An Introduction to EPON

Presentation to the SCTE Piedmont Chapter

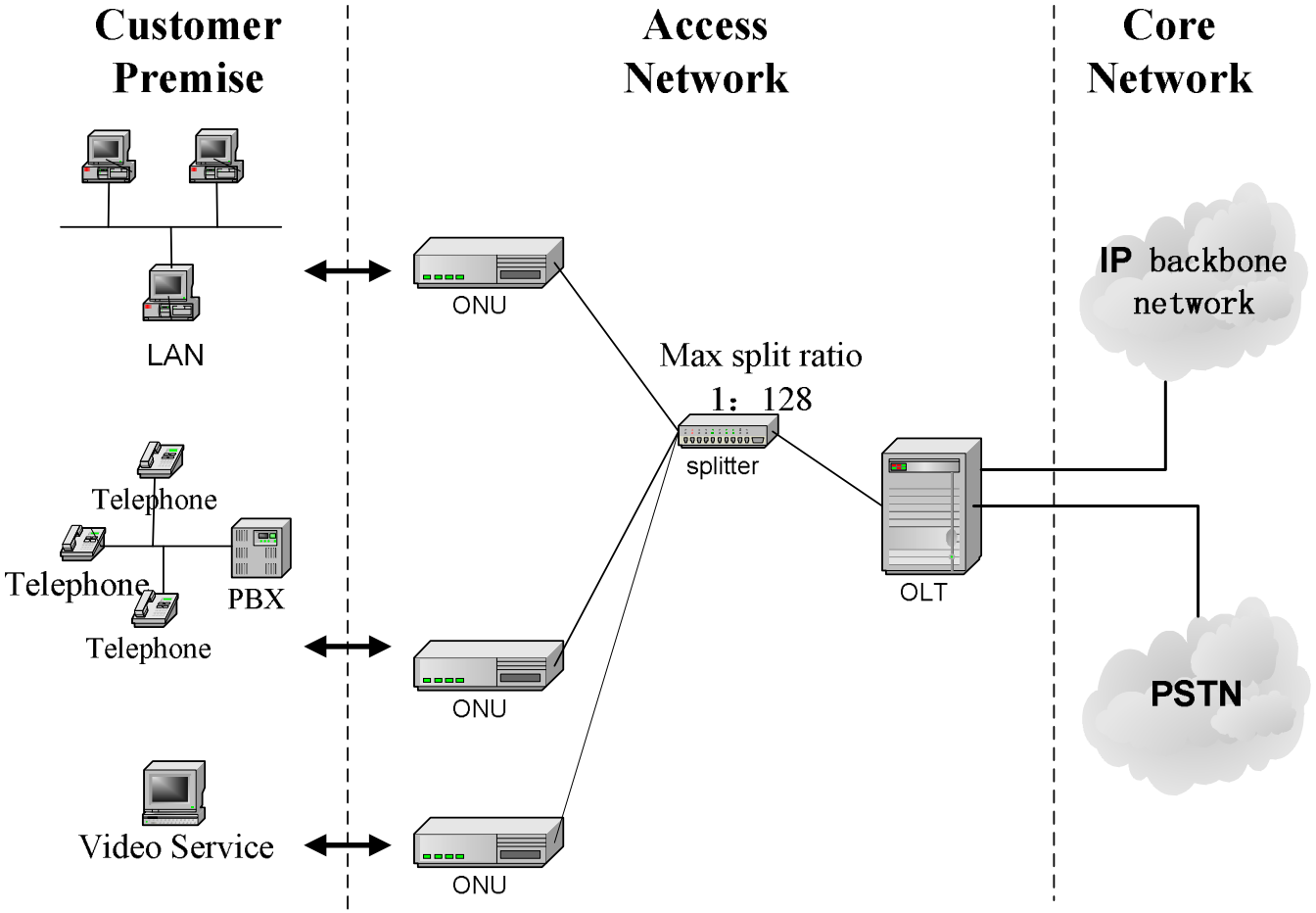
Jorge Figueroa
Sr. Systems Engineer

Contents

Definition of PON

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

Definition and Composition of PON

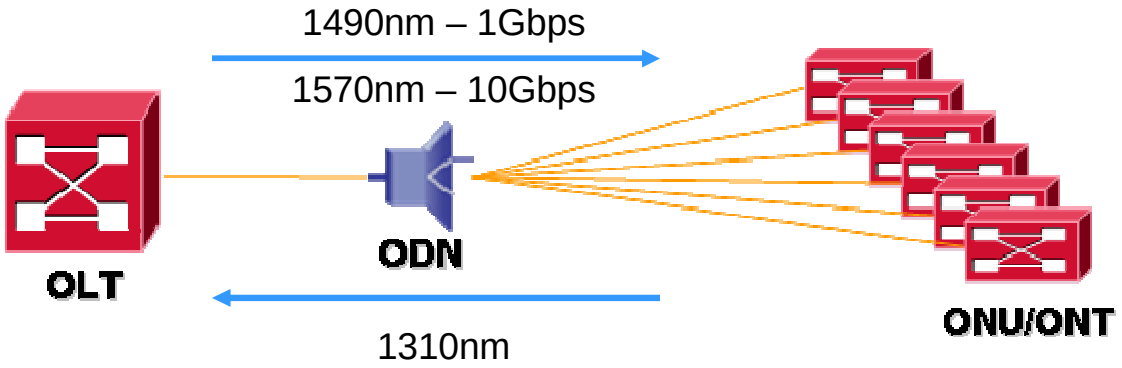


PON Development History

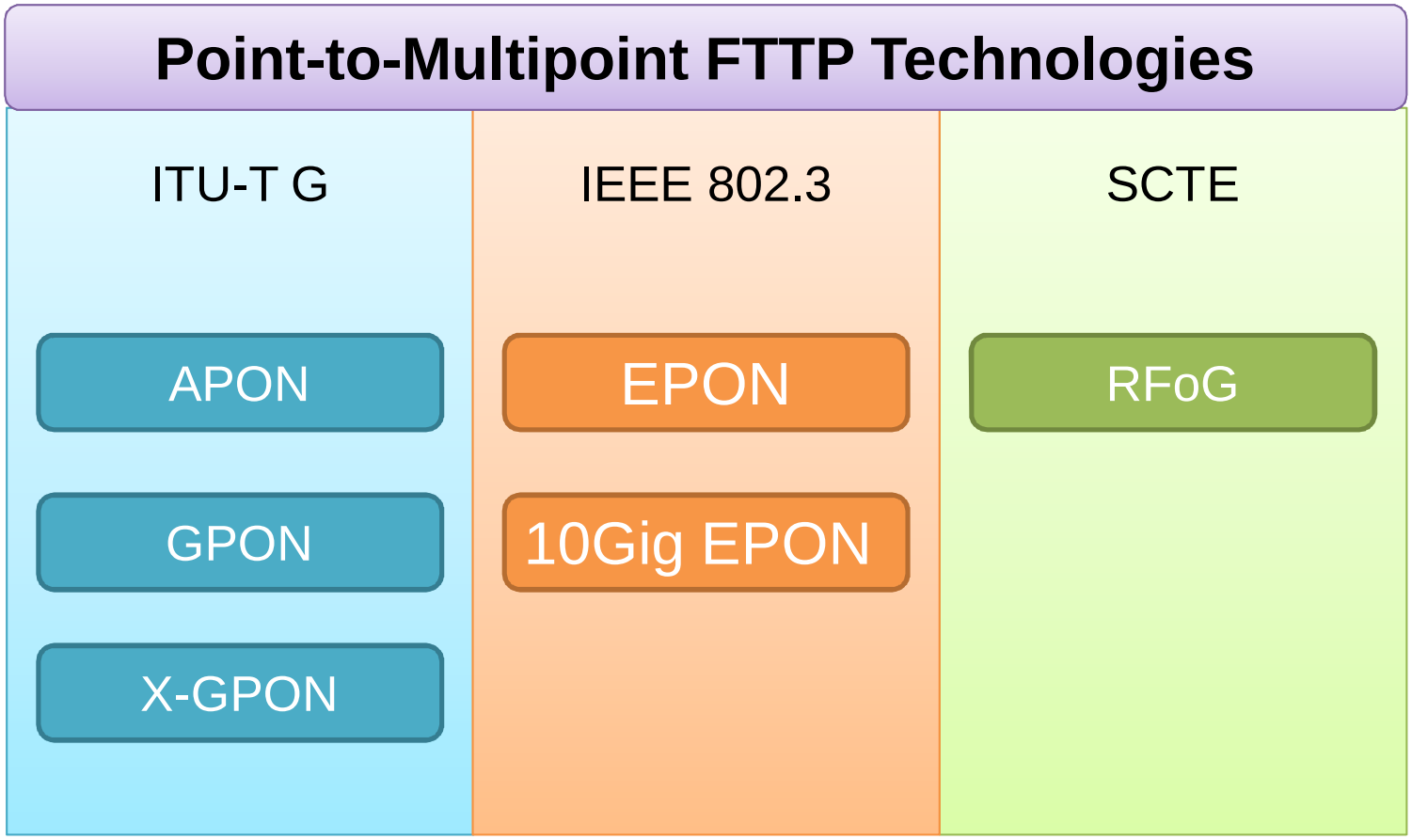
- PON was raised in early 1990s.
- FSAN（Full Service Access Networks) was established in 1995.
- ITU-T issued G.982 (PON standard protocol) in 1996.
- ITU-T issued G.983（APON standard protocol) in 1998.
- IEEE 802.3ah work group was established to draft EPON standard protocol in December 2000.
- ITU-T issued G.984（GPON standard protocol) in March 2003.
- APON was put into commercial use in late 1990s.
- Three American operators began to invite bidding for APON in June,2003.
- NTT of Japan started to invite bidding for EPON in Aug. 2003
- China Telecom started to test and deploy EPON test network in 2005.
- 10GEPON standards of 802.3av were issued in 2009

