Fundamentals of Passive Optical LAN
Brought to you by the Association for Passive Optical LAN (APOLAN)

Founding Members:

www.apolanglobal.org
Course Agenda

• Day 1
  – Passive Optical LAN: 101 – Tom Ruvarac
  – Passive Optical LAN: 102 – Dustin Bateman
  – Introduction to POL Components – Matt Miller
  – Introduction to POL Design with Hands-On – Mike Watts & Chad Hines
  – Power Survivability – Chad Hines
  – POL Testing Considerations – Mike Watts
  – POL Integration and Management – Matt Miller
  – POL Project Closeout Package Deliverables – Mike Watts
I am a...

A. Consultant
B. Designer
C. Contractor
D. Manufacturer
E. End User
F. Other
My experience with POL is...

A. I have installed one
B. I have turned one up
C. I have a project now
D. I have some knowledge
E. I am here to learn
Passive Optical LAN: 101

Tom Ruvarac
President, APOLAN
Section 1 Agenda

• Introduction to Passive Optical LAN
• Where did it originate
• Market adoption
• Knowledge Check
Let’s Imagine…

- Consumes twice the power!!
- Promotes inefficient use of bandwidth!!
- Costs 40 to 60% more!!

A Local Area Network that…

This describes a traditional LAN!
An exciting new way…

Passive Optical LAN

The infrastructure of tomorrow available today

“A Bandwidth Efficient LAN Architecture Providing Measurable CapEx & OpEx Savings”
Thoughts...

Henry Ford Wisdom…
“If I'd asked customers what they wanted, they would have said “a faster horse.””

Steve Jobs Wisdom…
“Man is the creator of change in this world. As such he should be above systems and structures, and not subordinate to them.”

“There aren’t many horse and buggies on the road and most of us don’t have typewriters sitting on our desks. So why are copper networks still so widely used although they have been rendered obsolete by next-generation technologies?” Scott Forbes, CEO Forbes Media
Key Acronyms

GPON

PON vs. POL

OLT and ONT
What is Passive Optical LAN?

- Revolutionary
- Economical
- Efficient
What is Passive Optical LAN?

- Fiber Based Local Area Network
- Point to Multipoint Topology
- Standards based/recognized technology:
  - ITU G984, G987, G989
  - ANSI/TIA 568C
  - BICSI TDMM 13
Why Passive Optical LAN?

**Reduced Costs**
- CapEx: ~40-60% One Time
- OpEx: ~50-75% Every Year
- Construction
  - Cable Tray, Conduit, and Pathways
  - Slewing, Coring, and Fire Stopping

**Technically Future Proof**
- Singlemode
- Unknown Bandwidth Capacity
- Migration
- Only upgrade users that need it

**Scale and Reach**
- Easy MACs
- Can save 8-10 minutes per MAC
- 20km/12.5mi
- No 300ft / 90+10m limitations

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Why Passive Optical LAN?

Security
- AES 128 Encryption in the downstream
- No crosstalk concerns with fiber
- No EMI/RFI or Tempest Shielding

Green IT
- Power: Switches, UPS, HVAC
- Floor Space: Reduce or eliminate TRs
- Building Weight: Cable, Trays, Racks, CRACs, etc.
- Waste: Less site waste and use of NRMs
- Fire Load: Reduced cable mass and fire stop
- USGBC/LEED: Potential Credits
Why Passive Optical LAN?

**Carrier Grade Electronics**
POL electronic components are designed and manufactured to have a service life greater than 25 years as required by carriers, compared to 5-8 years with Enterprise grade equipment.

**High Availability**
- Five 9s (99.999) with POL vs. Three 9s (99.9) with switches
  - Five 9s = 5.26 min/yr
  - Three 9s = 8.76 hr/yr
- Nearly six 9s (99.9999) of availability with POL using FSAN-B Redundancy

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Five 9s (99.999) with POL vs.
Three 9s (99.9) with switches

Five 9s = 5.26 min/yr
Three 9s = 8.76 hr/yr

Nearly six 9s (99.9999) of availability with POL using FSAN-B Redundancy
What should you know?

**Similar**
- Standards Based
- Local Area Network
- Enterprise Management
- Ethernet Frame Transport
- NAC Auth. – VLANs – PoE
  - 802.1x – 802.1Q – 802.3at

**Different**
- Point to Multipoint
- Multiple Services
- Guaranteed Bandwidth
- Single Strand of SM Fiber
- No Access and Distribution
Where did it come from?

Single Dwelling
- Voice
- Video
- Data

Carrier FTTH

MDU
- Fiber Hubs and Terminals
- Minimal Pathway Required
- No Power, Cooling or BBU
- No TR/IDFs Required

Copper Cabling
- No TR/IDF
- No Power
- No Cooling
- No BBU
- No Horizontal Pathway

Copper Cabling
- No Riser Pathway
- No Horizontal Pathway

Fiber Hubs and Terminals
- Minimal Pathway Required
- No Power, Cooling or BBU
- No TR/IDFs Required

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What’s the difference between a...

30 Story Apartment Building and a 30 Story Office Building

Furniture!
Target POL users

- Healthcare
- Campuses
- Casinos
- Hospitality
  - High Occupancy Buildings (Call Centers)
- Government and Military
- Multi-Tenant Units (Commercial and Residential)
- Education (K-12 and Higher Ed.)
- Sporting Venues
Example POL Implementation

Global Fortune® 225 Company – Americas Headquarters Melville, NY USA

Project Overview:
- Approximately 1 million sq. ft. (main building and 2 parking garages)
  - Planned growth for another 200,000 sq. ft.
- 1,500 employees
  - Planned growth for another 750
- Nearly 12,000 GPON Ethernet ports

Integrated Technologies over GPON:
- VoIP (PCs tethered through phone)
- Security
  - Access Control
  - Biometrics
  - Cameras (main building and parking)
  - Virtual turnstiles
  - Blue Phones in parking garage
- 480 WAPs
- Building automation
- Environmental controls
- IP Video content distribution
- Digital signage
- Point of Sale

Project Highlights
$1 million in CAPEX savings
Approximately $250,000/yr in energy savings
San Diego Downtown Central Library

**Optical LAN**
- Wireless Access Points
- Across library & courtyard
- Free access for patrons

- Rack Mount ONT
  - 24-ports GbE Ethernet
  - Mainly serving WAPs

- Chassis Style OLT
  - Located 4th floor data room
  - Serves all ONTs with 18 miles

- Surface Mount ONTs
  - 4-ports GbE Ethernet
  - Mainly mounted under desks

- Single Mode Fiber
  - Passive Optical Splitters
  - With Fiber Management

**San Diego Downtown Central Library ~ modern smart and green building**
- 9-story
- 3-story domed reading room
- 350-seat auditorium
- Technology center
- Outdoor plaza and café
- Coffee Bar
- LAN services Voice over IP, data & on-line video access
- Wi-Fi throughout the library and courtyard via 36 Meraki WAPs
- 3-D Printer Connectivity
- Nearly three hundred digital devices available
  - Workstations
  - iPads
  - iPad Minis
  - Chromebooks
  - Kindle
  - Sony eReaders
- Technology enable collaborative workspaces
- LEED Silver status
Knowledge Check
Passive Optical LAN is a standards based/recognized technology

✓ A. True

B. False
Guaranteed bandwidth is possible with...

- A. Passive Optical LAN
- B. Switch Based
- C. Both A and B
POL supports 802.1Q VLANs

☑️ A. True

B. False
AES 128 Encryption is present in __________ direction(s)

A. The upstream

✓ B. The downstream

C. Both upstream and downstream
Section 2 Agenda

• Verticals
• Bandwidth Requirements
• Dynamic Bandwidth Allocation
• Knowledge Check
Education Vertical

• K-12
  • Tight budgets vs. increased demand
  • Space constraints and non-traditional TRs/IDFs
  • Aging architecture vs. modern technology
    • Mondo Pads
    • AMX SchoolView
    • Smart Boards
    • Central content

• Post Secondary / Higher Education
  • Higher bandwidth demand
  • Increased BYOD
  • Valuable space lost with traditional
  • Lost revenue and added costs
    • Inefficient use of bandwidth
    • Inefficient use of space
    • Service providers profit
Hospitality Vertical

- **Hotels**
  - Industry groups driving POL advanced technology
    - HTNG – Hotel Technology Next Generation
    - HFTP – Hospitality Financial & Technology Professionals
      - HITEC – Hospitality Industry Technology Exposition and Conference
  - Higher port density in guest rooms and non administrative areas
    - Digital signage
    - Cameras
    - WAPs
    - IP card readers and locks
    - Four to eight data ports per guest room
  - Scalable solution with extended reach
    - Resort properties
    - Shared plot properties (Fairfield Inn, Courtyard, and Residence Inn)

