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Sandia National Laboratories

Gigabit Passive Optical Network
Design, Implementation, Performance, and Lessons Learned

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Topics To Be Covered

- Introduction to GPON
- GPON Topology and Operation
- GPON and PON equipment
- Installing GPON
- Protecting GPON
- GPON Performance
- Quality of Service
- VoIP Pilot
- GPON Troubleshooting
- GPON Power Consumption
- Lessons Learned
- Other GPON Deployments
- Future PON Advances

Introduction to GPON

- Gigabit Passive Optical Network (GPON)

- Access layer technology

- Supports triple play services

- FTTX

- Bit rates of 1.244 Gbps upstream and 2.488 Gbps downstream

- Operates at 1310 nanometers upstream and 1490 nanometers downstream

- Uses active and passive components

- VLAN based

- Downstream encrypted with AES

- Based on ITU-T G.984 standards

GPON Topology
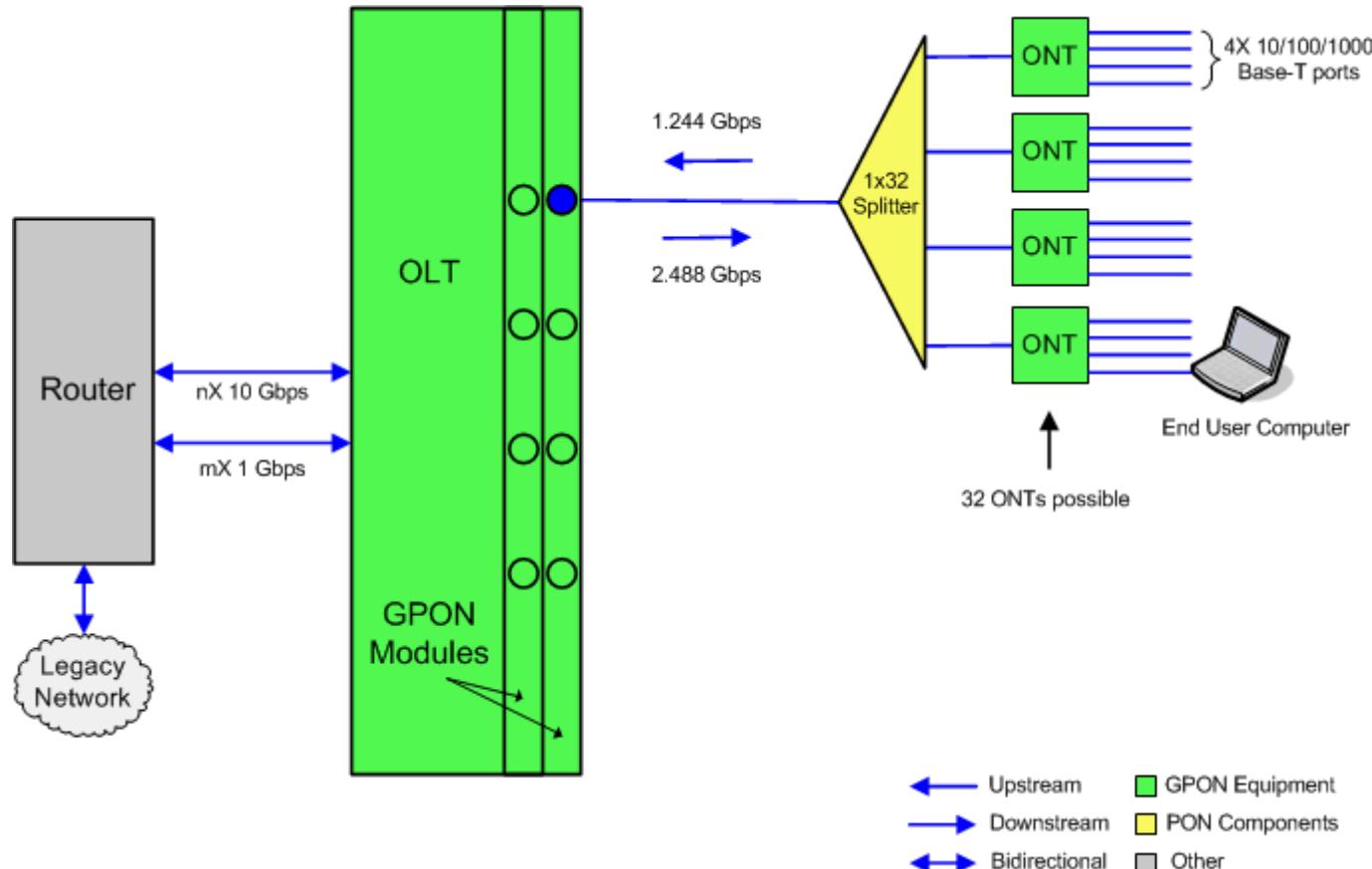
GPON Downstream Operation
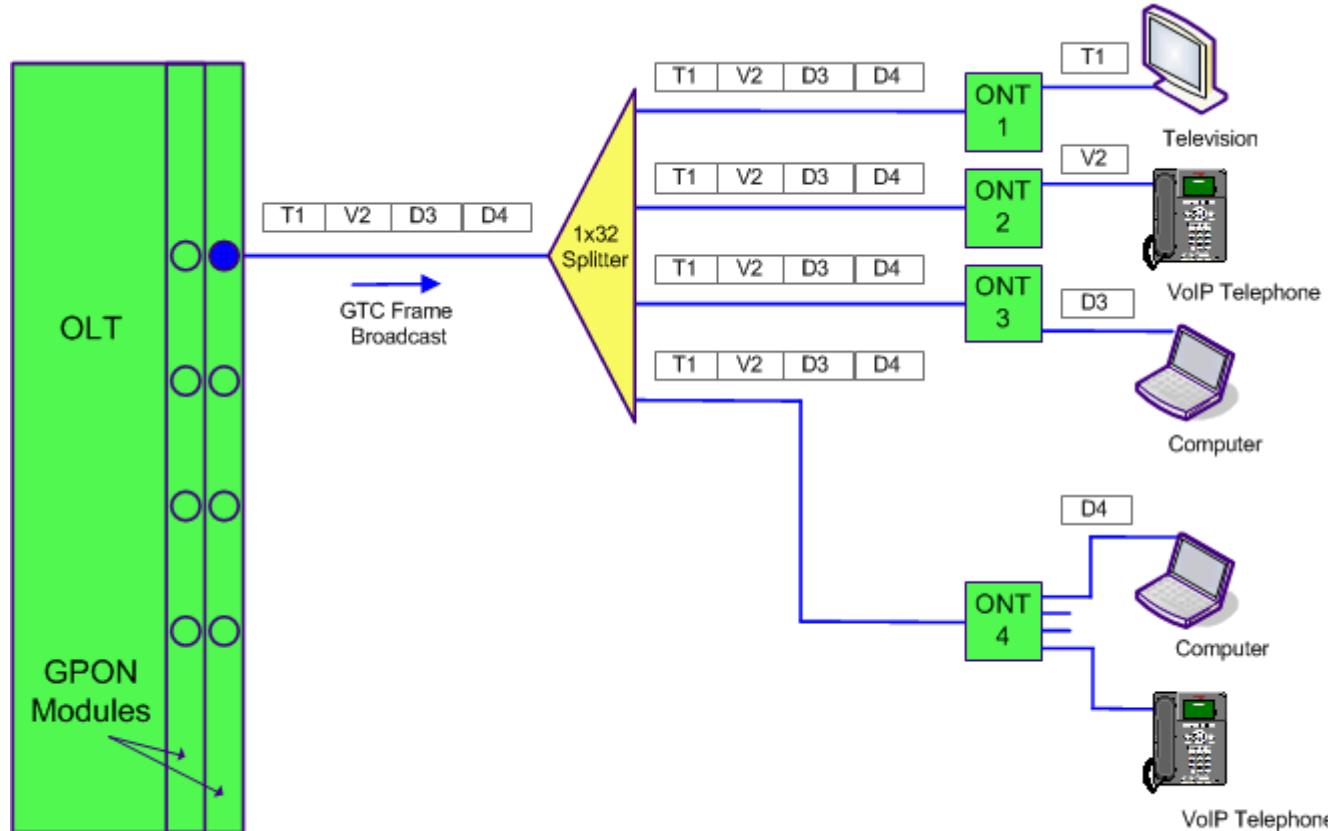
GPON Upstream Operation
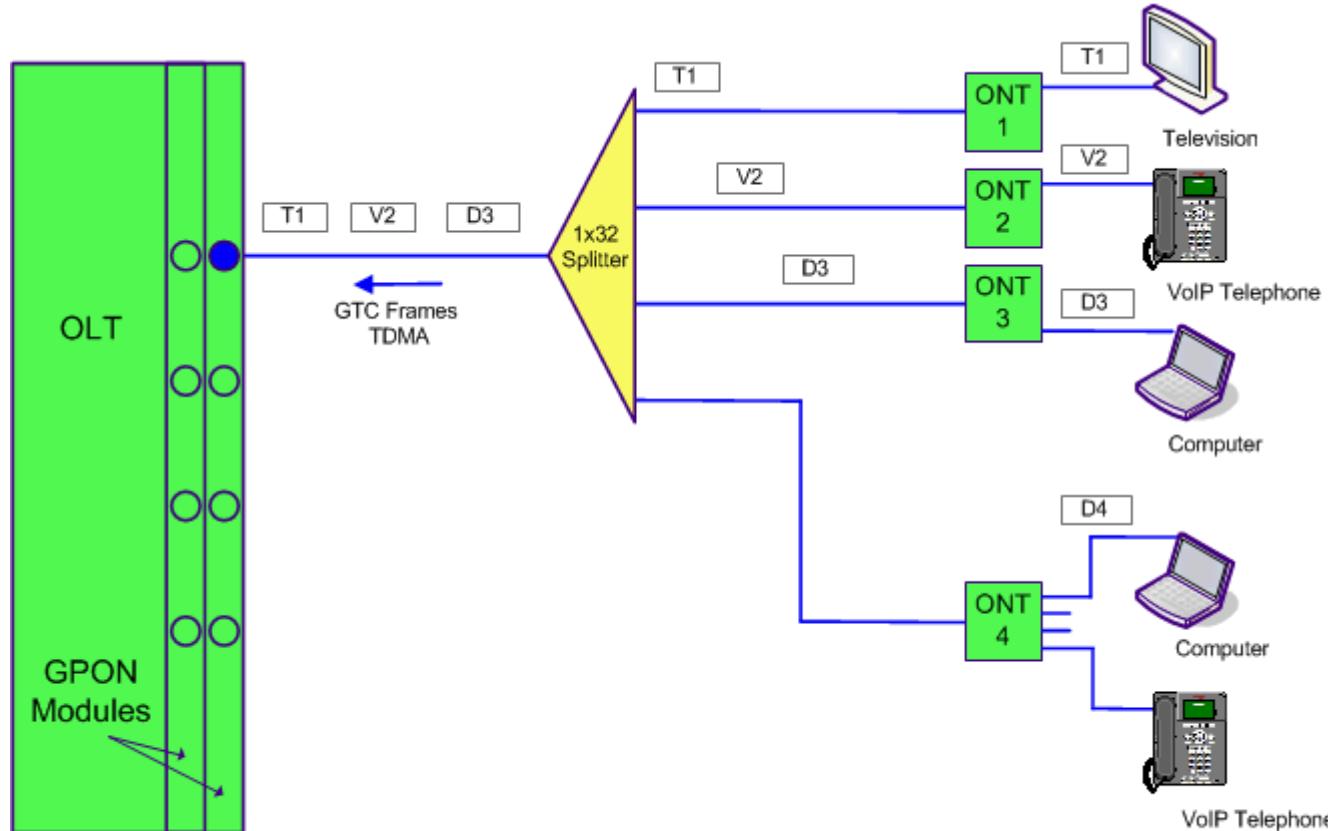
Optical Line Terminal (OLT)

