SCTE’S NYC CHAPTER PRESENTS

EPON AND RFoG TECHNOLOGY OVERVIEW
AGENDA AND HOUSEKEEPING ITEMS

- EPON Technology Overview
- Introduction to DPoE
- DPoE 2.0 and Next Generation EPON
- RFoG and HPON – Why? What How?
At the end of each presentation, there will be a chance for questions. If you are attending by webinar, please put your questions in the Adobe chat box.
SCTE’S
NYC CHAPTER
PRESENTS

EPON AND DPOE
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Agenda

- EPON Technology Overview
- Introduction to DPoE
- DPoE 2.0 and Next Generation EPON
EPON Technology Overview
• Access networks are part of a telecommunications network that connect users to their providers.

• Historically they were made out of twisted copper wires for telephone access. These providers are known as “telcos”.

• Another type of access technology is Cable TV service which is delivered through a coaxial cable, TV was the only service offered in the early days.
First, a bit of history on access networks...

- Over time the access network became capable of delivering other services, like high speed data, video, and voice.  
  – This created the need for more bandwidth.
- Technologies like xVDSL for telcos or DOCSIS 3.0 and 3.1 in the cable world have increased bandwidth over the years, keeping the existing networks alive.
- Regardless, these technologies are not enough to deliver multigigabit/s service to residential and commercial subscribers today
Fiber to the rescue!

• Unlike twisted copper pairs or coax cable, optical fiber is capable of delivering today symmetric 10Gbps of data, voice, and video services at distances equal or beyond 20 kilometers from a central location to a subscriber.
  – This is known as Fiber to the x (FTTx) service, where x = Home, Business, Premises, etc...
• Fiber can be deployed in the local access network using a point-to-point (PtP) or point-to-multipoint (PtMP) topology, with dedicated fiber runs from the HUB to each end-user (subscriber).
• One cost effective way of delivering FTTH service is with the use of Passive Optical Networks
OK, so what exactly is a PON?

• Definition of PON （Passive Optical Network）
  – Is a point-to-multipoint, Fiber-to-the-Premises (FTTP) network architecture.
  – Is called “passive” because unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 16-128.
  – It consists of Optical Line Terminals (OLT), and more than one Optical Network Units (ONUs) and connected through the Optical Distribution Network (ODN).
  – The ODN is an optical access network without any active electronic devices between OLT and ONU.
Components in a PON Network

- Headend
- ODN
- Subscriber
- OLT
- Splitter
- ONU
Different standard groups created different PON standards:

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<th>SCTE</th>
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EPON a Mature Technology Option

• EPON was initially chosen by MSOs as the preferred PON architecture based on several high level factors:
  – Simple Protocol based on Ethernet Framing instead of more expensive and complicated GPON specification (ATM) which affects future pricing
  – Momentum already made toward a DOCSIS based provisioning model
  – 10G specification was completed in 2009, with product available today!
In collaboration with CableLabs, MSO’s have spent 5+ years working with contributing vendors to develop specifications for DOCSIS Provisioning of EPON (DPoE). DPoE focuses on the following concepts:

- Multi-vendor interoperability
- Metro Ethernet services functionality for commercial services
- Multigigabit IP/HSD residential service
- Capable of provisioning millions of devices
- Use of existing MSO back office systems

Simplified provisioning and access network speeds of 10Gbps are key differentiators for MSOs against existing and new service providers.

Minimizes fiber deployment and number of transceivers in the field compared to CWDM (lower CAPEX)

No active devices in the field (lower OPEX)
EPON as Universal Fiber Access Architecture

- All Service Types
  - Residential
  - Businesses
  - Cellular backhaul
- All Configurations
  - MDU/MTU
  - FTTH
  - FTTC/FTTN
- All Data Rates
  - 1Gb/s (802.3ah 2004)
  - 10/1 and 10/10 (802.3av 2009)
- All supported on the same outside plant (ODN)!

- Home Networking
  - SFU
  - ONU
  - HGW
  - GE
  - STB / IP-STB
  - xDSL
- FTTH
- FTTB
- FTTC / FTTN
- Cellular Backhaul
  - MTU ONU in Wiring Closet / Basement
  - Clock Transport IEEE 1588

- OLT with Traffic Management
- MTU ONU per Floor

- Cellular ONU
- Business ONU
- ONU in Outside Cabinet
- xDSL
EPON Technology Roadmap

- EPON standard evolution:
  - 802.3ah: 1G/1G specification (2004)
  - 802.3av: 10G/10G specification (2009)
  - DPoEv1: DOCSIS Provisioning over EPON (2011)
  - DPoEv2: (2012)
  - SIEPON: Service Interoperability in Ethernet Passive Networks (2013)
  - NG-EPON: IEEE already working on next generation EPON for speeds of 40 or 100Gbps.

