EPON AND DPoE: HELPING NORTH AMERICAN CABLE MSOs MOVE UP-MARKET IN BUSINESS SERVICES

STRATEGIC WHITE PAPER

For several years, North American multiple-service operators (MSOs) have been focused on the commercial services market in an effort to increase and diversify their revenue base. Having addressed the low end of this market with DOCSIS®-based offerings, cable MSOs recognize that continued expansion will require fiber access technologies that can help them deliver the reliability, scalability and bandwidth required for the midmarket and enterprise segments.

Many MSOs see passive optical networking (PON) as an ideal technology for supporting commercial services. In the US especially, Ethernet PON (EPON) is increasingly being adopted by MSOs seeking to address business connectivity requirements between 10 Mbps and 1 Gbps and beyond , a range that covers the largest and fastest-growing segment of the commercial services market. But MSOs will need economical and scalable provisioning solutions for their EPON networks. With solutions that combine EPON with DOCSIS provisioning of EPON (DPoE™), cable MSOs will have the cost-effective, scalable service delivery platform they need to grow their commercial services business.

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INTRODUCTION

North American cable MSOs began offering cable-based broadband services to residential customers in the late 1990s. The rapid adoption of residential services inspired cable operators to extend premium broadband data and voice services to the lucrative business market shortly thereafter. Like their residential counterparts, these business service offerings have proven to be a great success for cable MSOs, especially in the small and medium business (SMB) segment of the market.

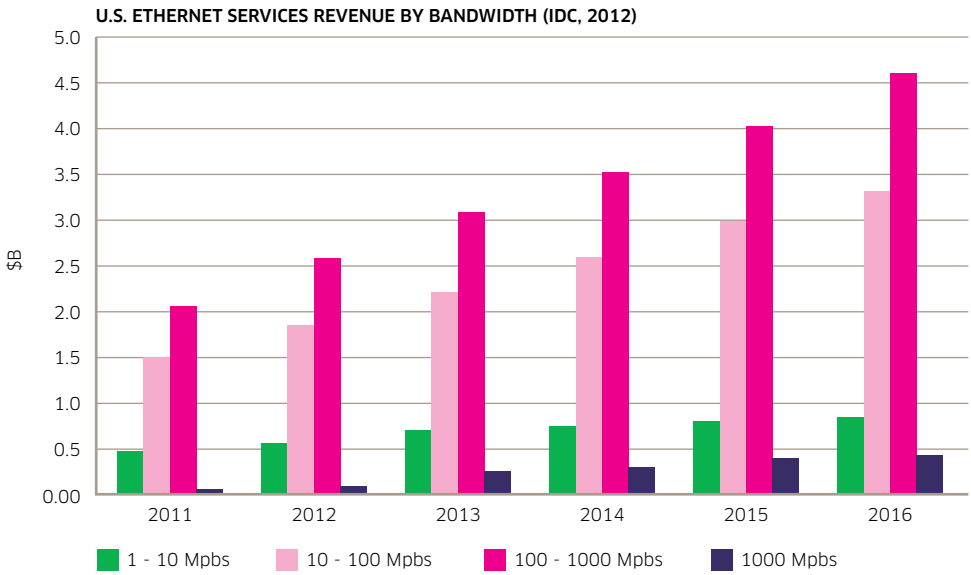
In recent years, MSOs have begun to extend services to larger and more sophisticated business customers. To expand into this segment, MSOs need the ability to scale their networks to accommodate higher bandwidth services and order volumes. As a result, cable operators have increasingly turned to fiber-based systems to meet the needs of these more demanding business customers. Because many MSOs rely on DOCSIS® provisioning systems to transactionalize the service order process for residential and small business customers, DOCSIS provisioning of EPON (DPoE™) will be a key enabler for the deployment of fiber networks that can serve midmarket and enterprise customers.

Sizing up the commercial services opportunity

The communications demands of businesses are growing dramatically, especially in North America. Total combined spending on communications services in the region is currently $140 billion[1] and rising. Spending is being driven by growing use of cloud and data center services, as well as Metro Ethernet-based high-bandwidth applications such as videoconferencing, distance learning and telemedicine.

Figure 1 highlights the increasing demand for Ethernet-based services by connection speed between 2011 and 2016.

Figure 1. U.S Ethernet services revenue by bandwidth



1 [1] "The Future of Cable Business Services 2012", Heavy Reading, November 2012.