- Sends and receives data to/from ONTs
- 160 Gbps per slot, 2.56 Tbps total for 16 slots
- 2 ESU controller modules for redundancy
- Can support up to 2048 ONTs or 8192 ports
- 4 x 10 Gbps and 8 x 1 Gbps uplinks
- LACP or Spanning Tree on uplinks
- Supports IPv4 and IPv6
- Supports triple play services
- Optical:
  - Maximum reach: 12.5 miles (20 km)
  - Split ratio: 1:32
- Supports multiple models of Tellabs ONTs
- Uses -48 VDC
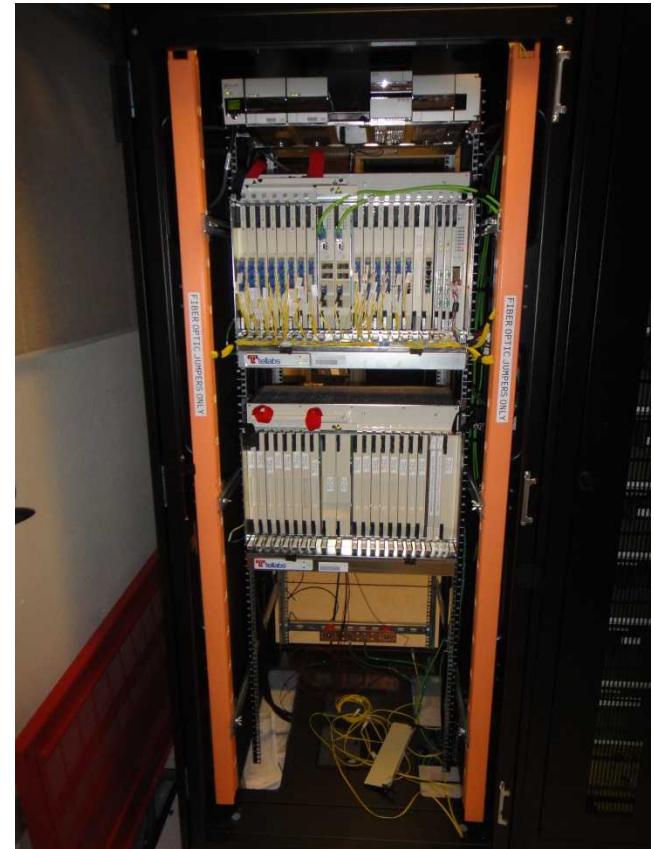
Optical Network Terminal (ONT)