- Future proof cabling infrastructure

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Healthcare Vertical

- **Assisted Living**
  - Patient wandering – WAP monitoring
    - In residence
    - Anywhere on the property
  - VoIP and Data needs in residence and administration
  - Security and Digital Communication

- **Critical Care**
  - Higher bandwidth demand
  - Higher port counts in patient rooms, nurse stations, and operating rooms
  - Building Automation and Intelligent Structures (converged networks)
    - Security
    - Monitoring
    - HVAC
    - Automated check-in / check out
    - Door sensors
  - No EMI/RFI concerns or Tempest shielding needed with fiber
  - Encrypted data pathways
Large Enterprise / Financial Verticals

• Large Office Building
  • Movement toward all BYOD
  • Converged networks (HVAC, Automation, Security, etc.)
  • Pathway and space constraints
  • Cost of traditional switch, cabling, and maintenance refresh
  • Increased technology
    • Pervasive wireless
    • Digital signage
    • Everything headed IP

• Financial (Banks and Trading Floors)
  • Higher bandwidth demand
  • Increased security
  • Increased port count
  • Redundancy, diversity, and automatic failover (FSAN-B)
  • Lost revenue and additional costs
    • Downtime (three 9s vs. five 9s)
    • Missed trades
    • Excess energy
Call Centers, Cities, and Retail

- **Call Centers**
  - High density areas
  - Low bandwidth requirements
    - IP Phones ~ 95Kb/s
    - Virtual “Dumb” terminals ~ 1Mb/s
    - Print/Scan/Fax ~ 500Kb/s

- **Cities, Towns, Neighborhoods, and MDUs**
  - Connect multiple buildings without distance limitations
  - Older buildings do not have pathways and spaces for traditional upgrades
  - Scalable solution for future expansion

- **Retail**
  - Digital signage
  - Customer Interactive Experience (pricing, web details, ordering, price compare)
  - Security, POS, multi-tenant service
Knowledge Check
Gigabit switches provide 1Gb/s connections to each WAO

A. True

✓ B. False
Most users consume bandwidth all day long

A. True

✓ B. False
This technology uses Dynamic Bandwidth Allocation

A. Switch Based

✓ B. Passive Optical LAN
Most users require a sustained GbE connection

A. True

✓ B. False
Questions?

Passive Optical LAN: 101

Tom Ruvarac
APOLAN
Passive Optical LAN:102

Dustin Bateman
Director, Emerging Technologies, VT Group
Section 3 Agenda

• Layout
• Primary Components
• Design Tips
• Support and Compatibility
• Knowledge Check
• Lunch
Traditional LAN vs. POL (GPON)
On a Campus

Optical LAN
Basic POL Schematic

Only upgrade the users that **need** 10G PON

* Methods vary by electronics vendor
The Migration to 10G PON (NG-PON1)

The cabling infrastructure stays the same and only the users that need it are upgraded.
The Migration to 40G PON (NG-PON2)

The cabling infrastructure stays the same and only the users that need it are upgraded.

<table>
<thead>
<tr>
<th>PON Name</th>
<th>Version</th>
<th>DOWN (Gbps)</th>
<th>UP (Gbps)</th>
<th>Industry Standard</th>
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<td>XG-PON</td>
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<td>10</td>
<td>ITU G.9807</td>
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<td>NG-PON2</td>
<td></td>
<td>40</td>
<td>40</td>
<td>ITU G.989</td>
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</tbody>
</table>
The Primary Components

**Optical Line Terminal (OLT)**

- -48VDC Carrier Grade Chassis
- After Layer 3
- Up to 14 Line cards
- Typically 4 singlemode output ports per card
  - 56 Outputs per chassis
  - 1792 ONTs (1x32 splitters)
  - 7168 Ethernet Ports (ONT has 4 copper output ports)
The Primary Components

**Optical Splitters**

Available Splits

- 1x2
- 1x4
- 1x8
- 1x16
- 1x32
- 2x4
- 2x8
- 2x16
- 2x32

Traditional 1U Rack-Mount Splitter
The Primary Components

**ONT – Optical Network Terminal**

- Active equipment provided by electronics manufacturers.
- Located near the user or device.
- Typically 4 RJ45 (10/100/1000) outputs with optional POE.
- Up to 60W of available POE (vendor specific).
- Standard HVAC is adequate.
- Optional internal or external battery back-up.
- POTS and COAX ports available.
- Establishes and maintains secure AES 128 Encryption.
- Supports multiple VLANs on each port.
ONT Sharing

128 Users = 4 SFP PON ports

128 Users = 2 SFP PON ports

128 Users = 1 SFP PON ports
Distance and Loss

OLT Output = +3dBm

Minimum of 15.5dB loss required!

ONT Range = -12.5dBm to -26dBm

1x32 Passive Equipment (Splitter)

12.5mi / 20km

Up to 100m (Solid Conductor Cable)
Cascade Splitting Loss

1x32 = 32
16.7dB

2x16 = 32
17.3dB

4x8 = 32
17.5dB
Split Ratios Do NOT “Change” Bandwidth

<table>
<thead>
<tr>
<th>Split Ratio</th>
<th>Bandwidth per ONT</th>
<th>Splitter Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x32</td>
<td>311 Mb/s</td>
<td>17.3 dB</td>
</tr>
<tr>
<td>1x16</td>
<td>311 Mb/s</td>
<td>13.5 dB</td>
</tr>
<tr>
<td>1x8</td>
<td>311 Mb/s</td>
<td>10.3 dB</td>
</tr>
</tbody>
</table>

Each ONT may require an Attenuator
Type B (FSAN-B) Redundancy

If any interruption is detected on the primary path (OLT to ONT), the OLT will switch to the redundant path instantaneously.

OLT chassis is “Carrier Grade” meaning that it is designed to be in service for 25+ years with 100 possible.

Type B Redundancy = Nearly Six 9s
Example Layout of Type B (FSAN-B) Redundancy

In IDF Area:
- TR 1 (Does not have to be a TR or IDF)
  - Path 1 (Primary)
    - RDT (6’x9’)
    - Includes 12F MPO on a spool
- TR 2 (Does not have to be a TR or IDF)
  - Path 2 (Redundant)
    - 12F MPO
    - RDT (6’x9’)
    - Includes 12F MPO on a spool

In Equipment Room:
- Layer 3 Device

In Office Area:
- CAT6 Patch Cord
- CNT
- Wall Plate
- 2x32 Splitter
- ZONE

If Path 1 is interrupted, Path 2 activates (typically <200ms)
# IP/Ethernet Protocol Support

## Network Integration
- Multiple 1G and 10G Ethernet Uplinks
- IEEE 802.3ad Link Aggregation Control Protocol (LACP)
- IEEE 802.1Q VLAN Encapsulation
- IEEE 802.1w Rapid Spanning Tree (RSTP)
- IEEE 802.1s Multiple Spanning Tree (MSTP)
- Virtual Router-to-Router Redundancy (VRRP)
- IPv4 / IPv6
- IGMPv2 / IGMPv3
- Network Access Control (NAC)
- IEEE 802.1x (Port-based Authentication)
- Dynamic Host Control Protocol (DHCP)
- DHCP Snooping and Option 82 insertion
- Port Security, Sticky MACs
- RFC-2267 (Denial of Service)
- Traffic Storm Control
- Bridge Protocol Data Unit (BPDU) Guard

## Service Delivery
- 802.1p: Class of Service
- IP differentiated services code point (DSCP)
- Quality of Service: Per-VLAN, Per-Port, Per-Service queuing / scheduling *
- Sophisticated QoS and Traffic Management
- Eight Queues per VLAN
- Policing, Scheduling, Shaping per Queue
- Congestion and Flow Control
- Hardware Based ACLs: L2, L3, L4
- Hardware Based Multicast Management
- IEEE 802.3af, 802.3at (PoE)
- Link Layer Discovery Protocol (LLDP)

## Monitoring / Management
- SNMP v1, v2, v3
- CLI Console Port
- Remote Monitoring (RMON) software agent
- RMON I & II
- Enhanced SNMP MIB support
- RFC 1213-MIB (MIB II)
- Extended MIB support
- Network Timing Protocol (NTP)
- RADIUS based authentication
- SSH v1, v2
- VMWare Support for EMS
- OLT SysLog support (2014)
- Y.1371 (2014)
- 802.1ag Fault Detection (2014)

*This represents a partial list of supported IEEE and IP/Ethernet protocols*
Knowledge Check
Upstream (ONT to OLT) analog video utilizes which wavelength?

A. 1550nm
B. 1490nm
C. 1310nm
D. 1625nm
E. None

✅ E. None
A cascaded 1x4 + 1x16 split is a good practice?