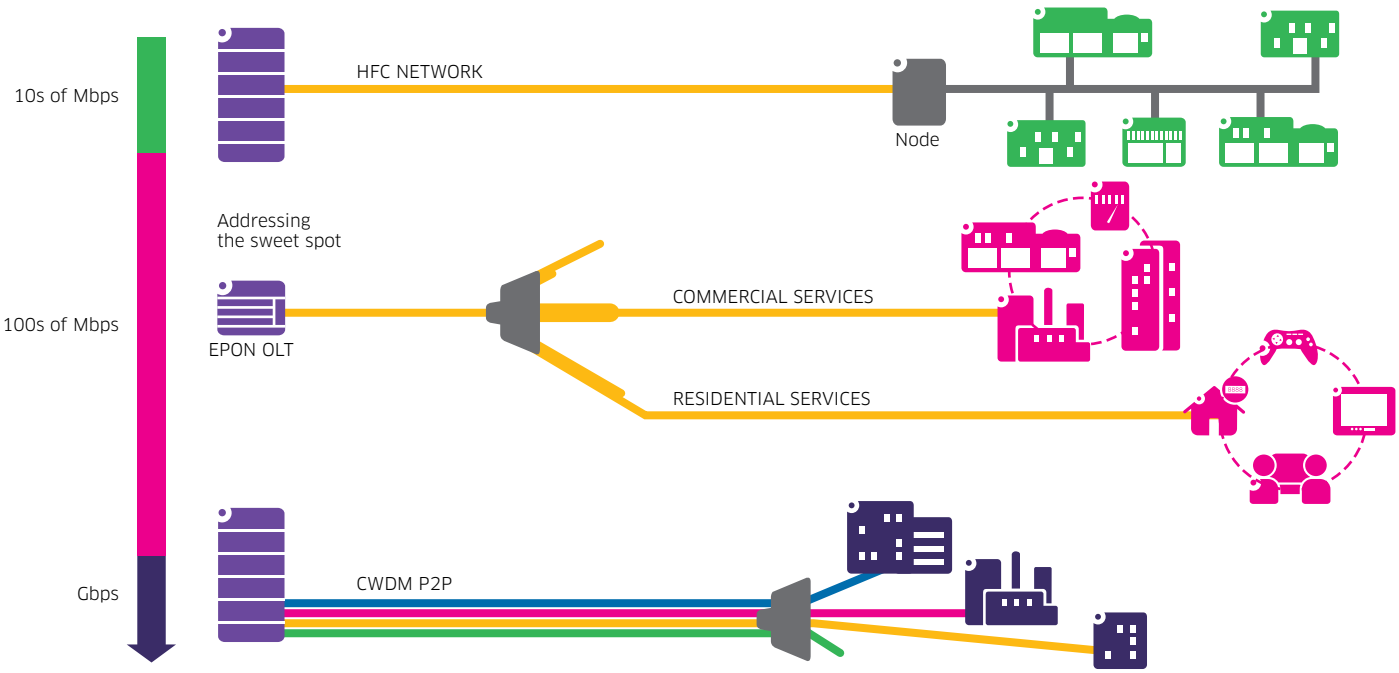
Businesses in the low-speed segment (Figure 1, green bars) require connections of less than 10 Mbps. Many cable MSOs use DOCSIS to address this segment because it enables them to reuse their hybrid fiber-coaxial (HFC) networks to deliver these modest bitrates. The use of DOCSIS also helps simplify operations: operators can provision and manage these services in the same way they manage their residential DOCSIS-based services. However, the limited capacity of DOCSIS can be a drawback, which makes it difficult for operators to use DOCSIS in networks that require symmetrical bandwidth or very high speed connections.

Although small in number, businesses requiring connections that exceed 1 Gbps can be a major source of revenue for cable MSOs. These customers are often supported with coarse wave division multiplexing point-to-point (CWDM-P2P) technology. This technology uses one dark fiber strand or CWDM wavelength per subscriber. While CWDM is suitable for connections of 1 Gbps or more, it is a more costly solution than PON for speeds below this level.

Business connectivity between 10 Mbps and 1 Gbps represents the sweet spot for North American cable operators. This is the largest and fastest-growing segment for Ethernet services. Today, MSOs primarily use CWDM-P2P or dark fiber technology to address the 10 Mbps–1 Gbps segment. But PON provides a more cost-effective and scalable solution. CWDM-P2P and dark fiber support only a limited number of customer connections per fiber strand, and both require a dedicated Gigabit Ethernet port for each customer at the hub location.

