

PON & RFOG TECH GUIDE

October 2008

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Assessing PON and RFOG

The cable industry is moving through this complicated landscape and shed some standards that would take the "H" and "C" out of the hybrid fiber/coax (HFC) architecture.

While the likely near-term application of these optical fiber standards is limited to niche markets, this attempt to forge a standard approach to fiber-to-the-premises (FTTP) technology still represents a remarkable turn for the industry.

But it's not happening within a vacuum, and that complicates matters. International standards for the larger passive optical networking (PON) category already exist, and the range of vendors with existing and forthcoming solutions relevant to cable's radio frequency over glass (RFOG) project is wide and varied.

Some traditional cable suppliers have already launched splitters, optical network terminals and other products friendly to this effort. Others are engaged, but holding back until the standard is more baked. Still other vendors have moved into this market from the PON arena, which has undergone its own twists and turns over the past several years.

This guide attempts to sort

through this complicated landscape and shed some light on options now facing the industry.

PROPHET BEFORE HIS TIME?

A little history can offer a lot of perspective.

It's been eight years since Jim Farmer, co-author of *Modern Cable Television Technology*, departed Antec to become CTO of FTTP startup Wave7 Optics.

In an interview at the time, Farmer raised some of the engineering and business tradeoffs that led him to create something positioned between PON, which then he regarded as too expensive, and HFC.

"By strategically placing an active device in the field," Farmer said, "we can have the best of both worlds."

It's not just the relative lack of actives, of course, but also network smarts—such as bandwidth allocation algorithms—that make PONs what they are. Over the ensuing years, Wave7 and other vendors on the optical side of the aisle continued not only to increase those smarts but also to adjust their platforms in conformance with

networking standards that emanated from two bodies.

One family of standards or official recommendations—asynchronous (A)PON issued in 1996, broadband (B)PON in 1998 and Gigabit (G)PON in 2003—emerged from projects sponsored by the International Telecommunications Union-Telecommunications Standardization Sector (ITU-T).

Another family derived from the Institute of Electrical and Electronics Engineers (IEEE), which got into the game in 2001 with its 802.3ah or Ethernet in the First Mile (EFM) working group. That led to approval of the Ethernet (E) PON standard in 2004.

These developments, supported by participating members of the ITU and IEEE, were hard to ignore. Within two years, cable industry leaders began signaling a shift in course.

The SCTE Advanced Plant Architecture Study Group, established to determine standardization needs for the increased use of fiber in cable plants, held its inaugural meeting at Cable-Tec Expo in June 2006. And on Aug. 17, a controversial article appeared in the *Wall Street*

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Glossary

RFOG: Radio Frequency (RF) over glass. An acronym associated with both specific fiber-to-the-premises products and an emerging standard being developed within working group 5 of the SCTE's Interface Practices and In-Home Cabling Subcommittee (IPS SP 910: "RF over Glass System Overview.") In either case, this technology involves transmitting RF over fiber, instead of coaxial cable, through splitters to a node or terminating unit deployed at the premises. It supports the use of existing customer premises equipment (SCTE55-1/55-2 set-top boxes and DOCSIS equipment). It requires the addition of an EDFA and return receiver in the hub to support bi-directional optical transport on an FTTH point-to-multipoint plant. Proposed and existing reverse path implementations vary. Data rates are limited to existing DOCSIS 1.1/2.0/3.0 data rates and use of existing DOCSIS CMTS is required.

PON: Passive optical network. Its distinguishing characteristic is point-to-multipoint (P2MP) with no elements between the hub and customer premises except for passive splitters. PON typically uses asynchronous time division multiple access (ATDMA)

continued on page 8



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	Cisco Systems (Scientific Atlanta)			● ¹	
	Commscope			●	
EPON Only	Corecess	●			
	UT Starcom	●			
	ZTE	●			
EPON+RFoG	Alloptic	●		●	
	Pacific Broadband Networks	●		●	
	Enablence (Wave 7 Optics)	●	●	●	
	Hitachi Telecomm (Salira Systems)	●	●	●	●
EPON + GPON	ECI Telecom	●	●		
	Huawei	●	●		
	Nokia Siemens Networks	●	●		
	Motorola		●		
	Alcatel-Lucent		●		

NOTES

1. Cisco Systems (Scientific Atlanta) previewed a "DPON" RFoG product in June 2007; Cisco also talked publicly in early 2008 of work on a true DOCSIS PON capable of delivering 1 to 10 Gbps cable modems.
2. This chart only lists GPON for EPON vendors that also offer GPON, it is not intended to be an exhaustive GPON vendor list. Missing would be Adtran, Alcatel-Lucent, Calix, TXP, NEC, Occam, Pannaway, Tellabs, and Zhone.
3. Likely future EPON vendors include: Alcatel-Lucent and Nokia Siemens Networks. Both companies are very active in P802.3av. Since neither currently offers an EPON product, the rational explanation is that they are either thinking about or actively planning such products.
4. This list does not include EPON vendors that do not offer products for sale in the US. There are a number of vendors that sell EPON products in Japan that do not offer them for sale in the US and do not want to sell or support those products in the US.

