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10G–EPON
Drivers, Challenges, and Solutions

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10G-EPON Drivers

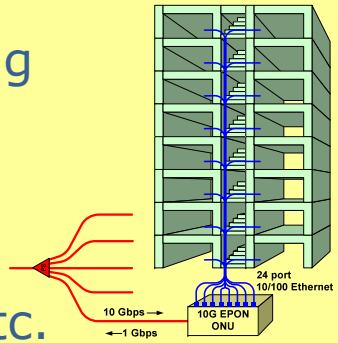
IPTV

- Bandwidth/channel is increasing
  - SDTV = 2 Mb/s per channel
  - HDTV = 10 Mb/s per channel
  - 3DTV = 50-90 Mb/s per channel
- Number of US households using HDTV (HD-IPTV) is increasing
  - 2010: 40% (20%)
  - 2020: 90% (80%)

L. K. Vanston, R. L. Hodges, and J. Savage, "Forecasts for Higher Bandwidth Broadband Services", Technologies Futures, Inc.

MDU Market

- The biggest emerging markets are predominantly MDU
  - China, India, Russia, Brazil, etc.



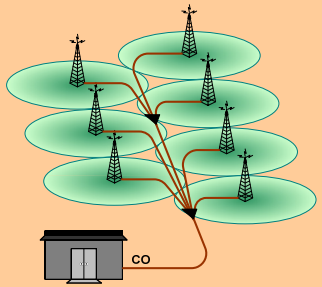
- **With 24-48 subs per ONU, PON should have 10 Gb/s capacity**

MSO Market

- MSOs are looking for post-DOCSIS 3.0, all-fiber solutions
  - DOCSIS 3.0 can provide a total of 5 Gb/s
  - **The EPON architecture is a perfect match for the MSO networks, but more bandwidth is needed**

Wireless Backhaul

- Desired access point density makes PON the only feasible solution



- 4G Wireless requires up to 1 Gb/s per access point ➔ **PON capacity of 10Gb/s is needed**

Why Next Generation EPON Now?

- **Ethernet PON opened floodgates for advanced services**
  - Video-on-Demand
  - High-definition IP TV
  - Time-shifted broadcast
  - Online video games
- **Users began to accept, like, and demand more bandwidth-intensive services**
  - File sharing, picture uploading, video conferencing
  - More simultaneous IP TV channels
  - More on-demand, less broadcast ("information pull" instead of "information push")
- **Successful deployments of 1G-EPON create strong demand for greater bandwidth**
- **In 2005-2006, carriers started looking for a next generation solution**
  - Compatible with existing outside plant
  - Compatible with existing NMS and OAM

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10G-EPON Challenges

- Access represents the most cost-sensitive segment of the network.
  - **Challenge**: Specify a solution that provides the required bandwidth and supports multiple carrier-grade services at the lowest cost.

- Today, 30 million users are served by EPON. Many of the deployed ONUs will not be replaced for a very long time.
  - **Challenge**: Specify a solution that will not rely on forklift upgrades and will not require any changes to the outside plant.