PON Transmission Mechanism

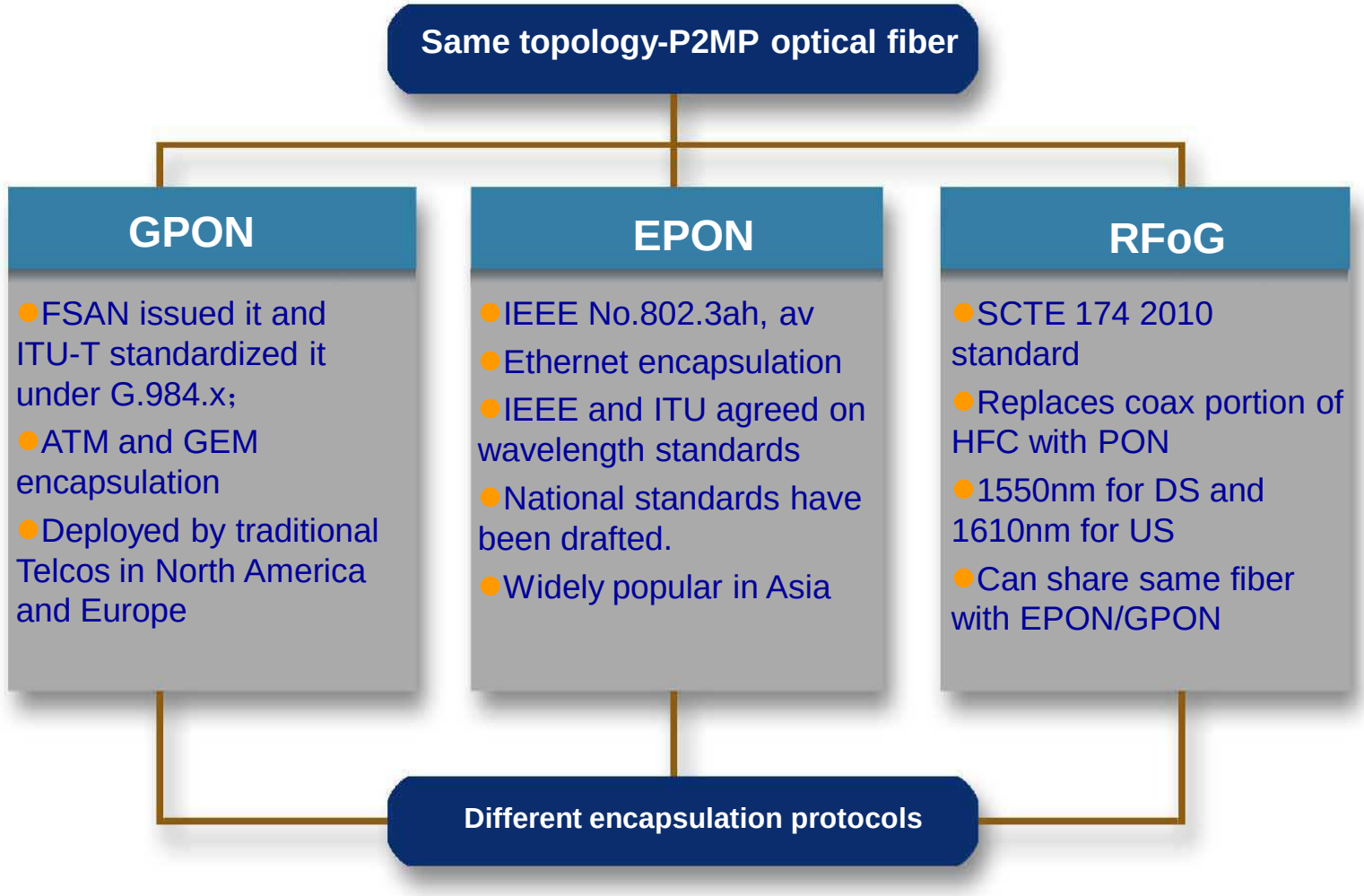
- The PON system uses WDM technology to achieve two-way transmission on a single fiber.



- Two multiplexing technologies are used:
  - Broadcast on the downstream flows
  - TDMA on upstream flows

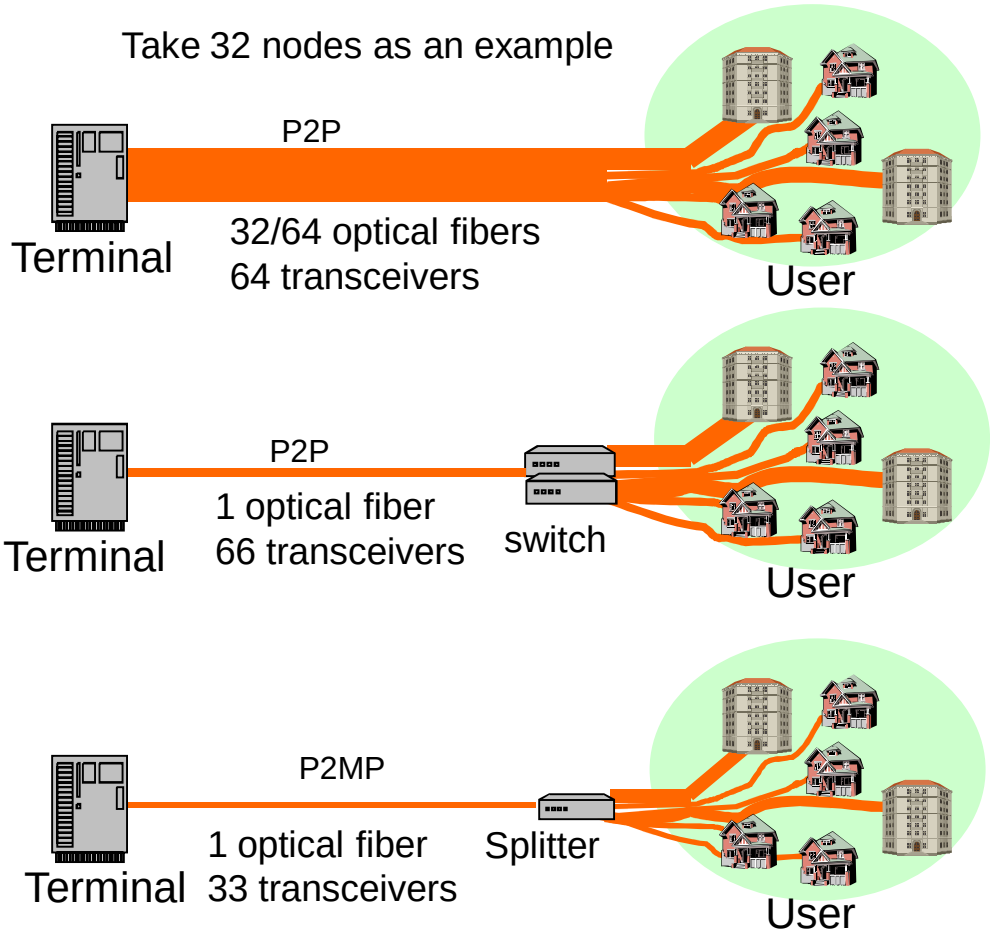


Overview of PON Technology

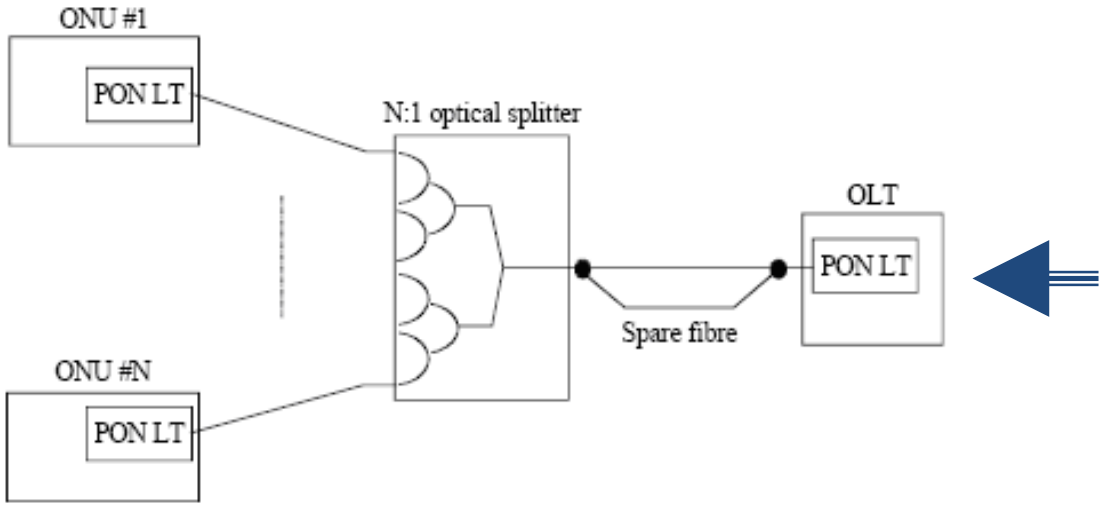


PON vs Active Point to Point

- Active Point to Point Mode:
  - P2P Ethernet access mode:
    - N*optical fibers, 2N* optical transceiver
    - Independent management
  - Switch Access Mode
    - Only 1 or 2 optical fibers are connected to user.
    - 2N+2* optical transceivers
    - Active device is needed in transmission.
    - Hierarchical device management
- PON access mode:
  - Only 1 or 2 optical fibers are connected to user.
  - N+1*optical transceiver
  - Active device is not needed in transmission.
  - Centralized device management

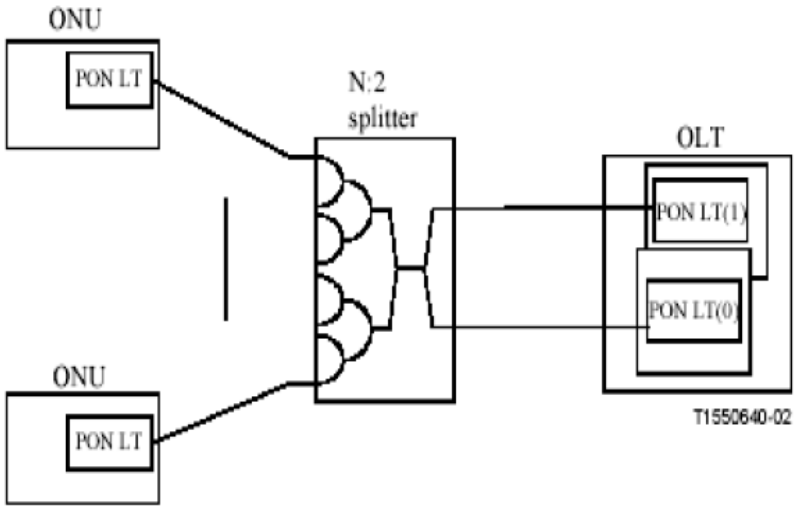


PON Redundancy Modes



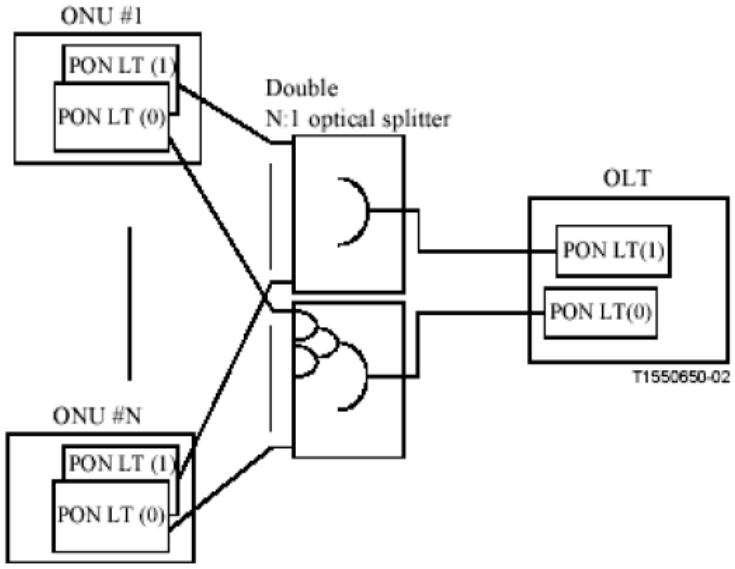
Type A:
Backbone fiber protection mode

PON Redundancy Modes



Type B: OLT and Backbone fiber protection mode

Type C :Full protection mode



Advantages of PON

- PON simplifies customer coverage
  - 1 Fiber
  - Passive splitters serve 32 to 64 ONUs in 1Gig EPON, or up to 256 in 10Gig EPON
  - ONU can be mounted outside the premises
  - Quick installation
- OPEX Savings & Lowest First Cost
  - Remote ONU activation, even easier with DPoE
  - Lower risk of fiber exhaustion
  - Minimal outside plant maintenance
  - No power needed on a passive fiber plant
  - Affordable “Managed UNI” demark
- High bandwidth
  - EPON: 1.25Gb/s or 10Gb/s of symmetric bandwidth
- Wide range of services (data, voice, video, MEF carrier Ethernet).
- Flexible bandwidth allocation and assured QoS