Table 1: Vendor Portfolio PON/RFoG Matrix

Journal citing a CableLabs study that indicated the industry might need to take fiber to the home to keep track with competitive threats, such as that posed by Verizon's BPON-based FiOS initiative.

Over the following year, the industry further warmed to the IEEE perspective. Ethernet pioneer Bob Metcalfe keynoted the SCTE Conference on Emerging Technologies in January 2007. Comcast, Suddenlink, Bright House Networks and CableLabs joined Cox and Time Warner Cable among other cable operators as members of the Metro Ethernet Forum, which had absorbed the EFM Alliance (803.ah). The MEF itself held its first workshop at Cable-Tec Expo in June that year.

Throughout 2007, several suppliers of EPON technology, including Wave7 Optics, added radio frequency (RF) functionality to their platforms. In the fall of 2007, the SCTE Engineering Committee approved the RFoG project, and work formally began within working group (WG) 5 of the Interface Practices Subcommittee (IPS) in March 2008.

Across this eight-year span, Farmer, whose company was acquired by Enablence Technologies in May 2008, continued to speak at cable industry gatherings. His paper at this year's Cable Show, for instance, contained a figure that formed the inspiration for the timeline on page 6

compiled by independent analyst Victor Blake.

Farmer's paper was also the basis for a column that first appeared in the July issue of *Communications Technology*, in which he encouraged others to join the SCTE work on IPS SP 910, or "RF over Glass Overview."

VENDOR MIX

Newcomers to cable are attending these meetings, but incumbent technology suppliers are inclined to emphasize constraints particular to the industry.

"The realm of HFC has very unique optical requirements and requires very careful interpretation of the laws of physics," said Bill Dawson, vice president product strategy, ARRIS access and transport division.

Whereas in the telephony world, optics have traditionally been an on/off phenomenon, Dawson said that cable's analog modulation of light "presents a whole new dimension of challenges."

"RFoG is actually a bridge between the two worlds," he said.

The migration strategy entails building outside plant components in such a way that a seamless switch to EPON or GPON electronics is possible down the road.

The cable-friendly aspect of RFoG technology has its appeal. From a pure technical standpoint, for instance, it is likely that DOCSIS upstream will perform faster under RFoG than HFC, because the optical transport will support a

higher RF Signal to Noise Ratio (SNR) than natively over coax.

From a vendor perspective, some existing pre-standard solutions look familiar enough. The catalog for Commscope's BrightPath system, which several multiple system operators (MSOs) have deployed and and trialed, features an optical tap, network interface unit (NIU),

specifically to meet the unique needs of cable operators for new build applications."

Others have launched products aimed at cable. At Cable-Tec Expo in June, Motorola announced that Canadian-based Compton Communications had selected its FTTH GPON-based technology. At Cable-Tec Expo in 2007, the

Blake argues, however, that GPON's sole adoption by Verizon, and EPON's rapid evolution as a standard combined with its widespread deployment, particularly in Asia, marks EPON as the winner. Then there is the matter of the ITU-T study group 15 agreeing with the IEEE on a converged PON standard based

"The realm of HFC has very unique requirements and requires very careful interpretation of the laws of physics,"

— Bill Dawson, ARRIS

backup power, optical cables, conduit and an optical node from standing partner Aurora Networks.

At Cable-Tec expo in June 2008, Harmonic announced that it also had teamed with Commscope to make its MAXLink forward transmitters and return path receivers compatible with the BrightPath system.

Introducing a new network interface device (NID) at Cable-Tec Expo in June, Commscope Vice President Marketing and New Business Development Carl Meyerhoefer underscored industry ties.

"We worked closely with cable operators to understand the needs at the customer premises and incorporated that feedback into this new NID design," Meyerhoefer said in a statement. The overall fiber-to-the-home (FTTH) solution, he added, was "designed

Scientific Atlanta branch of Cisco Systems previewed what it was calling DOCSIS (D)PON, which like the emerging RFoG standard, aimed at leveraging cable's existing infrastructure.