A.True

✓ B.False
GPON bandwidth can be increased by using a lower split ratio

A. True

✓ B. False
The minimum loss required between the OLT and ONT is...

A. 13.5 dB
B. 10.7 dB
C. 15.5 dB
D. 17.2 dB
E. None of these
PoE in a POL is administered at the...

A. OLT
B. ONT
C. Injector
D. PoE is not possible

✓ B. ONT
Section 4 Agenda

• Savings
• LEED and Environmental Benefits
• Largest POL deployment in the world
• Knowledge Check
• 15 Minute Break
Savings
## POL: Total Cost of Ownership Savings

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<th>Expense</th>
<th>250 Users</th>
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<th>1000 Users</th>
<th>Campus 5000 Users</th>
<th>Campus 10,000 Users</th>
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<td>46%</td>
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<td>68%</td>
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<td>CapEx</td>
<td>31%</td>
<td>41%</td>
<td>48%</td>
<td>55%</td>
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<td>OpEx</td>
<td>40%</td>
<td>50%</td>
<td>65%</td>
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<td>70%</td>
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<td>• Power</td>
<td>48%</td>
<td>61%</td>
<td>68%</td>
<td>75%</td>
<td>75%</td>
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<tr>
<td>• Cooling</td>
<td>48%</td>
<td>61%</td>
<td>68%</td>
<td>75%</td>
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## POL: Power Consumption Comparison

### Regional Medical Center
4000 drops

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<th>Description</th>
<th>Quantity</th>
<th>Rated Power</th>
<th>Total Power</th>
<th>Notes</th>
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<tr>
<td>Main Distribution Frame</td>
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<td>Traditional LAN</td>
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<td>Cisco WS-C3750X-48P-S(1715W)</td>
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<td>134</td>
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<td>UPS</td>
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<td>937</td>
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<td>1,125</td>
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<td>Intermediate Distribution Frames</td>
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<td>Main Distribution Frame</td>
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<td>Notes</td>
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<tr>
<td>WT21004</td>
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<td>9</td>
<td>11,295</td>
<td>Admin areas</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>11,295</td>
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</table>

### Price per kw hour $0.082

<table>
<thead>
<tr>
<th></th>
<th>W/HR</th>
<th>Annual $</th>
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</thead>
<tbody>
<tr>
<td>Total POL Budget</td>
<td>14,050</td>
<td>$10,081</td>
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<tr>
<td>Total Traditional Budget</td>
<td>37,171</td>
<td>$26,670</td>
</tr>
<tr>
<td>Difference</td>
<td>(23,121)</td>
<td>($16,589)</td>
</tr>
<tr>
<td>Total Savings Percentage</td>
<td>-62.20%</td>
<td></td>
</tr>
</tbody>
</table>

---

*Note: Calculations and values are based on the given data and assumptions.*
Potential* LEED Credits

- Energy and Atmosphere Credit 1 (1-3 pts).
  - Reduction in TRs, HVAC equipment, switch equipment, UPS, lighting and other energy needs.
  - The PON system helps the overall efficiency of the energy systems.

- Innovation in Design Credit 1 (1-4 pts).
  - The PON system utilizes less equipment, resulting in less raw materials, less garbage, less transportation and reduced time for implementation and commissioning.
  - In addition, utilizing a fiber system ensures the life of the system extends beyond the life of a conventional “switched” system.
“Eco-Friendly”

- **Reduced Power Requirements**
  - Savings between 40% to 60%
- **Reduced HVAC Requirement**
  - A Fortune 500 company saved about $450K on the Power distribution network (HVAC, backup etc) for a building project with 2000 Ethernet ports
- **Reduction in Non-renewable materials**
  - Reduction of up to 8000 pounds of plastic and copper versus a Cat 6 install for building of 4000 Ethernet ports
- **Floor Space Savings**
  - Traditional layer-2 solutions are bound by the 300ft Ethernet limitation
- **Fire Load Savings**
  - Savings in Sprinkler Systems
  - Fire Load and ceiling space savings

**Green Benefits**
- Reduction in power consumption
- Reduction in non-renewable materials
- Ceiling space and fire load savings
- Reduction in cabling costs
- Floor space savings
## Cabling Comparison

<table>
<thead>
<tr>
<th>Riser Rated Cables</th>
<th>Reduced Bend Radius Single-Mode</th>
<th>Category 5e UTP</th>
<th>Category 6a UTP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10G Distance</strong></td>
<td>40km</td>
<td>45m</td>
<td>100m</td>
</tr>
<tr>
<td><strong>Cable OD</strong></td>
<td>3mm</td>
<td>5.7mm</td>
<td>7.5mm</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>4lb / 1000’</td>
<td>22lb / 1000’</td>
<td>39lb / 1000’</td>
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<tr>
<td><strong>Minimum Bend Radius</strong></td>
<td>5mm</td>
<td>22.8mm</td>
<td>30mm</td>
</tr>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>48lbf</td>
<td>25lbf</td>
<td>25lbf</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
Largest Enterprise POL Deployment
Knowledge Check
Which of these are a benefit of POL?

A. Reduction in power
B. Reduction of fire load
C. Reduction of non-renewable materials
D. All of these are benefits

✅ D. All of these are benefits
LEED Credits are

A. Possible with POL
B. Automatic with POL
C. Guaranteed with POL
D. Not Possible with POL
So far, my knowledge depth of Passive Optical LAN increased so far today by...

A. A little
B. A lot
C. What is Passive Optical LAN?
D. None
Questions?

Passive Optical LAN: 102

Dustin Bateman
VT Group
15 Minute Break

*Please respect others and return on time.*
Introduction to
POL Components

Matt Miller
Associate Vice President, CallisonRTKL
Agenda

• Components
  – OLT
  – ONT
  – Video
  – DC Power

• Power Considerations

• Management
  – Centralized Management
  – Management Systems
  – Bandwidth Management
  – VLANs, QoS, LLDP and other Standards
Objectives

• Identify the various types of optical splitters and their principles of operation
• Identify the active electronic components in a Passive Optical LAN
• Understand the management principles for a POL
Components - OLT

- OLT is head-end component
- Typically located in MDF or Data Center
- Manages connected ONTs
- Typically consist of:
  - Management
  - Switch Fabric
  - Uplink Interfaces
  - PON Interfaces
- Out-of-band Management
Components – Large OLT Models

- Chassis-Based
- Fully Redundant
- Up to 224 PON Ports
- Thousands of ONTs
- DC Powered
Components – Small OLT Models

Small OLTs

- AC and DC Power
- Small Chassis and Standalone
- Small Office/Field Office
- 4 to 16 PON Ports
- Hundreds of ONTs
Components – OLT Uplinks

- Standard Ethernet uplinks to core
- Uplinks typically 1G or 10G pluggable optics
- VLANs trunked into uplink ports
- Uplinks can be combined into LAGs
Components – OLT PON Ports

• From 4 to 224 PON ports per OLT
• Each PON port typically supports 32 ONTs
  = Thousands of ONTs per OLT!
• Typically SFP based
• Class C+ optics feature 32dB loss budget
Components – OLT Redundancy

**Typically Redundant**
- Power
- Backplane
- Management
- Switch fabric
- Uplinks

**Sometimes Redundant**
- PON Ports
- PON Cards
- Entire OLT
Optical Splitters

- Splitters provide optical connections in pairs
- Each 1x2 split equates to ½ of the optical power
  - ~3dB loss
- Splitters range from 1x2 up to 1x64 splitters
- 1x32 is the most common split ratio for POL
## Splitter Loss

<table>
<thead>
<tr>
<th>Splitter</th>
<th>Max Loss*</th>
<th>Typical Loss*</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x2</td>
<td>3.8dB</td>
<td>3.1dB</td>
<td>1260-1360nm and 1480-1580nm**</td>
</tr>
<tr>
<td>2x2</td>
<td>4.3dB</td>
<td>3.2dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x4</td>
<td>7.2dB</td>
<td>6.6dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>2x4</td>
<td>7.8dB</td>
<td>6.7dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x8</td>
<td>10.3dB</td>
<td>9.7dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>2x8</td>
<td>10.9dB</td>
<td>9.8dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x16</td>
<td>13.5dB</td>
<td>12.8dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>2x16</td>
<td>14.1dB</td>
<td>12.9dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x32</td>
<td>16.7dB</td>
<td>16.0dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>2x32</td>
<td>17.4dB</td>
<td>16.2dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x64</td>
<td>20.4dB</td>
<td>19.7dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x2 + 1x16</td>
<td>17.3dB</td>
<td>15.9dB</td>
<td>1260 - 1635nm</td>
</tr>
<tr>
<td>1x4 + 1x8</td>
<td>17.5dB</td>
<td>16.3dB</td>
<td>1260 - 1635nm</td>
</tr>
</tbody>
</table>

