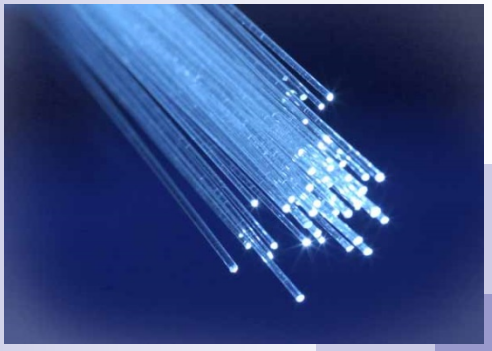


# FIBER TO THE HOME - PONs

# Why FTTH

- Bandwidth - BW @ 20 Km = 2 Gbps > 80 x BW ADSL 2 +
- Increased BW  of HFC or xDSL technologies
- WDM PON eliminates bandwidth sharing which further enhances BW
- Lowest BER = 10 E-10 BPON, GPON & EPON

# Optical Fundamentals

- Types of Fiber
  - Single mode (125 µm/8 -12 µm)
  - Multimode ( 125 µm/ 50 or 62.5 µm)
- Losses
  1. Dispersion
     - Chromatic – multiple lambdas
     - Modal – multiple modes
  2. Attenuation (dB/km)

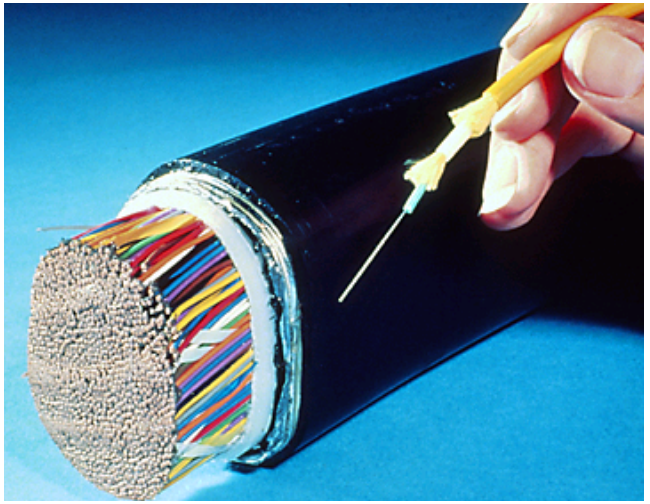
# Link Budget

- BR
- BER
- Tx Power
- Attenuation
- Coupler, splitter, connector, splice and other losses
- Amplifier Gain
- Quantum Efficiency

# Noise

- Thermal Noise
- Amplified Spontaneous emission
- Crosstalk
- Mode partition noise
- Margin for environmental disturbances, aging effects, temperature changes

# Advantages of Fiber



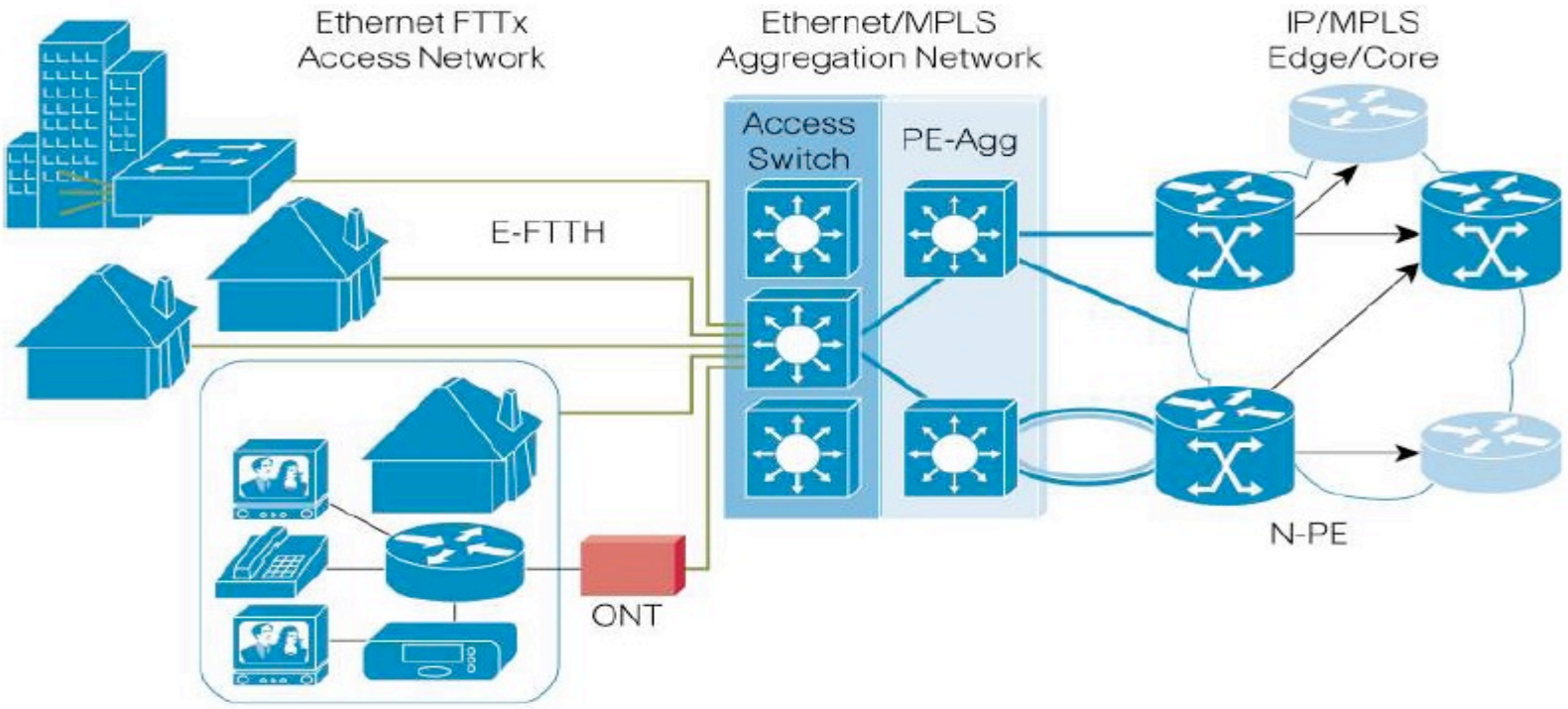
- Extremely light weight
- EMC
  -No Emanation
  -Not susceptible
- A single copper wire can carry 6 phone calls compared to single fiber which can carry 2.5 million simultaneous phone calls (64 channels at 2.5 Gb/s)
- Less than 1% the size and weight of copper