The use of that acronym is potentially confusing, however, given discussion of using DOCSIS over a more classic PON technology.

For instance, a paper presented at the SCTE ET Conference in January 2008 by Cisco Software Architect Alon Bernstein and PMC-Sierra Principal Engineer Steve Gorshe, and adapted for publication in the February issue of *CT*, proposed combining the best of DOCSIS and either GPON or EPON.

Which of those PONs is ascendant is a matter of some speculation Independent analyst Victor


on IEEE P802.av. (See Figure 1, p. 6.)

COST STRUCTURE

It's safe to bet that economics will drive both the PON and RFoG projects.

ARRIS's Dawson points to consumer premise equipment (CPE), as it bears the "lion's share of the cost"

Given that the CPE in a RFoG framework is essentially a sophisticated little node with correspondingly high requirements for reliability and mean times between failure (MTBF), optimizing the demands of engineering and manufacturing is no trivial task.

"If RFoG is to be successful, that will be because the necessary elements are in place to drive the cost of the CPE down," he said. 

—Jonathan Tombes



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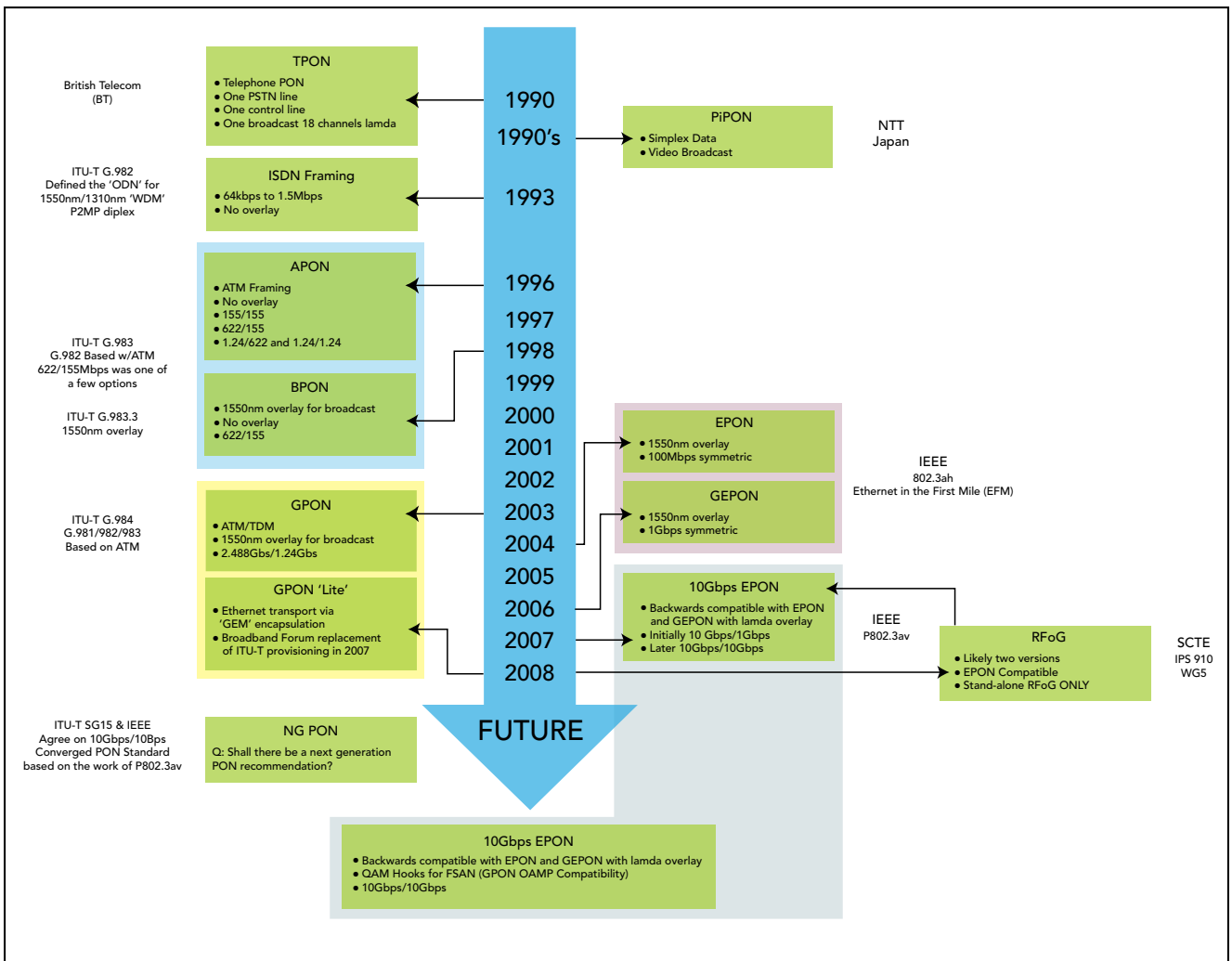