EPON offers huge efficiencies, supporting three to four times as many customers as CWDM-P2P technology on a single fiber. Services can be offered in increments of tens of Mbps to 1Gbps symmetrical speeds — in other words, up to 1Gbps upload and download — to meet the unique needs of larger businesses. MSOs can connect a few customers and expand services to others over time using the same fiber. As bandwidth demand grows, EPON solutions provide a smooth evolution to 10G connectivity (Figure 2).

Figure 2. Using EPON to serve the sweet spot between 10 Mbps and 1 Gbps



USING EPON AND DPoE TO TRANSACTIONALIZE FIBER

Cable MSOs must accelerate turn-up time for fiber-based services if they hope to cost effectively capture substantial market share in the midmarket and enterprise services segments. Currently, the average MSO order-to-activation time for fiber-based access services is somewhere around 38 to 45 days. This average includes shorter activation cycles for on-net customers and longer cycles for near-net and off-net customers. It reflects a provisioning process that requires well-paid engineering resources to manually activate each customer.

Cable operators can speed fiber penetration by addressing two major challenges. The first is to extend fiber to more businesses. The second is to streamline the provisioning process. Many MSOs are addressing the first challenge by building out fiber in a more proactive fashion. They then dispatch their sales force to canvass the area where fiber has been placed.

In an effort to streamline and transactionalize provisioning, MSOs are seeking to apply their DOCSIS systems to fiber-based services for business customers. MSOs are moving quickly to adopt and capitalize on the standards-based, scalable and cost-effective aspects of EPON technology. The use of DPoE allows them to integrate EPON into their existing provisioning and operations support systems. Because the DPoE approach and toolset are similar to those used by MSOs for their cable modems, DPoE provides a common look and feel for supporting fiber-based services.

With its support for fully automated service activation, provisioning and customer billing, DPoE gives MSOs an environment that mirrors their highly scalable DOCSIS business. Furthermore, it offers significant network cost savings by leveraging the economics of PON and Ethernet technologies.

With today's fiber-based solutions, cable MSOs can typically add only a dozen or so fiber customers per week. The combination of EPON and DPoE will enable operators to process thousands of transactions per week. Cable MSOs are extremely well equipped for transactional selling, activation, fiber plant extensions, installations, support and billing. Together, EPON and DPoE will provide the acceleration required to create the next billion-dollar cable business. This acceleration will materialize very quickly.

The combination of EPON and DPoE is ideal for cable MSOs seeking to use fiber to extend their reach into the midmarket and enterprise segments. It delivers the right bandwidth at the right price and integrates easily into existing networks.

Right bandwidth

EPON provides symmetrical bandwidth of up to 1 Gbps downstream and 1 Gbps upstream. This bandwidth is allocated to individual customers as needed. Customers with bandwidth needs of up to 300 Mbps are well served by EPON. As 10G-EPON becomes prevalent, it will be easier for cable MSOs to offer services of up to a gigabit to individual customers. This range covers all but the highest bandwidth needs and provides the most cost effective method for tapping the bulk of the revenue available in the commercial services market.

Right price

EPON is a scalable and flexible technology that enables cable operators to manage and extract more value from their fiber investments. In rolling out EPON, MSOs can start by connecting a few commercial customers and then use the same fiber to connect additional customers as time goes on.

A point-to-multipoint technology, EPON reduces fiber requirements by splitting one fiber across multiple subscribers. In a typical EPON configuration, an MSO can connect 16 customers with one fiber — three times more than it can with a typical CWDM-P2P configuration. If the MSO uses 10G-EPON on this fiber, it can meet the same bandwidth needs with even fewer fiber strands. As a passive technology, EPON also reduces operating expenditure (OPEX) in the outside plant. The lack of active equipment in the field results in low power consumption and reduced maintenance demands. The higher density of equipment results in a smaller footprint, which helps improve the efficiency of support operations.

Easy integration

With DPoE, an MSO can easily integrate EPON into its existing service provisioning and activation systems. Following installation, EPON data services can be transparently provisioned as DOCSIS cable modems are provisioned. There is no need to train personnel on new provisioning and operational support systems, so the cable operator can deploy services faster at lower cost. What's more, the operator can use EPON, 10G-EPON and CWDM-P2P on the same fiber because EPON and 10G-EPON use two different sets of wavelengths. This leaves several wavelengths available for CWDM-P2P services where customer bandwidth requires them. Operators can preserve their CWDM-P2P investments while complementing them with EPON in the same platform.

