Responding to Verizon FiOS

SCTE Cable-Tec Expo®

2008

Abstract

Verizon's FiOS product offerings in residential and commercial services are a threat to MSO business. Their BPON technology can offer a dedicated 20Mbps/5Mbps per subscriber. Verizon could honestly offer a 236Mbps downstream product using the same oversubscription ratio that we use today. Even with DOCSIS® 3.0, an enormous expense would be required to build serving groups of only 10 subscribers sharing four DOCSIS channels to achieve comparable services. Verizon's FiOS service is just beginning deployments of GPON which will offer 2.488Gbps/622Mbps or four times the capacity of their BPON platform.

DOCSIS 3.0 will allow MSOs to continue to offer competitive products with FiOS up to 160Mbps. The good news is that is we have life left in our technology as we grow from 20Mbps to 160Mbps or eight times the product demand we see in competitive markets today.

Cable can compete with Verizon's FiOS product offerings using the same EPON technology currently being used in cable for commercial customers with data rates up to 1Gbps/1Gbps. Retaining our existing service platform, tools, and processes we can build a competitive edge through the adoption of DOCSIS over EPON technology to extend our OSS support to EPON and simultaneously offer high-end Ethernet services for commercial customers on the DOCSIS service platform. With a combination of MEF on DOCSIS and DPON, our existing OSS can further the competitive edge for cable competition with FiOS.

Victor R. Blake

victorblake@victorblake.com

http://victorblake.com

Table of Contents

Introduction

Verizon's FiOS product offerings in residential and commercial services are a direct threat to the growth and even sustainability of the existing MSO commercial services and residential subscriber base. FiOS is both a tactical threat and a strategic threat. The vast majority of FiOS deployments to date have been based on BPON technology that is capable of 622Mbps downstream and 155Mbps upstream line rate. With 32 subscribers on a PON, BPON can offer nearly 20Mbps/5Mbps per subscriber. That's the equivalent of one-half of a DOCSIS 256QAM DS / 16QAM upstream pair MSO's currently offer shared across hundreds of subscribers. Verizon could honestly offer a 236Mbps downstream product using the same oversubscription ratio that we use today. Even with DOCSIS 3.0, an enormous expense would be required to build serving groups of only 10 subscribers sharing four DOCSIS channels to achieve comparable services. Verizon's FiOS service is just beginning deployments of GPON which will offer 2.488Gbps/622Mbps, or four times the capacity of their BPON platform.

DOCSIS 3.0 will allow MSOs to continue to offer competitive products with FiOS up to 160Mbps—the data rate possible with the specification's minimum bonding requirement of four downstream 256 QAM channels. The good news is that is we have life left in our technology as we grow from 20Mbps to 120Mbps or eight times the product demand we see in competitive markets today.

The competitive threat for FiOS in commercial service is even more immediate. The commercial services and high-end residential products are all based on the same technology. Cable can compete with Verizon's FiOS product offerings. Today cable operators offer EPON-based services for commercial customers with data rates up to 1Gbps/1Gbps. With dual-speed EPONs, cable can offer 2.5Gbps/1Gbps on their existing or new EPON deployments. The IEEE 802.3av 10GigE Study Group is making progress on a 10Gbps/1Gbps EPON that will beat the telco technology to market and offer greater capabilities than GPON with lower costs.

Cable's response to competitive commercial services is technically and economically competitive with Verizon's FiOS offerings. Cable's competitive advantages with EPON include lower capital equipment costs, more stable and reliable technology and products, and a lower cost operational model based on the proven and reliable technology of EPON. The marketplace for components and systems is mature and stable.

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

The Threat

Verizon's FiOS product offerings in residential and commercial services are a direct threat to the growth and sustainability of the existing MSO commercial services and residential broadband subscriber base. The vast majority of FiOS deployments to date have been based on BPON technology that is capable of

622Mbps downstream and 155Mbps upstream line rate with some reduction to transport data rate for ATM overhead. With 32 subscribers on a PON, BPON can offer nearly 20Mbps/5Mbps per subscriber. That's the equivalent of one-half of a DOCSIS 256QAM DS / 16QAM upstream pair that is shared across hundreds of subscribers. Verizon could honestly offer a 233Mbps downstream product using the same oversubscription ratio that we use today for a 15Mbps tier on DOCSIS 1.1 256QAM channel (see Table 1). A very aggressive MSO network might have 75 subscribers on one such DOCSIS 1.1 serving group. Although I know of no MSOs deploying serving groups with only 32 subs, I compared that best case scenario as well in Table 1.