Figure 1: Timeline on ITU-T, IEEE and SCTE PON standards projects

PON and DOCSIS

Excerpted from "Chasing Verizon FiOS: The Race is On," by Victor Blake, *Communications Technology*, August 2008. Drawn from paper presented at SCTE Cable-Tec Expo.

DOCSIS OAMP

The cable operator community has distinguished itself as a strong proponent of IEEE and Internet Engineering Task Force industry standard technologies. Cable operator adop-

tion of Internet protocol (IP)/ Internet/Ethernet architecture, for instance, was much more rapid and thorough than its telco competitors. With voice service, cable operators adopted voice over IP (VoIP) to the customer premises long before telcos.

EPON will be a similar challenge for cable. There is no technology risk as to whether it will work. Like VoIP, it is a cost-effective solution than can be integrated with existing

IP service architecture and even the fiber distribution plant for 1,550 nm forward video broadcast. While there are some small challenges for two-way video return, the bulk of the technical challenge is in operations, administration, maintenance and provisioning (OAMP).

IEEE 802.3ah and 802.3av are Ethernet protocols just like 802.3z (GigE). They are access protocols that lack service provider-specific OAMP. The

telcos are building a service overlay standard for GPON that they call FSAN. The cable community must build an overlay for EPON. DOCSIS is the natural candidate to hide the new EPON PHY/media access control (MAC) layers.

COMMON INTERFACES

As in previous cases, cable operators can work together to develop a common service interface for EPON that meets specific needs. DOCSIS over

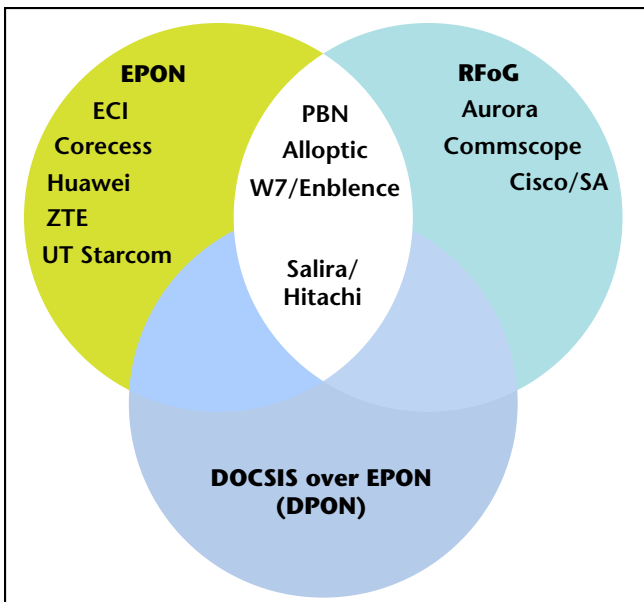


Figure 2: Current EPON, RFoG and DOCSIS over PON vendor portfolios


PacketCable Multimedia (PCMM), cable operators can integrate any additional applications with service agnostic quality of service (QoS).

DOCSIS is vertically integrated. It includes the service overlay layers, the MAC, and the various PHYs. Though it was originally organized as a vertically integrated protocol family, we can identify open systems interconnection (OSI)-like boundaries that separate the MAC from the PHY and the service control from the MAC. These layers have been peeled away further as we have added new PHYs such as synchronous code division multiple access (SCDMA) in 2.0, and later the MULPI overlays in 3.0.

SERVICE IDENTIFIER

The one cross-layer technology


is the service identifier (SID). It is no accident that EPON uses a logical link identifier (LLID) as its single, cross-layer service system, just as the SID in DOCSIS. The LLID can do everything a SID can do. Just like SIDs, LLIDs are deterministic and strictly scheduled. They are not probabilistic (like 802.1p and other QoS queuing schemes).

Operationally, cable operators can build an even more competitive edge through the adoption of DOCSIS over EPON technology to extend OSS support to include high-end Ethernet services for business customers. With a combination of MEF on DOCSIS and DOCSIS over EPON, the existing OSS can further the competitive edge for cable competition with FiOS. 