# Architecture

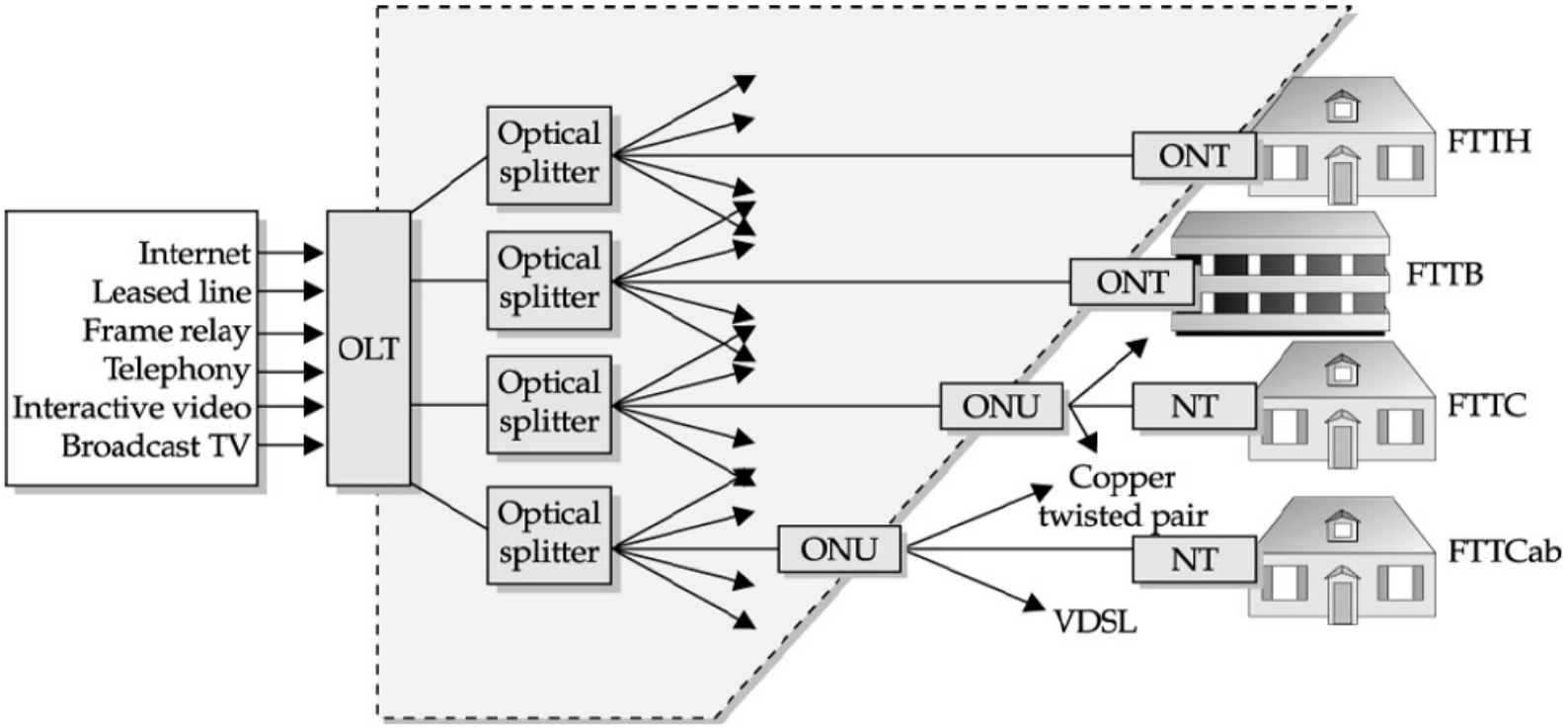
- Point to Point or star topology
- Ring Topology
- Point to Multipoint (P2MP) = PON

# E-FTTH Architecture – P2P

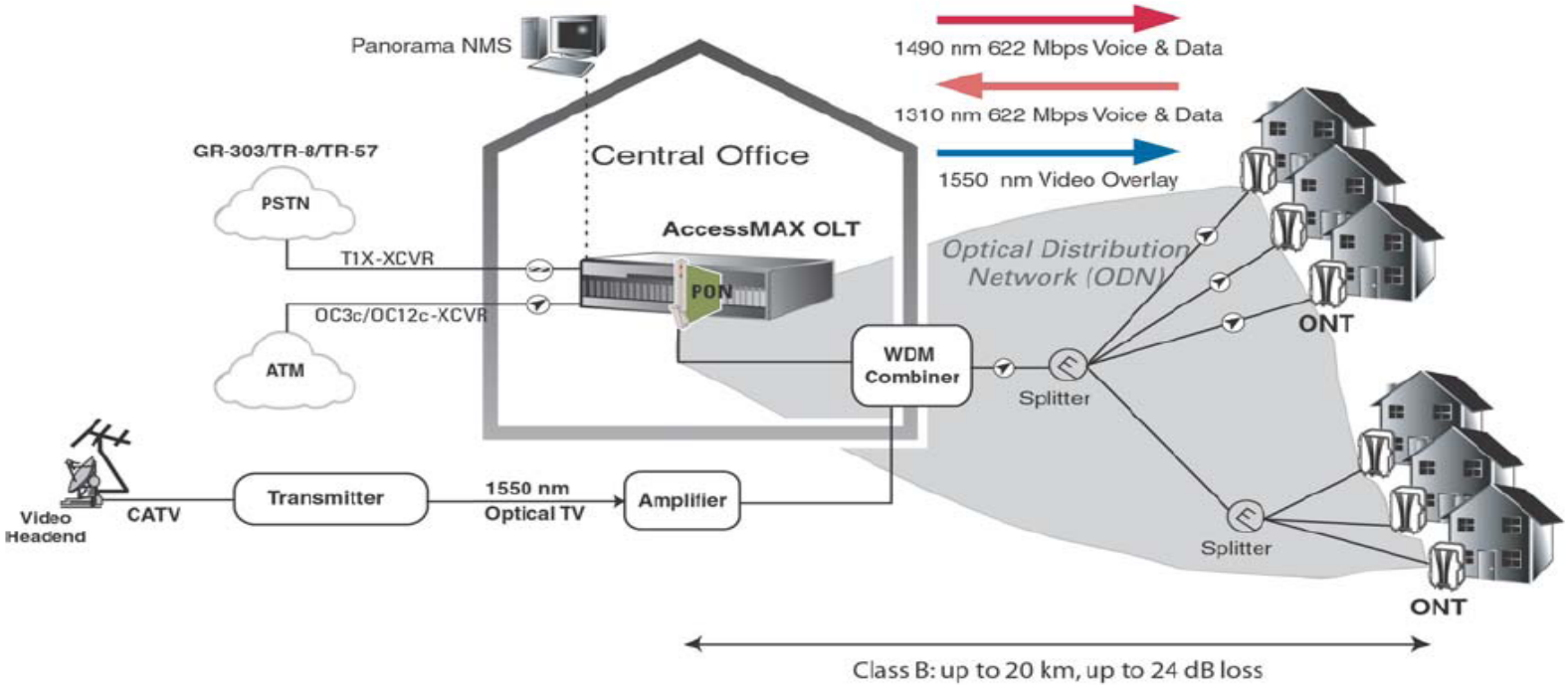
(can be implemented in a ring)