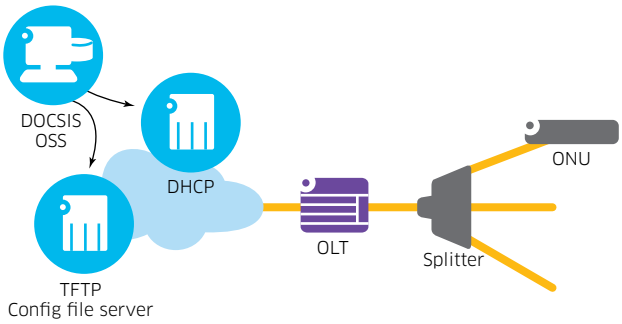
DPoE SPECIFICATIONS

DPoE is the bridge between regular EPON and DOCSIS systems. The DPoE specifications are divided into two parts: DPoE 1.0 and DPoE 2.0. DPoE 1.0 defines a virtual Cable Modem (vCM) structure that creates a software instance of a cable modem inside the EPON system. As a result, the DOCSIS operations support systems (OSSs) "think" they are communicating with a cable modem on a cable modem termination system (CMTS). DPoE 1.0 also defines the provisioning of basic Metro Ethernet Forum (MEF) Ethernet Private Line and IP High-Speed Data (IPHSD) services.

DPoE 2.0 brings additional capabilities for emulated LAN (ELAN) services along with support for network protocols such as Multiprotocol Label Switching (MPLS) and Border Gateway Protocol Auto Discovery (BGP AD). It supports near-complete automation of provisioning for end-to-end EPL and ELAN services. These sophisticated capabilities will greatly simplify the provisioning of complex network-wide services. This simplification will reduce the time required to establish an EPON-based network-wide service from hours to minutes.

The DPoE specifications are much more than a provisioning method. These specifications define OSS management information bases (MIBs) that allow the reuse of many home-grown cable modem support tools for extracting traffic and troubleshooting information. They also specify security and the communication message set between OLT and the ONU to allow for better interoperability between equipment from different vendors, as shown in Figure 3.

Figure 3. Using DPoE to specify the communication message set

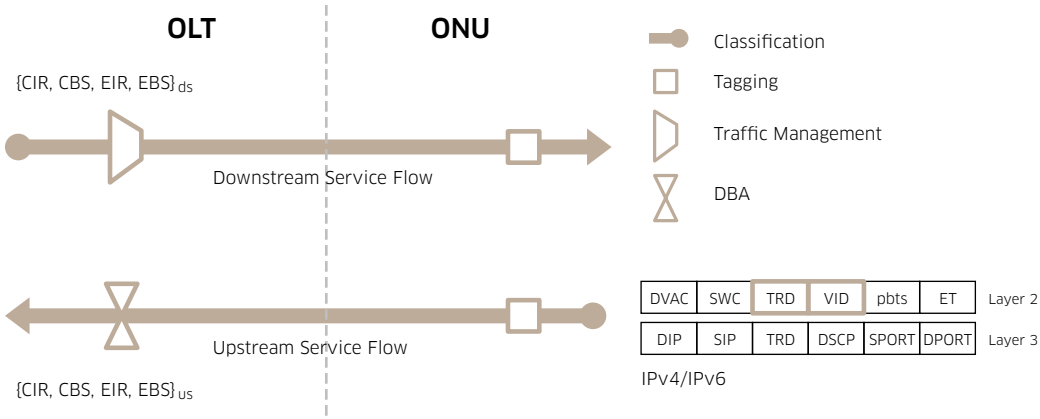


1. Service order is entered at DOCSIS OSS
2. Config file is created and loaded on TFTP server
3. ONU is connected to fiber
4. Virtual Cable Modem (CVCM) is created on OLT
5. vCM launches DHCP request
6. DHCP server responds with offer, TFTP address and config file name
7. vCM retrieves config file from TFTP server
8. vCM configures PON board HW and ONU through OAM messaging

Service flow model

The DPoE and DOCSIS specifications describe a service flow model that defines the bandwidth profile, quality of service, classification of incoming data, and encapsulation or tagging requirements of user data. Service flows are the basic elements of the services the operator sells to its customers. They are configured through a configuration file that is downloaded to the access node. To support operators that are not yet ready to use DOCSIS provisioning, Alcatel-Lucent has added command-line interface (CLI) commands to its EPON system to allow the generation of a configuration file within its ISAM 7360FX. These commands allow early adopters of EPON to make a smooth transition when they are ready to migrate to a full DPoE model. Figure 4 shows a high-level example of a service flow model, along with its associated attributes. Service flows are unidirectional. Upstream and downstream service flows are paired to create a bidirectional service.