* Includes PDL, WDL and TDL. Does not include connector loss

** May not be compatible with NG PON1 or NG PON2
The term "passive" in Passive Optical Network refers to the fact that the splitter requires no power as opposed to an "active" device like the OLT or switches in a traditional network. The splitter serves to optically replicate upstream signals to a number of downstream fibers. The typical number of fibers served in a PON network is 32. As the splitter provides a replicated optical signal to all 32 subscribers downstream, it is simultaneously combining those 32 fibers into a single feeder fiber in the upstream direction. Consequently the optical splitter is sometimes referred to as a splitter/combiner. The splitter will be housed in a number of form factors.
PLC Splitter

Planar Lightwave Circuit (PLC) Splitter

- More Expensive
- Uniform Output
- Most appropriate for outdoor use
- Manufacturing
  1. Waveguide used to split the optical signal is fabricated using a silicon dioxide chip.
  2. Involves a lithographic process similar to that used in the manufacture of silicon computer chips. PLC splitters provide the most uniformity between fiber outputs (the downstream fibers) with respect to the amount of optical loss measured on each fiber.
- Best choice when loss is critical
Planar Light Circuit/Planar Waveguide
FBT Splitter

Fused Biconical Taper (FBT) splitter

• Lower Cost

• Typically less uniform from fiber to fiber.

• Manufacturing
  1. Thermally fused two overlapping fibers together under tension
  2. The resulting fusion splice creates a two by two splitter.
  3. Typically, one of these fiber connections is trimmed off and the result is a single fiber subtending to two fibers.
  4. These two fiber outputs can then be fused to additional one-by-two splitters until the desired number of splits is achieved.

• Used where extreme temperature variations or other environmental factors are not likely to cause the optics connected at the ends of the fiber to drift from their optimum wavelength specifications.
2xN Splitters

- 2 Inputs
- 2 to 64 Outputs
- Second Input Allows
  - Redundant feeders/PON Ports/PON Cards/OLTs
  - Easier Migration to 10G
  - Flexibility for the Future
ONTs

- ONT located close to the end user
- Fiber input
- Variety of user interfaces available
- Provide PoE
- Consume ~7W power + PoE draw
ONT Models - Traditional

- Large variety of ONTs available
- AC and DC power options
- Desk-mount, In-wall, and Rack-mount
- Battery backup

- Match interfaces to user needs:
  - Ethernet Ports with PoE
  - POTS Ports
  - Coaxial Television
  - Wi-Fi
ONT Models - Unique

In-Wall

Rack-Mount

Industrial/Outdoor
ONT Connections

What Can I Connect?

- PCs
- Thin Clients
- VoIP Phones
- POTS Phones
- Wireless Access Points
- Coaxial Cable TV
- IPTV
- Access Control
- Security Cameras
- Building Management Systems
- Biometric Sensors
- Anything with an Ethernet, POTS, or Coax Interface!
ONT Compatibility

• EPON and GPON are not compatible
• Different manufactures typically choose not to interoperate
• Beyond the standards, some manufacturers implement additional features – especially true in EPON
ONT Security

• ONT security designed to assume the ONT is in the hands of the adversary
• ONT does not function without OLT
• Usually no management ports on ONT
• ONT receives all programming from OLT
Power Considerations

- ONTs report a loss of power or loss of service
- ONTs can be powered via AC or DC
- Battery backups for high availability
- PoE and PoE+ available
Components - Video

- **Laser Transmitter** – Electrical to Optical 1550nm Conversion
- **EDFA (Erbium Doped Fiber Amplifier)** – Amplifies Optical Signal to 18 – 21dBm
- **WDM** – Combines Wavelengths
Components - Video

- Laser Transmitter
- EDFA
- RF Nodes
- RFoG/two-way
Components – DC Power

- Most OLTs use -48V DC Power
- Same power used in telco central offices
- Rectifiers required to convert AC to DC
- Properly ground your equipment!
Components – DC Power

- Redundant Inputs
- Redundant Outputs
- Redundant Rectifiers
- Fuse or Circuit Breaker Protection
- Network Management
- Basically an external power supply!
Centralized Management

- ONTs Centrally Managed
- No physical ONT management ports
- Same concepts as traditional network
  - VLANs
  - PoE
  - QoS
Centralized Management
Management Systems

• Systems included standard CLI and EMS
• OLT runs without management server
• Application and Web/Mobile
• GUI is more important in PON than legacy networks
  ➢ Density is far greater!
• ONTs are an extension of the OLT
Profiles & Templates

• Create a standard profile or template for your services
• Apply that profile or template to many ONTs at once!
Management Systems Features

• Alarming and Notification
• Bandwidth Monitoring
• Central OLT & ONT Upgrades
• MAC Searches
• VLAN Member Reports
Bandwidth Management

• Bandwidth Management is Built-in!
• Guarantee every user bandwidth
  – Set a committed rate
  – Committed rates cannot exceed capacity of any link in the system
• Manage additional bandwidth as you desire
  – Set a peak rate
Managing All The Same Things

The same things you manage today...

- VLANs
- PoE
- QoS
- LLDP
- Network Access Control
What makes PON a POL?

1. Indoor ONTs
2. Power over Ethernet
3. Internal Packet Switching
4. Enterprise Ethernet Features
Questions?

Introduction to POL Components

Matt Miller
CallisonRTKL
60 Minute Lunch Break

Please respect others and return on time.
Introduction to POL Design

Mike Watts & Chad Hines
Section 9 Agenda

• POL Component and Budget Review
• POL Cable Design Options Overview
• Design Challenge Exercise
• Knowledge Check
APC and UPC

- Ultra Physical Contact Connectors (UPC)
  - Blue

- Angled Physical Connectors (APC)
  - Green
Splitter Deployment

Single Splitter
- One splitter in the Optical Distribution Network
- All splitter loss is at one location
- Works for 99% of POL deployments
Splitter Deployment

Cascaded Splits
• Used when end users are geographically dispersed
• Campus out-buildings
• Loss from splitters in path must be summed

Engineered Splits
• Loss may favor a particular output
Centralized Split Overview

FDH
Houses Splitters

Consolidation Point
Zone Cabling
Centralized Splitting

• Provides maximum ROI for POL
• Houses splitters in one location per floor
• Installation Labor hours are reduced
• Connection between Riser and Horizontal
# Centralized BoM

<table>
<thead>
<tr>
<th>Area</th>
<th>Product Description</th>
<th>Total Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF</td>
<td>Rack Mount Fiber Enclosure, 1U, holds 3 MPO Fiber cassettes</td>
<td></td>
</tr>
<tr>
<td>MDF</td>
<td>MPO Fiber Cassette</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>1 x 32 splitter used with FDH</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>288-Port capacity FDH accommodating 18 splitters and 24 MPO outputs</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>24 port Consolidation Point w/300 foot Plenum MPO Cable</td>
<td></td>
</tr>
<tr>
<td>ONT Fiber</td>
<td>SCAPC-SCAPC Plenum Yellow 3 (10’)</td>
<td></td>
</tr>
<tr>
<td>OLT Fiber</td>
<td>SCUPC-SCAPC Plenum Yellow 8 (25’)</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 23 (75’)</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 31 (100’)</td>
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</tr>
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<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 38 (125’)</td>
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<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 46 (150’)</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>4-port White Faceplate</td>
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<tr>
<td>WAO</td>
<td>SCAPC Singlemode adapter</td>
<td></td>
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<tr>
<td>WAO</td>
<td>Category 6 modular jack</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>RJ45 plug to RJ45 plug, T568B Blue</td>
<td></td>
</tr>
</tbody>
</table>
Zone Split Overview

[Diagram showing zone split overview with labels for FSB and IDF]

Zone Splitter Housing
Zone Splitting

- Eliminates the need for the IDF
- Places Splitter closer to user
- Location for cross-connects
- Termination for horizontal and feeder fiber
- Moves redundancy closer to the user in Type B applications.
## Zone BoM