# PON FTTx Architecture



# PON as FTTH


Panorama NMS
1490 nm 622 Mbps Voice & Data
1310 nm 622 Mbps Voice & Data
1550 nm Video Overlay
GR-303/TR-8/TR-57
Central Office
PSTN
AccessMAX OLT
T1X-XCVR
PON
Optical Distribution Network (ODN)
OC3c/OC12c-XCVR
ATM
WDM Combiner
Splitter
ONT
Video Headend
CATV
Transmitter
1550 nm Optical TV
Amplifier
Splitter
ONT
Class B: up to 20 km, up to 24 dB loss

# Equipment

- Optical Network Unit (ONU)
- Optical Line Terminal (OLT)
- Optical Distribution Network (ODN)
- Optical Amplifiers
- Splitters and Connectors
- Lasers Transmitters and Receivers

# ONU

- Optical Network Terminal is located near end users.
- Consists of
  - 1, Coax cable
  - 4, RJ-11
  - 1, RJ-45
  - 1310nm Laser
  - Triplexer Module
- Downstream voice, data – 1490 nm
- Upstream voice, data – 1310 nm
- Video – 1550nm
- UPS

# OLT

- Present at the head end or the central office end
- Consists of plug-in-card each of which can support upto 64 ONU's

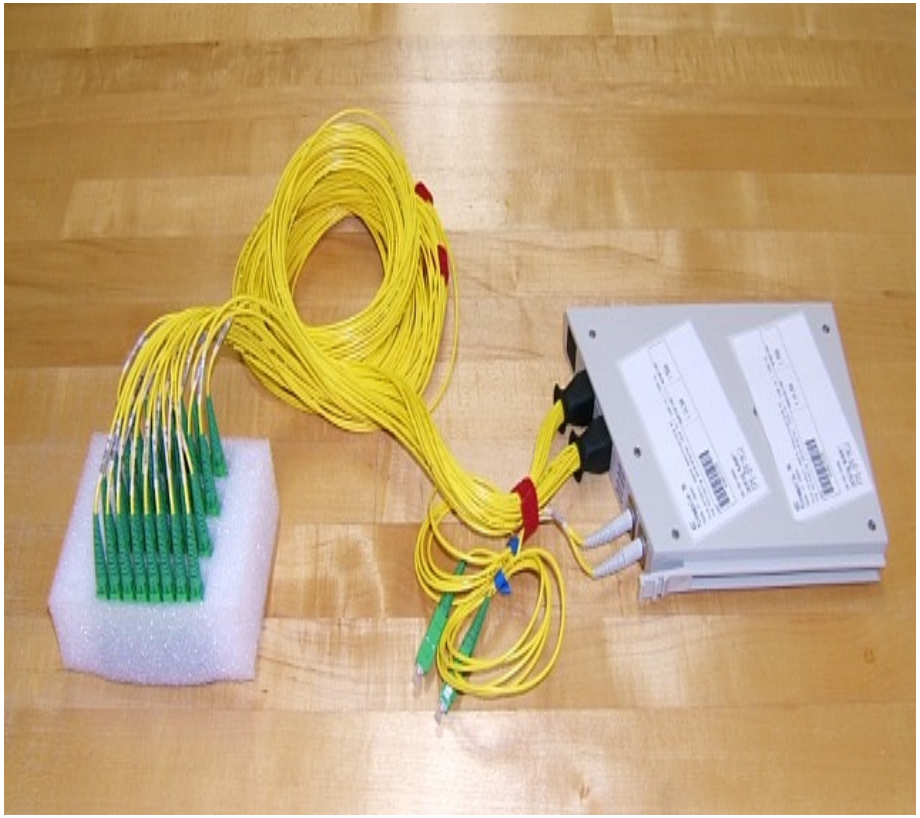

- Uses BPON, GPON or EPON protocols
- Supports Management and supervisory functions – GUIs
- Back Haul is handled by DS3, OC3 or Gigabit Ethernet card.

# ODN

- Passive Network
- No active Components between OLT & ONT.
- Eliminates the need for DC power
- Low network maintenance cost
- It involves splitter

# Splitter

- Passive Component
- Distributes optical signals to multiple Subscribers
- Also acts as a Coupler



# Splitter Losses

- Each split = 3dB loss of signal
- 16 splits = 12 dB of signal loss
  - 2E4 = 16
  - 4splits x 3dB/split = 12dB loss

# Video Overlay Equipment

- Optical Transmitter

  Video stream @1550 nm over Optical Fiber
- WDM Combiner (Optical Coupler)

  Couples Downstream video to upstream/downstream data and voice
- Optical Amplifier

  Amplifies 1550nm broadcast signal.

# Lasers

- Fabry-Perot lasers

  -lower in cost and power

  - poor wavelength stability
- Distributed Feedback (DFB) Lasers

  - Higher cost and power

  - Excellent wavelength stability

  - Excellent temperature stability

  - internally modulated – good for moderate power and distance

  - Externally modulated – Broadcast applications
- Vertical Cavity Surface Emitting Lasers (VCSELs)

# Wavelength Vs Lasers

- 1310 nm

  - Usually lowest cost lasers Used for shorter broadcast runs and short to moderate data runs

- 1550 nm

  - Can be amplified with relatively low-cost erbium doped fiber amplifiers (EDFAs)

  - Lasers are fabricated on a number of different wavelengths (about 1535 – 1600 nm) for wave division multiplexing (WDM) applications

    Slightly lower fiber loss at 1550 nm

- 1490 nm

  - Increasingly popular for downstream data. Cannot be amplified as easily. Somewhat higher device cost

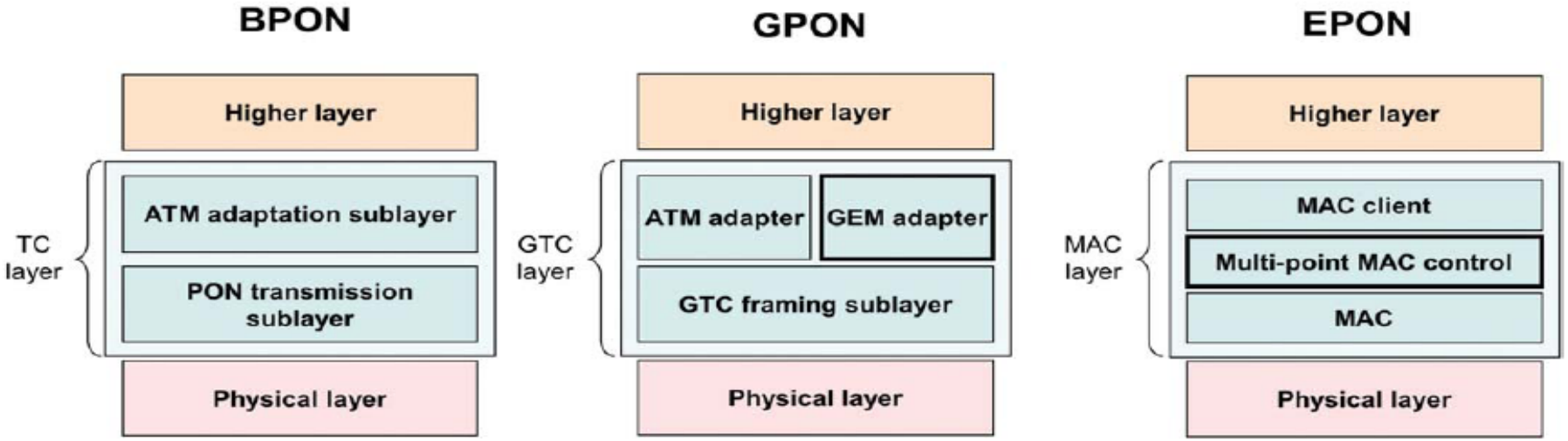
# Standards

- TDMA PON – First proposed in 1987 by researchers at BT laboratories
- ITU: FSAN (1996)
- BPON – G.983
- GPON – G.984
- EPON – IEEE 802.3ah