	Cable (DOCSIS 1.1 no DCC)	FiOS (BPON)
Access BW Line Rate	40Mbps	622Mbps
Advertised BW DS Per Subscriber	15Mbps	15Mbps
Typical Oversubscription Ratio	(75 Subs x 15 Mbps) / 40 = 28.125/1	(32 subs x 15Mbps)/622Mbps <= 1/1 NOT oversubscribed.
Cable's Best Case Oversubscription Ratio	(32 Subs x 15 Mbps) / 40 = 12/1	(32 subs x 15Mbps)/622Mbps <= 1/1 NOT oversubscribed.
Maximum Bandwidth Per Subscriber with No Oversubscription	40Mbps/75 = 546kbps	622Mbps/32 = 19.44Mbps

Table 1. Oversubscription ratio and current product

Another way of describing it is that Verizon is offering a matching advertised bandwidth with 15.6 times or 1,560% more bandwidth (see Table 2)

	Cable (DOCSIS 1.1 no DCC)	FiOS(BPON)
Shared BW Line Rate	40Mbps	622Mbps
Bandwidth Offering Per Subscriber with a 12/1 Oversubscription	15Mbps (32 subs per SG))	234Mbps (32 subs per PON)

Table 2. Verizon FiOS offering using cable's oversubscribed computation.

With DOCSIS 3.0 at 160Mbps using four broadcast downstream channels we could honestly offer a comparable product if we offered a 15Mbps product with no more than 10 subscribers per serving group. That's four 6MHz downstream channels for every 10 subscribers. A division with 1M HSD subs would require 100,000 serving groups to accomplish this. Anything short of that is a marketing tactic more than a technical comparison.

	Cable (DOCSIS 3.0 w/4 channels)	FiOS(BPON)
Shared BW Line Rate	160Mbps	622Mbps
Advertised BW DS	15Mbps	15Mbps
Bandwidth Offering Per Subscriber with No Oversubscription	(15Mbps x 10 subs)/160Mbps <= 1/1 NOT oversubscribed	(32 subs x 15Mbps)/622Mbps <= 1/1 NOT oversubscribed.
Network Description	DOCSIS 3.0 4x 6MHz DS with 10 subscribers	BPON with 32 subscribers per PON or GPON with 128 subscribers per PON

Table 3. Fictional cable offering using Verizon's non-oversubscribed computation.

But it's even worse than it looks. That's because the FiOS (and all PON technologies) do not typically share their access bandwidth until the cumulative total of provisioned bandwidth exceeds the number of subscribers on the PON. So even if we assume the maximum BPON and GPON split ratio of 1:32 (or 32 subscribers on the PON), they can offer up to 19.4 Mbps with NO OVERSUBSCRIPTION. If Verizon were to use the "cable math" of oversubscription, they could say that their product today is 233Mbps product. That's the performance capability we are competing against.

So why doesn't Verizon offer this? Basically, they do their math different than cable. And their math is done the way we do our commercial services math. And it really does not matter right now, because most Internet applications could not take advantage of the higher bandwidth capabilities that they could offer. With current products already at 50Mbps (downstream) in competitive markets, the challenge of Verizon's platform capability is immediate.

Comparing Costs

In the long run competitors need to offer the services that subscribers demand. If the market demands less elasticity in the bandwidth offering (a less oversubscribed service), that will be what providers need to offer. As Internet applications continue to consume more bandwidth and additional un-attended devices get added to the home, the increasing bandwidth demands and service compromises of high peak-to-mean ratios (elasticity) will become less tolerable for many subscribers.

When this occurs, cable operators will need to continue to expand the bandwidth capabilities. This can be done with DOCSIS 3.0. In Table 4 below I show what could be a typical configuration to provide a 15Mbps dedicated bandwidth service based on DOCSIS equivalent to a 15Mbps PON-based service.