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- 802.3ah
- 802.3av
- DPoE 1.0
- DPoE 2.0
- SIEPON
- NG-EPON
A typical EPON system is composed of an OLT, several ONUs and an ODN.

- The OLT (Optical Line Terminal) resides in the MSO’s hubs, or sometimes in a MDU, it connects the optical access network to the core. OLTs can be a switch or router and contain EPON interfaces. It’s the optical equivalent of a CMTS.

- The ONU (Optical Network Unit) is located at the end-user location (customer premises), it has an optical transceiver and provides services such as voice, data and video. It’s the optical equivalent of a Cable Modem.

- The ODN (Optical Distribution Network) connects the OLT and ONU. In the ODN one fiber carries the DS and US signals using WDM. Fibers are then split to serve individual ONUs. The optical splitter is a simple passive device.
An EPON system uses Wavelength Division Multiplexing (WDM) in order to achieve two way communication on a single fiber.

- **DS:** 1490±10 nm (1Gbps)
  1577 -2/+3nm (10Gbps)

- **US:** 1310 ±50 nm (1Gbps)
  1270±10 nm (10Gbps)

Two multiplexing technologies are used:
- Broadcast on the downstream flows (TDM)
- TDMA on upstream flows
EPON Architectures Models

- Tree topology (a) is typically used in China, US and Europe for residential and business customers with no physical layer resiliency requirements
- Bus topology (b) is typically used in Japan (where most fiber is deployed in aerial bus-type architecture)
- Ring topology (c) used typically for networks with high resilience (tree / trunk protection under SIEPON)
- The EPON protocol works on any ODN (optical distribution network) architecture
802.3ah (1Gig EPON)  
1000BASE-PX20 Transceivers

**OLT:**
- TX Wavelength: 1480 to 1500nm
- TX: +2 to +7dBm
- RX: -6 to -27dBm

**ONU:**
- TX Wavelength: 1260 to 1360nm
- TX: -1 to +4dBm
- RX: -3 to -24dBm

802.3av (10Gig EPON)  
10GBASE–PR–D3 Transceivers

**OLT:**
- TX Wavelength: 1575 to 1580nm
- TX: +2 to +5dBm
- RX: -6 to -28dBm

**ONU:**
- TX Wavelength: 1260 to 1280nm
- TX: +4 to +9dBm
- RX: -10 to -28.5dBm
Downstream Traffic

- OLT broadcasts data to every ONU
- ONUs receive a Logical Link ID (LLID) upon registration (can be more than one LLID). This is similar to a cable modem receiving a pair of service flows (US/DS) in DOCSIS.
- ONU only forwards traffic to its own set of active LLIDs.
- To broadcast data to all ONUs the OLT uses TDM (Time Division Multiplexing)
Upstream Traffic

- During ONU registration the OLT calculates the time delay (distance) from ONU and instructs it to adjust its transmission parameters.
- Each ONU only transmits during the assigned timeslots from OLT.
- Transmission from each ONU arrives at the OLT without collisions.
- To provide multiple access to a single fiber link for all connected ONUs, Time Division Multiple Access (TDMA) architecture is implemented for the Upstream channel.
DPoE
DOCSIS Provisioning of EPON
What is DPoE

- DOCSIS Provisioning of EPON (DPoE™) is a joint effort of operators, vendors, and suppliers to support EPON technology using existing DOCSIS-based back office systems and processes.
- Goal is to share the same Provisioning Platform for DOCSIS and EPON:

Today’s back office implementation can be reused
Reason’s for Developing DPoE Specs

• Neither 1G-EPON nor 10G-EPON as specified in IEEE 802.3 define any OAMP that allows forwarding of traffic between an ONU User Interface (UNI) and the PON.

• Before DPoE all provisioning of EPON services was a manual process, thus making it difficult to sustain for large deployments.

• Some automated tools have been developed but they are all proprietary and don’t integrate well with the MSO’s existing infrastructure.

• One of the primary goals of the DPoE specifications is to provide an interoperable method of reaching the controller for the ONU, identifying the ONU capabilities, and providing that information to the OLT so that it can configure service on an ONU.

• The other is to adopt DOCSIS-based back office provisioning and operations models to EPON. This is the core objective of the DPoE specifications.
The DOCSIS Mediation Layer

- The DOCSIS Mediation Layer (DML) is a process that resides on the DPoE system that translates all DOCSIS specific provisioning into EPON, as defined by the CableLabs DPoE 1.0 specifications.