# Standards

| | GPON | EPON | WDM-PON | PtP Ethernet |
|---|---|---|---|---|
| Standards | ITU-T G.984 | IEEE.802.3ah — P2MP | No standard | IEEE.802.3ah — P2P |
| Downstream (DS) | 2.5 Gb/s or 1.25 Gb/s | 1.25 Gb/s | | 1.25 Gb/s |
| Upstream (US) | 1.25 Gb/s or 622 Mb/s | 1.25 Gb/s | | 1.25 Gb/s |
| DS efficiency | 92% (8% of overhead) | 71.94% | | 74% |
| US efficiency | 92% (8% of overhead) | 66.9 % | | 74% |
| Split ratio (SP) | 1:32, 1:64 (1:128 planned) | 1:32, 1:64 (with FEC) | | 1:1 |
| DS throughput | 2.3 Gb/s or 1.15 Gb/s | 899.2 Mb/s | | 925 Mb/s |
| US throughput | 1.15 Gb/s | 836.3 Mb/s | | 925 Mb/s |
| Reach | 20 km (1:64 SP) | 20 km (SP 1:16) | | 1000BASE-L/BX: 10 km<br>1000 BASEPX20: 20 km |
| Supports transport of TDM services | Native via GEM or CE over Ethernet | CE over Ethernet | | CE over Ethernet |
| Encryption | AES is part of the standard | Not standardized | | Not standardized |
| Network protection | It is part of the standard | Not standardized | | Not standardized |

# PON standards




- Based on G.983 suite of standards covering all aspects such as physical, management, and control
- BPON maps all traffic to ATM cells
- ATM cells fit into BPON TC frames
- Can use Ethernet uplink

- Based on BPON G.983 and share similar attributes
- Specified as G.984 suite of standards covering all aspects such as physical, management, and control
- In addition to ATM, GEM allows native TDM and Ethernet transport

- Ratified by IEEE as Clause 64 of IEEE 802.3 standard
- Other important aspects are out of the scope of EPON spec

# BPON G.983 – 155/622 Mbps

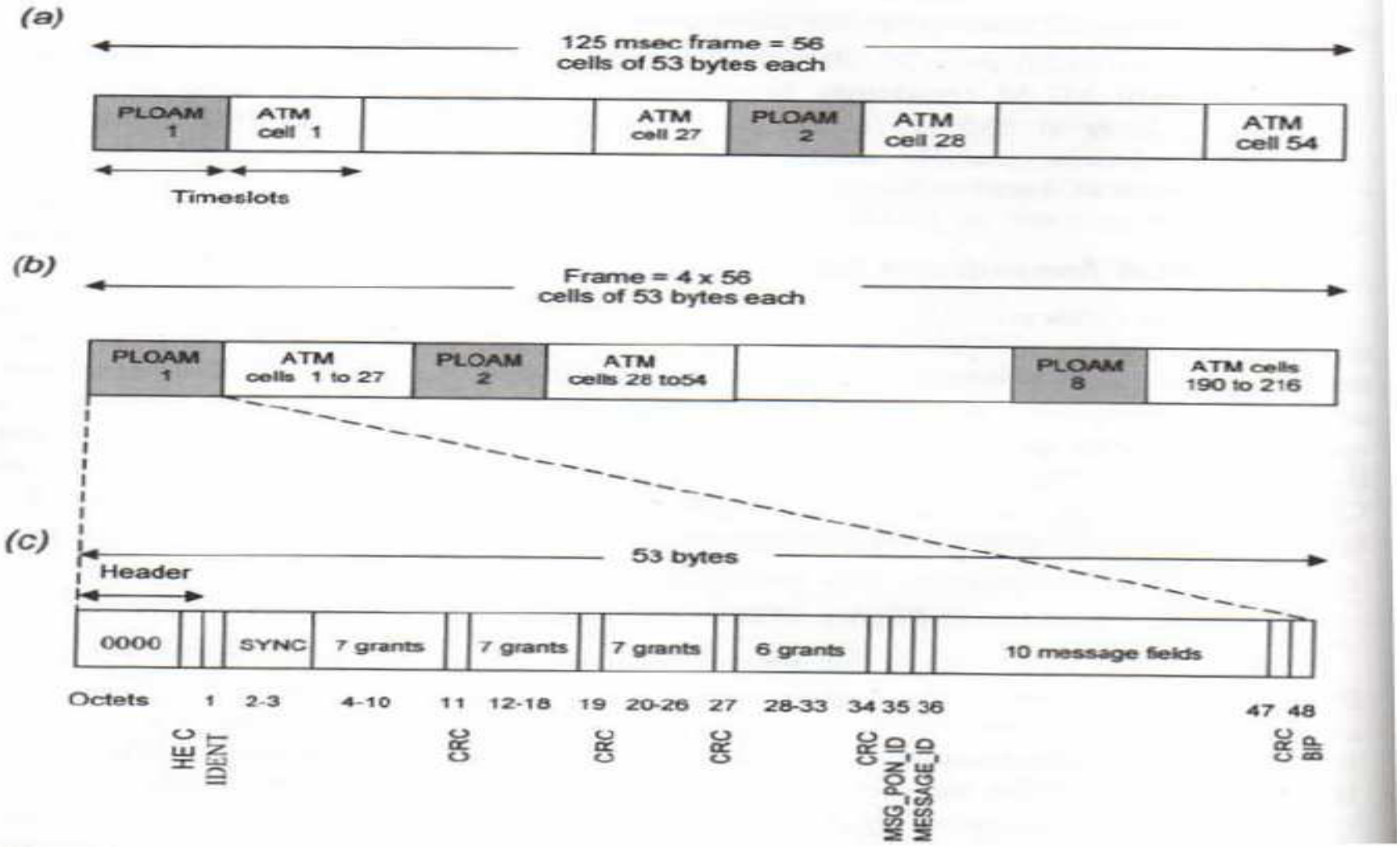
- Physical Medium Dependent Layer
- BPON Transmission Sub layer of TCL
- BPON Adaptation Sub layer of TCL

  - Conversion between ATM and PDUs

- Security

  - Churning: Downstream in Pseudorandom way & permutation key changed once per sec

# BPON Downstream Format



# Downstream Fields – OLT to ONT

- Physical Level Operations and Maintenance – PLOAM
- ATM Cells
- Message Fields

# PLOAM Function

- IDENT,MSG and BIP fields are common to both Up and Downstream PLOAMs
  - IDENT – frame delineation
  - MSG – CPE to Network communication
  - BIP – parity check (layer 2)