Figure 4. Service flow model



The fundamental parts of the service flow model are bandwidth profile, classification, tagging and quality of service (QoS). Link layer attributes such as logical link identifiers (LLIDs) do not need to be specified.

ONU registration and provisioning

In the traditional provisioning and registration model, optical network units (ONUs) are statically pre-provisioned and activated once the ONU is discovered at its specific location — rack, shelf, slot, PON — within the equipment. Services are then enabled, and the system provisions the interfaces on the ONU and data path within the optical line termination (OLT).

In contrast, DPoE uses a dynamic registration paradigm that emulates the cable modem environment. The location of the ONU is not pre-determined, and the ONU and associated service configurations reside outside the access node. The configuration process involves downloading a configuration file that describes the applicable service flows and QoS.

With DPoE, there are two ways to register ONUs:

1. Downloading the ONU configuration: ONUs are not always pre-provisioned in the access node using the virtual cable modem paradigm described in the DPoE specifications. In these cases, the access node communicates with the operator's operations and business support systems (OSS/BSS) using Dynamic Host Configuration Protocol (DHCP) and Trivial File Transfer Protocol (TFTP) and downloads the ONU configuration. This is the typical behavior of the DPoE system. It must be supported as the initial configuration option.
2. Pre-provisioning the ONU: The ONU and associated services can be pre-provisioned and entered into the DPoE system. Alcatel-Lucent has implemented CLI commands that support the creation of a configuration file that resides on the ISAM 7360FX. The configuration is applied based on the specific ONU, which is identified using a media access control address (MAC@). During the registration process, the system examines the MAC@. If the database specifies that the address requires local provisioning, the system downloads the configuration file from the controller on the ISAM 7360FX rather than from a network file server. Alcatel-Lucent has made this function available for operators that are not yet ready to fully implement DPoE or that desire a manual provisioning process.

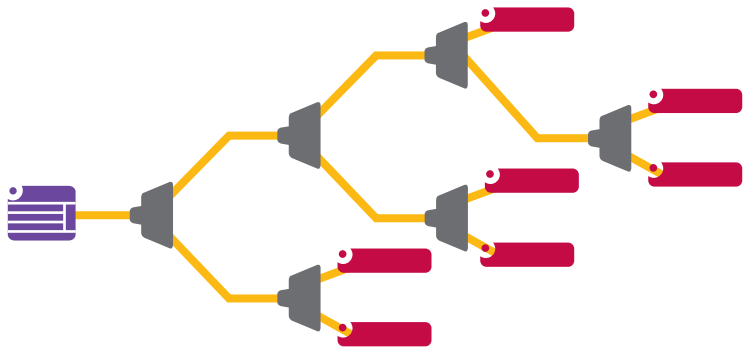
TYPICAL EPON DEPLOYMENT TOPOLOGIES

North American cable operators typically deploy EPON in a tree, linear or ring topology. The choice between the three is based on the operator's network environment.

Tree topology

In a tree topology like that shown in Figure 5, 50/50 splitters are typically used to split the EPON signal. However, other splitters can be used to further optimize the OSP. Up to 5 50/50 splitters can be used in one path, which means that each EPON port can support a total of 32 subscribers. At each stage, the fiber can be terminated to a customer or split to cover a larger area or to connect additional subscribers.

Figure 5. EPON deployment – tree topology



Linear topology

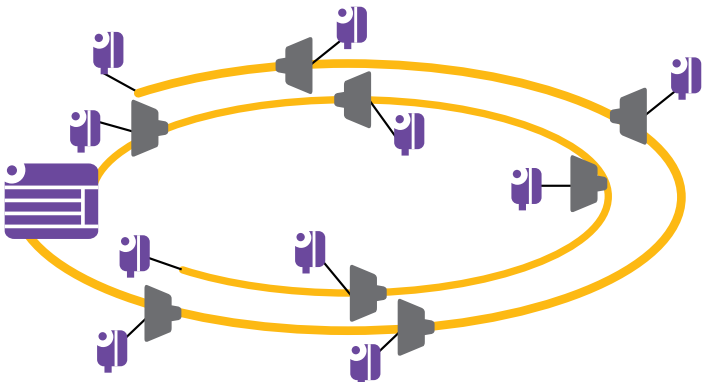
A linear topology typically uses one fiber line to support up to 16 subscribers. A fiber line can support more customers as long as the optical budget is not exceeded. At each stage, one leg of the split is used to connect a subscriber. The other leg is used to continue down the fiber. In this model, asymmetrical splitters are normally used to allow as many connections as possible, as shown in Figure 6. However, some operators are exploring ways to split the leg even further.