- Provides a connection for the user equipment
- One or more RJ-45 Ethernet ports
- Two main types of ONTs
  - Single Family Unit (SFU)
  - Multi-Desktop/Multi-Dwelling Unit (MDU)
- ONTs may have:
  - POTS ports
  - Power over Ethernet (POE)
  - Battery backup
  - Desk or wall mounting capability
  - Indoor or outdoor placement
 - RF Video

Typical ONT

- Remotely managed
- 4 x 10/100/1000 Mbps ports
- Each port is a member of a VLAN
- Low power – Less than 15 Watts
- Indicator LEDs for diagnostics
- Wall mounted is preferred
- Requires an OLT
- Additional form factors:
   - 2 port
    - 24 port

Passive Optical Splitter

- Distributes the GPON transmission to ONTs
- No power or cooling required
- Virtually unlimited MTBF
- Higher split ratios allow for more ONTs per GPON port
- Higher split ratios decrease the available bandwidth per ONT and distance
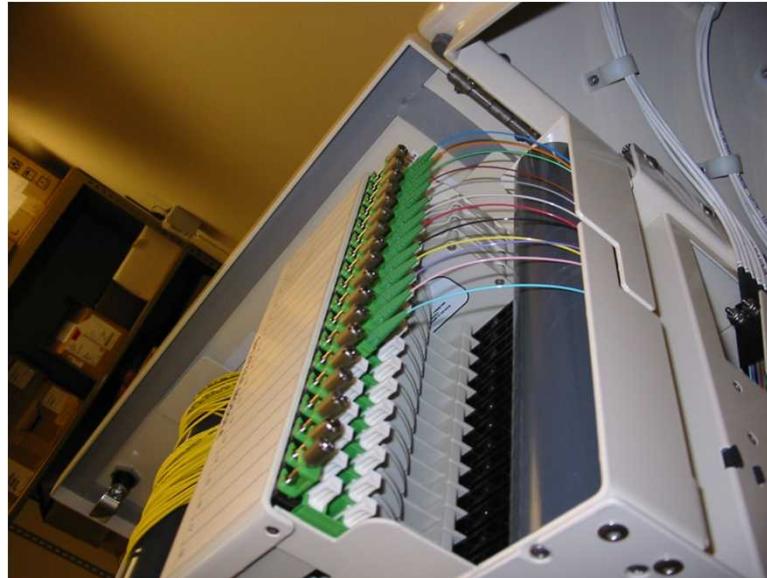
Fiber Distribution Hub (FDH)

- All passive
- Houses passive optical splitters
- Connects to Rapid Fiber Distribution Terminals
- Factory terminated connections
- Placed indoors or outdoors
- Lockable cabinet
- 72 to 864 fiber capacity
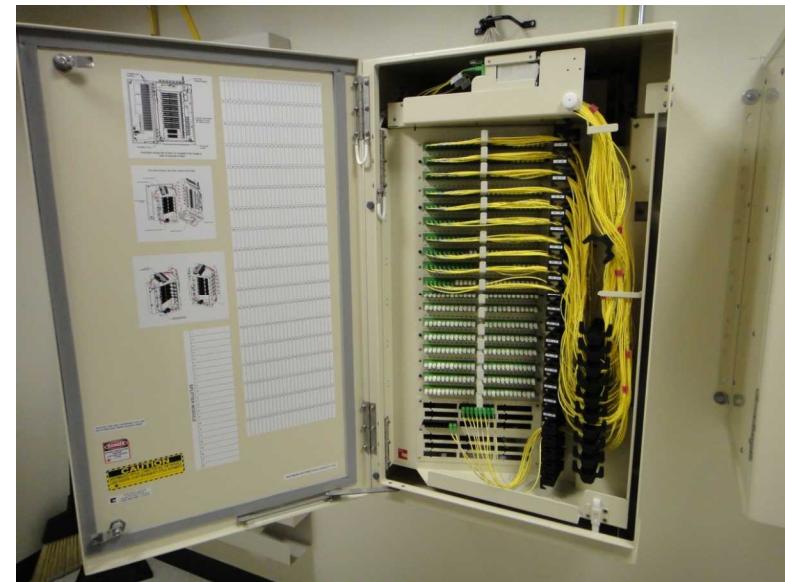
Rapid Fiber Distribution Terminal (RDT)

- Used to connect FDH to ONT drop cables

- Placed in the plenum

- Built-in spool with 2 MTP® or MPO terminated 12 count fiber cables

- SC/APC connectors are used on ONT drop cables
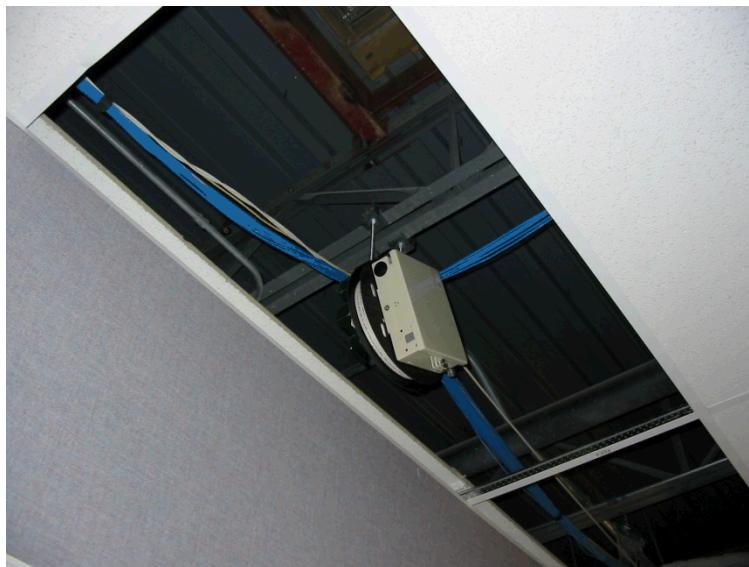
Fiber Infrastructure

