CT'S PON & RFoG TECH GUIDE

July 2009

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RFoG/PON: Review Essay

In retrospect, the timing looks bad. The SCTE Advanced Plant Architecture Study Group, established to determine standardization needs for the increased use of fiber in cable plant, held its inaugural meeting at Cable-Tec Expo in June 2006.

The misalignment had to do with economic fundamentals. "It's over," *Fortune* Senior Writer Shawn Tully wrote in May 2006. "The great housing bubble has finally started to deflate."

The booming housing market had been a primary driver for fiber-to-the-home (FTTH). Real estate developers had encouraged telecommunications providers to pull fiber, especially to homes in planned communities. Technologies such as RF over Glass (RFoG) were designed to accommodate those requirements while supporting existing cable infrastructure, products and services.

Yet the housing market continued to deflate. By June 2009, the U.S. Census Bureau reported that new housing construction for April 2009 hit a 50-year low.

Hard as it has been to acknowledge, that economic collapse removed a once-looming opportunity. One consolation prize: The contraction in demand did give those developing cable's emerging RFoG standard some breathing room.

Like any committee effort, standards work takes time. The chairman of Working Group 5 of the SCTE Interface Practices Committee (IPS) predicted last summer that the work on RFoG, known formally as IPS910, would be completed by spring 2009. Drafts have advanced, significantly in ways that created compatibility between Ethernet Passive Optical Networking (EPON), 10G-EPON and RFoG, but work yet continues.

ON THE OFFENSIVE

Housing downturn notwithstanding, several countervailing trends were also at work.

Although large MSOs insist on the viability of the HFC architecture, especially when enhanced with DOCSIS 3.0 channel-bonding technology, competitors such as Verizon have continued to overbuild fiber into residential neighborhoods, shifting customer expectations and behavior in ways that put the cable industry on the defensive and make them attentive (if quietly) to developments in FTTH and PON technologies.

Two other trends put operators in a more offensive posture. First, policy shifts in Washington, D.C., favoring the expansion of broadband to rural and underserved areas put some wind into the sails of FTTH-related technology.

True, wireless technology is a strong contender for funds tied to the Broadband Stimulus package, but several operators have proven business cases with pre-standard RFoG related solutions in low-density markets using equipment from Alloptic, Aurora, Cisco, and CommScope. Manufacturers of various fiber components have announced acceptance by the USDA's Rural Development Telecommunications Program.

Second, the same economic downturn that cratered housing and shifted government policies has had a generally positive impact for the delivery of business services.

Small, medium and large business alike have cut expenses for travel and now rely more heavily on conference calls and online meetings and collaboration. Businesses that are seeking to reduce their operational expenses have looked beyond their incumbent local exchange carriers (ILECs)

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Glossary

RFOG: Radio Frequency (RF) over glass is 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.") 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) scheduling technology to transport data from an optical line termination (OLT) device to a set number of optical network termination (ONT) units at