Contents

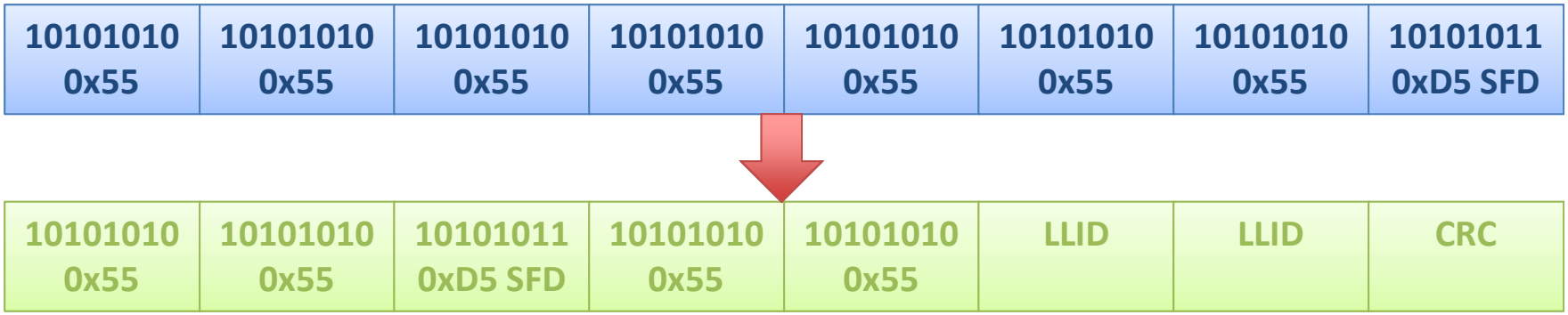
Review of an Ethernet Frame

<table>
<tr><th>Preamble</th><th>Start of Frame Delimiter</th><th>MAC destination</th><th>MAC source</th><th>802.1Q tag (optional)</th><th>Length</th><th>Payload</th><th>Frame Check Sequence (32-bit CRC)</th><th>Interframe gap</th></tr>
<tr><td>7 octets of 01010101 (0x55)</td><td>1 octet of 11010101 (0xD5)</td><td>6 octets</td><td>6 octets</td><td>(4 octets)</td><td>2 octets</td><td>42–1500 octets</td><td>4 octets</td><td>12 octets</td></tr>
<tr><td colspan="2"></td><td colspan="6">64–1522 octets</td><td></td></tr>
<tr><td colspan="8">72–1530 octets</td><td></td></tr>
<tr><td colspan="9">84–1542 octets</td></tr>
</table>

- A frame viewed on the physical wire would show preamble and start frame delimiter (SFD), in addition to the other data.
- The preamble of an Ethernet frame consists of a 7-octet pattern of alternating 1 and 0 bits (0x55), which allows devices on the network to easily detect a new incoming frame.
- The SFD is designed to break this pattern and signal the start of the actual frame
- The SFD is the octet value marking the end of the preamble of an Ethernet frame.
- The SFD has the value 10101011 (0xD5) and is immediately followed by the destination MAC address.

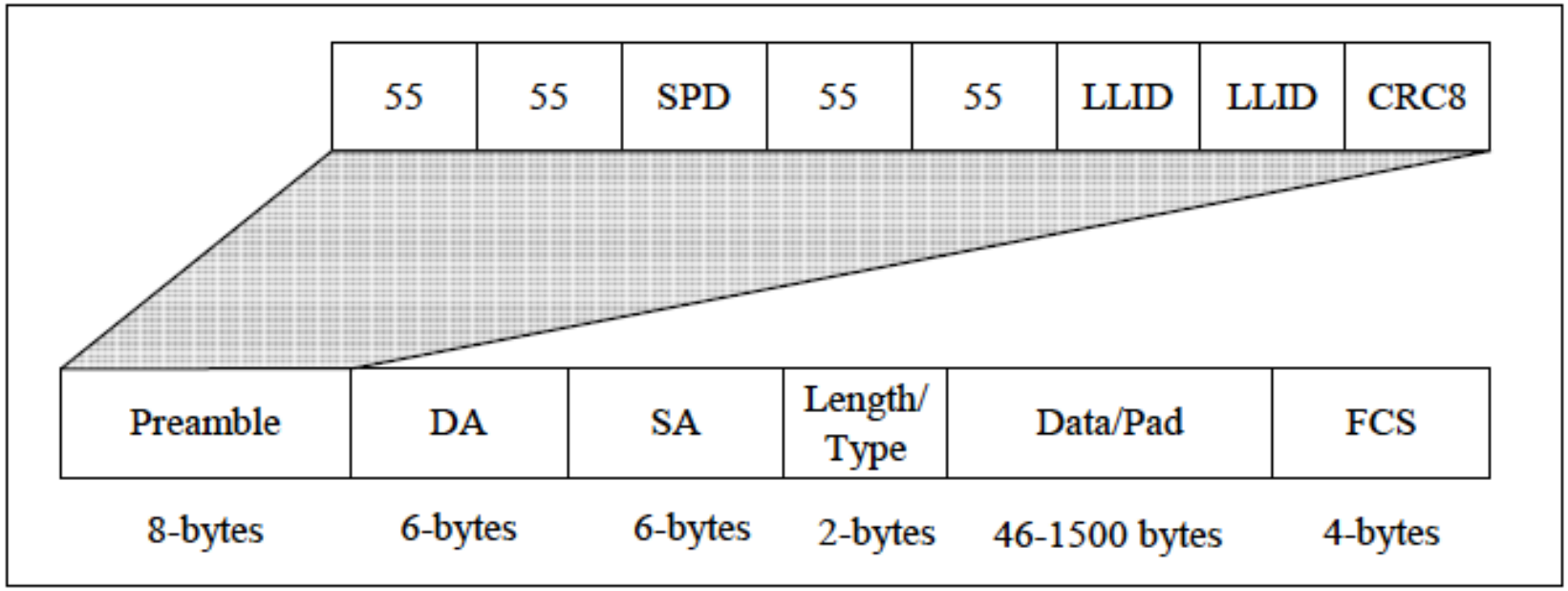
The EPON Header

- The 8-byte (octet) Ethernet preamble consists of:
  - 7 bytes of alternating ones and zeros, 10101010 or 0x55
  - 1 byte of SFD 10101011 (0xD5)
- EPON modifies the preamble by overwriting some of the preamble bytes:



- Logical Link Identifier (LLID) field is 2 bytes (16 bits) long
  - First bit is called MODE and it determines if the frame is unicast or multi/broadcast:
    - 0 when ONU sends traffic upstream
    - 0 for OLT unicast, 1 for OLT multicast/broadcast
  - Actual Logical Link ID (15b)
    - Identifies registered ONUs
    - 7FFF or 7FFE for broadcast (1Gig or 10Gig EPON)
- CRC protects from SFD (byte 3) through LLID (byte 7)

EPON Work Principles-Frame Structure



Based on 802.3 frame format

Logical Link Identifier (LLID) is a functional equivalent of SID and is used to identify different services and QoS guarantees

Detailed Definition of LLID

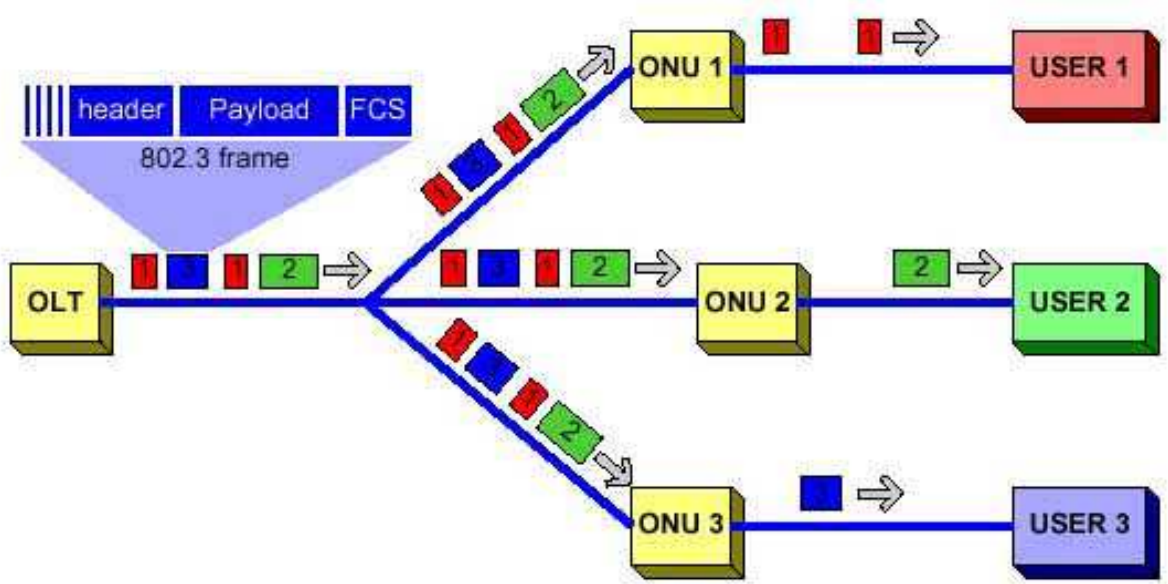
Offset	Field	Preamble/SFD	Modified preamble/SFD
1	-	0x55	same
2	-	0x55	same
3	SLD	0x55	0xd5
4	-	0x55	same
5	-	0x55	same
6	LLID[15:8]	0x55	<mode,logical_link_id[14:8]>[a]
7	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
8	CRC8	0xd5	The 8 bit CRC calculated over offsets 3 through 7

[a]mode maps to TXD[7], logical_link_id[14] maps to TXD[6], logical_link_id[8] maps to TXD[0]
[b]logical_link_id[7] maps to TXD[7], logical_link_id[0] maps to TXD[0]

- Broadcast and unicast :
  - Broadcast: MODE=1 or LLID=0x7FFF
  - Unicast: MODE=0 and LLID!=0x7FFF

