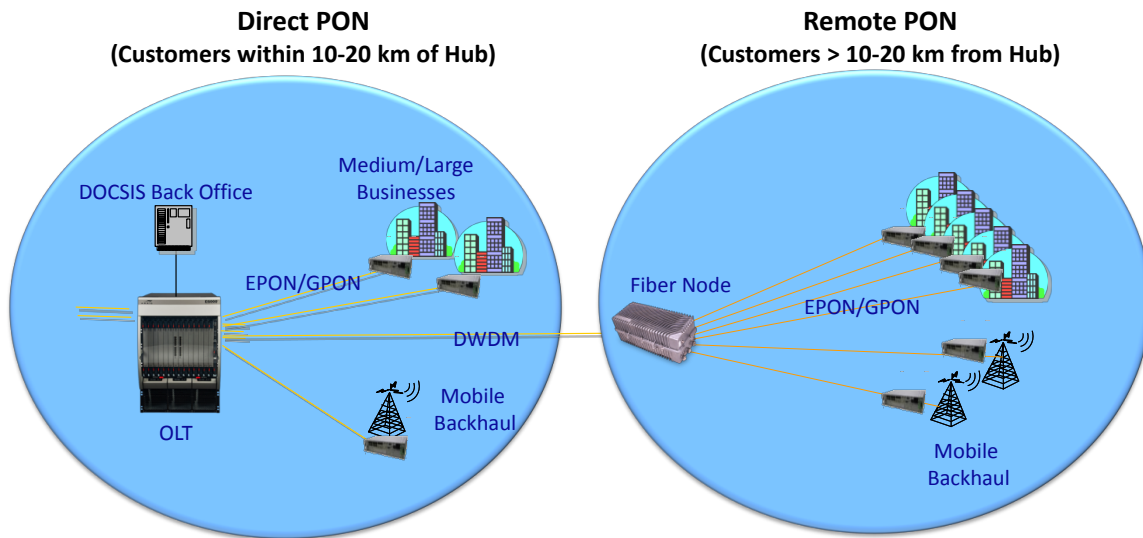


Figure 6 PON Extender

Remote OLT

One method of creating a long distance PON is to put the OLT in the node. The basic function of an OLT is to relay traffic between Ethernet interfaces on its WAN port and the PON interfaces that serve customers. Since OLTs use standard Ethernet optics on its WAN ports, it is simple to envision how specific wavelengths that don't interfere with existing signals can be selected for use on the trunk fiber. The remote OLT architecture is shown in Figure 7.

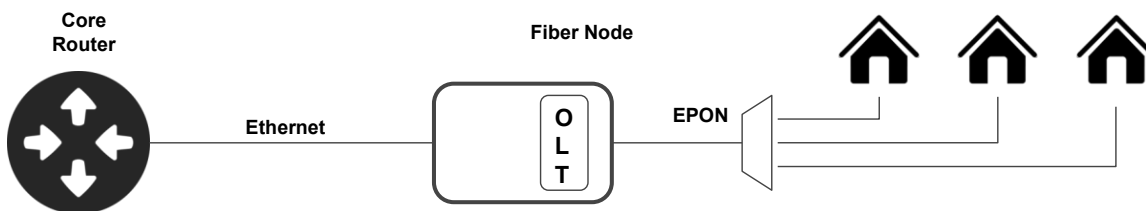


Figure 7 Remote OLT Architecture

It is clear that a remote OLT meets the three goals of a PON extender defined in the previous section. However, there are some disadvantages of placing an OLT in the HFC node. The most important disadvantage is that the OLT needs to fit in the node. This will generally require that the OLT be manufactured by the same vendor that manufactures the node. This could prove to be very inconvenient for the service provider. In order for a service provider to deploy a PON network, that operator needs to fully test and qualify the PON products to be deployed. Most of the primary PON vendors are not the same vendors that create HFC nodes. In the cases where the same vendor does both, it is possible, but not very likely, that the qualified OLT vendor is the same vendor that manufactured the nodes deployed in the target market. The need to link the OLT vendor to the node vendor is a significant disadvantage.