Figure 6. EPON deployment – linear topology

EPON ring topology

A ring topology uses two fibers to create a ring that provides exceptional survivability. With typical ring technologies, the network has to reconfigure itself and switch to its standby path if there is an equipment or power failure at one location. With an EPON ring, a power or equipment failure at one location does not affect any other locations on the ring. The light travels passively through the other locations, so customers at these locations do not experience the outage. If there is a fiber cut, the topology allows traffic to switch and take the other path around the ring.

Figure 7. EPON deployment – ring topology



ACCESS NODE AND CPE CONSIDERATIONS

To support commercial services, cable operators need to ensure that their networks meet specific requirements. These requirements apply to the head end or hub as well as the customer premises. For an EPON network, the following features are commonly required for commercial services:

- Redundancy: Commercial services need enterprise-class reliability to ensure that the network is up at all times. A redundant controller and redundant uplinks can provide this level of reliability.
- Layer 2, layer 3 (L3) and Multilevel Protocol Switching (MPLS) forwarding.
- DPoE: With DPoE, an MSO can use the same processes to manage its EPON and DOCSIS networks. Because there is no need to learn a new system, the operator can get the EPON network up and running quickly and easily. EPON data services can be transparently provisioned in the exact same way as DOCSIS cable modems.

- Uplink capacity: To guarantee the higher bandwidth required for commercial services, the operator must ensure that it has sufficient uplink capacity to avoid blocking any data in the system.
- Form factors: EPON can be deployed from the head end or from any hub in the network. It can be close to or far from a given business, and can serve a small or large number of subscribers. An operator may need to make different sizes of the EPON platform available so that it can address different locations and subscriber base sizes.
- Flexibility and upgradeability: Cable operators need to be able to provide all fiber technologies using the same platform. Using a single flexible platform will save space and make it easier to upgrade from one technology to the next. To support higher bandwidths, the platform must be ready to provide non-blocking 10G-EPON capabilities.
- Wavelength compatibility with CWDM-P2P: Many cable operators have already invested in fiber networks for CWDM-P2P technologies. To reuse this fiber network for EPON, operators need ONUs that can filter the EPON signal out of the CWDM-P2P signals.
- Reuse current Network Interface Devices (NIDs): In delivering commercial services, operators want to reduce capital expenditure (CAPEX) by reusing the gateways they have installed at customer sites. Operators need an easy way to upgrade these NIDs to an EPON network.

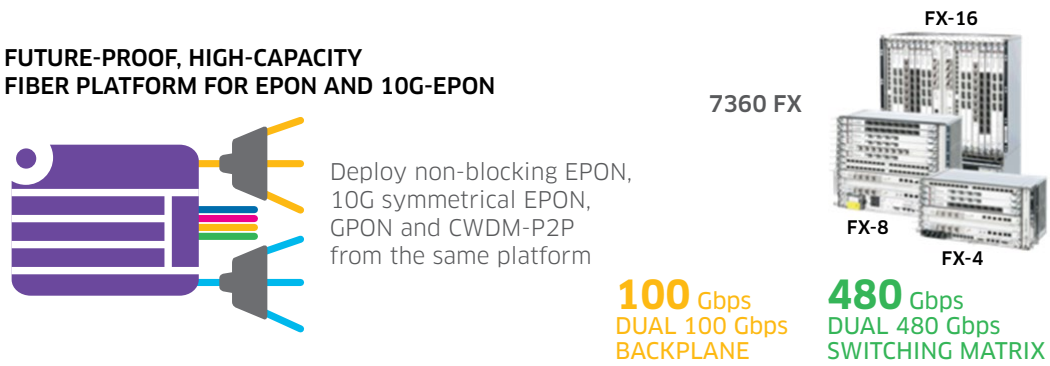
A HIGH-CAPACITY SOLUTION FOR THE COMMERCIAL SERVICES MARKET

Alcatel-Lucent offers its 7360 Intelligent Services Access Manager (ISAM) FX platform to help MSOs address the growing opportunity in the commercial services market. This high-capacity platform includes DPoE functionality that can be easily integrated into any MSO network. It supports three different form factors — FX-16, FX-8 and FX-4 — to address a wide variety of network needs. It also provides flexible mounting options that can work with 19- or 23-inch racks.