EPON Work Principles - Downstream

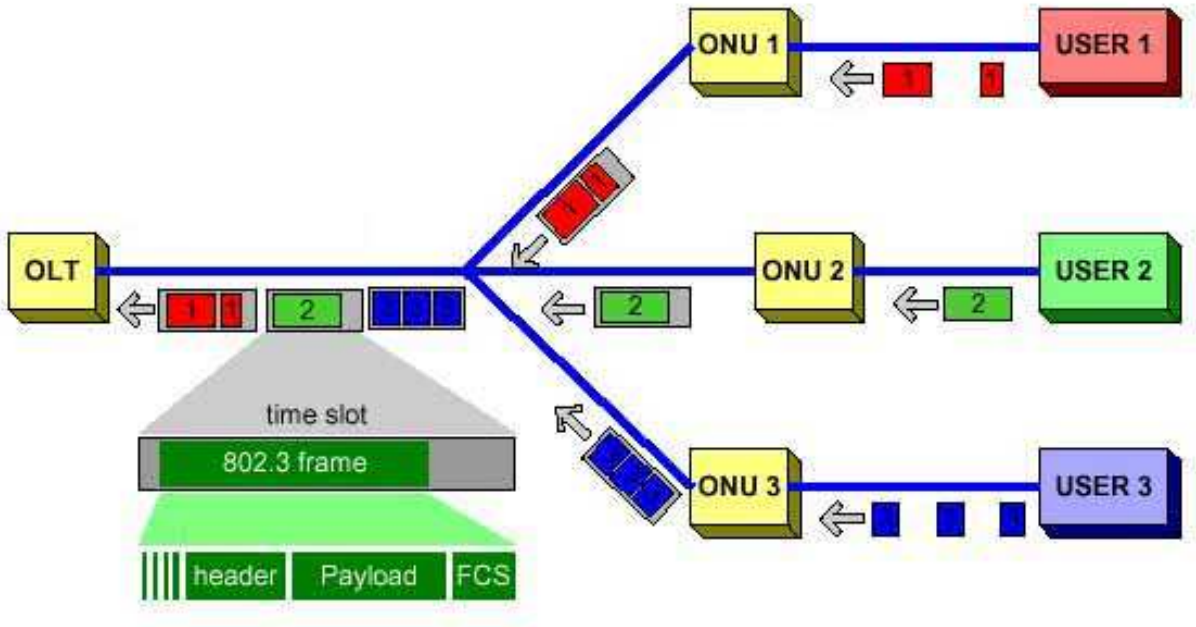
Broadcast



- Each ONU receives a unique LLID upon successful registration.
- The LLID replaces the last two bytes of the Ethernet preamble. It is added just prior to transmission.
- The OLT forwarding table knows which MAC addresses are behind each ONU. It then adds the LLID to the frames.
- An ONU only receives frames or broadcast frames that are in compliance with its own LLID.

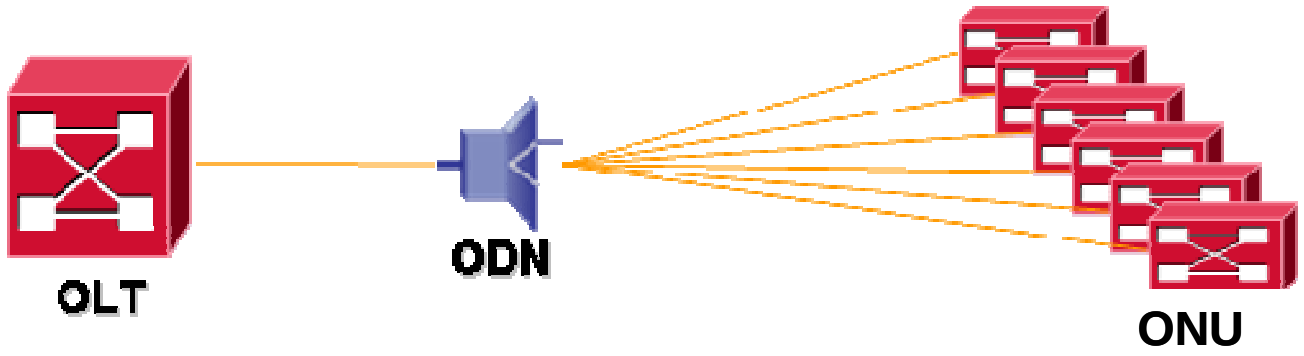
EPON Work Principle - Upstream

TDMA



- An OLT compares all incoming upstream traffic with its own LLID register before forwarding traffic to the network.
- Each ONU sends data frames in the timeslots allocated by the OLT
- The allocated timeslots compensate for any time delay. This prevents collisions between ONUs.

Workflow of an EPON System



OLT Tasks

- Generates timestamp messages used for time reference
- Allocates bandwidth to ONUs through MPCP frames
- Performs initial and periodic ranging of ONUs
- Controls ONU registration

ONU Tasks

- Each ONU synchronizes with the OLT through the time stamps of the downstream control frames
- ONU waits for the discovery gate.
- ONU performs discovery processing, including ranging, obtaining an LLID, and requesting bandwidth
- Once registered, ONUs can send data only in the allocated time slots.

Key Technologies of an EPON System

- LLID and emulation sub-layer
- MPCP
- Auto-registration and ranging

LLID and Emulation Sub-layer

- Purpose：
  - To make the lower-layer P2MP network processing similar to an aggregation of multiple P2P links
  - Goal is to make the P2MP network emulate a P2P network while keeping the Ethernet frame intact.

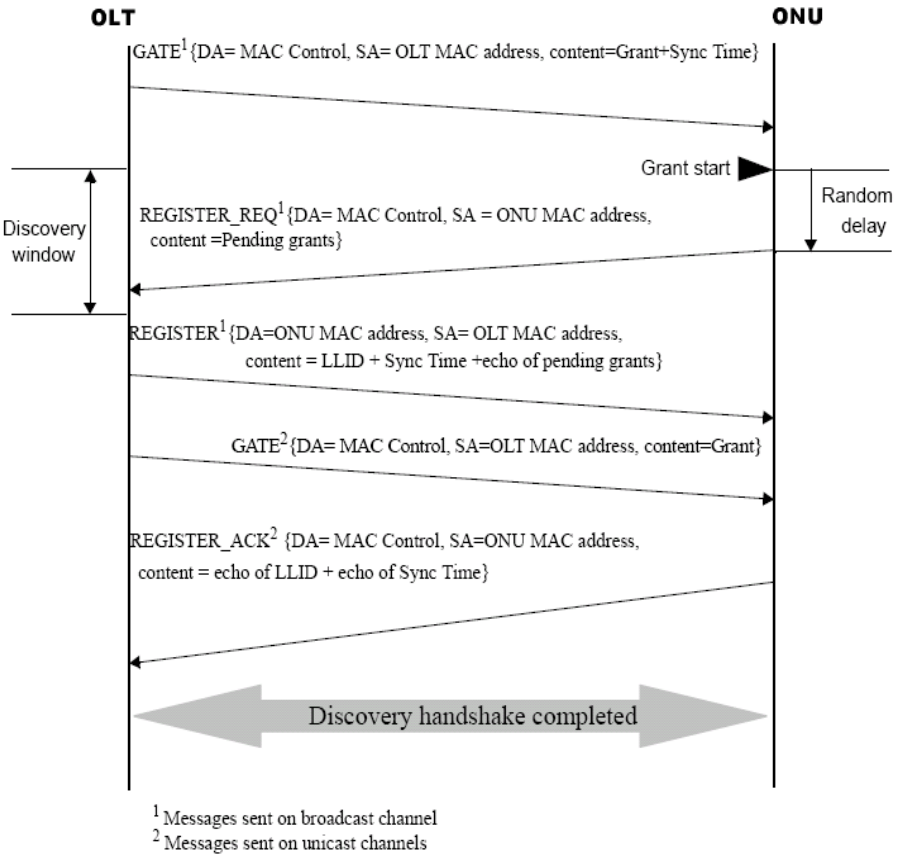
- How to achieve this:
  - By replacing the last 2 bytes of the Ethernet preamble with an LLID
  - Each LLID is unique and assigned automatically after an ONU is registered.
  - When an OLT receives data it compares it with the LLID register list.
  - An ONU only receives data with its own LLID or broadcasts.

Multi-Point Control Protocol (MPCP)

- MPCP is the control mechanism between an OLT and an ONU
- MPCP ensures that data is sent and received effectively:
  - By having the OLT compensate for distance differences of each ONUs.
  - By allowing only one ONU to send data upstream at any point in time.
  - By polling each ONU periodically to verify if it needs to send data.
- All these are accomplished by using GATE message exchanges between the OLT and the ONUs.
- MPCP has two GATE operation modes: Initialization mode and Normal mode
  - Initialization mode is used to detect any newly connected ONUs, measure loop delay, and verifying ONU MAC addresses.
  - Normal mode is used to allocate the transmission bandwidth to all initialized ONUs and to perform periodic maintenance.

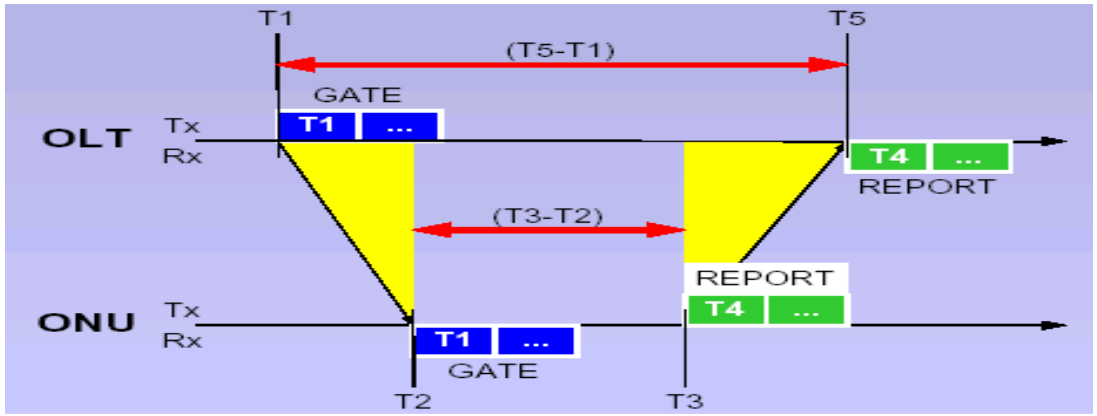
Auto-Registration of ONUs

- ONU tries to register with an OLT upon initialization.
- This process is called “Discovery”, during which the OLT performs the following operations:
  - OLT must periodically send Discovery frames.
  - All “Discovery Gate” frames are sent in broadcast mode.
- An ONU performs the following operations:
  - When powered on or reset, ONU enters the Discovery status and waits for the “Discovery Gate” message from the OLT.
  - If the received message type is Discovery and the LLID is the default or the ONU’s LLID then the ONU responds to this message.