EPON is this effort.

It is a competitive advantage that cable operators already have in DOCSIS a strong and mature service overlay tech-


nology. Within the DOCSIS family, there is imbedded, best-effort, high-speed data service and voice with PacketCable 1.5. With PacketCable 2.0 and



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RFoG Overview and Application

From "RF over Glass for Business Services," by Michael J. Emmendorfer, senior director, solution architecture and strategy, ARRIS. Published in January 2008, Communications Technology. Drawn from a paper presented at the SCTE Symposium on Business Services, October 2007.

OVERVIEW

...The SCTE Advanced Plant Architecture Study Group is using the term RFoG. The RFoG solution uses existing business support system/operational support system (BSS/OSS) and headend elements...in the cable operator's network. The traditional cable installation practices are leveraged as well as customer premises equip-

ment (CPE) and services such as analog, digital, and DOCSIS services.

An RFoG service group size will likely be in the range of 32 homes passed; however, combining at the headend will remain an option as with traditional HFC. This allows CMTS equipment to be shared over a larger pool of service groups for even greater economies of scale.

The reasoning behind RFoG may be found in service providers deploying an all-passive optical network, like RFoG or passive optical network (PON) systems, which find lower operational costs than fiber-to-the-node approaches with active or copper wiring in the


outside plant....

APPLICATIONS

...The emergence of RFoG enables a fiber-to-the-business (FTTB) or fiber-to-the-home (FTTH) passive optical network solution to use all-passive fiber networking that carries all services traditionally delivered over HFC. These services include the carriage of analog and digital services as well as the transport of data and voice services over DOCSIS.

If an operator prefers to deploy fiber solutions to resolve operational concerns regarding active outside plant or to support future capacity growth of the business customer, RFoG may offer an

alternative to traditional fiber solutions.

The use of RFoG and DOCSIS may be an excellent combination because this includes an all-passive optical network direct to the business, which incorporates the redundancy schemes found on high-end CMTS equipment. These redundancy schemes may not always be available on Ethernet switching or PON network elements. The business service unit will also consider back office implications of each network technology alternative and the costs and time to market to support the expected explosive growth in coming years...

GLOSSARY

continued from page 1

scheduling technology to transport data from an optical line termination (OLT) device to a set number of optical network termination (ONT) units at the premises. Upstream signals are combined using a multiple access protocol. It is contrasted with more capital-intensive point-to-point (P2P) architectures.

BPON: Broadband PON. One of three PON recommendations issued by the International Telecommunications Union, BPON (ITU-T G.983) is the successor to asynchronous PON (APON). BPON supports the 1550m broadcast overlay. It specifies 622 Mbps downstream data on 1,490 nm

and 155 Mbps on 1,310 nm upstream. It is the PON standard that Verizon initially deployed with FiOS until approximately November of 2007. Its successor is ITU-T G.984 (GPON).

GPON: Gigabit PON (ITU-T G.984); the successor to BPON. It provides for transport of asynchronous transfer mode (ATM), time division multiplexing (TDM) and Ethernet, but has effectively shifted over several years to primarily an Ethernet standard, operating at 2.488 Gbps downstream and 1.244 Gbps upstream. Verizon began deploying GPON in late 2007 and standardized on GPON for

all new deployments in early 2008. ITU-T SG15 (Study Group 15) has adopted IEEE 10GigEPON (P802.3av) as the foundation for its Next Generation (NG-PON) recommendations.

EPON: Ethernet PON (IEEE 802.3ah). EPON initially supported 100 Mbps symmetric and has evolved as Gigabit Ethernet (sometimes called GE-PON) to support 1 Gbps symmetrical, with dual-speed EPONs capable of 2.5 Gbps/1 Gbps. The IEEE 10 Gbps EPON study group (P802.3av) is completing work on the first 10G/1G standard, with chipsets expected in 2009. A number of cable operators

already have deployed EPON to serve business customers.

DPON OR DEPON: DOCIS over EPON. A combination of EPON and DOCSIS that leverages a cable operator's DOCSIS networks and operational support systems (OSSs). While RFoG relies on a CMTS and RF transport (over optical), DPON moves the compatibility back to the OSS interfaces, making an EPON OLT look and act like a CMTS. While eliminating the need for the DOCSIS CMTS, it offers seamless compatibility for provisioning and operations. Unlike RFoG, it will support EPON data rates up to 10Gbps/1Gbps. 