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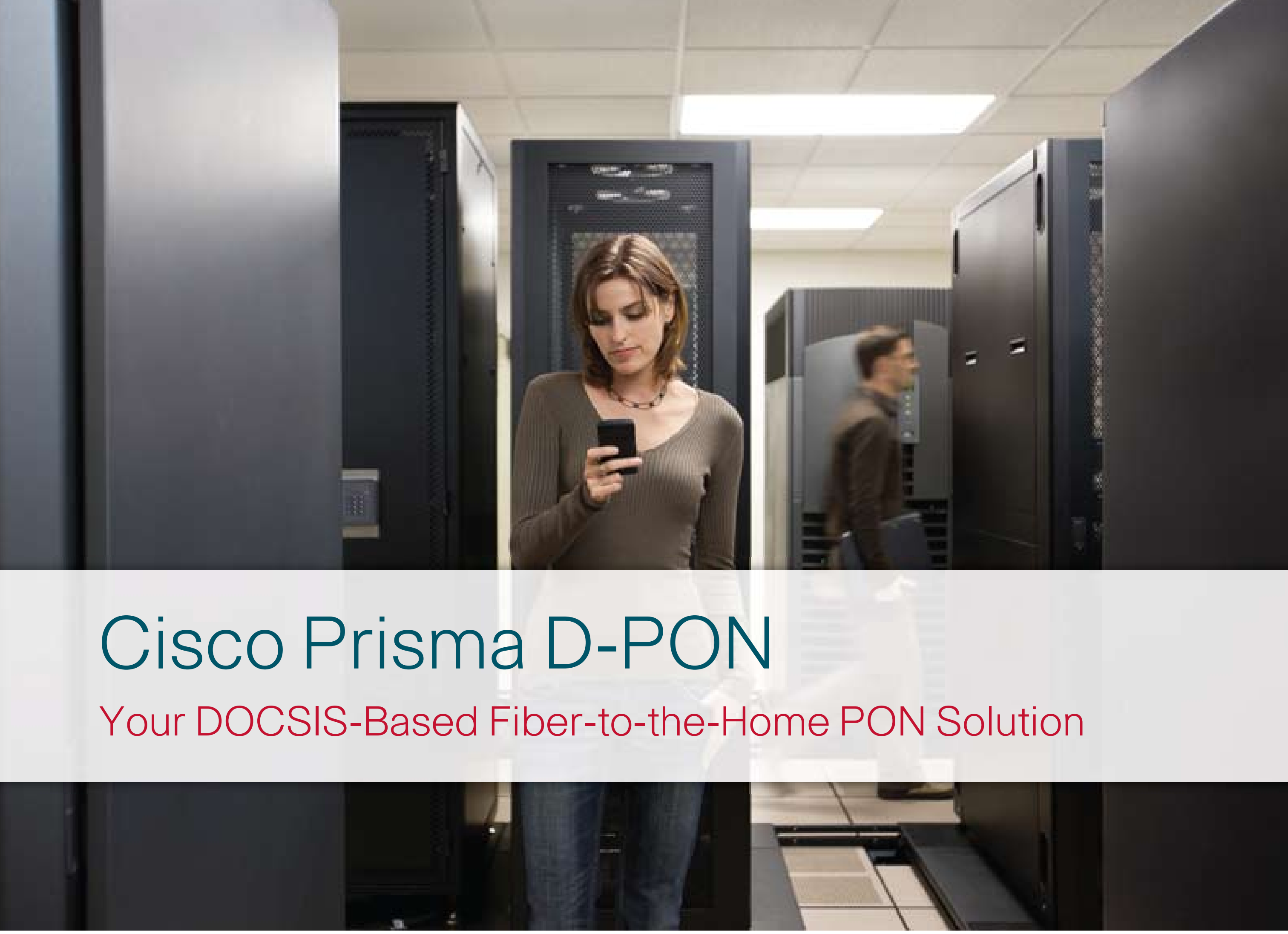

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The cable industry has been the beneficiary of much if not all of that growth. Years of work in the business services market—more than a decade for Cox Communications—has intensified across the board for operators and vendors alike. Several indicators would be the distance learning, telehealth and telepresence exhibits seen in various venues at The Cable Show in April this year.

So while FTTH has been put on the back burner, fiber to the premises (FTTP)—or to outposts of business premises, even competitive ones, such as cell towers—is growing significantly. As it happens, it was in business services that EPON first emerged as a solution in cable. For services beyond the capabilities of DOCSIS 3.0 and RFoG, MSOs are now looking to EPON as a way to serve those same business customers.

DOCSIS OVER EPON

As MSOs scale their business services, the challenges of FTTP operations will look increasingly like those they've faced before with DOCSIS. This is the challenge of quickly deploying, provisioning and supporting services. Thus, the still-emerging DOCSIS over EPON market.