Ranging

- Measures the RTT (Round Trip Time) for each ONU and compensates accordingly
  - Measured during ONU registration
  - OLT uses RTT to adjust the timing of each ONU.
  - OLT can recalculate RTT every time an MPCP PDU is received from an ONU
- Ranging also implements collision avoidance during the Discovery window by having each ONU wait a random time before sending a REG-REQ



RTT = （T2-T1）+（T5-T3）

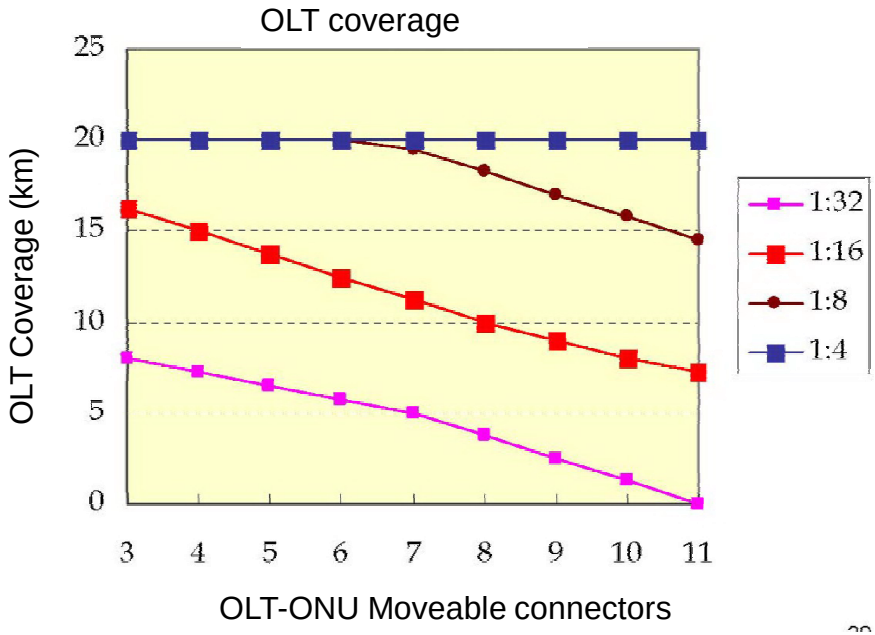
Key Issue of FTTP - OLT Coverage

Fiber loss coefficient * Transmission distance + optical splitter loss + moveable connector loss + ODN optical channel loss + optical cable line margin < Max. loss that EPON allows

Splitter insertion loss

1x2	3.6
1x4	7.3
1x8	10.7
1x16	14
1x32	17.5

- Using 1000BASE-PX20 EPON transmitters, the Max. loss that upstream/downstream allows is 25dB.
- Fiber loss coefficient: 0.4dB/km(upstream)，0.3dB/km(downstream)
- Optical cable line margin
  - Transmission distance<=5km，assume 2dB
  - Transmission distance<=10km，assume 2~3dB
  - Transmission distance>10km，assume 3dB
- Fiber connector loss：0.5dB/pc
- OLT coverage:
  - Urban areas:
    （Typically 7 fiber connectors)
    - 1:32 split ratio：5km
  - Rural areas
    （ Typically 5 fiber connectors ）
    - 1:32split ratio：6.5km
    - 1:16 split ratio ：13.75km
    - 1:8 split ratio ：20km



Optical Power Levels from 802.3ah for 1000BASE-PX20 Transceivers

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

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

Optical Power Levels from 802.3av for 10GBASE–PR–D3 and 10GBASE–PR–U3Transceivers

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

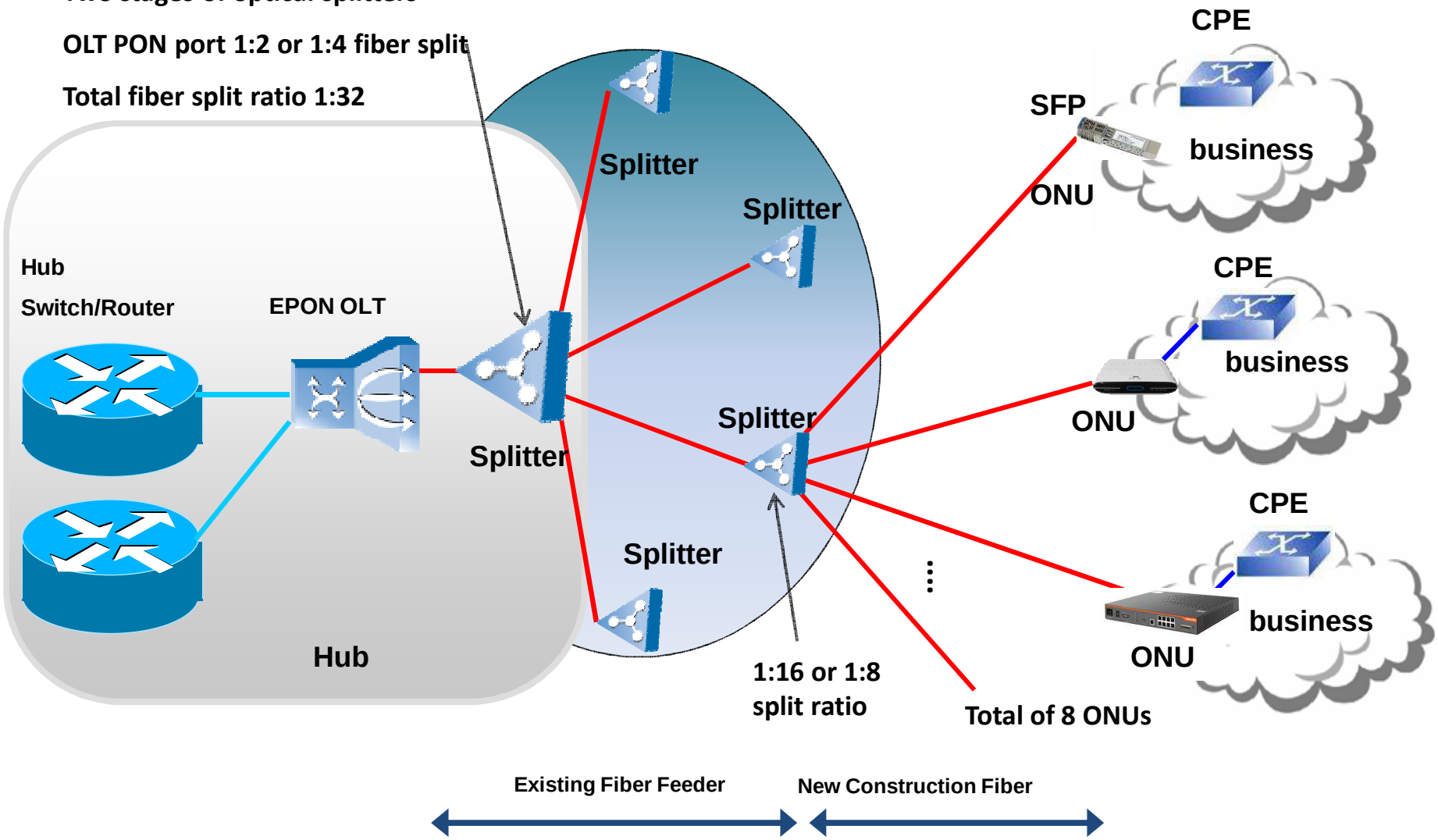
- **ONU:**
  - TX Wavelength: 1260 – 1280 nm
  - TX: +4 to +9dBm
  - RX:-10 to -28.5dBm