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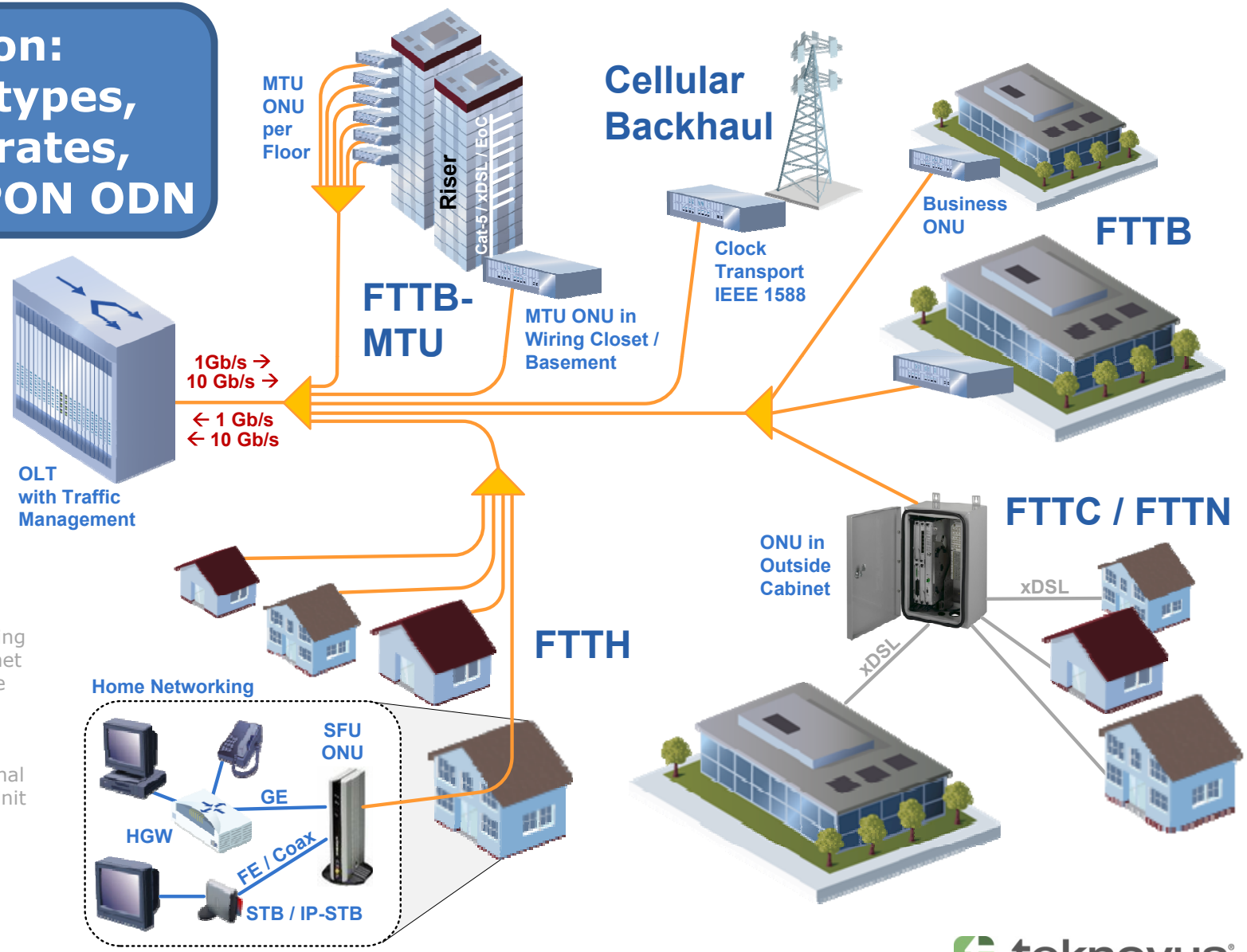
EPON is a Unifying Architecture

IEEE vision:
All user types,
All data rates,
Same EPON ODN



FTTB – Fiber to the Building
FTTC – Fiber to the Cabinet
FTTH – Fiber to the Home
FTTN – Fiber to the Node
HGW – Home Gateway
MTU – Multi-Tenant Unit
OLT – Optical Line Terminal
ONU – Optical Network Unit
SFU – Single-Family Unit
STB – Set-Top Box