# Downstream PLOAM Fields

- Grants – in first 2 PLOAMS
  - Each of these 2 carry grants for 27 Time Slots
    - Total 54 Time Slots per Frame
      - Act as Media Access Control
- Message Fields determine grant usage and ranging parameters
- ATM – carry traffic

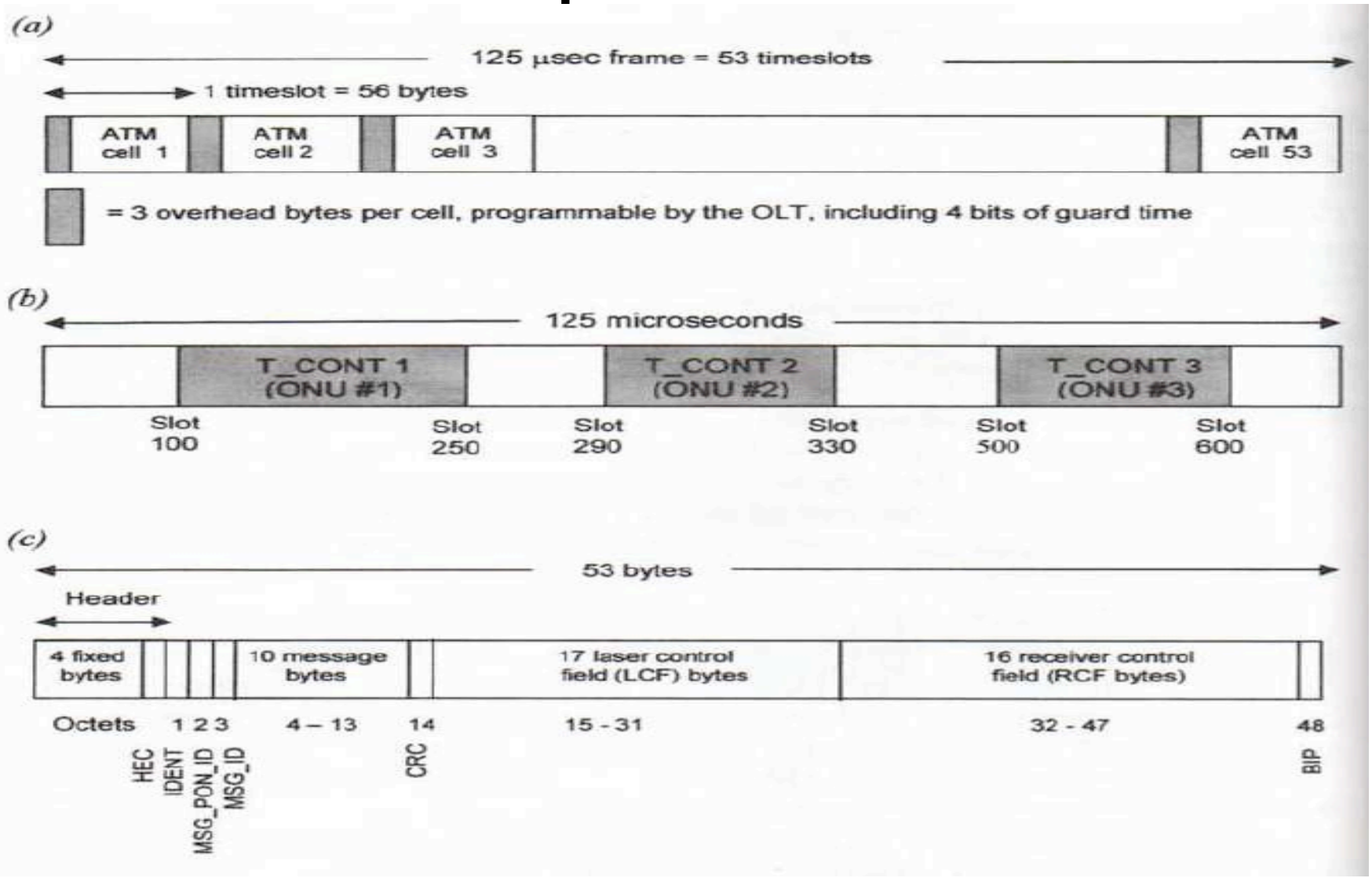
# Ranging Grants

- ONU's are located at different distances from the OLT
- PLOAM cell address the station to be ranged and open up a window wide enough to receive the upstream PLOAM cell.
- OLT range determines an equalization delay, providing the ONU a window within which it is allowed to start sending.

# Upstream Only Fields – ONT to OLT

- Laser Control Field
  - ONU reports power level and extinction ratio of its own Laser to maintain proper TX level.
- Receiver Control Field
  - OLT detects its own threshold level for distinguishing of “zero” from “one”

# BPON Upstream Frame



# GPON G.984

- Uses GEM ( GPON Encapsulation): Enable to host different packetsize traffic formats such as Ethernet
- Uses Advanced Encryption Standard (Symmetrical crypto system)
- X-ORing of the payload with AES key for encryption and same X-OR at receiver for decryption

# GPON Features

- Scalable framing structure
  - 622Mb/s to 2.5Gb/s, as well as asymmetric bit rates support.
- Exceptionally high bandwidth utilization/efficiency for any type of service
- A variant of Generic Framing Procedure (GFP) encapsulation of any type of service (both TDM and packet) into 125 µsec periodic frames.