	Cable (DOCSIS 3.0 w/4 channels)	FiOS(BPON)
Shared BW Line Rate	160Mbps	622Mbps
Advertised BW DS	15Mbps	15Mbps
Bandwidth Offering Per Subscriber with No Oversubscription	(15Mbps x 10 subs)/160Mbps <= 1/1 NOT oversubscribed	(32 subs x 15Mbps)/622Mbps <= 1/1 NOT oversubscribed.
Network Description	DOCSIS 3.0 4x 6MHz DS with 10 subscribers	BPON with 32 subscribers per PON or GPON with 128 subscribers per PON
Ratio of Fiber Strands to Subscribers	1:10	1:32 or 1:128
Capital Construction Cost to the Node Comparison	320% of Verizon Cost	3% of Cable Cost
Capital Construction Cost to the Subscriber	$	$$$$

Table 4. Comparing Construction Costs.

We can see that DOCSIS is capable of competing at this level. At a comparable service level, DOCSIS uses more fiber and is, therefore, more costly. Beyond the fiber costs, the DOCSIS technology itself is more

costly per Mbps than any of the PON technologies. (Although Verizon's BPON and GPON technology, and the products they use, are by far the most costly of all of the PON technologies--more on this later.)

The challenge for cable will be to continue to follow the needs of its broad base of subscribers, but also remain slightly ahead of the demand by anticipating the needs for emerging applications. Cable is well positioned to do this by observing the bandwidth needs and trends of its own embedded base of early adopters. This is well represented in cable by the typical 7% to 15% of subscribers that take premium service offerings. As it turns out, these same subs correlate highly with the highest ARPU base.

Four Times the Threat

The biggest risk for cable has just begun. Verizon's FiOS service is just beginning deployments of GPON which will offer 2.488Gbps/622Mbps or four times the capacity of their BPON platform. This April Verizon announced that they will continue to grow their BPON platforms in facilities already using BPON. For all new facilities that do not currently have PON service, they will cease new BPON site deployments and begin all-GPON deployments.

Clearly DOCSIS 3.0 will allow MSOs to continue to at least market a competitive product with FiOS up to 160Mbps. The good news is that is we have life left in our technology as we grow from 20Mbps to 160Mbps or five times the product demand we see in competitive markets today.

Unfortunately the competitive threat for upstream bandwidth is a possible, more imminent concern. Even with DOCSIS 3.0, upstream bandwidth is at best limited to 40Mbps of shared bandwidth or 12.8MHz of bandwidth possible at 16QAM. Fortunately the ratio of downstream to upstream traffic appears to be on a path that keeps it within the 4:1 parameters that both the DOCSIS and BPON standards were designed to offer.

Other Competitors

It isn't just Verizon that is using FTTH. In April of 2008, AT&T confirmed (at OFC/NFOEC 2008) that they are deploying BPON for most Greenfield applications. They continue to field trial GPON and are likely to move to GPON deployments for new build within the next year. In the US, some small telcos, power companies, and even competitive cable operators have started using PON technologies for customer access technology.

Interestingly, PONs are now being used for wireless backhaul. This will indirectly lower the costs of wireless (voice, data, and video) backhaul – allowing wireless operators to more readily compete with cable for broadband data and voice services. Verizon wireless is already heavily using the "FiOS" (BPON) access network for cell tower backhaul.

It's also true that wireless backhaul can be (and is) a great application for cable operators to develop strong revenues from their PON networks. SONET and even Ethernet over CWDM backhaul will not have sufficient capacity to meet the needs of 4G networks. As cell tower densities increase, SONET and all of

the dedicated P2P architectures will not scale because of fiber exhaustion. 10GigE PON will offer multiple tower backhaul for 4G on a single strand of glass leaving a hub (facility).

Cable's Response: Timing Is Critical

In the long term, the distinctions between the performance capabilities of the networks will become more evident. It may well be that timing of when to invest in FTTH will benefit cable. If it turns out that their performance advantages are not really necessary (are excessive) now, then cable's decision to delay the spending for FTTH will retrospectively be a wise decision. The risk with timing is that it does take time to design, develop, and deploy new technologies, products, and services. If cable times its FTTH too late, it could lose market share. This is something we have seen historically as many dial-up operators failed to time their transition to broadband (although this was complicated by the lack of a UNE arrangement for xDSL and no unbundling in cable). Today we are also seeing another example as users abandon their primary line telephone service in favor of cellular service.

Commercial Services Threat

The competitive threat for FiOS in commercial service is even more immediate. Today, Verizon already is offering commercial products over FiOS that simply cannot be offered in DOCSIS 1.1. They also offer products that cannot be guaranteed even with DOCSIS 3.0. Below the limits of DOCSIS 3.0, DOCSIS remains a cost-competitive technology, but above the limits of DOCSIS 3.0, MSOs must use alternative technologies. That is exactly what MSOs are doing.