EPON ODN Recommendation

Two stages of optical splitters

OLT PON port 1:2 or 1:4 fiber split

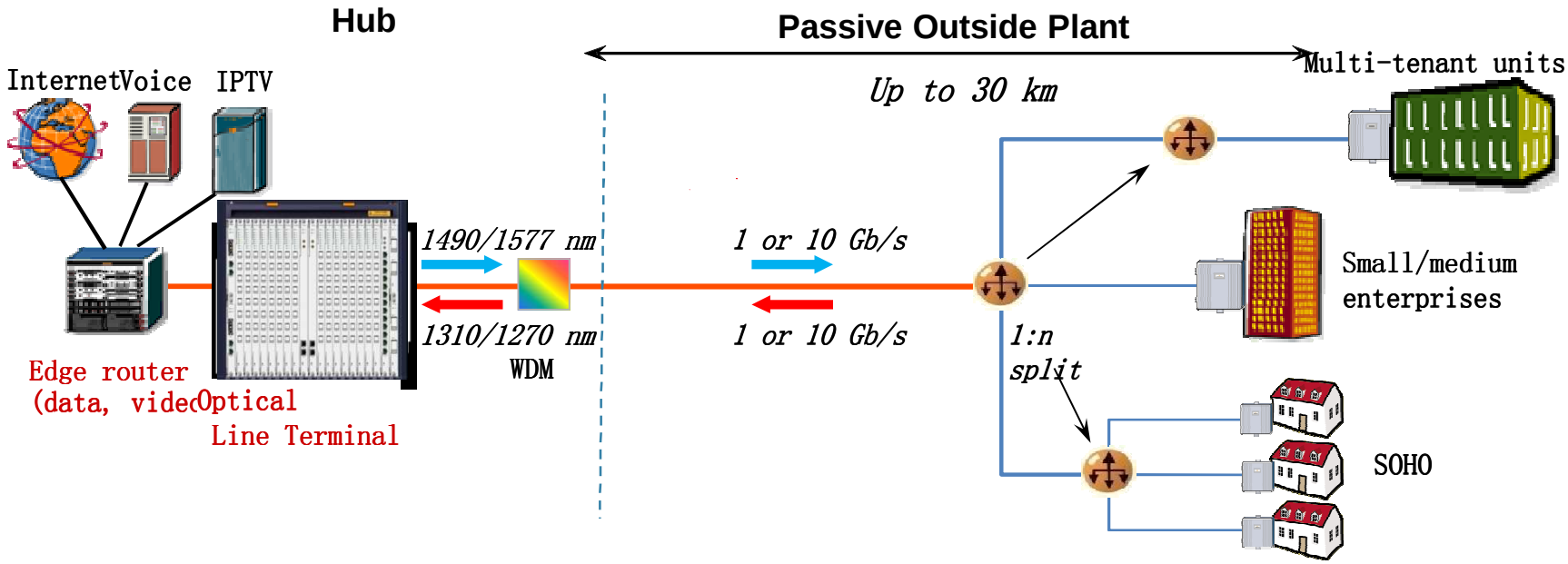
Total fiber split ratio 1:32



Contents

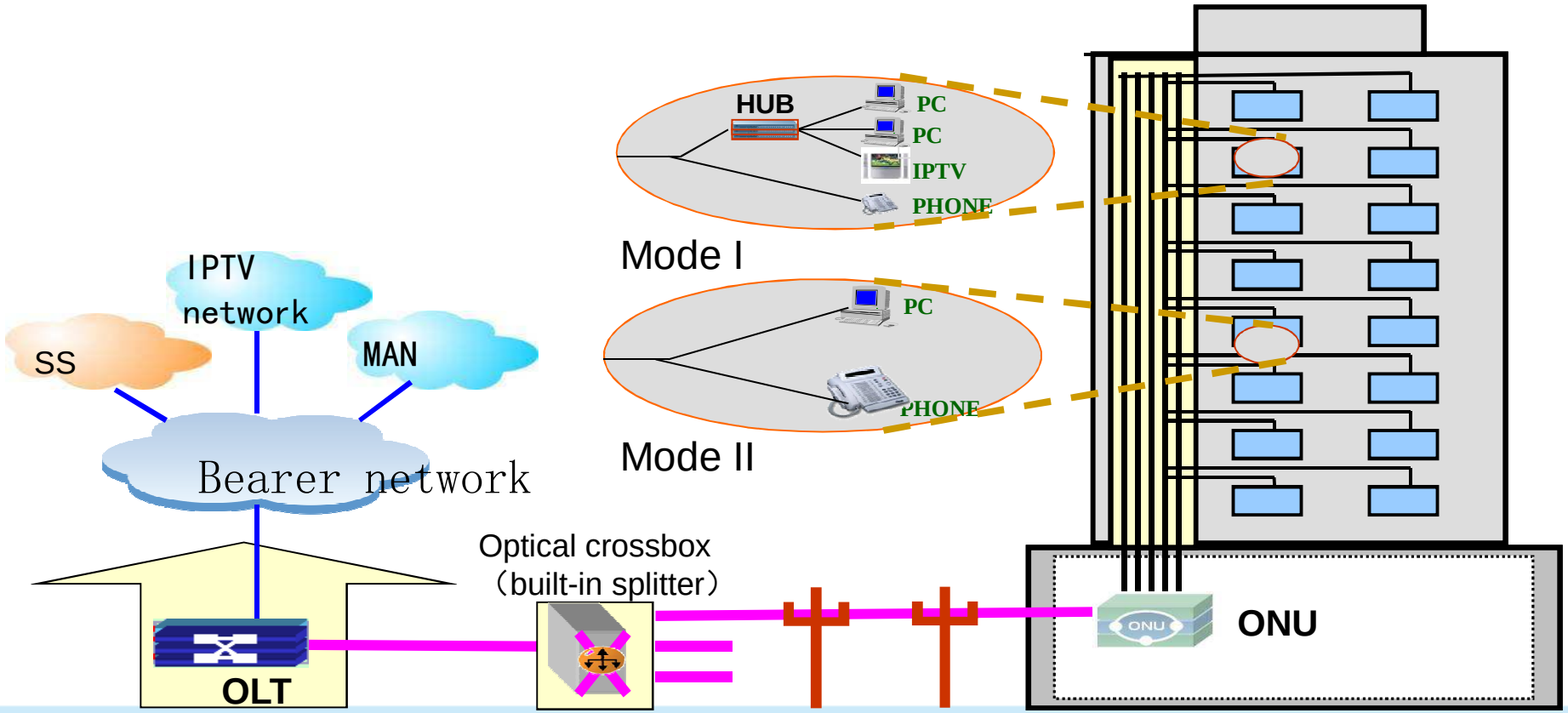
EPON for Business Services

- Passive Outside Plant
  - Lowest OPEX
  - Minimal outside plant maintenance
  - PON prevents fiber exhaustion
  - Leverage / recover existing fiber infrastructure (reduce new fiber construction)

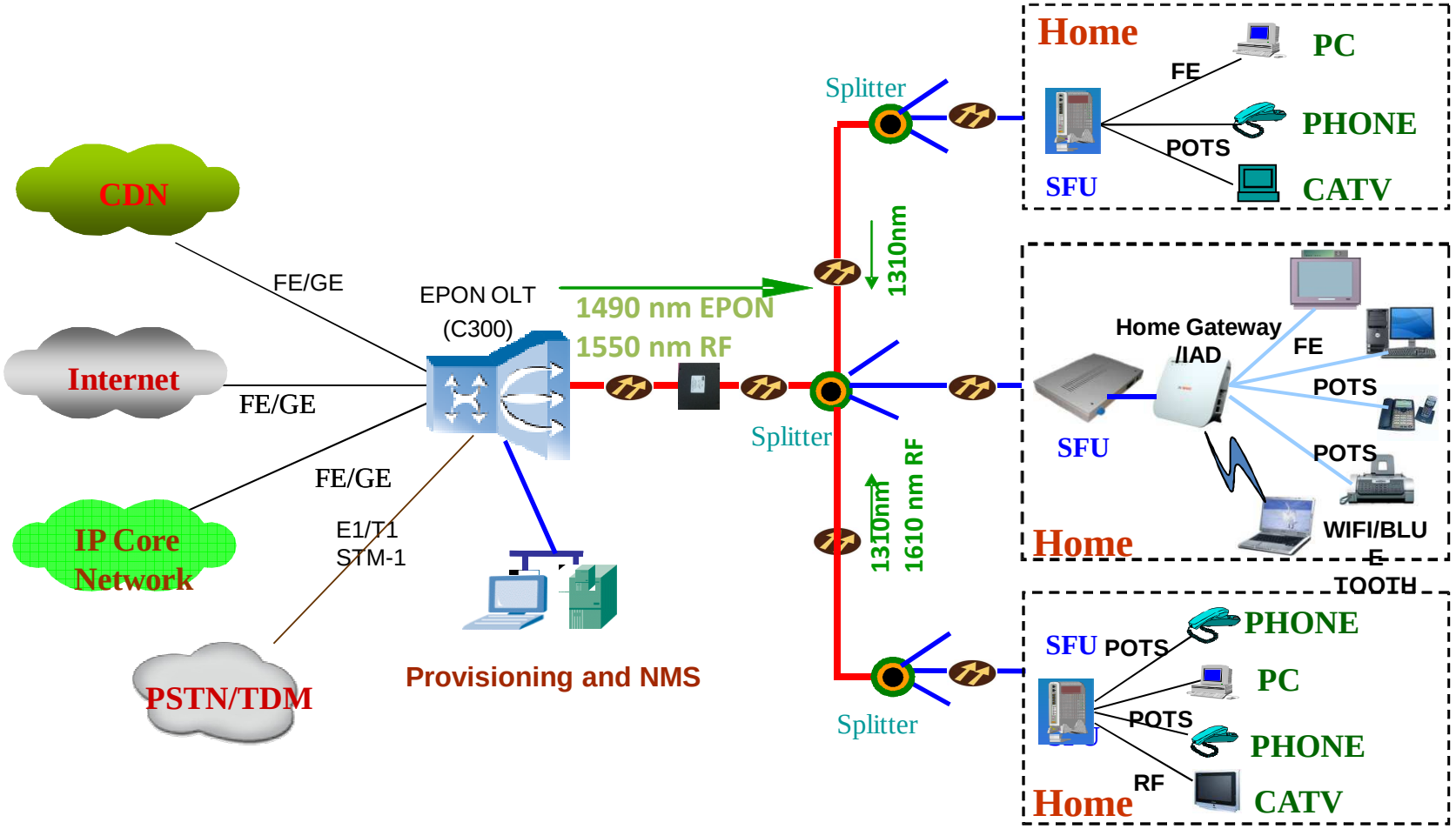


FTTB（xPON + LAN）Application

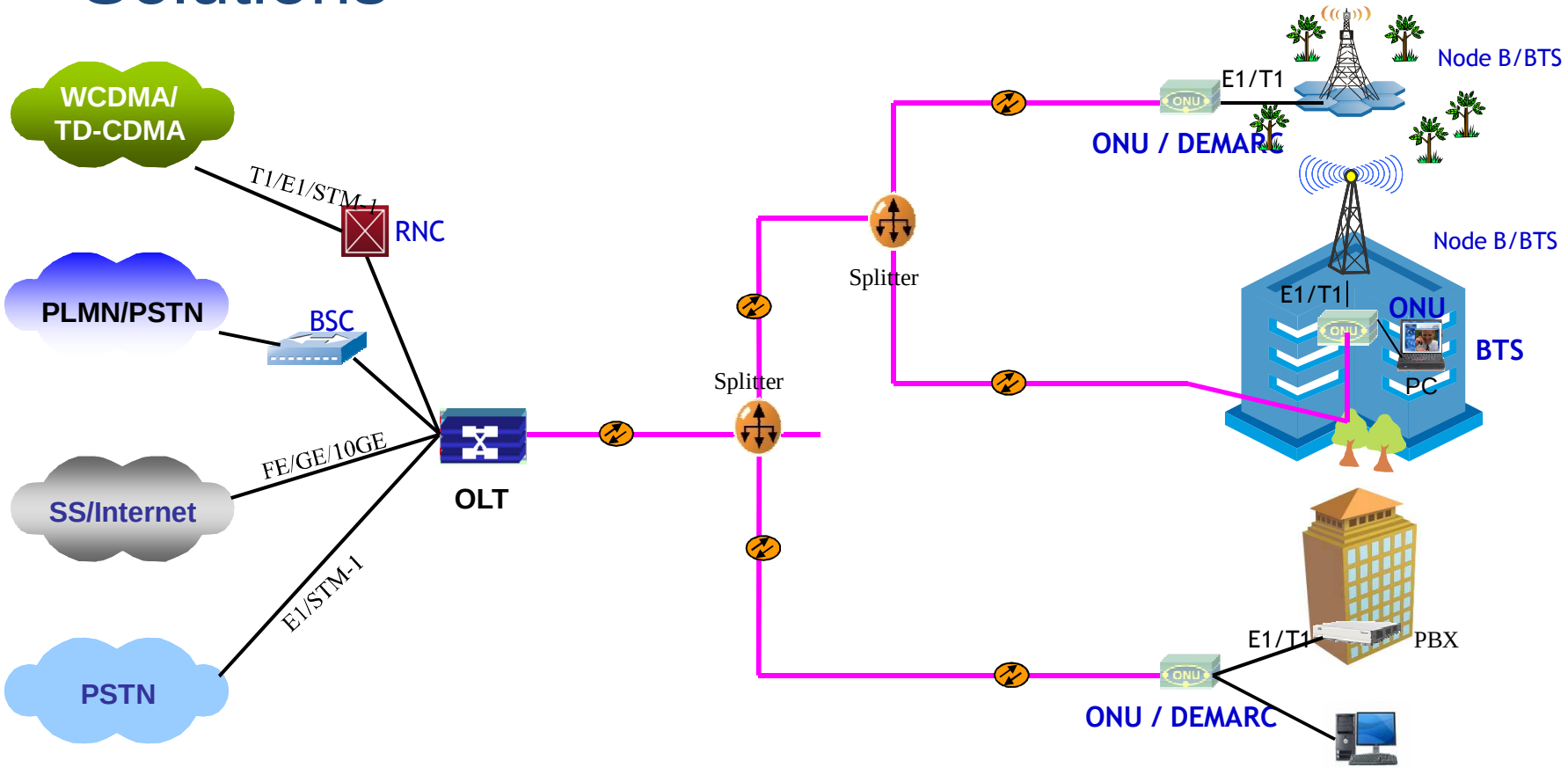
- Primarily applied in new residential lot or office; This application mode satisfies the requirements for high broadband service access, saves fiber and upstream data port resources. Its network establishment cost is lower than FTTH. CAT-5 network cables are used on terminals. The copper wire access distance is within 300 ft. The ONU devices are placed inside buildings.