Another disadvantage of placing an OLT in the node is that the OLT is a software intensive and very expensive device. One can question the wisdom of putting such a high value product in an insecure location. Additionally, while software upgrades will most likely be designed so that they can be applied remotely, one cannot be certain that a visit to the node will not be necessary if something goes wrong with a software upgrade. The prospect of needing to roll trucks to all the nodes to fix a failed software upgrade is not very pleasant.

PON Repeater

Another method of implementing a PON extender is to use a PON repeater in an HFC node. Unlike a remote OLT, the PON extender does not modify, queue or manage traffic. Its job is simply to receive, clean, and retransmit the data that comes in one port and send it out the other port. A PON repeater is shown in Figure 8.

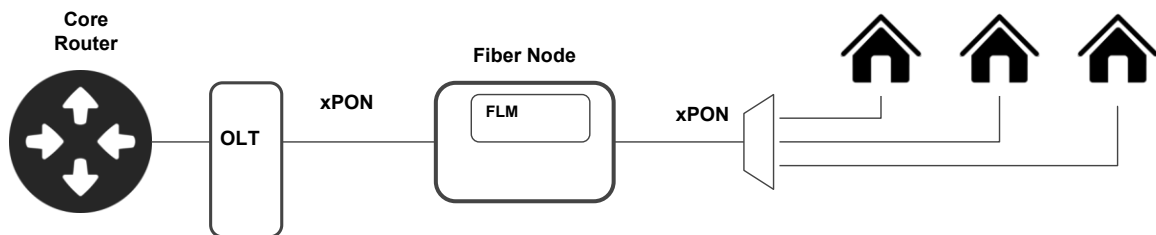


Figure 8 PON Repeater Architecture

On the surface, this concept sounds simple. However, since the upstream traffic is burst mode, care must be taken in the design of the repeater so that the burst mode data, along with the preamble on each upstream burst, is relayed without corruption. The repeater performs a wavelength translation (O-E-O function), preserving the time-domain characteristics of the PON signals while preserving OLT-ONU interoperability. A basic block diagram of a PON repeater is shown in Figure 9.

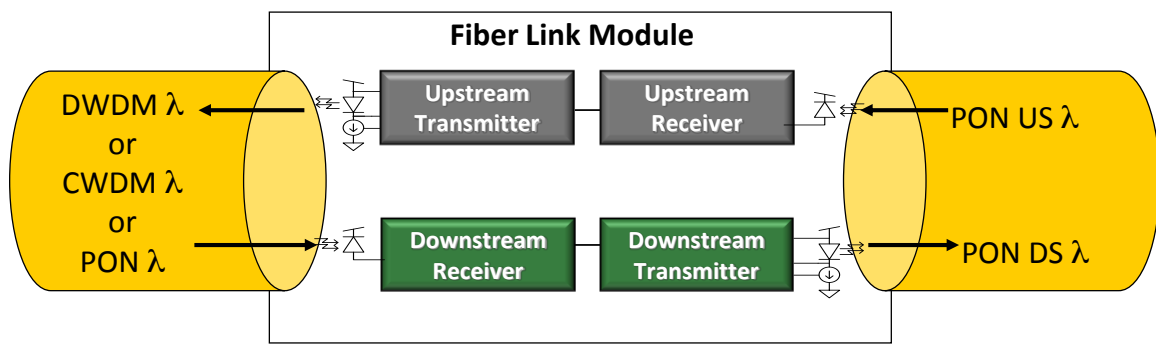


Figure 9 PON Repeater Functional Diagram

The PON repeater has all the same advantages as the remote OLT with the additional advantage that it will work with any vendor's OLT and ONU. This allows the service operator to decouple their selection of OLT vendor from their node vendor. This is a critical differentiator for most deployments, since most operators have or are currently taking great care to qualify their PON equipment vendors so that they can deploy PONs to the areas that can be directly fed from their hubs (as shown in Figure 5). The PON repeater enables operators to use that same qualified PON equipment to serve areas that are a long distance from the hub. The PON repeater also aligns with the traditional HFC node architecture by keeping the OLT intelligence in the hub (where the CMTS is also located) and allows node maintenance practices to remain consistent with existing node modules.