<table>
<thead>
<tr>
<th>Area</th>
<th>Product Description</th>
<th>Total Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF</td>
<td>Rack Mount Fiber Enclosure, 2U, holds 6 MPO Fiber cassettes</td>
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</tr>
<tr>
<td>MDF</td>
<td>MPO Fiber Cassette</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (100 foot)</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (200 foot)</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (300 foot)</td>
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</tr>
<tr>
<td>Horizontal</td>
<td>1 x 32</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>Fiber Zone Box</td>
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</tr>
<tr>
<td>Horizontal</td>
<td>Fiber Zone Box Installation Kit</td>
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<tr>
<td>ONT Fiber</td>
<td>SCAPC-SCAPC Plenum Yellow 3 (10')</td>
<td></td>
</tr>
<tr>
<td>OLT Fiber</td>
<td>SCUPC-SCAPC Plenum Yellow 8 (25')</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 23 (75')</td>
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<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 31 (100')</td>
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<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 38 (125')</td>
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</tr>
<tr>
<td>Horizontal</td>
<td>SCAPC-SCAPC Plenum Yellow 46 (150')</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>Faceplates 4-port White Alpine</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>SCAPC Singlemode adapter</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>Category 6 modular jack</td>
<td></td>
</tr>
<tr>
<td>WAO</td>
<td>RJ45 plug to RJ45 plug, T568B Blue</td>
<td></td>
</tr>
</tbody>
</table>
Rack Mount Split Overview
Rack Mount Splitting

- Customer used to look and feel
- Splitters are rack-mounted or installed in fiber housing modules
- Fiber is terminated on patch panels
- Can use Pre-terminated or field connectorized cable
<table>
<thead>
<tr>
<th>Area</th>
<th>Product Description</th>
<th>Total Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF</td>
<td>Rack Mount Fiber Enclosure, 2U, holds 6 MPO Fiber cassettes</td>
<td></td>
</tr>
<tr>
<td>MDF/IDF</td>
<td>MPO Fiber Cassette</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>Wall Mount 2-Post Open Frame Rack Cabinet 8U</td>
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</tr>
<tr>
<td>IDF</td>
<td>Rack Mount Fiber Enclosure, 1U, holds 2 MPO Fiber cassettes</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>Rack Mount Fiber Enclosure, 2U, holds 6 Panels</td>
<td></td>
</tr>
<tr>
<td>IDF</td>
<td>SC Adapters, Simplex, APC, 12 F, Single-mode</td>
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</tr>
<tr>
<td>Riser</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (100 foot)</td>
<td></td>
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<td>Riser</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (200 foot)</td>
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<tr>
<td>Riser</td>
<td>MPO Fiber Trunk 12 Strand Singlemode Plenum (300 foot)</td>
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</tr>
<tr>
<td>IDF</td>
<td>Rack Mounted 1 x 32 splitter</td>
<td></td>
</tr>
<tr>
<td>ONT Fiber</td>
<td>SCAPC-SCAPC Plenum Yellow 3 (10')</td>
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<tr>
<td>OLT Fiber</td>
<td>SCUPC-SCAPC Plenum Yellow 8 (25')</td>
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<tr>
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<td></td>
</tr>
</tbody>
</table>
Hybrid Deployments

• Some deployments choosing hybrid deployments
• Hybrid Ideas
  – Keep IDF for rack-mount ONTs, but use fiber zone hubs
  – Put ONTs in active zone box and run category cabling to user
  – Use 100% rack-mount ONTs in retrofit scenario
Campus Overview
OSP Deployment

• OSP options can be mixed with LAN options
• Be careful of mixing manufacturer product lines due to incompatibility issues
• Many options due to PON history in telecommunications
Good Design Practices

✓ Meets customer requirements
✓ Provides a value to the customer:
  ✓ Reduced Cost
  ✓ Power/Space/Cooling
  ✓ Performance
  ✓ Longevity
✓ Is not overly complex
✓ Makes customer happy!
Design Questions

- What design challenges do you see?

- What problems do you see POL solving?

- What problems do you see POL causing?
Questions?

Passive Optical LAN Design
15 Minute Break

Please respect others and return on time.
Passive Optical LAN
Power Survivability

Chad Hines
ITConnect, Inc.
Section 6 Agenda

• Survivability
• Verticals
• Types
• Hardware and Cabling
• When, Where, and How
• Knowledge Check
What is survivability

- Survivability: the capability of a system or organization to withstand a disaster or hostile environment, without significant impairment of its normal operations.
Why Would We Need Survivability

POWER OUTAGES
Power Over Ethernet Requirements

- VoIP Handsets
- PTZ Camera
- Wireless
- VTC
- AV Control Systems
- RFID
- Access Control

Diagram shows the flow of power from AC to DC through an AC/DC converter, followed by Power Over Ethernet (PoE) to various devices.
Non-PoE Requirements

- Analog Voice
- RFoG Capabilities

Diagram:
- DC Power Feed
- AC/DC Converter ("power brick")
- AC Power Feed
- Analog Voice
- RFoG Capabilities
What’s The Impact

Closed due to power outage!
ONT Placement Can Define Powering

AC = Local

DC = Remote
What Needs to Survive

- VoIP Handsets
- VTC
- RFID
- PTZ Camera
- AV Control Systems
- Wireless
- Access Control
Call Centers/ DoD/ Financial
Healthcare
Hospitality
Commercial Business and Education
Different Ways to Survive

• Local battery
• Remote:
  – Powered
  – Battery
  – Generator
• AC power on generator
  “Emergency power”
Local Batteries

• PROs
  – Place them only where needed
  – Low cost/ commitment
  – May already be using UPS at desk

• CONs
  – Replacement after several years
  – More items to manage
  – Limited uptime
  – Battery failure
Remote Power

- Remote power means to power multiple devices from a DC power station which can be either distributed or centralized.
  - Distributed remote power is typically located in an IDF or zone distribution box and can be remotely powered from a DC power plant from the MDF
  - Centralized remote power is typically in the MDF feeding localized power distribution units to feed ONT’s
- Voltage options: 48vdc – 54vdc
Why Remote Line Power?

- AC access not required at each ONT
- Uses low cost copper cables
- Battery backup provided in centralized location rather than at each ONT

Reduce CapEx and OpEx

Reduces time to market & enables rapid deployment
Power Connectors

Locking preferred for remote power applications
Power Connectors

Non-locking connector introduces risk
Power Connectors

Be creative but not sloppy
48vdc Centralized

Distributed remote power with AC in IDF converted to 48vdc-54vdc which feeds ONT
Centralized remote power with AC in MDF converted to 48vdc which feeds proper size gauge (8-2AWG) THHN riser to 32 unit PDU in zone box, then to ONT.
Remote Power

• PROs
  – Survivability, battery back up can be sized to any customer requirement
  – Eliminates AC plug and wallwart at ONT
  – Centralizes battery backup
  – Remote power reset of an ONT and device

• CONs
  – Level 4 DC Technician
  – Power Engineer is required
  – Requires additional power in MDF
  – Electrical contractor will take a loss
Cost Savings Summary

Capex Savings

- Eliminating need to run AC power to each ONT location reduces cost for cabling, conduits, and electricians
- **Reduced space** required at each ONT
- NEC Class 2 system eliminates cost of using armored cable to comply with standards

Opex Savings

- Eliminating batteries at remote sites reduces ongoing battery maintenance cost
- Remotely accessible system minimizes need for site visits for troubleshooting & alarming
- **Reduction in power consumption** through improved power conversion efficiency and lower HVAC requirements
Remote Power Caution

- What happens when you have a coil of copper cable and send constant DC voltage through it?
- Trimming to avoid the coil means you’ve limited future flexibility
- Not all ONTs are 48vdc
- Certified UL/CSA Listed and NEBS class 2 certified product
- Consult a Certified DC Engineer for proper design
AC Generator Power

- Alternating Current (AC) power
  - Installed on dedicated “emergency” circuits
  - Circuits fed from dedicated panels
  - Panels powered with dedicated feeders from generator power
AC Generator Power

• PROs
  – Survivability
  – Not limited to run time of battery

• CONs
  – Added cost / complexity
  – Requires licensed electrician to install vs. low voltage contractor
  – Requires space outside of facility to house
Rectifier Hardware Options
PDU Hardware Options
Cabling Options

- Solid vs. Stranded
- Hybrid composite cable
- Separate cables
- Use existing copper
Solid vs. Stranded Conductor
Solid vs. Stranded Conductor

Pictured: NOT what is meant by “stranded” RJ45.

Identifying Stranded VS. Solid RJ45s:
- Stranded: pointed, shallow connectors pierce jacket & connect to strands
- Solid: longer, staggered connectors straddle conductor
Composite Cable
Separate Cables
Considerations for Cabling

• Will the copper and fiber originate in the same location? This will significantly impact your decision for Composite or Separate cables.