- Needed wherever GPON is to be deployed
- Uses single-mode fiber
- Used by all GPON components
- Pre-terminated fiber is preferred
- Bend-insensitive fiber eases deployment
- Should be tested before deployment
- Angled Polished Connectors may be used for lower loss
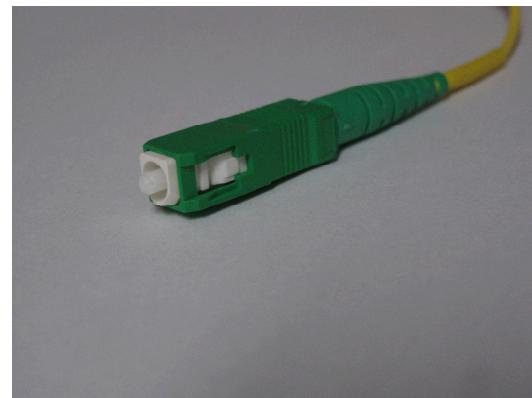
GPON Building Deployment
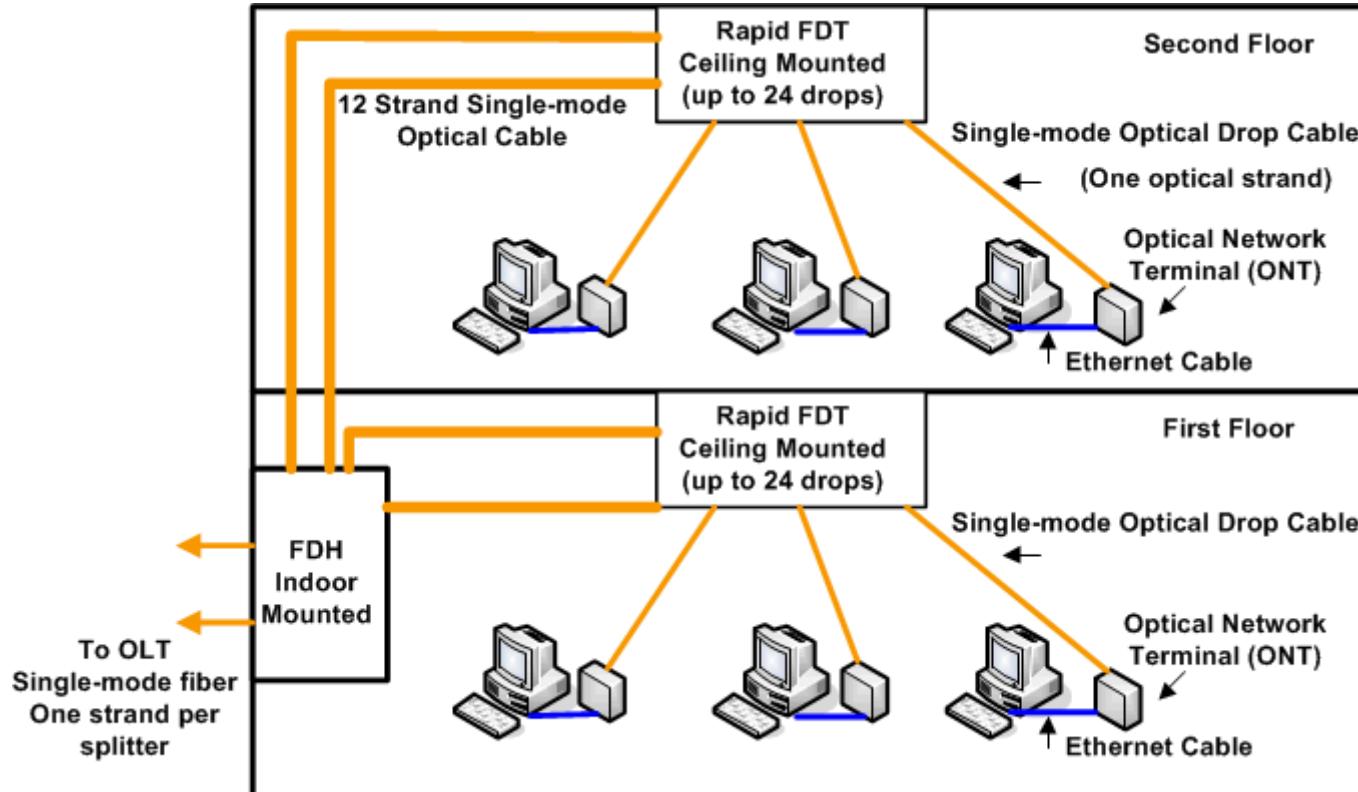
Installing GPON

- Preliminary setup
  - Carefully plan locations of OLTs, FDHs, RDTs, and ONTs
  - Physically deploy and connect all equipment and single-mode fiber
  - Provision VLANs and route points on routers and or switches
  - Install GPON management software on management platform
- OLT Provisioning
  - Perform initial turn up
  - Add the OLT to the GPON management application
  - Provision other information such as DHCP, Radius, SNMP, NTP and Protection Group
  - Provision Uplinks
- ONT Provisioning
  - Discover and register ONT
  - Assign ONT Port to VLAN
  - Assign profiles for various parameters (QoS, security, LLDP, etc.)
- Connect computers to ONTs and test