PON EXTENDER ARCHITECTURE COST BENEFITS

General

There are many factors to take into account when comparing costs across different PON architectures. These include deployment and equipment costs (CAPEX) as well as operating costs (OPEX). The best solution is one in which the MSO can leverage existing deployed assets as much as possible. These will include the current deployed base of fiber and HFC nodes. The high cost of fiber deployment will be the largest savings for an operator looking to deploy PON services over its existing network.

The paper will highlight the benefits of using an extender in an RFoG network and a repeater in a 10G EPON network. The goal is not to compare RFoG and EPON networks, but to showcase the benefits (cost or reach) of PON repeater integration.

This paper will largely look at CAPEX cost models for each of the following architecture comparisons:

- RFoG with 20km reach (no repeater) and RFoG 60km reach (with field EDFA)
- 10G EPON with 10km and 20 km reach (no PON repeater) and 10G EPON with 60km reach (with PON repeater)

CAPEX

CAPEX in this model includes the deployment costs for a constructed network. These costs can be broken down into equipment costs, which can vary among the different technologies, and infrastructure costs ("the plumbing"), which are similar regardless of the technology deployed:

- Equipment costs include: OLT, PON Extenders, optical transceivers, Erbium-Doped Fiber Amplifier (EDFA's), optical passives, ONT and ONU devices.
- Infrastructure costs include: fiber (backbone, distribution and drop), splice enclosures, installation labor, engineering and testing. An equal mix of aerial and buried construction was considered in the cost model.

In PON-like networks, infrastructure costs will be similar regardless of the technology deployed assuming that similar splitting ratios are used. There will be a larger difference in equipment costs between xPON and RFoG due to RFoG's ability to utilize existing headend and CPE equipment.

PON Extender Advantage

There are two cost advantages to utilizing an extender in a passive optical network. The first advantage is the ability to maintain low cost, low reach ONU optics in the network, and the second is the ability to leverage existing fiber and node infrastructure for deployment of PON services by utilizing CWDM and DWDM optics versus standard PON optics. There are large cost benefits of being able to support 4 or more PON serving areas with a single fiber.

PON networks reach their optimum value when the number of subscribers is maximized. The equipment cost per sub is high during initial deployment due to heavy investment in the headend PON OLT chassis and cost per blade. This improves as the number of subs increases and the chassis equipment costs are distributed over a higher number of subscribers.

Typical PON networks utilize a link budget that provides a services distance of 20km. This provides an optimal balance between serving area and optics costs and is similar for RFoG and EPON networks. However, there are a number of HFC networks that have service distances much larger than 20km. The cost of high power, long reach optics make migration to a PON network unfeasible.

RFoG

As MSOs look to convert their HFC networks to FTTP the first logical step is RFoG. This migration requires less capital investment as the CMTS and CPE in the existing network can be maintained in an RFoG deployment. The additional investment will largely come from optical splitters, ONUs and additional fiber deployment to the customer premise.

Table 1 contains a relative cost comparison of equipment and deployment costs between a standard 20km RFoG deployment and an extended reach 60km network utilizing field EDFAs in the node. There is a 7% increase in equipment that is driven by total optics cost. This happens as cost is migrated from the headend to the hub where

the EFA is located. Once deployment costs are combined with the equipment costs and averaged across the total number of subscribers the total cost per sub increases by only 2% for a 300% increase in service area.