- Some of its tasks are:
  - Interprets the DOCSIS MIBs
  - Creates virtual Cable Modems (vCMs) for management purposes since ONUs do not have an IP stack
  - Requests IP addresses and configuration files for vCMs
  - Translates the parameters received in the DOCSIS configuration file for each vCM to EPON OAM messages for the ONU
  - Keeps the ONU firmware up to date using the DOCSIS secure software download mechanism with digitally signed software images
  - CLI that “looks and feels” like a CMTS
• CableLabs defined two main applications to be delivered through DPoE:
  - Business services as defined by the Metro Ethernet Forum 1.0 specifications.
  - MEF is the defining body for Carrier Ethernet, its mission is to accelerate the worldwide adoption of Carrier-class Ethernet networks and services.
  - These are all “layer 2” applications
  - IP High Speed Data services, either residential or commercial
  - This is a “layer 3” application
MEF 1.0 Services

- MEF 1.0 defines 3 basic services:
  - Point-to-Point: E-Line
  - Multipoint-to-Multipoint: E-LAN
  - Rooted Multipoint: E-Tree
Commercial DPoE Applications

• Cell Tower Backhaul
  – ONU is installed at the cell tower location providing seamless interconnection between the cell tower and the controller

• Interconnectivity for remote office locations
  – Small/Medium Businesses that require connectivity across multiple branches.

• Internet and Voice
  – EPON is the last mile delivery mechanism for Dedicated Internet Access (DIA) service and SIP PRI (hosted PBX)
• The second main application defined by DPoE is support for IP High Speed Data Services for residential or commercial markets

• Initial focus for DPoE was commercial applications, but due to market and competitive pressure residential has now taken the lead among North American MSOs

• IP HSD services are configured identically as in a DOCSIS CMTS, using exactly the same configuration files used by cable modems.
  – Only exception is the higher data tiers (i.e. Symmetrical 100Mbps, 500Mbps, or 1Gbps).
IP HSD Applications

• Residential Greenfield
  – Greenfield applications offer a great opportunity for EPON/PoE, offering speeds up to 10Gbps

• MDUs
  – High rises and condominiums can be easily migrated to an FTTH architecture

• WiFi Hotspots
  – Most advanced APs offer an SFP cage, where an SFP ONU can be connected, allowing up to 1Gpbs best effort connectivity with 802.11ac
Challenges for EPON and DPoE

• For commercial applications:
  • Even though DPoE greatly simplifies the provisioning of the CPE, some challenges remain:
    – The provisioning system needs to be modified slightly in order to monitor and track the VLAN assignment on each OLT chassis
    – Most MSOs still provide fiber based commercial services through a dedicated Active Ethernet connection. This configuration is very manual and group performing activations might be reluctant to move to an automated provisioning system

• For residential:
  – Residential took the back burner at CableLabs but is turning out to be the main driver for EPON and DPoE.
  – Automated voice provisioning (fiber based MTA like device) has not been defined
  – Other useful items defined by DOCSIS like IPDR or Legal Intercept also remain undefined.
  – Video delivery through IPTV has remained “2 years out” for the last 5-6 years. Thus video still requires an RFoG ONU which increases the cost of the CPE equipment.
DPoE 2.0 and Next Generation EPON
What’s coming up in DPoE 2.0

• DPoE 2.0 is the latest version of the specifications, released in late 2012.

• It contains the following enhancements:
  - Full set of MEF 1.0 services (E-Line, E-LAN, E-Tree)
  - MPLS
  - IPv6
  - Multicast, allowing full support for IPTV services
  - Y.1731 Service OAM, allows end to end performance management of an EVC
  - IEEE 1588v2 Precision Time Protocol, useful for CTBH applications
What’s next for EPON

• The IEEE in November 2013 began a study group for Next Generation EPON
  – This study group is exploring market potential and technologies capable of delivering data rates >10Gbps
In order to achieve speeds > 10Gbps there are a few things that can be done:

- Increase the line rate to 25, 40, or even 100Gbps
  - Not a good idea due to loss of sensitivity and dispersion loss. This means higher Tx power and cost

<table>
<thead>
<tr>
<th>Rate</th>
<th>Sensitivity (vs 10Gbps)</th>
<th>Dispersion loss @20km</th>
<th>Total loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>25Gbps</td>
<td>-4dB</td>
<td>-3.5dB</td>
<td>-7.5dB</td>
</tr>
<tr>
<td>40Gbps</td>
<td>-7dB</td>
<td>-9.5dB</td>
<td>-16.5dB</td>
</tr>
</tbody>
</table>

- Use modulation so that each baud carries more than one bit (ie. OFDM).
  - Very immature technologies for optical transmission. Very high cost and complexity, especially for ONUs
- ... Or use multiple 10G wavelengths!
  - This will be chosen mechanism. Is like channel bonding for PON
  - Wavelength allocation is currently being explored
IEEE is recommending the following as of the latest draft:

For OLTs:
- For residential applications the aggregate DS bandwidth should be at least 100Gb/s for DS and 40Gb/s for US per PON port
- For commercial applications the aggregate DS and US bandwidth should be at least 100Gb/s per PON port

For ONUs:
- Two classes of ONUs are being specified:
  - Residential: Should support at least 1 wavelength in DS and US directions (10Gb/s each)
    • Intended for asymmetric services
  - Commercial: Should support at least 4 wavelengths in DS and US directions (at least 40Gb/s each)
    • No upper limit on number of DS or US channels supported
    • Intended for symmetric services
SCTE’S NYC CHAPTER PRESENTS

RFOG AND HPON – WHY? WHAT HOW?
NOVEMBER 3, 2015
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WHAT’S THE PLAN?