The Response: EPON, the Next Generation Access for Cable

Commercial Services EPON Deployed

From a technology perspective the commercial services and high-end residential products are all based on the same technology. Cable can compete with Verizon's FiOS product offerings. Today, cable operators offer EPON-based services for commercial customers with data rates up to 1Gbps/1Gbps. With dual-speed EPONs, cable can offer 2.5Gbps/1Gbps on their existing or new EPON deployments. Cable's choice of EPON is not only economically attractive, but will scale faster than the ITU-T GPON specification. The IEEE 802.3av 10Gbps Ethernet PON study group[1] was initiated in March of 2006 with the support of chip vendors, system vendors, and operators including a North American MSO.

EPON Economics

Cable's response to competitive commercial services is technically and economically competitive with Verizon's FiOS offerings. Cable's competitive advantages with EPON include lower capital equipment costs, more stable and reliable technology and products, and a lower cost operational model based on the proven and reliable technology of EPON. The marketplace for components and systems is mature

[1] IEEE P802.3av Task Force on 10Gbps Ethernet Passive Optical Network. See http://ieee802.org/3/av/index.html.

and stable. Cable's selection of EPON technology will also scale faster to 10Gbps/1Gbps and later 10Gbps/10Gbps than the GPON technology. Joining in the global marketplace for EPON technology, cable will also benefit from the technological innovation, scale of manufacturing, and quality joining with the cable and telco communities in Japan, Korea, India, China, and portions of Europe that have already deployed some 12 million plus subscriber lines. The combined markets of these regions that have committed to EPON added to the North American MSO community will grow to somewhere between 100 and 210 million EPON subscriber lines.

	Cable Subs (Broadband and/or CATV)	**Population**	**BB Penetration**	**Estimated EPON FTTB Candidates** (BB Penetration – FTTH candidates / avg. MDU) Set avg MDU to 64.	**Estimated EPON FTTH Candidates** (from telco and cable in countries where telco is adopting EPON)
China	144	1,321	51	6.8	20 to 80
Japan	*Cable & Telco using EPON*	127	28	1.6	25
Korea	*Cable & Telco using EPON*	49	15	<1	8.5
India	*Cable & Telco using EPON*	1,129	2.5	unknown	20 to 70
US	56	301	64.6	0.25	18
			Sub-Totals	9	91 to 201
			Total		100 to 210

Table 5. Cable subscribers by market (All numbers in millions)[2].

Table 5 shows only direct EPON candidates. It doesn't include the likely use of EPON for FTTB for MDUs without FTTP/FTTH. If EPON is this successful (and all of the growth and trend charts show it being so), it will clearly become a commodity technology. We know from the history of technologies like Ethernet

[2] Most statistics in this chart are from http://www.internetworldstats.com/.

itself, that commodity technologies can dominate, even where they are judged to be academically inferior.

EPON will be to GPON what Ethernet is to ATM, the clear winner economically, technologically, and practically.

Lower Capex

EPON's tactical advantage right now is its high volume based on the global adoption of EPON technologies. EPON was purposefully designed to be a low-cost commodity technology. Like the other IEEE 802.x Ethernet standards, the intellectual property behind EPON is royalty free and based on established and proven technologies that can be manufactured in mass at low cost. With lower component laser and chipset costs, the overall product cost for EPON is dramatically lower than competing BPON and GPON technology. If we compare a dual-speed EPON solution (which is 2.5Gbps) to a comparable GPON solution, we find that the cost of the ONU is grossly 1/10th the cost.

Even as Verizon continues to expand its GPON rollout, their prices have not dramatically improved. With the exodus of Tellabs from the GPON business, Alcatel-Lucent and Motorola remain their only two primary suppliers. Globally, a number of vendors still offer GPON, but among those we are already beginning to see dual product offerings. The following companies originally introduced GPON products only, but are now offering both GPON and EPON products.

- Fujitsu
- Hitachi
- Nokia Siemens Networks (NSN)
- ECI Telecom (the #1 provider of DSLAMs to DT and #2 to FT)

In addition, a number of formerly GPON only vendors are actively working on new EPON products. The list includes nearly every GPON vendor except for Motorola[3] and a number of formerly BPON only vendors. Notably Alcatel-Lucent and NSN are very active in the IEEE P802.3av 10Gbps Ethernet PON Task Force.