Panorama ONT Connections Screenshot
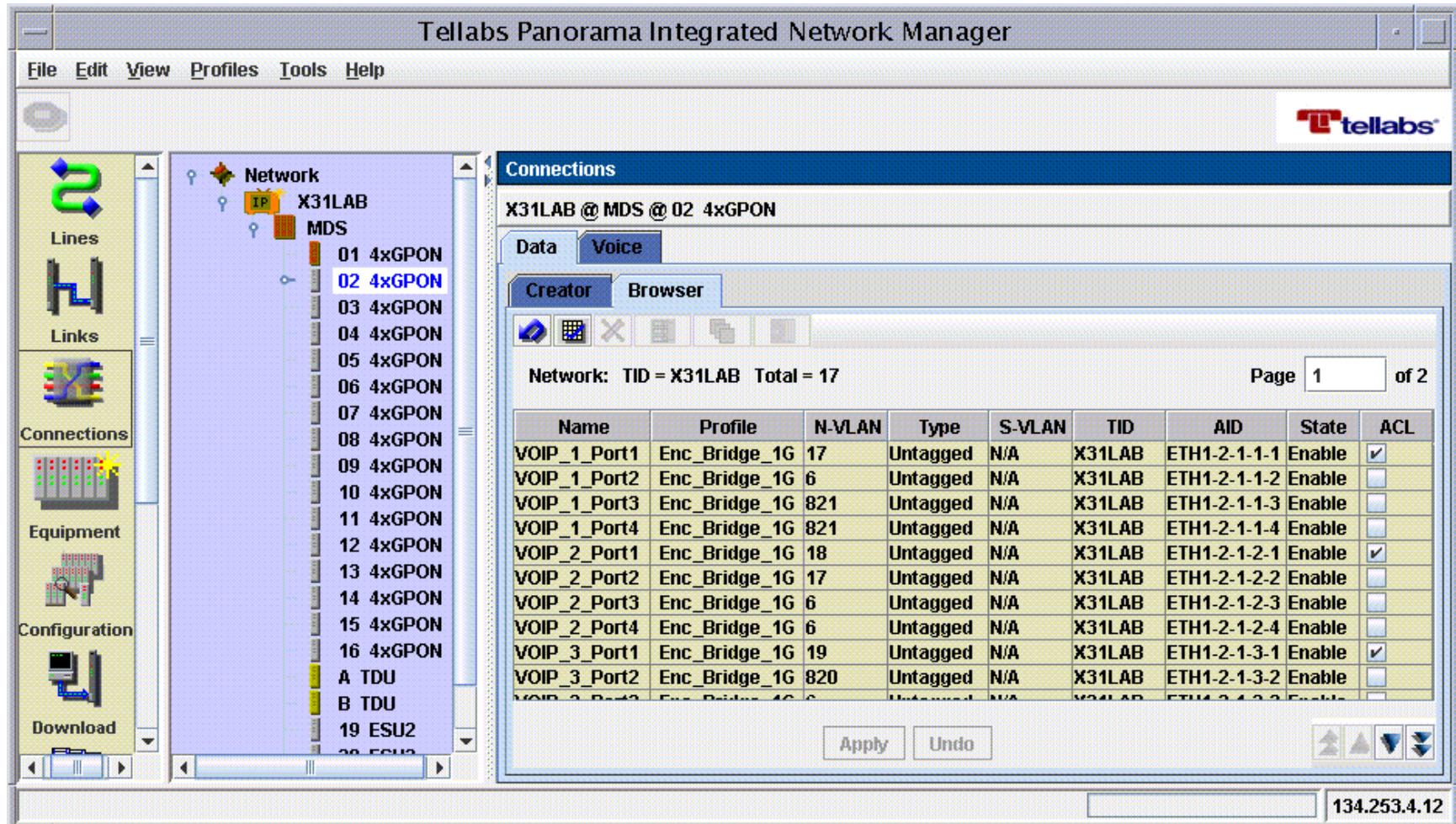
OLT Command Line Provisioning Screenshot

```
Console
Window  Edit  Options                                                    Help

ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A> create cross-connect auto-enable-port network-vlan=17 port-id=2-1-4-3 pro
file=Enc_Bridge_1G user-LABEL=demo


Successfully created connection [N1-NV17-ETH1-2-1-4-3].

ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
ESU2A>
```

Protecting GPON

- Important to have control of fiber plant and all devices

- Access control lists on ONTs

- MAC address limiting to prevent flooding overflow

- 802.1X

- Unexpected ONT detection

- Upstream broadcast rate limiting and filtering

OLT Performance

- Extensive laboratory testing performed at SNL
- Delivers rates close to GPON G.984 specifications
- Upstream and downstream rates are independent
- Smaller Ethernet frame sizes will reduce performance due to more overhead
- Uplink(s) should have sufficient bandwidth
- ONT is not a switch
- Not intended for the Data Center