In *CT*'s first RFoG/PON tech guide, published last October, there was a single entry in this category from Hitachi Communications' Salira Systems group. In April this year, two months after Motorola became the exclusive distributor for its RFoG products, Alloptic announced the availability of its DOCSIS PON Controller (DPC) software, designed to enable DOCSIS provisioning and control of its EPON system.

In May, two months after entering the RFoG market with its FTTMax 1000 optical network unit (ONU), ARRIS launched an EPON optical line terminal (OLT) and EPON ONU as extensions to its CHP Max 5000 chassis.

Adding validity—and generating buzz at The Cable Show—was an announcement at the event by chipset vendor Teknovus of a DOCSIS Mediation Layer (DML) technology. In effect a middleware, it enables system vendors to run DOCSIS OSSI service interfaces, PacketCable and PacketCable Multimedia on existing GigEPON and future, forthcoming 10G-EPON systems.

This development at the chip level is likely to drive the production of additional products based on the same technology, as it facilitates the entry of any systems vendor into the MSO market. Dozens of vendors already are supplying tens of millions of ports in Japan, Korea, and now China. (See sidebar, page 7.)

> "Several operators have proven business cases with pre-standard RFoG... in low-density markets."

At least some of the largest suppliers are likely to develop those some products, with some software accommodations, for the U.S. MSO market.

STANDARDS: IEEE, SCTE

Meanwhile, the 10G-EPON standard, IEEE P802.3av, is progressing as expected. The task force should complete its work early this fall. Once the standard is approved, product announcements and products themselves should follow.

The initial 10G-EPON standard will support a 10 Gbps downstream channel, 1 Gbps downstream channel (to be compatible with existing EPON in place), and a shared 1 Gbps upstream channel for both existing 1GigEPON ONUs and new 10/1GigEPON ONUs. The 10Gbps capability opens the door for even more substantial and larger business.

The standard also positions 10G-EPON as the most suitable and scalable access technology for 4G cell tower backhaul services. EPON is already in use for 2.5G and 3G cell tower backhaul in the United States and abroad. With the shift to 4G and focus on mobile broadband, the demand for backhaul will push beyond the single-digit Gbps barriers of EPON, GPON, and SONET.

Which technology will be able to support the need for hundreds of Mbps for multiple sites on a single strand of glass? Possibly the only candidate for that role is 10G-EPON.

As mentioned, SCTE's IPS WG 5 continues its work on RFoG. The sustained appeal of RFoG is the proposed capability to support FTTP or FTTH by operating gateways at both the hub and customer premises site that would support existing forward and reverse optical systems at the hub site and coaxial-based devices, including both unidirectional

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and bidirectional set-top boxes and DOCSIS devices, at the customer premises.

RFOG APPLICATIONS

In the potential greenfield market, RFoG is appealing because of its light touch: In theory, nothing in the system would need to be changed except for the construction to the premises. As discussed at the outset, however, greenfields have all but dried up.

While that has left RFoG without its largest expected market, the technology is potentially useful for operators that might want to offer video services to fiber-based Ethernet customers. When the bandwidth demands justify it, DOCSIS over EPON is likely to supplant RFoG as the FTTH strategy of choice.

Yet RFoG will continue to be useful for operators for as long as there is an inventory of non-DOCSIS (DAVIC)-based set-top boxes. With inventories in the tens of millions, many of which are new HD and HD-DVR systems, the technology will have some shelf life.

An equally important application of RFoG is the use of FTTH in more rural developments. (See above.) As homes-passed density drops, the cost of traditional HFC plant rises, as the number of amplifiers and length of coax copper plant rises. With the rising price of copper and falling fiber costs, most new rural development is more cost-effective with fiber. Once the cost of active plant powering and supporting operational costs are considered, passive fiber solutions become even more attractive.

In a rural development with, for example, a dozen or so homes in a 20 km span, RFoG could offer both a lower cost and, with DOCSIS, more than enough bandwidth for 12 subscribers.