• Repurposing existing Cat-X cable as your power carrier is a benefit and reduces costs for cable and installation.
## Power System Design Process

<table>
<thead>
<tr>
<th>Step 1: Get the Numbers</th>
<th>Step 2: Follow the Fiber Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>• How many ONTs are required?</td>
<td>• Where are the distribution points?</td>
</tr>
<tr>
<td>• Per floor?</td>
<td>• Are IDF closets or electrical rooms available for power?</td>
</tr>
<tr>
<td>• Per building?</td>
<td>• What is the maximum distance from a distribution point to an ONT?</td>
</tr>
<tr>
<td>• Per sector?</td>
<td></td>
</tr>
<tr>
<td>• What is the rated power consumption of the ONTs?</td>
<td></td>
</tr>
<tr>
<td>• Will PoE+ be supplied by the ONT?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3: Consider Other Factors</th>
<th>Step 4: Determine Power Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What is the desired runtime?</td>
<td>• Distributed DC Plants</td>
</tr>
<tr>
<td>• Which circuits are considered Emergency circuits?</td>
<td>• Centralized DC Plants</td>
</tr>
<tr>
<td>• What are future growth and expansion expectations?</td>
<td></td>
</tr>
</tbody>
</table>

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How Far Can It Reach?

- 6Vdc allowable voltage drop in cable to meet PoE+ standard at ONT
- 1Vdc drop across ONT
Design Architecture: Centralized DC Plants

**Pros**
- Single DC plant and batteries to maintain
- Less space per floor required for power equipment

**Cons**
- Cabling cost to run Class 1 circuits to each Zone
  - Conduit
  - Electrician
  - Large AWG cable
- 48Vdc Plant and Battery must be larger to offset cable losses
Design Architecture: Distributed DC Plants

Pros
- All DC cabling will be NEC Class 2 compliant
- Installation cost
- Equipment cost

Cons
- Space must be found for power equipment in IDFs
- Distributed batteries are more difficult to maintain
- Additional AC circuits required to each rectifier location
### Design Example

<table>
<thead>
<tr>
<th>ONT Count by IDF</th>
<th>1-2 Port ONT</th>
<th>DC WATTS</th>
<th>4 Port ONT</th>
<th>DC WATTS</th>
<th>8 Port ONT</th>
<th>DC WATTS</th>
<th>24 Port ONT (AC)</th>
<th>500W 120VAC</th>
<th>Total ONT</th>
<th>Total DC load</th>
<th>DC Power system Load</th>
<th>Total AC load (W)</th>
<th># of Ch</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDF 3D</td>
<td>47</td>
<td>30</td>
<td>3</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>51</td>
<td>1650</td>
<td>2145</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>IDF MDF</td>
<td>47</td>
<td>30</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>55</td>
<td>1970</td>
<td>2561</td>
<td>500</td>
<td>500</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>IDF 3A</td>
<td>45</td>
<td>30</td>
<td>12</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>58</td>
<td>2310</td>
<td>3003</td>
<td>500</td>
<td>57</td>
</tr>
<tr>
<td>IDF 2F</td>
<td>48</td>
<td>30</td>
<td>10</td>
<td>80</td>
<td>2</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>61</td>
<td>2400</td>
<td>3120</td>
<td>500</td>
<td>60</td>
</tr>
<tr>
<td>IDF 2E</td>
<td>50</td>
<td>30</td>
<td>11</td>
<td>80</td>
<td>7</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>69</td>
<td>2940</td>
<td>3822</td>
<td>500</td>
<td>68</td>
</tr>
<tr>
<td>IDF 1A</td>
<td>58</td>
<td>30</td>
<td>21</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>80</td>
<td>3420</td>
<td>4446</td>
<td>500</td>
<td>79</td>
</tr>
<tr>
<td>IDF 2A</td>
<td>56</td>
<td>30</td>
<td>18</td>
<td>80</td>
<td>5</td>
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<td>1</td>
<td>500</td>
<td>80</td>
<td>3520</td>
<td>4576</td>
<td>500</td>
<td>79</td>
</tr>
<tr>
<td>IDF 4A</td>
<td>62</td>
<td>30</td>
<td>24</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>80</td>
<td>3780</td>
<td>4914</td>
<td>500</td>
<td>86</td>
</tr>
<tr>
<td>IDF 2C</td>
<td>77</td>
<td>30</td>
<td>18</td>
<td>80</td>
<td>3</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>99</td>
<td>3990</td>
<td>5187</td>
<td>500</td>
<td>98</td>
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<tr>
<td>IDF 1Z</td>
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<td>30</td>
<td>36</td>
<td>80</td>
<td>1</td>
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<td>1</td>
<td>500</td>
<td>99</td>
<td>4790</td>
<td>6227</td>
<td>500</td>
<td>98</td>
</tr>
<tr>
<td>IDF 3C</td>
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<td>30</td>
<td>34</td>
<td>80</td>
<td>1</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>112</td>
<td>5080</td>
<td>6604</td>
<td>500</td>
<td>111</td>
</tr>
<tr>
<td>IDF 5A</td>
<td>87</td>
<td>30</td>
<td>28</td>
<td>80</td>
<td>7</td>
<td>80</td>
<td>1</td>
<td>500</td>
<td>123</td>
<td>5410</td>
<td>7033</td>
<td>500</td>
<td>122</td>
</tr>
<tr>
<td>Total ONT</td>
<td>714</td>
<td>222</td>
<td>26</td>
<td>12</td>
<td>500</td>
<td>53638</td>
<td>6000</td>
<td>974</td>
<td>41260</td>
<td>53638</td>
<td>6000</td>
<td>962</td>
<td></td>
</tr>
</tbody>
</table>
Deployment Methodologies

• What is the design architecture?
• What is the end user survivability requirement?
• Cabling and infrastructure approach
• Maintaining flexibility and future management in your network.
Knowledge Check
Does a 48VDC remote power system fed by an AC plug in require a licensed electrician for installation?

A. Yes
B. No

✅ C. Sometimes
Can a class 2 circuit be installed in plenum space without the use of conduit?

✅ A. Yes
B. No
C. Sometimes
Questions?

Power Survivability
Chad Hines
ITConnect Inc.
POL Testing Considerations

Mike Watts
Vice President of Noovis
Fiber Connectors

SC/APC is default standard in PON networks

- APC connectors reduce reflectance
- Reduce damage to transmitters and amplifiers
- Allow injection of Analog Video
APC and UPC

• Ultra Physical Contact Connectors (UPC)
  – Blue

• Angled Physical Connectors (APC)
  – Green
Endface Comparison

Source: FOA.ORG
APC vs. PC (un-mated)

RL = \sim 14.7\text{dB}

PC/UPC – Not Angled

RL = \text{Return Loss}

RL = \textgt 60\text{dB}

APC - Angled

8\degree \text{Angle}
APC vs. PC (mated)

RL = ~ 50-55dB

PC/UPC – Not Angled

RL = Return Loss

RL = >60dB

APC - Angled

8° Angle

Start PC

Start APC
Importance of Cleaning

No. 1 cause of fiber network failures is contaminated connectors

- NTT-Advanced Technology Research, 2010

80% of network problems are due to dirty connectors!
Importance of Cleaning

Fiber Core

Fiber Cladding

Particulate

125µm

8.3µm

Information courtesy of USCONEC, Hickory, NC. Used with permission.
Common Contaminants

- Dust
- Skin oil
- Alcohol residue
- Distilled water residue
- Vegetable oil
- Hand lotion
- Dryer lint
- Saltwater residue
- Graphite

End face should be free of any contamination or defects,
Contaminate Transfers

Contamination transfers from the contaminated to the clean ferrule reducing optical performance.

Information courtesy of USCONEC, Hickory, NC. Used with permission.
Dirt on connectors moves to the middle of the ferrule!!!
Testing

- Key is to verify cable plant performance and connectivity
- Splitters are passive, usually trouble free
- Look for issues at connectors and jumpers
- Be aware if disconnecting before a splitter, a number of users on the channel will lose service
Testing

• Test in one direction. Light source at the OLT and power meter at the ONT locations.