GPON Performance Testing Configuration
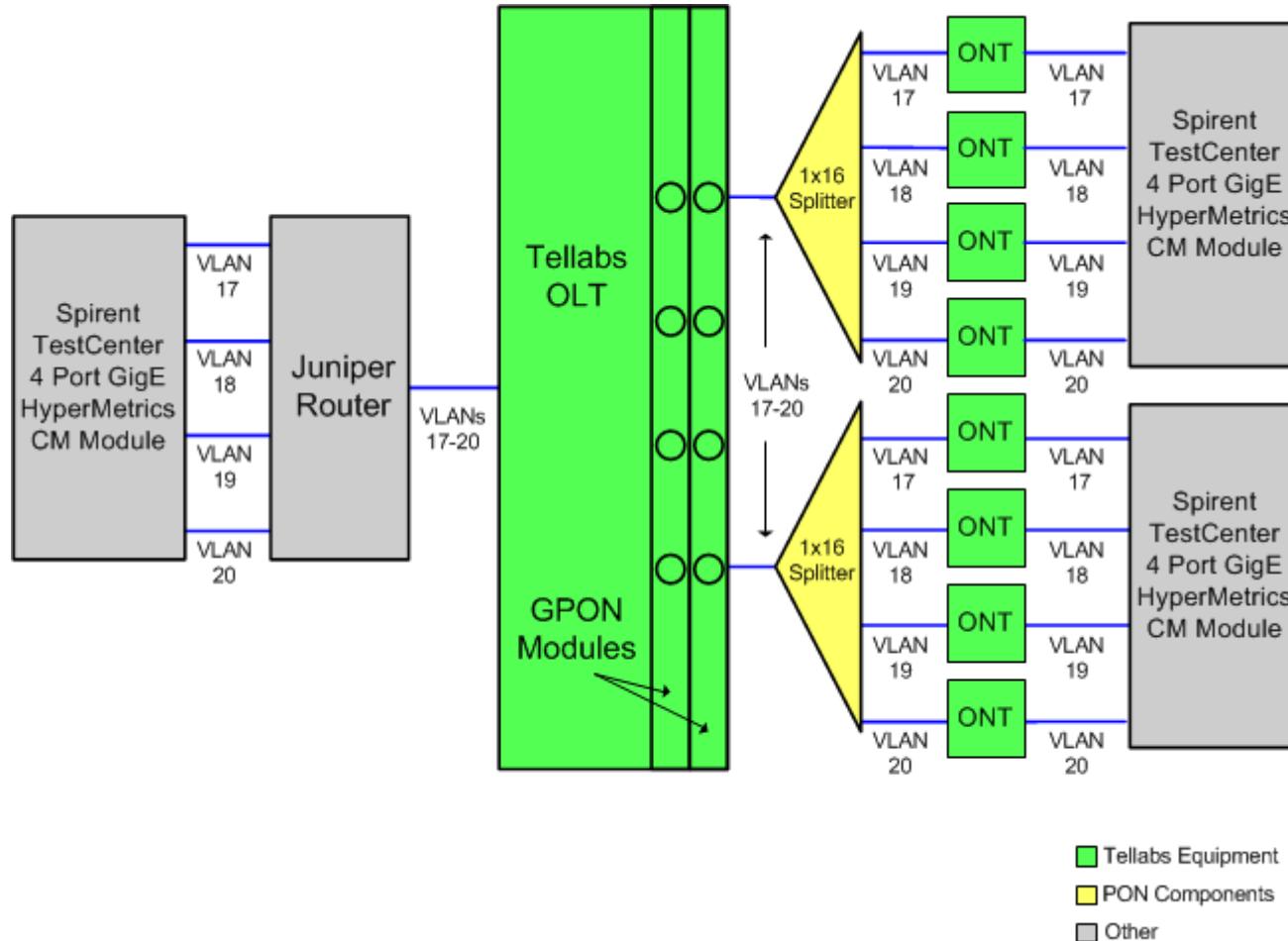
Tellabs OLT Upstream Performance Test Results
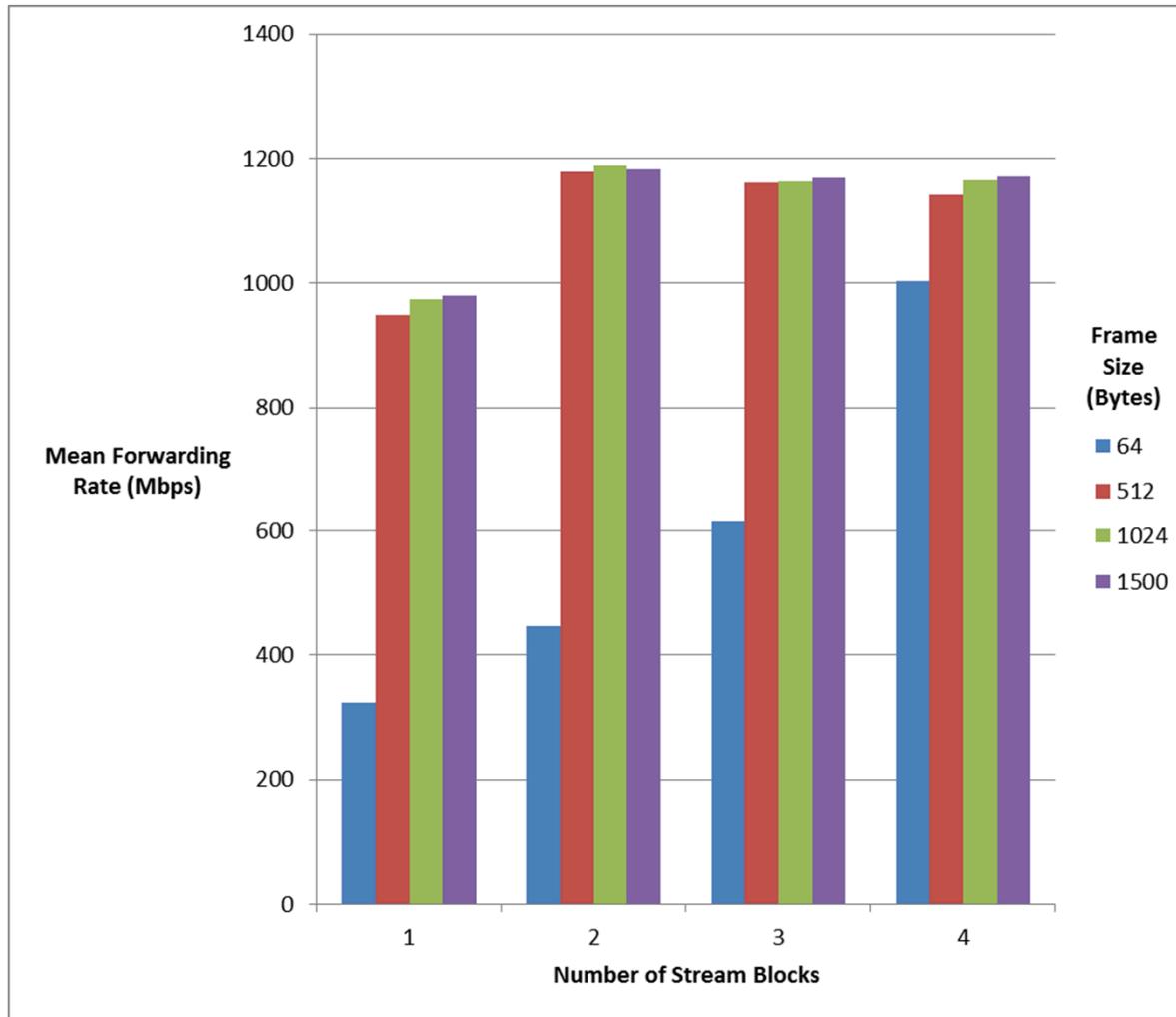
Tellabs Downstream Performance Test Results
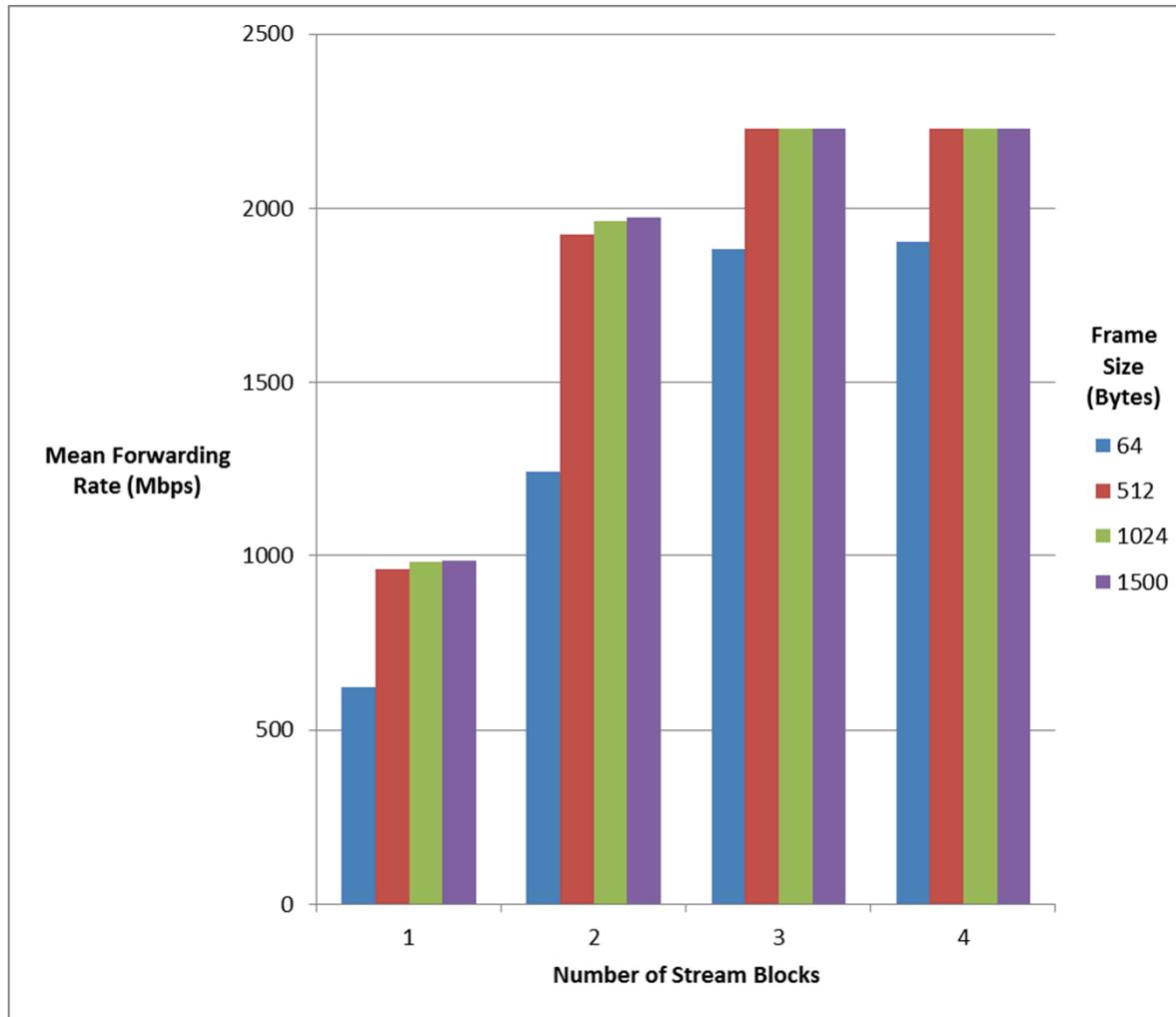
Quality of Service for the Tellabs OLT