Yet a combination of challenges continues to add on the complexity to RFoG. Operators have been surprised to find some RFoG systems are only compatible with DSG and DOCSIS and not DAVIC. Other RFoG systems support DAVIC and DOCSIS 1.0, 1.1, and 2.0, but do not support DOCSIS 3.0.

While economically proven in certain cases, a solution with FTTH using RFoG does requires expense, yet with no increase in available bandwidth. Limiting the future potential of such a network by not supporting DOCSIS 3.0 is a difficult strategy to support.

> “When that transition (to IP) occurs is a big question. One near-term appeal of RFoG is its link to the installed base of millions of non-DOCSIS set-tops.”

DOCSIS 3.0 having arrived, some RFoG solutions are now outdated. Solutions being explored could potentially support DOCSIS 3.0, but with added cost.

DOCSIS DILEMMA

PONs typically employ some type of scheduler to manage the transmission and reception from multiple transmitters and receivers on a shared or multi-access optical network. Unlike PONs, most RFoG technology (including the proposed RFoG standards) does not use a scheduler.

To keep costs down, most RFoG systems on the market simply turn on (burst) an upstream laser whenever they sense the beginning of an upstream DOCSIS or DAVIC transmission. These systems rely on the low data rates of DAVIC and DOCSIS and count on a statistically low chance (improbability) of the simultaneous transmission (collision) of two devices.

In DOCSIS, this is a reasonable assumption because the DOCSIS system itself manages each of the clients to avoid a simultaneous transmission. In the case of an actual collision, all of the data protocols allow for network level retransmission. DOCSIS 3.0 channel bonding allows for the independent and possible simultaneous transmission of multiple upstream channels.

DOCSIS 3.0 is different from DOCSIS 1.1 and 2.0 in that clients in a (shared) serving group can transmit at the same time (albeit on different channels). As a result, the probability of a collision (not in RF but) in the optical domain is significantly higher. If that were not enough, the variations in DOCSIS 3.0 configurations make it ever more challenging.

Take DOCSIS 3.0 upstream channel configurations, which allow for 3.2 MHz, 6.4 MHz, or 12.8 MHz wide channels in any variation adding up to a minimum of 12.8 MHz of combined upstream channel bandwidth. Vendors and operators developing the technology must struggle with the balance between keeping RFoG cost low and the need for forward compatibility.

An RFoG product not compatible with DOCSIS 3.0 defeats one of the principal goals of the initiative. If these challenges can't be met cost effectively, RFoG may be relegated to "video duty" for EPON and long-reach low-density rural applications.

CONCLUSION

Long-term, DOCSIS over EPON appears to have cost-structure advantages. Even today, an EPON ONU costs less than an RFoG gateway (or R-ONU).
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RFoG and PON at ET

Fiber continues to be a news item. Passive optical networking (PON) in particular is hot. A late May report by the Dell'Oro Group indicates that worldwide PON equipment revenues grew 9 percent sequentially in the first quarter of this year. (For more, see sidebar, page 7.)

RF over Glass (RFoG) also generated news, with several vendors announcing products designed to support it. (For more on RFoG vendors, see page 6.)

Despite all that, there was relatively little emphasis on fiber optics at the SCTE's Conference on Emerging Technologies this year. James Chen, CTO of Salira Systems, presented "DOCSIS Management of Ethernet PON Infrastructure," and Oleh Sniezko, CTO of Aurora Networks, presented "RFoG—How to Make It Work and How to Expand It." Both deal with evolutionary approaches to fiber, working with existing cable infrastructure rather than doing a prohibitively expensive wholesale rip-and-replace.

DEPON

Chen's paper advocates a DOCSIS over EPON (DEPON) architecture designed to enable EPON fiber access networks to be managed by existing DOCSIS infrastructure and operations support systems (OSSs). DEPON provides a middleware layer to translate DOCSIS management into language the fiber network can understand, thus preserving the cable operator's DOCSIS investments while expanding bandwidth.