➡️ Why do something different?
➡️ What is RFoG?
➡️ Why RFoG?
➡️ Wait, RFoG doesn’t work??
➡️ RFoG and HPON - the rest of the story. How we’re going to kick some OBI butt.
• The HFC network still lots of life left in it, but......

What’d you say about my HFC network?!?!

Why I oughta.....
Why Do Something Different?

1990s  Letter to Email

2000s  Music, Pictures online

2010s  Streaming Video, Multiscreen

2020s  Immersive Video Holographic / Cloud

Letter to Email

Music, Pictures online

Streaming Video, Multiscreen

Immersive Video Holographic / Cloud
Why Do Something Different?
Why Do Something Different?

One word......

OK, not that one, but this one....
Why Do Something Different?

432 Park Ave, New York, NY

432 Park Ave, State College, PA
What is RFoG?

Today’s HFC System

- Fiber
- Coax
- 54 MHz - 1 GHz
- 5 MHz - 42 MHz
- ~64 HHP Per Segment

RFoG System

- Fiber
- 1550 nm
- 1611 nm
- 54 MHz - 1 GHz
- 5 MHz - 42 MHz
- 1 - 32 HHP
- Node moves from field location to side of home
Key Components of an RFoG System

RFoG System

- 54 MHz - 1 GHz
- 5 MHz - 42 MHz
- 1550 nm
- 1611 nm
- Forward Transmitter and Analog Return Receiver
- EDFA
- WDM Mux
- 32-way Optical Splitter
- RFoG ONU with built-in WDM Mux

Fiber
Why RFoG?

RFoG System

Uses the same:
- In-house coax wiring
- Cable Modem or eMTA
- Settop Box

Uses the same hub equipment, including:
- Billing system
- Provisioning Systems
- Video Control Systems (DAC/DNCS)

Fiber

Splitter

WDM Mux

1550 nm

1611 nm

54 MHz - 1 GHz

5 MHz - 42 MHz

1 - 32 HHP

WDM Mux

1550 nm

1611 nm
What about EPON?

RFoG and EPON – arch enemies?

Nope. Just two warriors with a job to do.

More on this later......
Wait, RFOG doesn’t work?

Today’s HFC System

- Fiber
- Coax
- ~64 HHP Per Segment

54 MHz - 1 GHz
- 5 MHz - 42 MHz

RFOG System

- Fiber
- 1550 nm
- 1611 nm

54 MHz - 1 GHz
- 5 MHz - 42 MHz
- 1 – 32 HHP
- 1550 nm
- 1611 nm
Optical Beat Interference (OBI)

- Occurs when multiple RFoG ONUs in a cluster transmit simultaneously on a single fiber to a single receiver.
Optical Beat Interference (OBI)

- One optical signal hitting the return receiver
- Nice clean return path
• Two optical signals, close in wavelength, hitting the return receiver
• OBI causes an increase in the noise floor
• OBI appears as wide band noise at the receiver output
Optical Beat Interference (OBI)

- Two optical signals, at the same wavelength, hitting the return receiver
- OBI causes a rising of the noise floor
- OBI appears as wide band noise at the receiver output
Some ways to deal with OBI

Wavelength Control of ONUs

- Both techniques appear to reduce OBI
- At higher speed and throughput offered by DOCSIS 3.0 and 3.1, they may be inadequate

Upstream Bursts Managed by CMTS

- Each has limitations due to:
  - Cost
  - Scalability
  - Capacity restrictions
  - Operational complexity
  - Limited effectiveness
HPON™ – Hybrid PON
Kick OBI’s butt once and for all

HPON System

54 MHz - 1 GHz

1550 nm

WDM Mux

1 – 32 HHP

1550 nm

1611 nm

WDM Mux

5 MHz - 42 MHz

1611 nm

WDM Mux

Fiber

WDM Mux
HPON™ – the benefits

- All of the benefits of RFoG
- Complete elimination of OBI
- Compatible with any version RFoG ONU and CMTS
- Simplifies bandsplit changes
- EPON overlay – plug & play
• Questions?
This presentation was brought to you by the NYC Chapter.