Residential RFoG Analysis Element	RFoG Traditional 20 km	RFoG Ext. Reach 60 km
CAPEX		
Equipment:		
Relative Optics Price/Sub	100%	107%
Deployment:		
Relative Total Price/Sub	100%	102%
Homes/TX/PON Port	512	512
Homes per Splitter	32	32
CMTS Included?	No	No
Model area	512	512
Penetration	100%	100%
Avg. BW/Sub (Mbps)		
Downstream	22.4	22.4
Upstream	14.4	14.4
Notes:		
1. Prices illustrated are for Greenfield plant. If PON Extender can leverage existing HFC fiber, additional price savings may result.		
2. Pricing is based upon 100% penetration of homes passed for all equipment.		
3. RFoG Avg. BW/Sub is based upon 1 CMTS port feeding 16 PONs, 512 homes passed with 50% penetration and 10% simultaneous use rate.		

Table 1 Residential RFoG Cost Comparison

10G EPON

PON networks reach their optimum value when the number of subscribers is maximized. The equipment cost per sub is high during initial deployment due to heavy investment in the PON OLT chassis and high cost per PON blade. Average cost improves as the chassis equipment investment is distributed over a higher number of subscribers.

Table 2 contains a relative cost comparison of equipment and deployment costs between a standard 20km 10G EPON deployment, a reduced 10km 10G EPON deployment, and an extended reach 60km 10G EPON deployment utilizing a PON repeater. The reduction in service area from 20km to 10km allows the use of low cost, short reach optics. The result is a 28% cost savings per sub in the optics costs alone. This showcases the influence the optics cost has on the total network investment. As deployment costs are factored in the total cost per sub shows an overall reduction of 10% by utilizing the lower cost optics.

Residential 10G EPON Analysis Element	10G EPON 20 km	10G EPON 10 km	10G EPON 60km w/ PON Ext.
CAPEX			
Equipment:			
EPON Relative Optics Price/Sub	100%	72%	68%
Deployment:			
EPON Relative Total Price/Sub	100%	90%	89%
Homes/TX/PON Port	256	256	256
Homes per Splitter	32	32	64
Model area	12288	12288	12288
Penetration	100%	100%	100%
Avg. BW/Sub (Mbps)			
Downstream	35.2	35.2	35.2
Upstream	34.0	34.0	34.0
Notes:			
1. Prices illustrated are for Greenfield plant. If PON Extender can leverage existing HFC fiber, additional price savings may result.			
2. Pricing is based upon 100% penetration of homes passed for all equipment.			

Table 2 Residential EPON Cost Comparison

The 60km extended 10G EPON network utilizes the same low cost, short reach optics from the 10km deployment scenario due to the addition of the PON repeater. While there is a shift of headend optics costs from the headend to the hub, the overall cost per subscriber remains relatively the same with a 600% increase in serving area.

It should also be noted that additional savings result where existing backbone fiber is shared between an existing resource such as an HFC network and the PON network. Since existing fiber is in place between headend/hubs and HFC nodes, and the physical distance between the node and farthest customer rarely exceeds 3km, it makes sense to leverage existing resources as much as possible. This is where the PON Extender shines. Enabling PON Extenders to co-exist with existing nodes in the HFC network provides a logical transition path for natural evolution from HFC to a PON network. New residential or commercial extensions within the bounds of the existing HFC footprint can take advantage of introducing PON-like architectures, whether they be RFoG or PON technology, where and when they are needed. This truly enhances the flexibility of the HFC network in addition to providing logical launch points for PON-like network transitions.

OPEX

Determining OPEX costs is truly a challenging task. In the HFC world, when questioned on the subject, many MSO's freely admit they don't maintain good information on network OPEX. Some continue the ongoing practice of just using last year's OPEX costs to budget for next year's expenses. Calculated estimates have been attempted for HFC network OPEX relative to outdoor plant nodes, amplifiers, taps, passives, power supplies and cost of power. These, based upon active device failures and powering costs

(excluding programming costs, headend and in-home devices and cable breaks) have been estimated to be in the \$700/mile/year range. Most of that cost is in power.