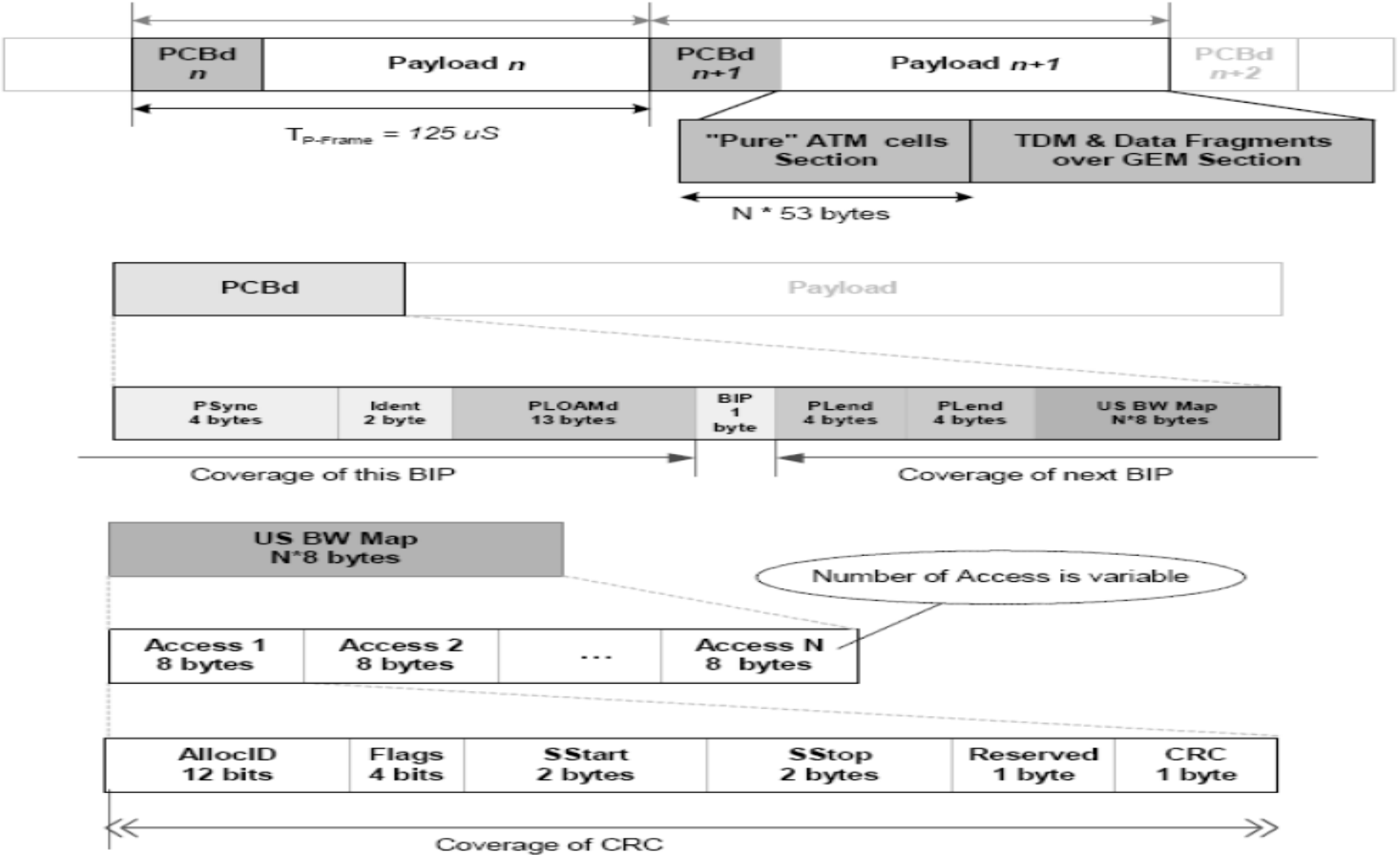
# GPON Features

- High efficiency with no overhead transport of native TDM traffic.
- Dynamic Allocation of upstream bandwidth via bandwidth maps (pointers) for each ONT – Asymmetric Services
- Uses a variation of GFP

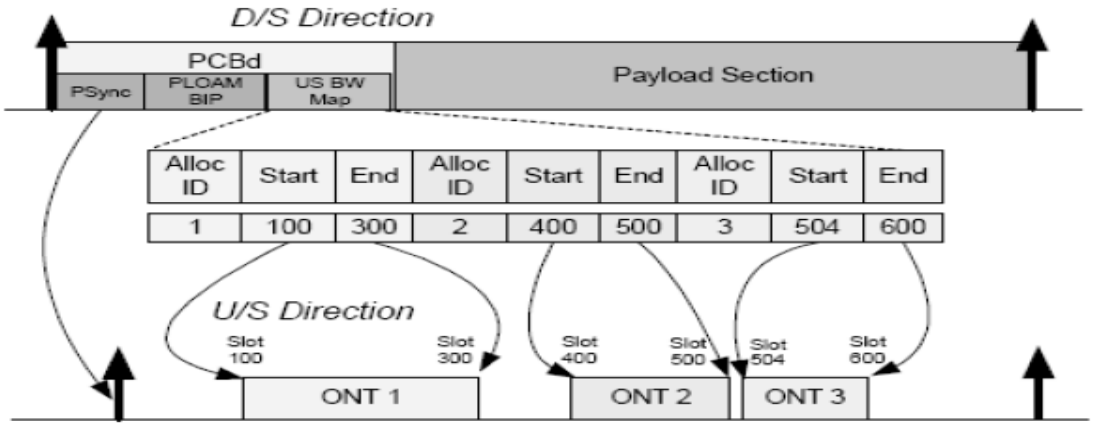
# GPON Encapsulation - GEM

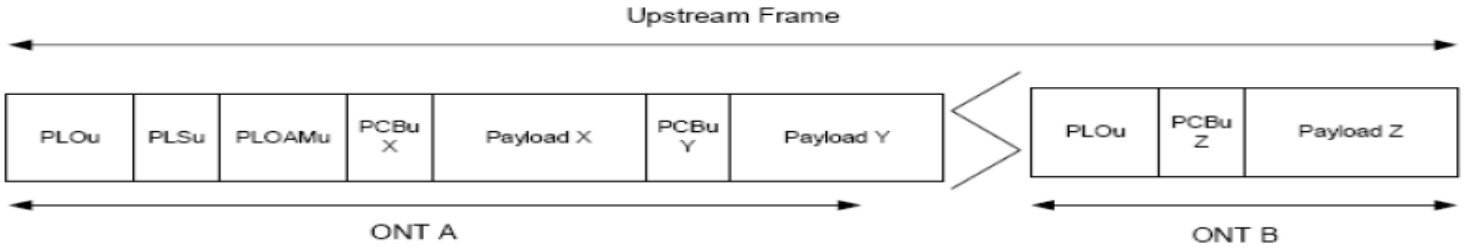
- ITU-T recommendation G.7041 = GFP
- SONET/SDH and ITU-T G.709 (ONT)
- Supports
  - IP/PPP (IP/Point-to-point Protocol
  - Ethernet MAC)
  - Constant Bit Rate streams
    - Ex – TDM  - as it uses 125us framing