- Uses 802.1P for QoS

- Based on VLAN-ID, 802.1p bit, or ToS/DSCP

- Can mark 802.1p

- Has ToS/DSCP to 802.1p mapping

VoIP Pilot Project at SNL New Mexico

- Uses Avaya equipment
- Currently H.323 based
- Starting to deploy SIP phones
- Currently ~250 VoIP phones are installed

VoIP Testing Configuration
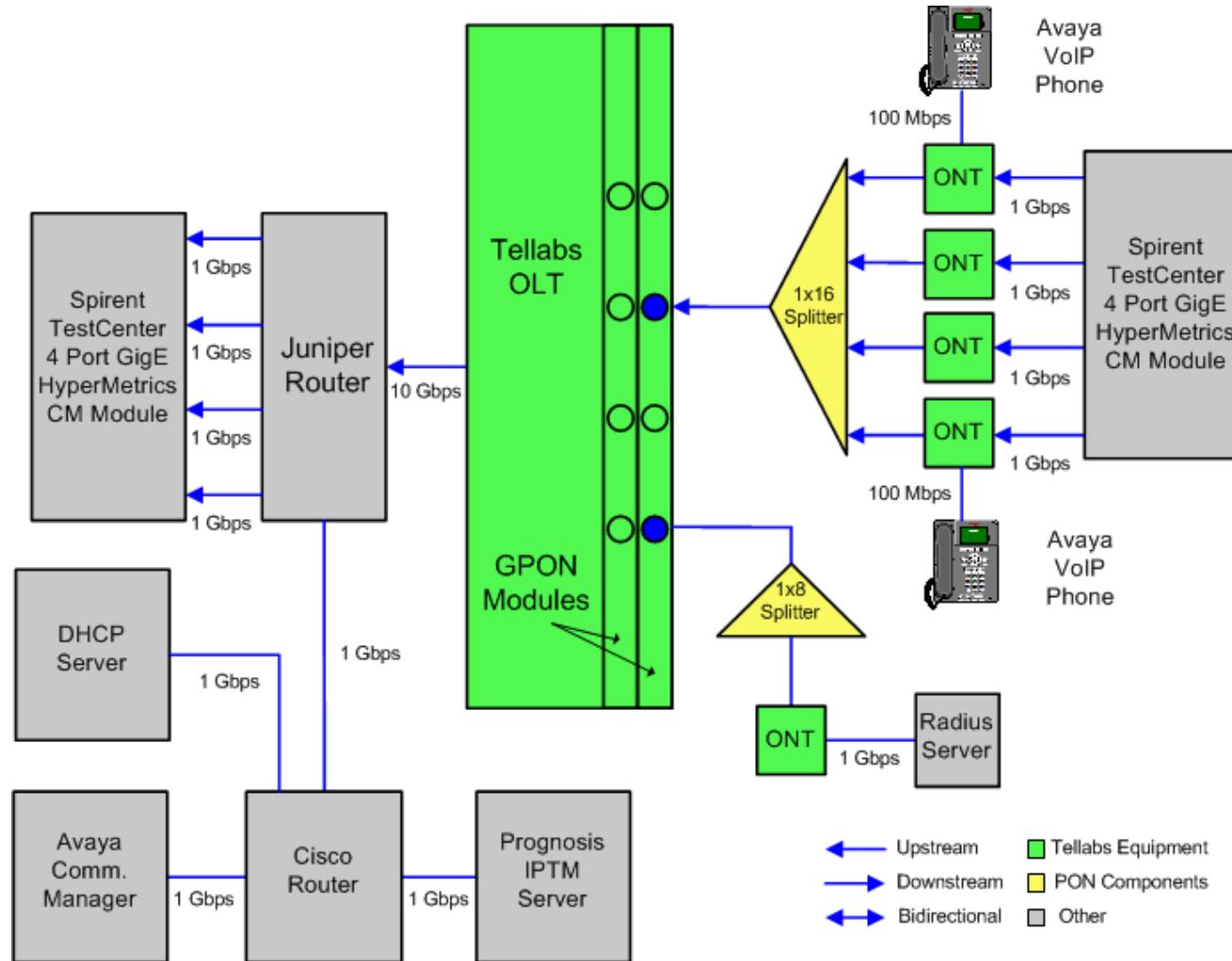
GPON Troubleshooting

- Conventional light meters will not work because ONT will not transmit unless it receives grant from OLT
- Need inline GPON light meters
- Panorama or other GPON manager Alarm reporting
- Tcpdump on GPON port
- GPON Analyzer
- Sniff uplink

GPON Power Consumption

- Tellabs OLT fully populated at peak load: 1200 Watts
- Tellabs ONT:
  - 4.1 Watts idle
  - 6.7 Watts peak load
- When fully realized, SNL New Mexico will reduce power consumption by 1 Million KWh annually
- Will save $87K in annual power costs

Lessons Learned I

- Over 14,000 ONTs installed in 270 buildings

- 17 OLTs installed

- GPON implementation provides a total cost savings of $20M over 5 years in CapEx and OpEx

- Keep installation crew ahead of provisioning crew

- Don't assume office access, space, or power

- Wall mounting is preferred in unclassified areas

- Upgrading the core network at the same time can cause difficulties

- A network upgrade will be blamed for almost all IT problems

Lessons Learned II

- Be sure you can replace the legacy network, otherwise you will now be supporting and providing power for two networks