Application — FTTH
Triple play with IPTV and Traditional Video

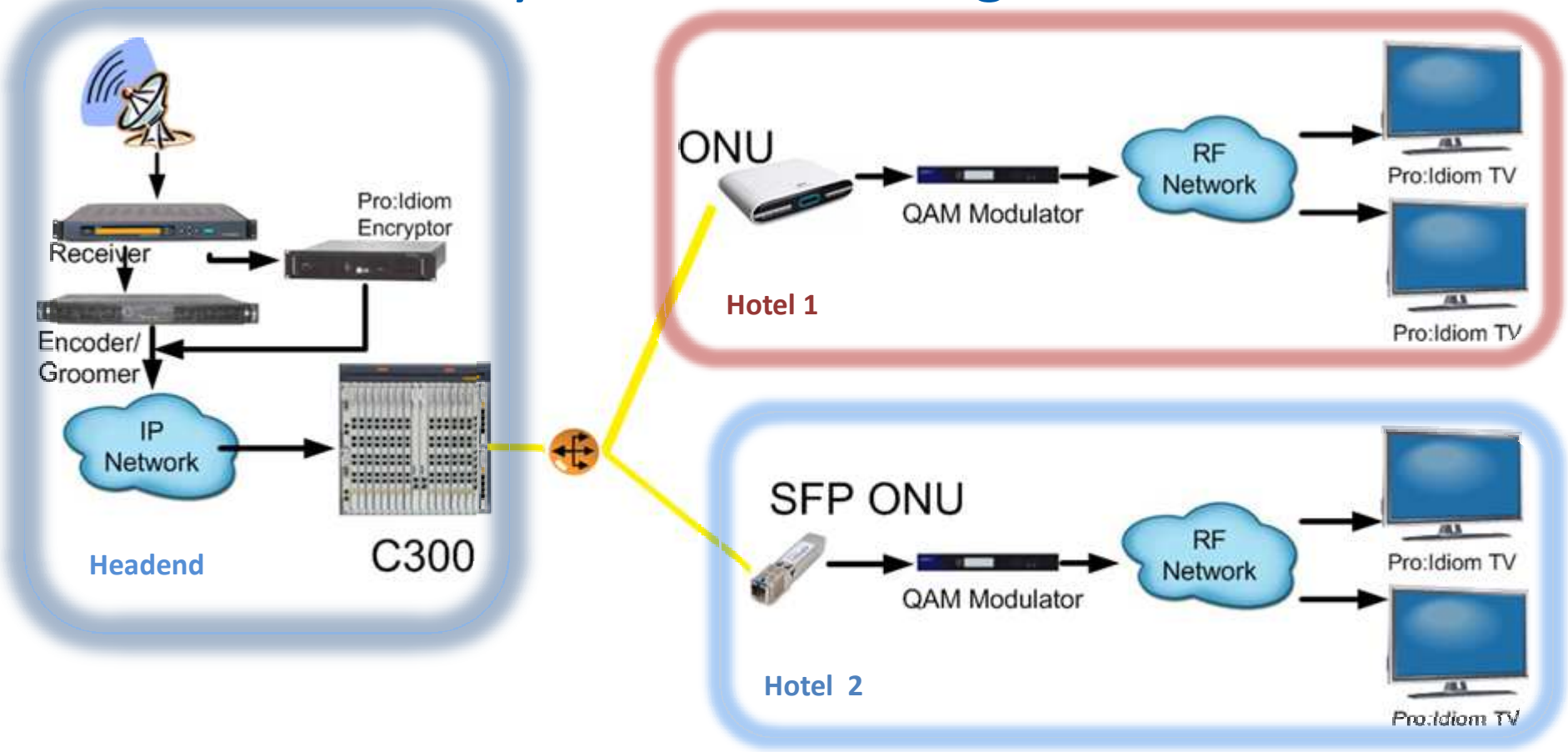


Cell Tower Backhaul and Leased Line Solutions



- Uses the existing PON system as the transport mechanism
- Ethernet used for transport, no need to set up TDM channels
- Provide a low-cost way for FMC and network migration
- Active equipments replaced by PON, easy for maintenance

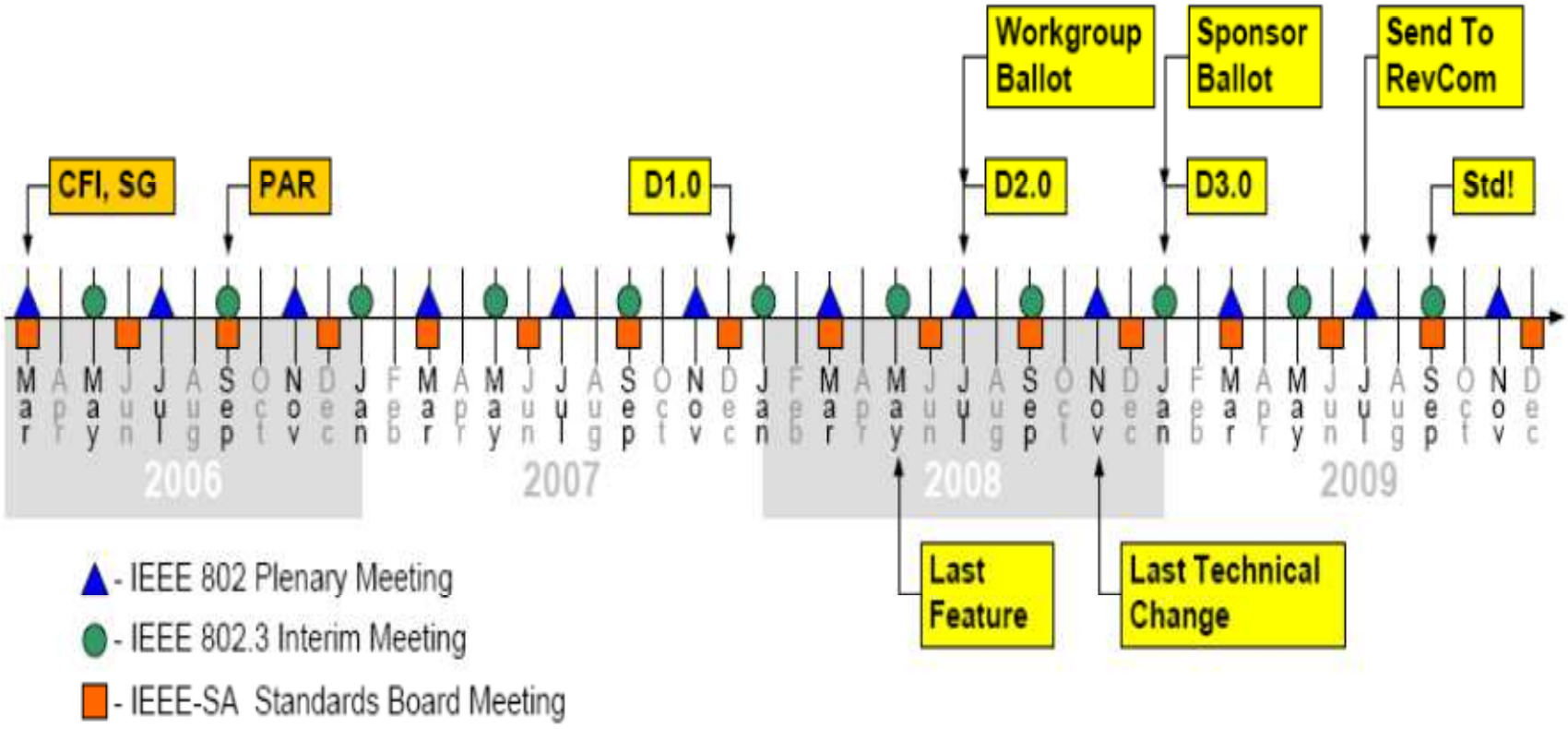
On Site Delivery of Video through EPON



- TV: Any TV with a QAM tuner and optional Pro:Idiom module to watch encrypted content

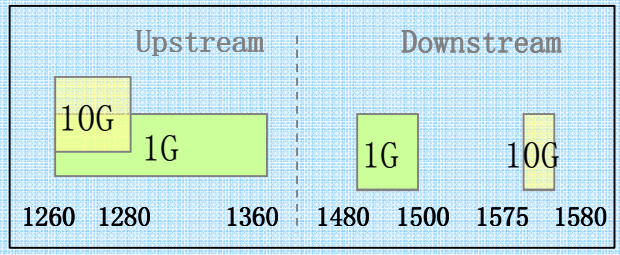
Contents

Evolution of xPON— 10GEPON



Summary of 10G-EPON Technology

Wavelength division compatible with 1G-EPON



Both 10G and 1G upstream adopt TDMA mode for smooth evolution

MPCP ensures coexistence of 10G-EPON ONU and 1G-EPON ONU

Three types of ONU coexist:

- 10G down 10G up **(**10G symmetric ONU**)**
- 10G down 1G up **(**10G asymmetric ONU**)**
- 1G down1G up **(**1G ONU**)**

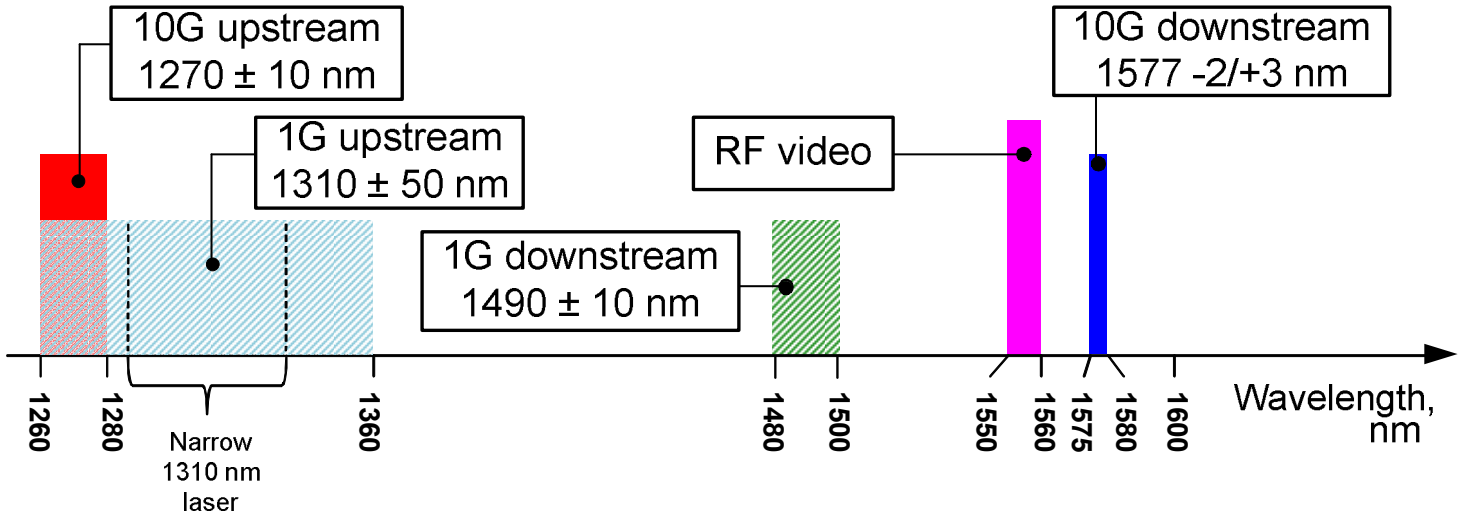
The split ratio is increased **with** the optical power budget