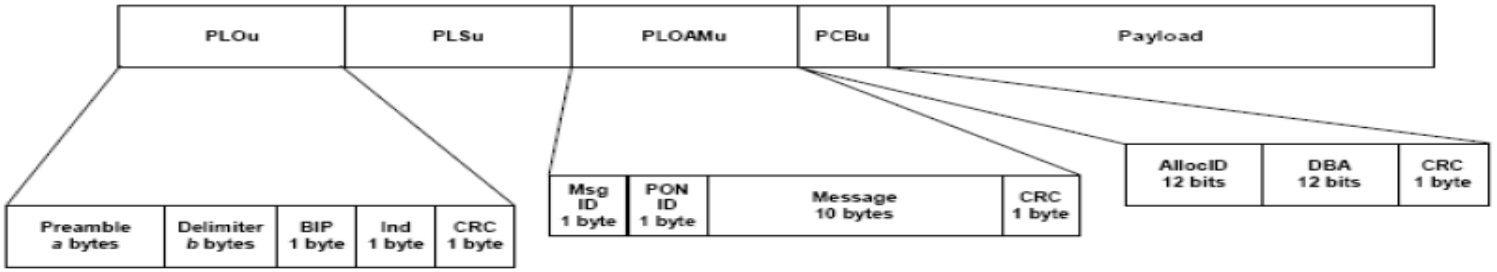
# GPON Downstream Format



# GPON Upstream Format



# Ethernet Based PON - EPON

- P2MP
- Splitters
- MPCP as the MAC layer
  - Uses a LLID – Logical Link ID

# MPCP - Function

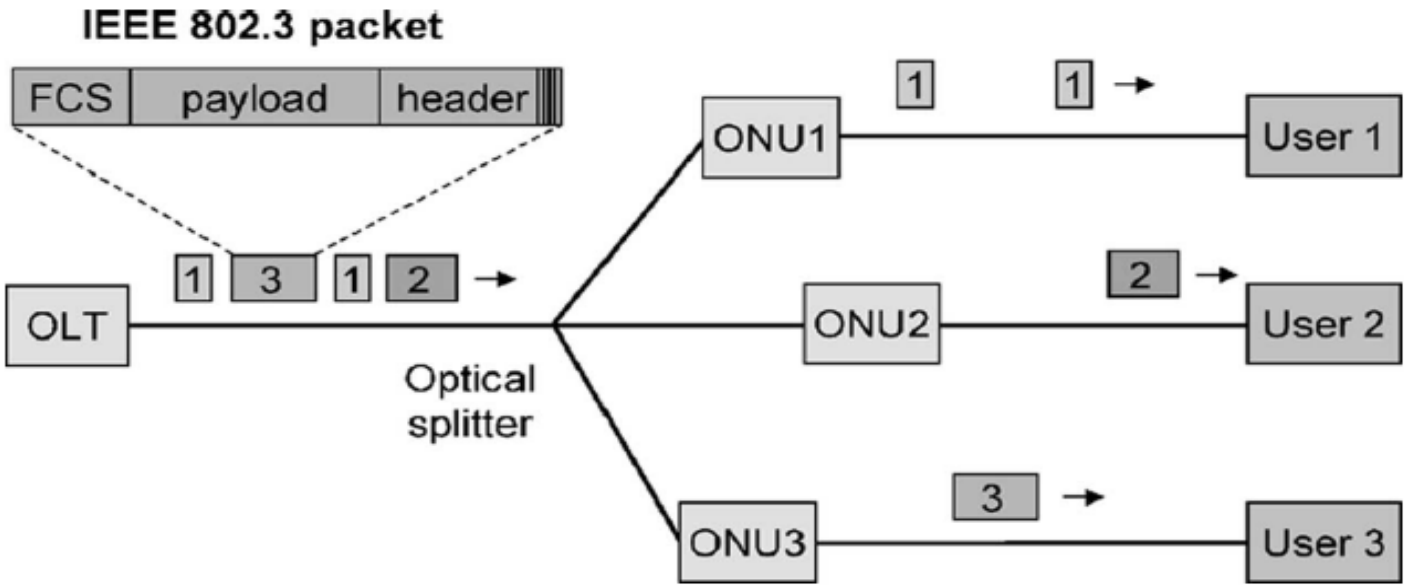
- OLT sends discovery gate message request to all unregistered ONUs
- ONUs acknowledge by using Registration Request (REGISTER REQ) message
- When received and approved the OLT registers the ONU using the REGISTER message
- The handshake ends with the ONU acknowledgement REGISTER_ACK

# Ethernet Based PON - EPON

- Does not support TDM services
- Uses 8B/10B line encoding
  - 20% BW Penalty – due to added bits
    - DC leveling