The 7360 ISAM FX delivers enterprise-class reliability by combining redundant controllers and uplinks with L3 and MPLS forwarding. Its maximum uplink capacity is 160 Gbps (16 x 10 Gbps). This capacity makes the system non-blocking and provides the bandwidth MSOs need to support midmarket and enterprise customers.

With a backplane capacity of 2 x 100 Gbps and a switching capacity of 2 x 480 Gbps, the 7360 ISAM FX is an investment in future growth and evolution. It enables operators to deploy EPON, gigabit PON (GPON), CWDM-P2P and 10G-EPON from the same platform today and will support evolution to non-blocking future technologies.

Figure 8. Alcatel-Lucent 7630 ISAM FX positions MSOs for growth and evolution



Additional elements of the Alcatel-Lucent EPON solution can also help MSOs leverage and reuse existing investments in end-user customer premises equipment (CPE). Cable operators use Alcatel-Lucent EPON small form-factor pluggable optical network units (SFP ONUs) with existing business CPE so that they can preserve previous investments in CPE while upgrading their networks. The EPON SFP ONU is wavelength compatible with CWDM-P2P. The fiber used for CWDM-P2P can also be used for an EPON connection.

CONCLUSION

The fiber-based commercial services market is an important growth opportunity for North American cable operators. Boosted by increasing demand among midmarket and enterprise customers, it has the potential to become the next billion-dollar cable business.

With their transactional provisioning, installation, support and billing capabilities, cable MSOs are well positioned to roll out high-bandwidth fiber networks and capture a sizeable share of this market. To succeed, they need cost-effective solutions that will enable them to accelerate fiber turn-up time and meet the more demanding requirements of the midmarket and larger business customers.

The combination of EPON and DPoE will be essential in helping MSOs use fiber to support and capitalize on high service demand generated by midmarket and enterprise customers. EPON and DPoE will allow cable MSOs to turn up networks faster and more cost effectively. This will help them capture more market share. With EPON and DPoE, cable MSOs will be well equipped to move up in the commercial services market.

With the 7360 ISAM FX, Alcatel-Lucent offers high-capacity platform for addressing the growing commercial services market. This platform is an investment in the future: Operators can deploy EPON, 10G-EPON, GPON and CWDM-P2P from the same platform.

Alcatel-Lucent is the number one fiber to the home (FTTH) vendor in North America and number two worldwide. The company has shipped more than 13 million PON lines worldwide, including 2.2 million in North America. Globally, it serves more than 140 PON FTTH customers, including 10 cable operators around, and is ranked the #1 FTTH vendor by Infonetics Research. With 4 international development sites and the core MSO function located in Raleigh, North Carolina, Alcatel-Lucent combines a global presence with local expertise.

ABBREVIATIONS

BSS	Business support system
BGP AD	Border Gateway Protocol Auto Discovery
CAPEX	Capital expenditure
CLI	Command line interface
CWDM	Coarse wave division multiplexing
CPE	Customer premises equipment
DBA	Dynamic Bandwidth Allocation
DHCP	Dynamic Host Configuration Protocol
DOCSIS®	Data Over Cable Service Interface Specification
DPoETM	DOCSIS Provisioning of EPON
EPON	Ethernet Passive Optical Network
FTTH	Fiber to the home
GPON	Gigabit Passive Optical Network
IPHSD	IP High-Speed Data
ISAM	Intelligent Services Access Manager
L3	Layer 3
LLID	Logical link identifier
MAC@	Media access control address
MIB	Management information base
MPLS	Multiprotocol Label Switching
MSO	Multiple-system operator
NID	Network Interface Device
OLT	Optical line termination
ONU	Optical network unit
OPEX	Operating expenditure
OSS	Operations support system
P2P	Point to point
PON	Passive optical network
QoS	Quality of service
SFP	Small form-factor pluggable transceiver
SMB	Small and medium business
TFTP	Trivial File Transfer Protocol
vCM	Virtual cable modem

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