• Ideally use a PON specific Light Source/Power Meter set to test 1310/1490/1550nm

• An alternate option is to use a standard Light Source/Power Meter at 1310nm and 1550nm

• OTDRs can be used for troubleshooting faults found in power meter testing, but are not used to certify links
Testing

- Testing with splitters: 3dB loss for each 1:2 split (excludes connections)

- ANSI/TIA 568C.3 = max .75dB per mated pair

- Singlemode cable = 0.5dB/km

- Bend insensitive cable can be helpful
Optical LAN Link Budget

- Max distance limited by attenuation, fiber loss. Splitters and connections contribute.
- Most budgets between 15.5 & 28dB; smaller splits and shorter cables require attenuators

<table>
<thead>
<tr>
<th>Loss Contributor</th>
<th>GPON Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splitter (1:32) =</td>
<td>16.7dB</td>
</tr>
<tr>
<td>Fiber Loss 10Km=</td>
<td>5dB</td>
</tr>
<tr>
<td>Conn/Splice Loss=</td>
<td>3.6dB</td>
</tr>
<tr>
<td></td>
<td>25.3dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attenuation</th>
<th>Loss (Maximum)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Loss 1310 nm</td>
<td>0.5</td>
<td>dB/Km</td>
</tr>
<tr>
<td>Optical Loss 1490 nm</td>
<td>0.5</td>
<td>dB/Km</td>
</tr>
<tr>
<td>Optical Loss 1550 nm</td>
<td>0.5</td>
<td>dB/Km</td>
</tr>
<tr>
<td>Splice Loss per unit</td>
<td>0.3</td>
<td>dB</td>
</tr>
<tr>
<td>Connector Loss</td>
<td>0.75</td>
<td>dB</td>
</tr>
<tr>
<td>1x32 PON Splitter</td>
<td>16.7</td>
<td>dB</td>
</tr>
<tr>
<td>1x16 PON Splitter</td>
<td>13.5</td>
<td>dB</td>
</tr>
<tr>
<td>1x8 PON Splitter</td>
<td>10.3</td>
<td>dB</td>
</tr>
<tr>
<td>1x4 PON Splitter</td>
<td>7.2</td>
<td>dB</td>
</tr>
</tbody>
</table>
Centralized Split Test Layout (Downstream)

- Measure at 1310nm/1550nm
- Document admin/labeling scheme
- Less than 23dB = Pass* (at points 2 or 3)
- Paths on the same splitter should be uniform in loss

- Assumes 1x32 or 2x32 Splitter

Fiber Distribution Housing

1. Light Source

Consolidation Point

2. Measure here for ports that go to a WAO

3. Measure here for ports that are connected to a splitter and stop at the RDT

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Zone Split Test Layout (Downstream)

- Measure at 1310nm/1550nm
- Document admin/labeling scheme
- Less than 20dB = Pass* (at points 2 or 3)
- Paths on the same splitter should be uniform in loss

- Assumes 1x32 or 2x32 Splitter
Zone Split (Cascaded) Test Layout (Downstream)

- Measure at 1310nm/1550nm
- Document admin/labeling scheme
- Less than 21.5dB = Pass* (at points ② or ③)
- Paths on the same splitter should be uniform in loss

① Light Source
② Measure here for ports that go to a WAO
③ Measure here for ports that stop at the Fiber Splitter Box
④ Measure here for ports that stop at the first Splitter
  - 1x2 Splitter = 5.2dB max.
  - 1x4 Splitter = 8.7dB max.
⑤ Measure here for ports that stop at the Fiber Splitter Box

*Pass if less than 21.5dB
Rack Mount Split Test Layout (Downstream)

- Measure at 1310nm/1550nm
- Document admin/labeling scheme
- Less than 19.75dB = Pass* (at points ② or ③)
- Paths on the same splitter should be uniform in loss

① Light Source
② Measure here for ports that go to a WAO
③ Measure here for ports that stop at the Splitter Panel

* Assumes 1x32 or 2x32 Splitter
Hybrid PON/Traditional Test Layout
(Downstream/Upstream)

Test Category X Twisted Pair cable per appropriate Category Standard*

* In addition to required fiber testing
Move, Add, Change (MAC) Testing

Once the splitter input is connected to the OLT, it cannot be disconnected for testing of MACs without disruption to the other users. When a move, add, or change is made on an active PON circuit, verification must be made to ensure that the proper range of power in dBm will be fed to the ONT. There is a minimum and a maximum value that is acceptable per ITU G.984X. This is verified by placing the connector that will connect to the input of the ONT into an Optical Power Meter and measuring the power in dBm to verify that it is between the minimum and maximum level.

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Acceptable Power Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1310nm</td>
<td>-12.5 dBm to -26 dBm</td>
</tr>
<tr>
<td>1490nm</td>
<td>-12.5 dBm to -26 dBm</td>
</tr>
<tr>
<td>1550nm</td>
<td>-12.5 dBm to -26 dBm</td>
</tr>
</tbody>
</table>

**Diagram:**

- OLT
- Wall Plate: All Passive Components between the OLT and wall outlet.
- Connection to the ONT input
- ONT Input
- Optical Power Meter:
  - 1310nm: -12.5 dBm to -26 dBm
  - 1490nm: -12.5 dBm to -26 dBm
  - 1550nm: -12.5 dBm to -26 dBm
- Maximum: 18.06 dBm
- Minimum: -26 dBm

**Store:**
- dB
- dBm
- mW
Referencing the meter

Optical Power Meter
-3.87 dBm

Store Optic Light Source
1310 nm
1490 nm
1550 nm

Referenced Launch Lead
Non-Referenced Receive Lead
(Never include this lead when referencing/zeroing the power meter)
Link Test with WAO

![Diagram showing an optical light source, a referenced launch lead, a wall plate, and an optical power meter. The diagram illustrates the connection between the optical light source and the wall plate, with a reference launch lead and a non-referenced receive lead. The diagram also shows the power meter reading 18.06 dB at 1310 nm, 1490 nm, and 1550 nm wavelengths.]
Poke Through

All Passive Components between the OLT and wall outlet.

Referenced Launch Lead

Drop Cable from Poke-Through

Optical Power Meter

18.06 dB
Mid-Point Verification

Optical Light Source

Adapter Plate

Referenced Launch Lead

Non-Referenced Receive Lead

Optical Power Meter

18.06 dB

λ

1310nm

1490nm

1550nm

dBdBmW

Store

dBmW
Knowledge Check
This is the common POL connector

- [✓] A. SC/APC
- B. ST
- C. MT-RJ
- D. FC
POL Networks use this fiber...

A. Multimode

✓ B. Singlemode

C. Unimode

D. OM3
It is important to ensure connector endfaces are clean prior to mating

A. True

B. False
Contaminate on fiber connectors can

A. Transfer
B. Migrate
C. Block light
D. All of the above
You should always use a wet cleaning method to remove contamination

A. True
✓ B. False
A reduction of 3dB of light signal reduces the received power by...

A. 10%
B. Half
C. 12 Volts

**B. Half**
When testing a POL with an OTDR, you should test in this direction...

A. Upstream
B. Downstream
C. Sideways
Loss budgets should be determined by advertised “Typical” performance values

A. True

✔️ B. False
Passive Optical LAN Integration & Management

Matt Miller
Associate Vice President, CallisonRTKL
Agenda

- PON Communications
- ONT Ranging Process
- RF Video Injection
- Centralized Administration
  - Management Server vs CLI
- Templates & Profiles
- VLAN Creation
- Uplink Provisioning
  - Link Aggregation Groups
- ONT Deployment & Discovery
- ONT Provisioning
  - FSAN Type B Protection
- Bandwidth Calculations & Assignment
- Traffic Flow
- Tagging, LLDP, PoE, QoS
- STP & Loop Detection
- Multicast
Objectives

After successfully completing this course, you should be able to:

• Understand the differences between ITU and IEEE PON Standards
• Describe the ONT ranging and provisioning process
• Understand the basic steps for deploying a POL
• Understand the future PON standards
Standards – IEEE vs. ITU

• ITU and IEEE have separate standards for PON
• Both standards use the same passive infrastructure (fiber & splitters)
• The primary difference is the electronics
## Popular Standards Comparison

<table>
<thead>
<tr>
<th></th>
<th>EPON</th>
<th>GPON</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>IEEE 802.3ah</td>
<td>ITU G.984</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>1Gbps Symmetrical</td>
<td>2.4Gbps Down / 1.2 Gbps Up</td>
</tr>
<tr>
<td><strong>Framing</strong></td>
<td>Ethernet (mostly native)</td>
<td>GEMS Encapsulation</td>
</tr>
<tr>
<td><strong>Wavelengths</strong></td>
<td>1490nm/1310nm</td>
<td>1490nm/1310nm</td>
</tr>
<tr>
<td><strong>Dynamic Bandwidth</strong></td>
<td>Optional Vendor Specific</td>
<td>Built-in</td>
</tr>
<tr>
<td><strong>Encryption</strong></td>
<td>Optional Vendor Specific</td>
<td>AES-128 Downstream</td>
</tr>
</tbody>
</table>
Standards Timeline

**IEEE**

- 1995 – APON Standard Introduced (155M)
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014

- 2004 – EPON Standard Approved (1G)
- 2009 – 10G EPON Standard Approved (10G)
- 2012 – Extended EPON Task Force Formed

**ITU**

- 1995 – APON Standard Introduced (155M)
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014

- 1999 – BPON Standard Approved (622M/155M)
- 2003 – GPON Standard Approved (2.4G/1.2G)
- 2010 – XGPON1 Standard Approved (10G/2.5G)
- 2013 – NGPON2 (40G TWDM)
WDM Methodology

- Multiple wavelengths over the same physical strand of glass
- Wavelengths do not interfere with each other
- Allows multiple discreet communications
WDM in PON

1490nm Downstream (TDM) – Voice, Data, Switched Video

1310nm Upstream (TDMA) – Voice, Data, Signaling Video

1550nm Downstream ONLY – RF Video
PON Types

- **BPON – (Broadband PON)** is an older version of PON technology which is based on ITU specifications and is characterized by an asymmetrical 622 Mbps downstream and a 155 Mbps upstream optical line rate. Earlier versions of Verizon’s FiOS™ offering in the U.S. are based on BPON but more recent implementations of FiOS use GPON technology.