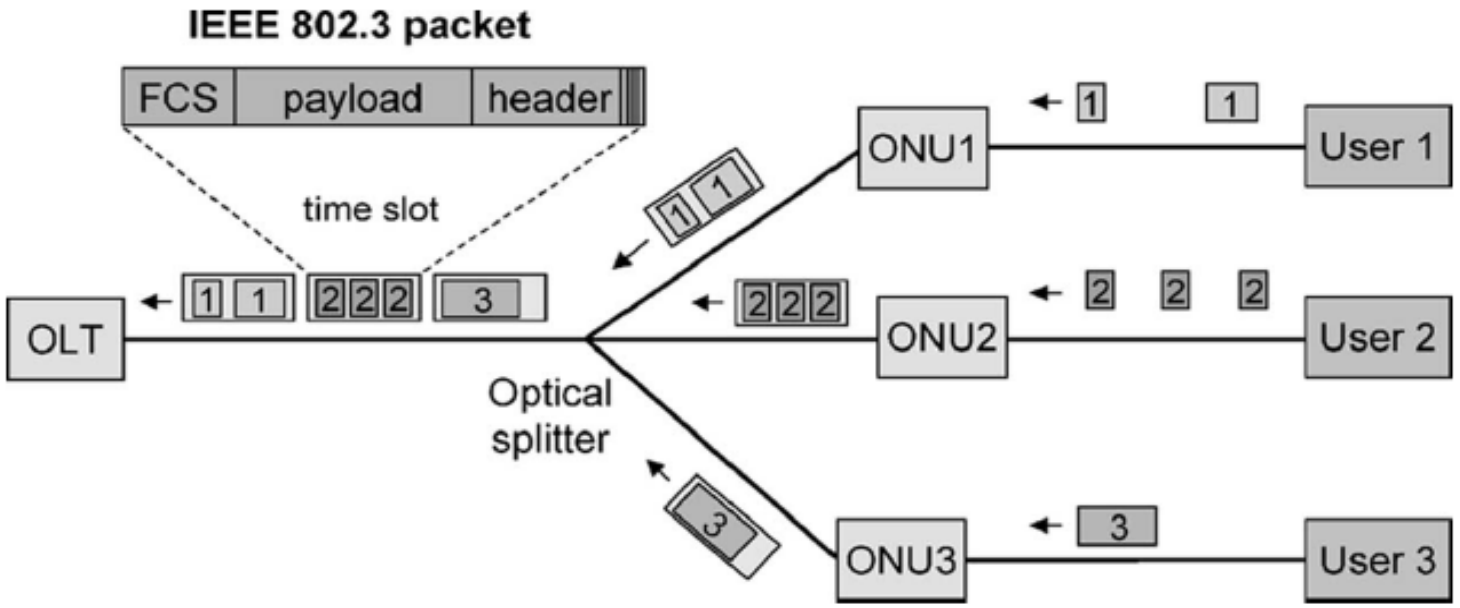
Note - BPON/GPON – use scrambling

# EPON Downstream




*Downstream traffic in an EPON.*

# EPON Upstream



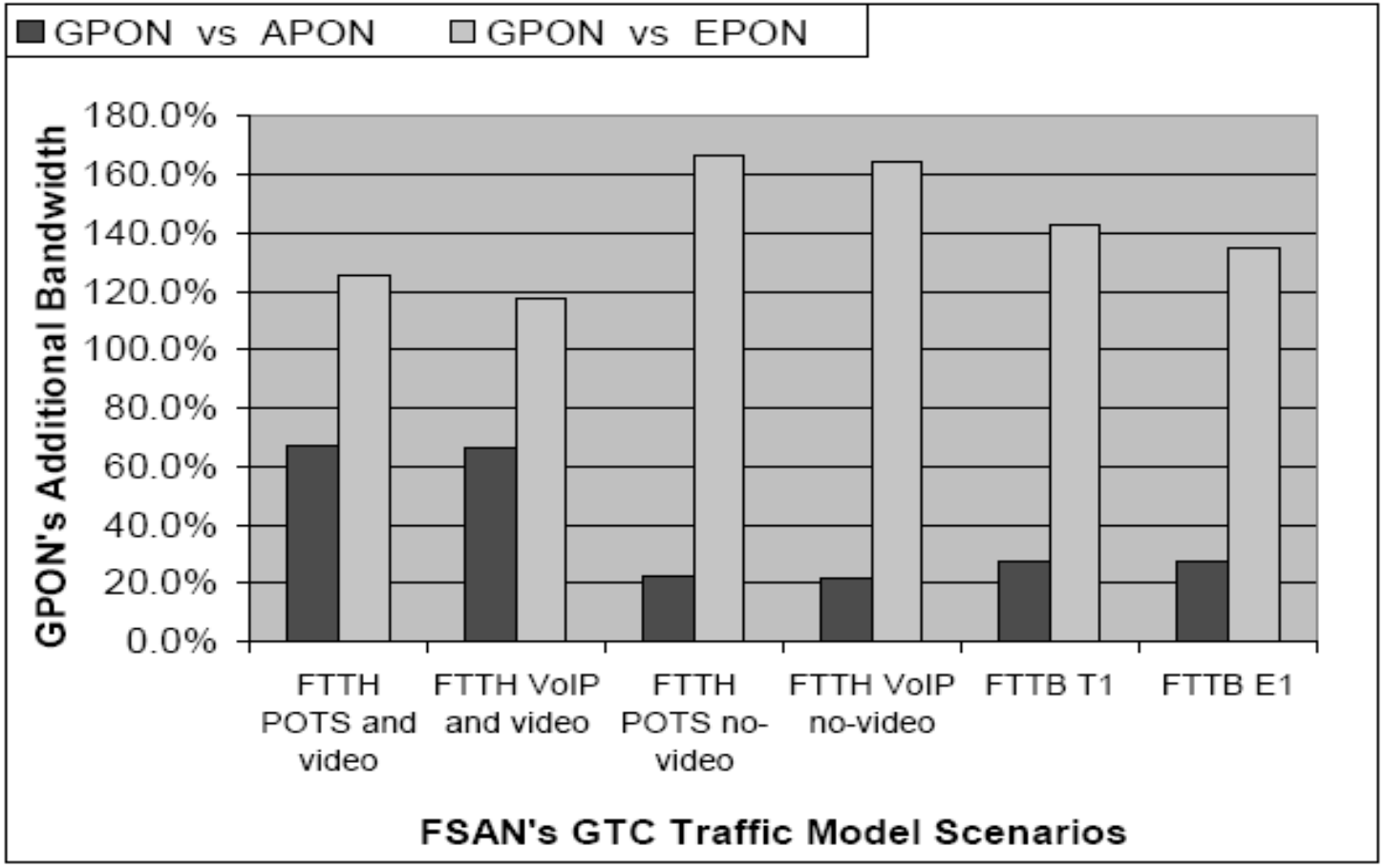

*Upstream traffic in an EPON.*

# Efficiency Comparison

| | Line Coding | PON TC Layer Efficiency | Bearer Protocol Efficiency | Service Adaptation | |
|---|---|---|---|---|---|
| | | | | T1 | FE |
| APON | 100% | 96% | 90% | 98% | 80% |
| EPON | 80% | 98% | 97% | 72% | 63% |
| GPON | 100% | 99% | 100% | 96% | 94% |

| | Overall Efficiency 10% TDM, 90% Data | Overall Efficiency 20% TDM, 80% Data |
|---|---|---|
| APON | 71% | 72% |
| EPON | 49% | 49% |
| GPON | 93% | 94% |

# PON system Performance

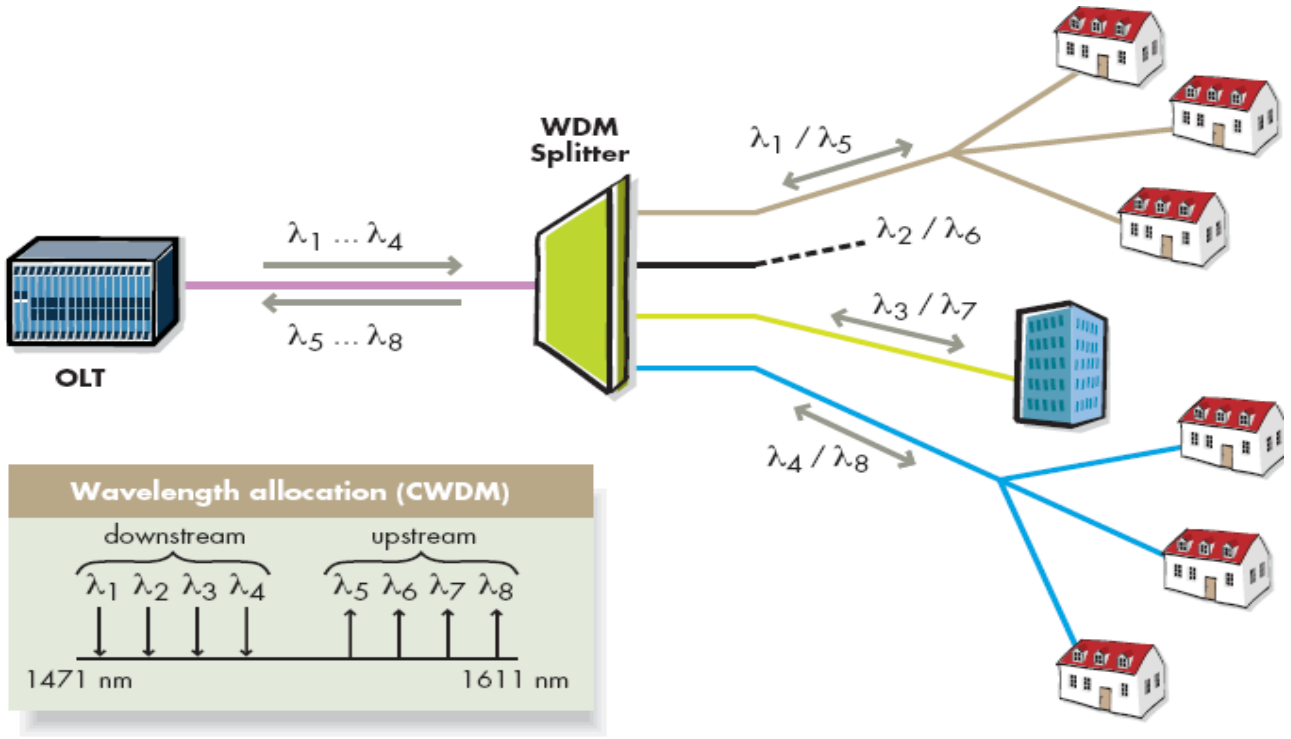



Additional Bandwidth provided by GPON

# WDM - PON

- 1 lambda per ONT
- 1 Gigabit per second
- Point to Point access –P2P
- Lower Laser Power Required

# WDM PON




**CWDM:** Coarse Wavelength Division Multiplexing