Although we cannot underestimate the value of price sensitive standards development, the most significant factors influencing EPON has been its stability as a standard and its wide deployment. EPON is widely deployed with over 11 million ports installed. It is by far the most dominant PON standard globally. GPON market share is simply a replacement for the market share previously held by BPON. Even accounting for GPON's potential growth to all of Verizon's high ARPU markets, it will pale by comparison to EPON's market in Japan, Korea, China, India, and not least North American MSOs.

[3] I have no public information stating that Motorola is working on an EPON product. If they are, they have not publicly disclosed such.

Lower Opex

EPON's tactical advantage right now is its high volume based on the global adoption of EPON technologies. That volume also translates directly into operational cost savings. As a widely deployed and proven technology there are fewer problems in hardware, software, and overall system maturity. In my own experience this was evident from lab trials conducted with one of my customers in cable. Many of the new technology "bugs" have been found and corrected by previous customers. Despite EPON's status as a new technology to cable, it is far from new. EPON will offer as little technical challenge to cable as 10GigE was compared to 1GigE. Like any good mature technology, there are a wide variety of both lab-based and field test sets and tools available that are specific to EPON. There are also mature product and training technology programs and literature available. An outstanding example is the FTTx PON Technology and Testing[45] (2005) text, offered to operators free of cost by EXFO. Note the date, yes, it was published in 2005. That's how long this technology has been widely available and deployed.

EPON technology is also more stable than the competing GPON technology. While both the GPON specifications themselves, and most especially their service overlay standards (FSAN), continue to undergo changes, EPON has remained stable.

The next generation EPON technology, IEEE P802.3av 10Gbps Ethernet PON will be 100% backwards compatible with existing EPON technology on the same PONs. Although there are obviously underlying PHY improvements, and some very minor service distinctions (to allow for greater split ratios and higher data rates) the change will be transparent to operators.

Technology Leadership

The MSO community has distinguished itself as a strong proponent of IEEE and IETF industry-standard technologies. Cable's adoption of IP/Internet architecture was much more rapid and thorough than its telco competitors. With voice service, cable adopted VoIP to the customer premises long before telcos, who still use PSTN technologies.

Although cable has in the past taken some technology risks, these have largely been the risks of OAM&P integration and scaling. Again, VoIP is an excellent example. With VoIP, cable did not take any technology risks on the use of CODECs, interconnection architectures, and Class 5 features or services. Instead, cable took on the limited risk of OAM&P integration and scaling of VoIP. In the process of doing so, the cable community developed valuable experience overlaying a new service onto an existing network. There were no significant challenges to whether VoIP worked or not. But there were many

---

[5] Girard.

challenges to reducing the installation time, cost (provisioning) and enabling the remaining administration, operations, and maintenance – including performance and quality monitoring.

EPON will be a similar challenge for MSOs. There is no technology risk as to whether it will work. Like VoIP, it is a cost-effective solution that can be integrated with the existing IP service architecture and even the fiber distribution plant for 1550nm forward video broadcast. While there are some small challenges for two-way video return, the bulk of the technical challenge is in OAM&P.

As the MSO community has done before, we can come together to develop a common service interface for EPON that meets our specific needs.

Technology Advantage

IEEE 802.3ah and 802.3av are Ethernet protocols just like 802.3z (GigE). They are simple transport-oriented protocols that like service-provider specific OAM&P. Just as the Metro Ethernet Forum (MEF) is adding service layer overlay standards, so to must the MSO community build an overlay for EPON. The telcos are building a service overlay standard for GPON which they call FSAN.

Cable's competitive advantage is that it already has a strong and mature service overlay technology called DOCSIS. Within the DOCSIS family there is embedded best-effort HSD service and voice with Packet Cable 1.5. With Packet Cable 2.0 there will be available deep and more service agnostic QoS for multimedia services.

Today, DOCSIS is a value meal package. It includes the service overlay layers, the MAC, and the various PHYs. Although DOCSIS was originally organized as a vertically integrated protocol family, we can clearly identify some of the familiar looking OSI-like boundaries that separate the MAC from the PHY and the service control from the MAC. These layers have been even more explicitly peeling away as we have added new PHYs such as SCDMA in 2.0, and later the MULPI transport overlays in DOCSIS 3.0. The one technology that is a cross-layer technology is the Service Identifier. (SID).