Chen writes that DEPON can scale up available bandwidth beyond the capabilities of current DOCSIS 3.0 implementations and is cost effective. He also argues that the same concepts can be extended to include similar functionality for PacketCable 1.5, PacketCable 2.0, PacketCable Multimedia, L2VPN, Business Services over DOCSIS (BSoD), DOCSIS Set-top Gateway (DSG), and other operations built on the DOCSIS foundation.

RFOG

Sniezko's paper treats RFoG as a hedge against competition. It's essentially transitional technology designed to facilitate moving from HFC to FTTH, with the same RF signals appearing at customer outlets as in HFC networks. RF signals are carried via fiber to the premises, where they transition to coax.

Sniezko describes RFoG's current status, compares it with HFC, analyzes ways to make RFoG more appealing to cable operators, and presents some technical and architectural solutions intended to improve RFoG's performance and ease of operation.

	Vendor Name	EPON	RFoG	DPON
RFoG Only	Aurora Networks Cisco Systems Commscope		x x x	
EPON	ECI Telecom Huawei ZTE Pacific Broadband Networks Enablence	x x x x x	 x x	
DPON (DOCSIS + EPON) + RFoG	Hitachi Telecomm (Salira Systems) Arris Corporation Alloptic Networks	x x x	x x x	x x x

Note:
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.

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With multiple suppliers and now off-the-shelf chipset and middleware solutions, the economics of DOCSIS over EPON as a solution for 1Gbps now and 10Gbps later looks even better.

The key for DOCSIS over EPON success will be a transition to DOCSIS based set top boxes (Docsis Set-top Gateway) or ultimately a transition to IP-based video distribution. When that transition occurs is big question. One near-term appeal of RFoG is its link to the installed base of millions of non-DOCSIS set-tops. Or, at least, all RFoG products should be able to serve the base, as that is a major point the of initiative.

Perhaps the most significant development during the last year has been the effort to create compatibility for both EPON and RFoG. Neither standards is yet complete, current drafts would allow for the operation of both in parallel on the same fiber serving the same or different customers.

REPORT: PON MARKET SHINES

The Dell'Oro Group's "Access Quarterly Report" issued in May 2009 indicates that worldwide PON equipment revenues grew 9 percent sequentially in the first quarter of this year, despite a weak global economy. The report indicates that both GPON and EPON had robust sequential growth.

In a statement, Tam Dell'Oro, president of the Dell'Oro Group, said, "PON revenue growth in the first quarter was higher than what we had expected due to rapidly increasing EPON buildouts in China, strong GPON ONT shipments for Verizon's FiOS service, and continued strong EPON demand in Japan."

The report says that Mitsubishi remained the leader in the overall PON market, benefiting significantly from being the primary EPON supplier to NTT, Japan's largest service provider. Alcatel-Lucent recaptured the No. 2 position with higher GPON ONT shipments to Verizon. Huawei's revenue share nearly doubled from last quarter, and the company vaulted to the No.3 spot because of strong EPON shipments to China, as well as higher GPON shipments to customers in Europe and the Middle East.

GLOSSARY

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the premises. Upstream signals are combined using a multiple access protocol. It is contrasted with more capital-intensive point-to-point (P2P) architectures.

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 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 Next Generation (NG) PON.

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 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 compatibility for provisioning and operations. Unlike RFoG, it will support EPON data rates up to 10Gbps/1Gbps.

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- Trans Max- Outdoor Optical long haul transmission platform and components

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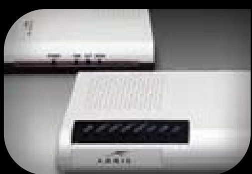

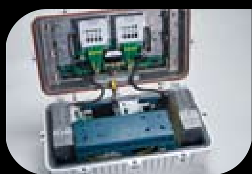
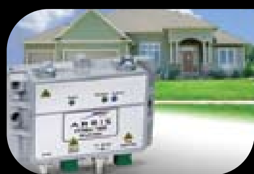

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