OPEX for PON-like networks is a bit different:

- **Outdoor Network:** Unlike in an HFC plant, the network plumbing in PON is passive and does not contain the active, power consuming elements that reside in HFC. So in a PON-like network, from the output of the Headend/Hub to the side of the residence, the OPEX costs can be considered equal regardless of technology deployed. Basically the calculated \$700/mile/year OPEX cost in an HFC network is recovered.
- **In Home Elements:** RFoG requires an ONU plus a cable modem. PONs require an ONT plus a wireless router. Which is more reliable, a cable modem or a wireless router? Discounting these devices as a wash leaves the ONU/ONT. Some could argue that these residential node elements actually increase the network active counts to 50/mile as opposed to the traditional 6 actives/mile in HFC. Which PON technology is more reliable? That depends upon the functionality of each device which continues to evolve.
- **Headend/Hub:** RFoG requires CMTS, optical transmitters, receivers, EDFA's. PON requires OLT's. Here, the edge may reside with PON from a power and space perspective as the CMTS is eliminated as are the optical transmitters, EDFA's and receivers required with RFoG. That is, of course unless an RF overlay is required for the PON which can add some of that back.

As is evident, there are a lot of variables to consider in estimating OPEX costs but from an outdoor plant perspective, RFoG vs. PON are about equal given like splitting arrangements.

CONCLUSIONS

There are a number of benefits to including a PON repeater in a passive network. The PON repeater aligns with the traditional HFC node architecture of maintaining the network intelligence in the hub while node maintenance practices remain consistent with existing node modules. While the capability to extend network reach utilizing low cost, short reach optics is powerful, the ability to support multiple PON service groups utilizing CWDM or DWDM on a single fiber is compelling. The OEO wavelength translation of the PON repeater removes the limitation of a single PON service group per fiber while being PON vendor agnostic.

MSOs are looking to utilize as much of their HFC network as possible when migrating to a FTTP network. The optimal scenario is one that minimizes additional investment as fiber is deployed to the customer premise while leveraging as much of the existing network as possible. The PON repeater maximizes the reuse of the existing HFC network while allowing the MSO to dramatically increase their network capability with fiber deployment to the home.

MEET ONE OF OUR EXPERTS: Leon Venton

Leon Venton is currently Product Manager of RF Products and Advanced Technologies at ARRIS, where his responsibilities consist of managing RF amplifier products, as well as advanced node modules in the Access and Transport Group. This includes managing a MEF-compliant node Ethernet switch supporting fiber based commercial services and PON Extenders, as well as the Company's Cable Wi-Fi vendor relationships.

Venton came over to ARRIS with the Motorola merger in April 2013, and joined Motorola five years earlier as an RF engineer. During those years, Venton worked on the development of RF amplifiers and optical node products, and the development of DOCSIS backhauled Cable Wi-Fi programs.

Prior to joining Motorola, Venton spent several years working in Wi-Fi radio development at Intersil, and then at Conexant, after it acquired the Wi-Fi division of Intersil.

Venton holds a Bachelor of Science in Computer Engineering from the Florida Institute of Technology.

ABBREVIATIONS & ACRONYMS

ATDMA	Advanced Time Division Multiple Access
BPON	Broadband Passive Optical Network
CMTS	Cable Modem Termination System
CPE	Customer Premise Equipment
CWDM	Course Wavelength Division Multiplex
DOCSIS	Data over Cable System Interface Specification
DWDM	Dense Wavelength Division Multiplex
EDFA	Erbium-Doped Fiber Amplifier
EPON	Ethernet Passive Optical Network
FTTH	Fiber to the Home
FOTP	Fiber to the Premise
GPON	Gigabit Passive Optical Network
HFC	Hybrid Fiber Coax
MAC	Media Access Control
OBI	Optical Beat Interference
OLT	Optical Line Terminal
ONU	Optical Network Unit
PON	Passive Optical Network
RFoG	Radio Frequency over Glass
SCDMA	Synchronous Code Division Multiple Access

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