It is no accident that the one cross-layer technology in EPON is the analogous Logical Link Identifier or LLID. The simplest way to explain an LLID is that it can do everything a SID can do. The only challenge is that EPON ONUs are typically limited to a few or slightly more LLIDs. But just like SIDs, LLIDs are deterministic and scheduled with ATDMA. They are not probabilistic (like 802.1p and other QoS queuing schemes).

Cable has the distinct advantage of being able to create a seamless transition with the continuous use of DOCSIS services from the existing DOCSIS/HFC network to a next-generation DOCSIS over EPON network. All the while we will need to run only one OSS. And we can offer all of the same services (expect of course at lower data rates in some cases) to both DOCSIS-RF and DOCSIS-EPON customers.

Growing and Extending DOCSIS Capabilities

What is DOCSIS anyhow?

DOCSIS is composed of a PHY, MAC, service control, and a set of OAM&P interfaces including primarily the Operations and Support System Interface (OSSI) and Cable Modem CPE Interface(CMCI). It is also used colloquially to refer to the larger set of CableLabs® standards including PacketCable™, Packet Cable Multimedia (PCMM), and even DOCSIS Set-top Gateway (DSG). Together these provide for all of the pieces for triple-play services. As with many cable technologies, DOCSIS is a vertical technology, which in many instances defies the rules of the Open Systems Interconnect or OSI model that we often make reference to in standards-based networks. These are the so-called Layer 1, Layer 2, Layer 3, etc. – up through Layer 7 functions.

Operational Advantages in Scaling and Extending DOCSIS

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

Continuous Transition

To accomplish a continuous transition plan, we need only be able to make an EPON OLT look and act like a CMTS. All of the EPON technology in the OLT and the ONU can be hidden behind the OLT acting like a CMTS. This is possible because all traffic going to and from an ONU must, by definition, pass through the OLT. So the complexities of the service interfaces in CMCI, for example, can be hidden by the OLT. The outcome is that an EPON system running DOCSIS over EPON can make an ONU act like a cable modem, using CMCI, without a single code change to existing and shipping ONUs!

The DOCSIS standards already anticipate possible new PHYs. Much of the work of Modular-CMTS (M-CMTS) could be readily adopted to add EPON as a new PHY shelf to a modular CMTS system. In fact, this is exactly the kind of architectural approach some vendors, like Cisco Systems, could offer. This may have been the method that Alon Bernstein of Cisco Systems used when he demonstrated a 1Gbps EPON-based cable modem which he called "DOCSIS 4.0[6]"

Because of the way that EPON provides separate logical services with LLIDs, it would also be possible to run DOCSIS over EPON virtually on one port of the ONU, and configure another as a MEF-compliant Ethernet Line (E-Line) service – simultaneously. As we will see next, DOCSIS services will soon incorporate MEF functionality, so that we could eventually use the DOCSIS OSS to provision MEF services as well.

[6] Bernstein.

Adding Ethernet to DOCSIS

DOCSIS currently supports Layer 2 virtual circuits through the L2VPN protocol specified in DOCSIS 1.1 and 2.0 standards. With the advent of DOCSIS 3.0 these same services, and additional functionality, are offered under the Business Services over DOCSIS (BSoD) specification.

Today L2VPN and BSoD offer a point-to-point (P2P), Layer 2 VPN from the CM to the CMTS. From that point on, service providers are left to use off-the-shelf protocols to extend the L2VPN to its far-end destination (be it a MEF service or other).

Recognizing the limitation of this access only transport, the MSOs are actively working in the context of the CableLabs organization to incorporate MEF OAM&P compatibility into BSoD.

At the same time, some of the same MSOs (and others) are also operating EPON services for business solutions. Some of the EPON systems are MEF compliant, while others are not. Ultimately, it would be preferable to have a single solution that works across both the DOCSIS RF, and DOCSIS PON platforms. By incorporating MEF into DOCSIS (on existing CMTS) and working to do so for DOCSIS PON in the future, we can create an end-to-end system to provide seamless P2P and point-to-multipoint (P2MP) Ethernet services as outlined by the MEF. Today two vendors are already working on such products.

Ethernet transport services are not just for “commercial.” Ethernet could well be the fifth play in residential. Economics continue to drive more companies and employers to work at home or remotely. Challenges with software, configurations, and do-it-yourself IP-VPN solutions leave many companies looking for a simpler solution. MEF services to the home could be a significant market opportunity to add on a new service and create a new revenue stream in residential dwelling units, but funded by commercial business opportunities.