PR/PRX 10：20 dB
PR/PRX 20：24 dB
PR/PRX 30：29 dB
PR/PRX 40：34 dB
PR/PRX 50：37 dB

Others

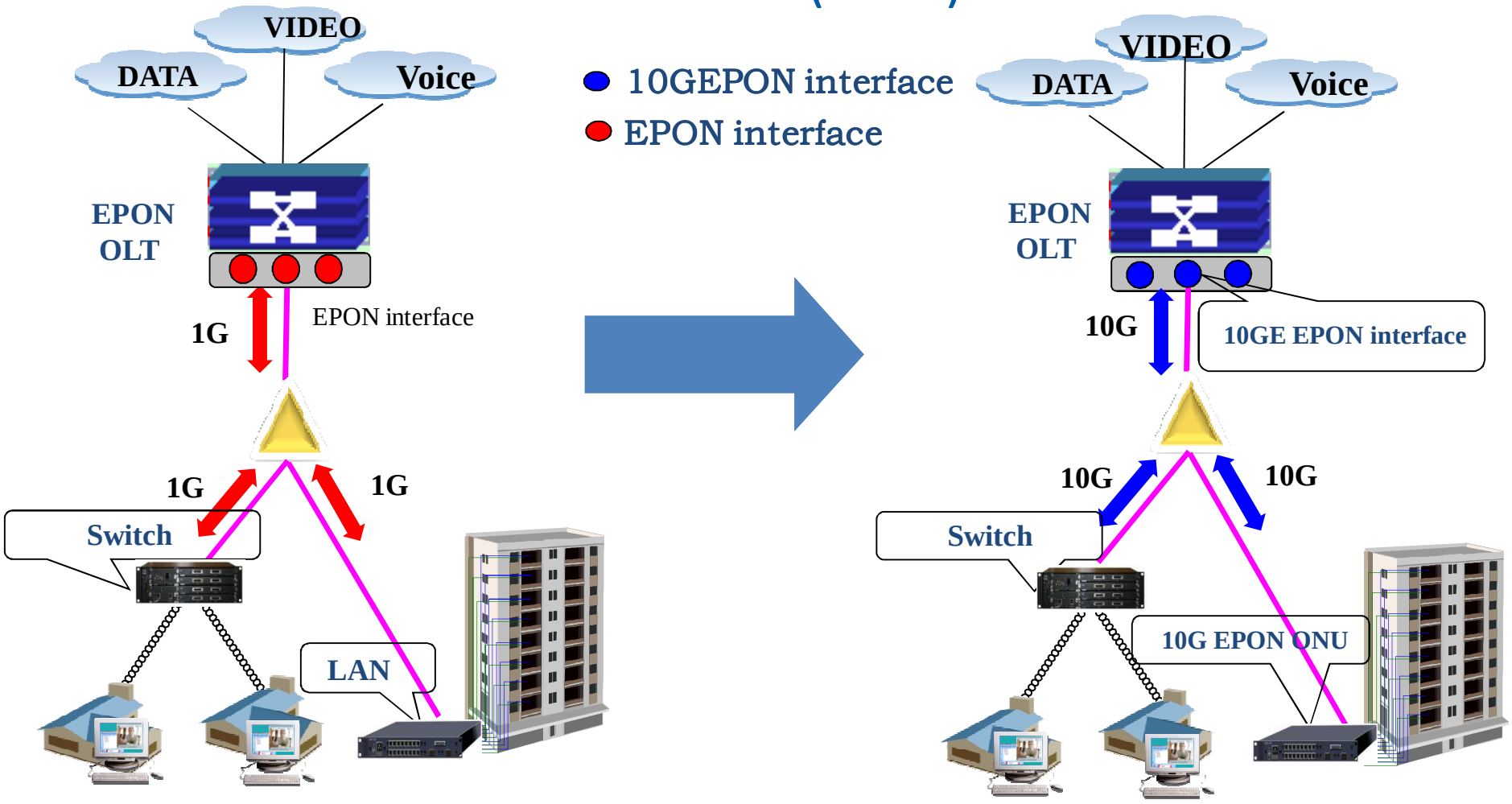
- Line coding
  64B/66B with the efficiency reaching 97%
- **FEC**
  Mandatory RS (255, 223)
  More than 3 dB of additional gain

10Gig EPON Wavelengths



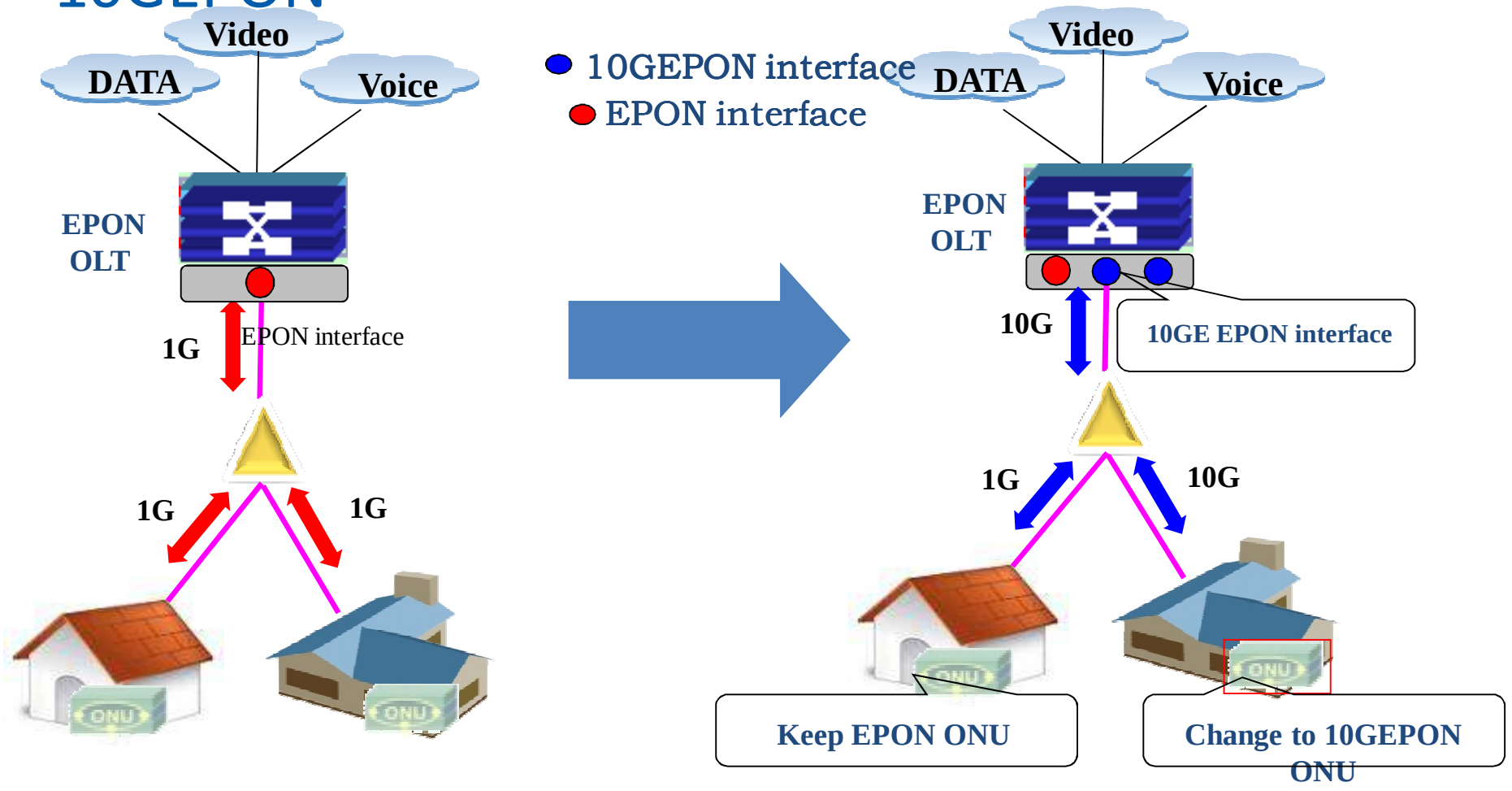
- Both 10G and 1G upstream use TDMA, making 10G EPON compatible with 1G EPON
- 10G EPON is compatible with RFoG

Smooth evolution from EPON (FTTB) to 10GEPON



Smooth evolution from EPON（FTTB）to 10GEPON with low cost

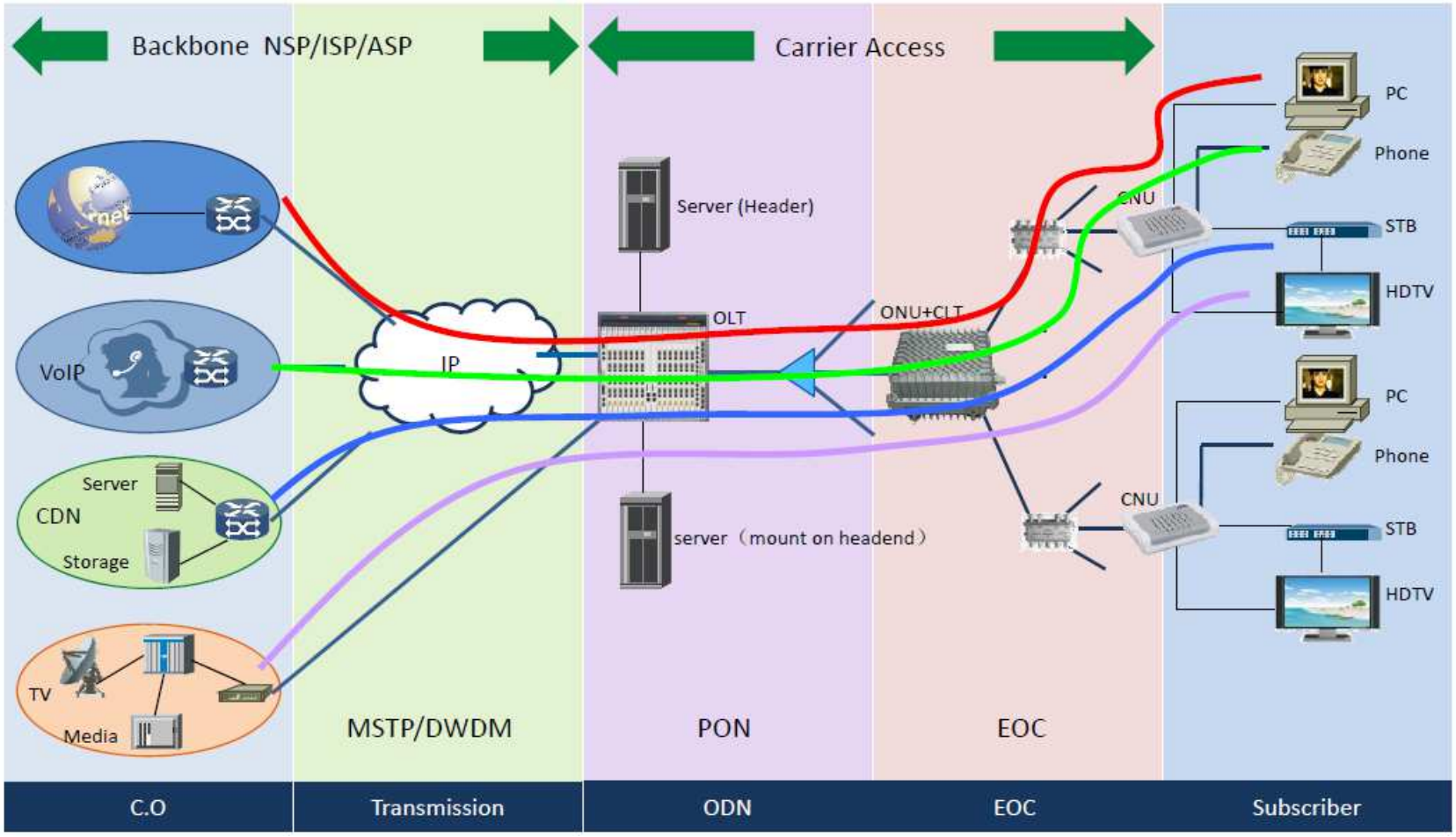
Smooth evolution from EPON (FTTP) to 10GEPON



EPON Protocol Over Coax (EPoC)

- Goal is to have an optical to coax interface (Coax Media Converter or CMC) at the node so that the EPON protocol would run over traditional coaxial networks
- Modulation would be OFDM, just like 4G LTE and DVB-C2
- Theoretical studies give about 1Gbps of BW with ~120MHz of bandwidth

Simplified EPoC architecture



Bringing you Closer

Thanks!