- Retain smaller decommissioned switches to replace larger switches supporting a limited number of legacy ports that can not be migrated such as server rooms and labs

- Firmware upgrades should be tested thoroughly prior to implementation on production networks

- Scripting or bulk provisioning is important for large deployments

Popular Science Grand Award Winner
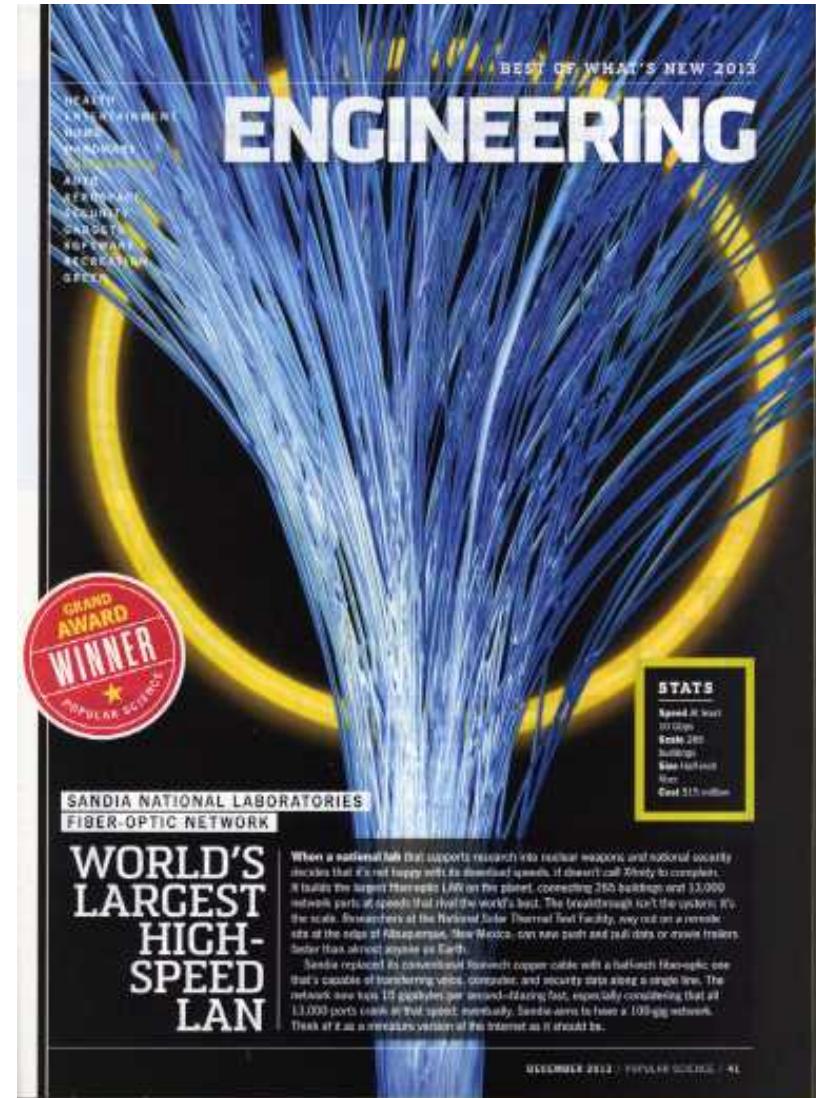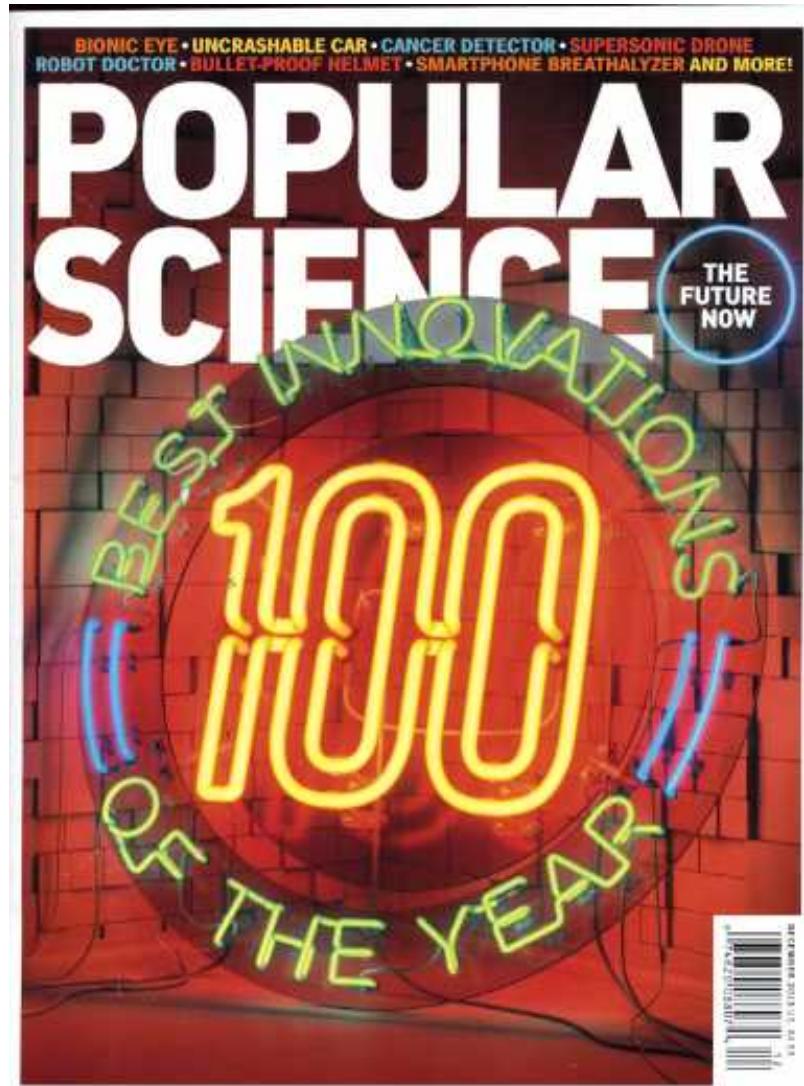
Other GPON Deployments

- According to Broadband Trends:
  - Global OLT port shipments were 2.94 million in 2013
  - Global ONT port shipments were 30.1 million in 2013
- China Mobile recently awarded contracts to ZTE, Alcatel-Lucent, and FiberHome for 614,000 ONTs and 3,000 OLTs
- Verizon FiOS has 5 million customers
- AT&T U-Verse with GigaPower
- Andrews AFB
- DHS
- US Army Netcom HQ
- USMC Okinawa
- City of San Diego Downtown Library
- DFW International Airport
- Unpublicized

Future PON Technologies

- EPON (an existing technology which is widely deployed)
- 10G-EPON
- XG-PON or 10G-PON
- XG-PON2
- WDM-PON
- Secure PON
- Other technologies