EPON Fits DOCSIS Service Architecture

EPON technology is familiar to cable engineers and technologists because EPON Logical Link Identifier (LLID) is quite similar to DOCSIS Service Identifier (SID) concept. EPON Optical Network Units (ONU)s can support multiple LLIDs. A prototypical deployment could include one LLID each for voice, video, Ethernet, and Internet access. EPON’s service model is well suited to fit the needs of our customers and cost competes with FiOS without sacrificing margins.

Deployment Strategy

The purpose of DOCSIS over EPON is to offer a seamless OSS, operations, and subscriber experience. It should make the product and service offerings transparent in all but performance capabilities. Each service provider’s economics are different. MSOs have varying labor, construction, permitting and franchise expenses or costs across their various systems and markets. Revenue opportunities and competition also vary by market.

Each MSO will have a unique and specific transition strategy that will likely vary by market. The most significant factors influencing an FTTH decision will include variations in constructions costs, the competitive market, and, most importantly, the timing of capital expenses.

Greenfield

The most logical case for FTTH for MSOs is in Greenfield. This is exactly the same strategy that we see both Verizon and AT&T using as they deploy FTTH in 100% of their Greenfield nationwide. Since most of the cost of FTTH is construction cost, the additional cost of FTTH becomes negligible compared to HFC construction. This is particularly so because most of the cost of construction is labor related, not based on materials.

Over the last few years many MSOs have been moving in this direction by moving fiber deeper in the HFC architecture, using conduits for new plant construction (to facilitate the lower cost addition of fiber later), and now actually deploying FTTH. Some cable operators have publicly announced their Greenfield FTTH strategy. Others are deploying FTTH without announcing it, and yet others are field testing the new architectures.

The most likely Greenfield FTTH will be those controlled by private developers who require FTTH and can, while the properties and roads are still in their ownership and control, prevent HFC and copper builds. Although the new housing market is slower today than in the past, the compounding affect of new housing construction will make avoiding this challenge impossible in the coming years.

Premium in High Density HP

As the dividing line between residential and business subscribers blurs, we may expect to see FTTH offerings priced as business services rates in residential markets. In short, if one of our residential customers is willing to pay the cost of a business service for FTTH, would we respond to that opportunity? The answer may be no now, but as we see the top 12% of our ARPU base threaten to move to our competitors, we may decide that the time is right to offer premium FTTH services. Verizon's continued raising of their FiOS product prices is solid evidence that among our premium customer base there is demand for such a service.

Premium in Lower Density HP

With lower HP density, this market will emerge later than in higher HP urban environments. But the ARPU here may on average be even higher because of the more homogenous geographic clustering of high-ARPU customers.

Urban and Suburban Mainstream

As data rate expectations in the market continue to raise the economic case, and ultimately the business demand, FTTH will move from early adopters to premium customers to the mainstream customer base representing approximately 48% to 50% of the HSD base in mainstream residential broadband. (The remaining 10% to 12% are premium and 40% or so may be the lite tier and low HP rural areas).

Remainder

We may never see a day when there is 100% FTTH for either telcos or MSOs. The homes passed density in some rural areas is cost prohibitively low. Because of their lower HP density, it will likely be more rational to serve these users with DOCSIS technology with lower subscriber counts per serving group, effectively offering high data-rate services. Nonetheless, FTTH could still have a place in these markets, particularly where there may be rural subsidies or where the lower opex advantages of FTTH make a solid case to eliminate the expense of long cascades of amplifiers and power systems in the coaxial plant. I would speculate that for as much as 40% of the broadband data subscribers of North American MSOs it will not make financial sense to move to FTTH for many years to come. Other options for these subscribers include wireless services such as IEEE 802.16d WiMAX (which I use myself).

Summary

In summary, a combination of DOCSIS 3.0 services in residential and EPON services in commercial can offer competitive products to the threat of Verizon's FiOS service. DOCSIS over EPON will over a seamless OSS and operational transition from DOCSIS over RF to DOCSIS over PON. With the DOCSIS over PON technology MSOs can time their introduction of PON services when it makes the most economic sense. In Greenfield deployments that might be right now. For overbuilds, it may vary depending on the ARPU and other revenues and expenses. DOCSIS over EPON can offer MSOs the opportunity to run their same OSS and back office system providing uniform services to 100% of their subscriber base, while also investing in a competitive forward capable technology. Combined with DOCSIS, EPON isn't just competitive, it is superior. The reduced operational costs of a single seamless OSS transition will translate into a lower cost basis and greater profitability for MSOs.