- **GPON – (Gigabit PON)** is the latest ITU specified PON network and is characterized by a 2.4 Gbps downstream and a 1.25 Gbps upstream optical line rate. The first significant commercial deployments of GPON began in early 2008. Most carrier implementations of GPON are in the U.S. however it is beginning to proliferate in European markets as well.

- **EPON – (Gigabit Ethernet PON or GEPON)** is an IEEE standards based PON system characterized by a symmetrical 1.25 Gbps optical line rate. EPON is the predominant PON solution since it has been commercially available since 2001. GEPON has been primarily deployed in Asian Pacific markets. Recently, 10Gbit/s EPON or 10G-EPON was ratified as an amendment (IEEE 802.3av) in the IEEE 802.3 standard and provides for an asymmetrical 10 Gbps downstream/1 Gbps upstream rate as well as a symmetrical 10 Gbps rate.

- **WDM PON – (Wave Division Multiplexing PON)** is an emerging technology which leverages the optical advances of dense wave division multiplexing (DWDM) to provide a dedicated wavelength to a single ONT. Implementations range from “tunable” optics which must be matched to the ONT’s optics to a dynamic optical locking capability which automatically assigns a wavelength to the ONT at the ranging phase. WDM PONs utilize an arrayed waveguide grating (AWG) to multiplex up to 32 wavelengths of light onto a single fiber in the same way a passive optical splitter does. Unlike a typical optical splitter however, an AWG utilizes a phase shift in the optical light to provide an output on each fiber that only receives a certain wavelength of light.
Downstream Communication

The OLT transmits a signal downstream that all of the ONTs receive (point-to-multipoint). In the downstream direction, the information is broadcast on a specific color (wavelength) of laser light. The information is encoded into digital form and given a specific address that matches a specific ONT. The ONT that matches the address receives the signal and forwards the information to the end-user Ethernet port as depicted below.
Upstream Communication

Since many ONTs are placed on the same fiber, each with their own laser, upstream communications must be coordinated so that they do not interfere with each other. This is done by synchronizing the ONTs and requiring each to send information to the OLT (Upstream) in a specific time window (TDM). The upstream laser color is different from the downstream laser, so the upstream signal will not interfere with other ONTs on the PON. Using the WDM technique, ONTs do not interfere with each other; the upstream signals do not interfere with downstream signals, and the upstream and downstream signals can communicate at the same time (full duplex). This mechanism for converged, duplex communication is depicted below.
GPON Bandwidth

- GPON upstream bandwidth is directly correlated to TDMA time slot
- Each ONT will get a number of timeslots allocated. Each frame is 125μs in length

- Static bandwidth management
- Dynamic Bandwidth Allocation (DBA)
  - DBA is specified in ITU 984.3. This feature is used to grant upstream bandwidth to ONUs based on their demand
  - Used for oversubscribing GPON links
ONT Ranging Process

1. Authorize ONT to be on the PON
2. Determine distance from OLT
3. Setup OMCI communications
4. Assign bandwidth timeslots
5. Upgrade ONT software
6. Assign VLANs, QoS, PoE, security, etc.
Additionally, an analog signal can be injected onto the same PON fiber, using yet another color of light (WDM techniques). This is called an overlay and is generally used to carry broadcast TV to the user’s location. As with data and voice propagation, the light is a different color and therefore does not interfere with the other signals being carried on the fiber cable.
RF Video

1. Video Source (Coax)
2. Laser Transmitter
3. Erbium Doped Fiber Amplifier (EDFA)
4. WDM
Centralized Administration

- Reduce Operations & Maintenance (O&M) by reducing the amount of equipment managed
  - ONTs are managed by the OLT
- No powered devices in the middle of the network
  - Same location as user
- Co-locate OLT with other IT gear
  - Same location as other gear
- OLT handles activation, administration, and provision
- No administration ports on ONTs
15 Minute Break

Please respect others and return on time.
Knowledge Check

• What is a VLAN?

• Difference between Layers 1, 2 and 3

• Have you provisioned a Cisco/Brocade/Juniper switch?
VLAN Creation

- POL uses VLANs just like Ethernet switches
Uplink Provisioning

- Pick 1G and 10G Ethernet ports to connect to the core network
Uplink LAGs

- Add individual ports to Link Aggregation Groups
- Configure LACP
ONT Discovery

- ONTs will notify the OLT when they are connected
- Administrator determines next steps
ONT Ranging

- Know your ONT locations before they are deployed
- Assign a name and location as they are ranged
ONT Provisioning

- Assign VLANs once ONTs are ranged
Optical Levels

- OLTs and ONTs will report optical transmit and receive levels
- Provides basic indication of connection problems
- Not intended to replace cable plant certification
Type-B Protection

- Provides sub-80ms switchover protection between PON ports on same OLT
- Redundant OLTs an option
- Switchover between OLTs sometimes requires re-ranging
OMCI

- OLTs communicate with ONTs using ONT Management and Control Interface (OMCI)
- OMCI is part of the GPON standard and operating outside of GEM Ports
- OMCI is established after ONT is ranged
Bandwidth Assignment

• Bandwidth management is built-in to the GPON standard

• Required during provisioning
Bandwidth Management

Committed rates cannot exceed capacity of any link in the system.
Upstream Granting

• The “Grant” is the permission sent from the OLT to the ONT to:
  – Allow the ONT to transmit traffic in its assigned timeslot on the Upstream data train
  – Control the flow of Upstream traffic from the ONTs to the OLT so collisions of traffic from different ONTs on the PON do not occur
Traffic Flow

Internal switching separates POL from carrier PON vendors

1. Within ONT
2. Within PON Card
3. Within OLT
GPON Encapsulation

- VLANs mapped to GEM Ports
- GEM Ports assigned to traffic containers
- GEM Ports mapped to ONTs
Tagging, LLDP, PoE, QoS

- Tag VLANs from ONT
- Deliver power
- Configure connected devices with LLDP
- Customize QoS
STP & Loop Detection

• Full STP is not required in POL networks
• Loop detection is important
Multicast

- Multicast compliments PON topology
- OLTs and ONTs feature IGMP snooping
- Specific multicast VLAN required
Templates & Profiles

• Templates and profiles allow admins to create common settings
Rules & Auto-Port Provisioning

• Auto-provision ONTs upon detection
• Set rules or selectors based upon ONT properties (location, model, etc.)
• Copy Configurations
Converging Standards

- IEEE and ITU working to converge standards in future generations
- 10G EPON and XGPON use same PHYs
Future Standards

• EPON/GPON Networks can co-exist on the same fiber & splitters as 10G EPON/XGPON Networks
• 10G EPON and XGPON use same PHYs
• IEEE and ITU working to converge standards in future generations
• Next standards may combine multiple wavelengths in each direction for additional bandwidth
Complimentary Wavelengths

**EPON/GPON**
1490nm Down / 1310nm Up

**10G EPON/XGPON**
1577nm Down / 1270nm Up

**RF Video**
1550nm Down
Migration to 10G

- 10G PON can coexist on the same fiber as GPON
- Bandwidths available as 10G Downstream and 10G/2.5G/1G Upstream
- Uses same infrastructure/splitters as GPON
- Casual migration – upgrade only the ONTs that you want
The Migration to 10 & 40G PON

The cabling infrastructure stays the same and only the users that need it are upgraded.

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Questions?

Passive Optical LAN
Integration & Management

Matt Miller
CallisonRTKL
POL Project Closeout Package

Mike Watts
Vice President of Noovis
Suggested Contents

• Rack Elevation Drawings
• As-Built Drawings
• Interconnect Documentation
• Test Results
• Datasheets and Documentation
Rack Elevation Drawings
As-Built Drawings
# Interconnect Documentation

<table>
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<th>Building</th>
<th>OLT Rack</th>
<th>OLT Chassis</th>
<th>PON Card</th>
<th>PON Port</th>
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Test Results

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<th>Loss B-&gt;A (dB)</th>
<th>Ref. B-&gt;A (dB)</th>
<th>Average (dB)</th>
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Datasheets and Documentation
Questions?

POL Project Closeout Package

Mike Watts
Noovis
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