Abbreviations and Acronyms

ARPU	Average Revenue per User
ATDMA	Advanced Time Division Multiple Access
ATM	Asynchronous Transfer Mode
BPON	Broadband Passive Optical Network
BSoD	Business Services over DOCSIS
BW	Bandwidth
CODEC	Coder/Decoder
CM	Cable Modem
CMCI	Cable Modem to Customer Premises Equipment Interface
CMTS	Cable Modem Termination System
CWDM	Coarse Wavelength Division Multiplexing
DCC	Data Communication Channel
DOCSIS	Data over Cable Service Interface Specification
DPON	DOCSIS over Passive Optical Network
DSG	DOCSIS Set-top Gateway
E-Line	Ethernet Line

EPON	Ethernet Passive Optical Network
FSAN	Full Service Access Network
FTTB	Fiber to the Business
FTTH	Fiber to the Home
FTTP	Fiber to the Premises
GPON	Gigabit (Ethernet) Passive Optical Network
HFC	Hybrid Fiber/Coax
HP	Homes Passed
HSD	High-Speed Data
L2VPN	Layer 2 Virtual Private Network
LLID	Logical Link Identifier
MAC	Media Access Control
M-CMTS	Modular Cable Modem Termination System
MDU	Multiple Dwelling Unit
MEF	Metro Ethernet Forum
MSO	Multiple System Operator
MULPI	MAC and Upper Layer Protocol Interface
OAM&P	Operations, Administration, Maintenance and Provisioning
OLT	Optical Line Termination
ONU	Optical Network Unit
OSI	Open Systems Interconnect
OSS	Operation Support System
OSSI	Operations Support System Interface
P2MP	Point to Multipoint
P2P	Point to Point
PCMM	PacketCable Multimedia
PHY	Physical (layer)
PON	Passive Optical Network
PSTN	Public Switched Telephone Network
QoS	Quality of Service
SCDMA	Synchronous Code Division Multiple Access
SID	Service Identifier
SONET	Synchronous Optical Network
UNE	Unbundled Network Element
VoIP	Voice over Internet Protocol
WiMAX	Worldwide Interoperability for Microwave Access
xDSL	any variant of Digital Subscriber Line technology

References

Blake, Victor R. (2008).”DOCSIS over EPON: OSS integration and scalability with off the shelf EPON for Multiple System Operators,” OFC/NFOEC, San Diego.

Bernstein, Alon and Steve Gorshe (2008).” A Proposal for DOCSIS 4.0: The best of both worlds DOCSIS and PON.” SCTE Conference on Emerging Technologies,

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification Modular CMTS: Downstream External PHY Interface Specification.” CM-SP-DEPI-I05-070223

CableLabs, Inc. (2006). “Data Over Cable Service Interface Specification Modular CMTS: DOCSIS Timing Interface Specification.” CM-SP-DTI-I04-061222

CableLabs, Inc. (2005). “Data Over Cable Service Interface Specification Modular CMTS: Edge Resource Manager Interface Specification. “ CM-SP-ERMI-I02-051209

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification Modular CMTS: Operations Support System Interface Specification.” CM-SP-M-OSSI-I04-070223

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification 3.0: MAC and Upper Layers Protocols Interface Specification.” CM-SP-MULPIv3.0-I03-070223

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification 3.0: Operations Support System Interface Specification.” CM-SP-OSSIv3.0-I02-070223

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification 3.0: Physical Layer Specification.” CM-SP-PHYv3.0-I03-070223

CableLabs, Inc. (2007). “Data Over Cable Service Interface Specification 3.0: Security Specification.” CM-SP-SECv3.0-I03-070223

Frazier, Howard M. and Wael William Diab. (2006).“Ethernet in the First Mile: Access for Everyone,” IEEE Press, New York.

Girard, Andre. Ph.D. (2005). “FTTx PON Technology and Testing,” EXFO.

Kramer, Glen. (2005). “Ethernet Passive Optical Networks,” McGraw Hill, New York.

Next Generation Network Architecture, LLC (2004). “NGNA Plan: Integrated Multimedia Architecture. “ www.nextgennet.net