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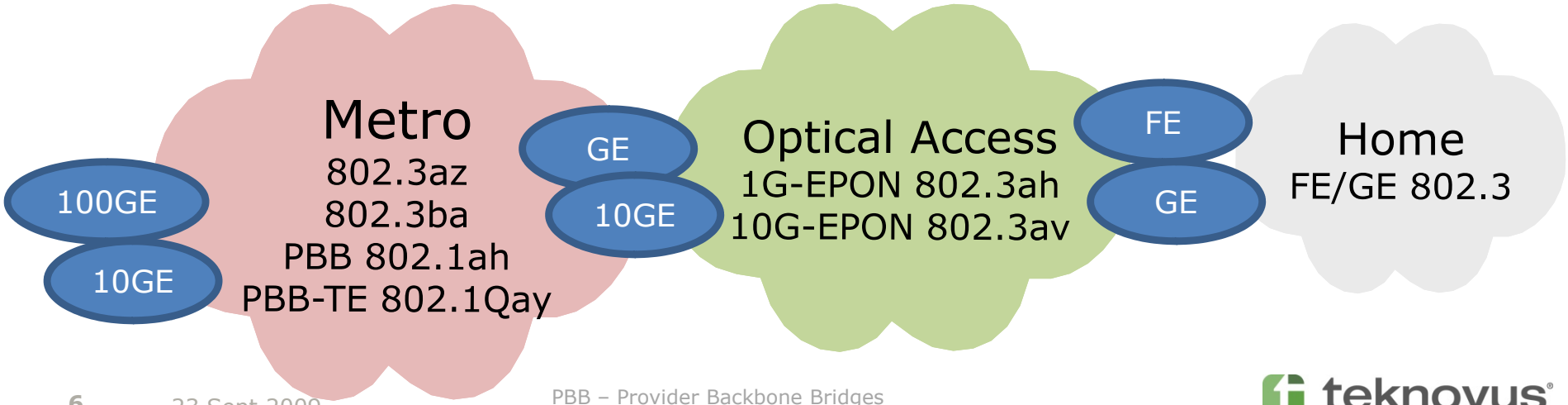
The World is Connected via Ethernet

- **Data is being born and dies as Ethernet (IEEE 802.3)**
- **The family of IEEE 802 standards covers multiple functions**
  - **Transport:** 802.3z, 802.3az, 802.3ah, 802.3av, 802.3at, 802.3az, 802.3ba …
  - **Traffic Engineering, QoS:** 802.1p, 802.1Qay, 802.1Qau, 802.1Qaz, 802.1Qbb …
  - **Network Config. & Management:** 802.1Q, 802.1s, 802.1v, 802.1ad, 802.1ah …
  - **Survivability:** 802.1w, 802.1AB, 802.1ag, 802.1Qaw
  - **Authentication and Security:** 802.1X, 802.1AE, 802.1af, 802.1AR
- **All 802 standards are governed by a common architectural model and <u>fit together perfectly</u>**
  - Matching interface rates
  - Matching data formats



PBB – Provider Backbone Bridges
PBB-TE – Provider Backbone Bridges - Traffic Engineering

IEEE Process Creates Robust Standard

- **In–scope functions are fully specified**
  - Nothing left "For Future Study"
  - Each standard clause has a Protocol Implementation Conformance Statement (PICS) section
- **"<u>One solution for one problem</u>", no multiple options**
  - Eliminates vendor implementation ambiguity
  - Ensures interoperability and lowers development cost
- **Must demonstrate technical feasibility**
  - Close tracking of technology evolution
  - Preference is given to reuse of existing mature solutions
- **Must demonstrate economic feasibility and broad market potential**
  - Constant focus on finding the lowest cost solution
  - The EPON standard is developed for the worldwide market
  - The EPON standard is driven by carriers, system vendors, ASIC vendors, PHY vendors, and optics vendors
    - Broad representation ensures lowest total cost

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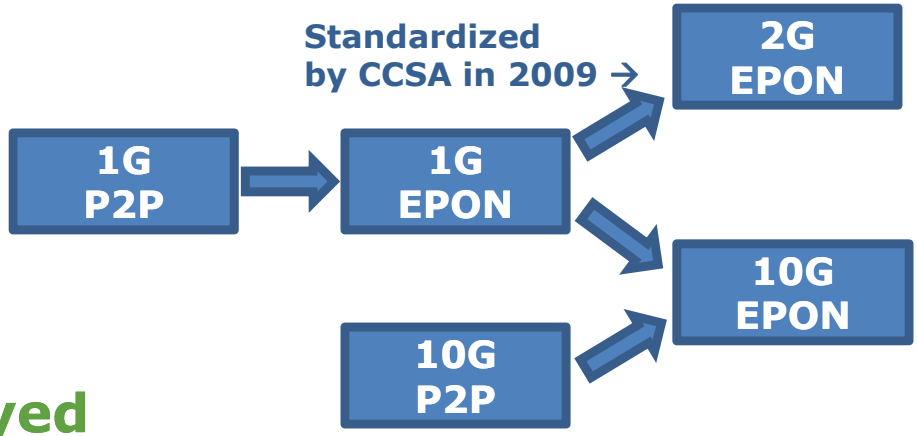
EPON Roots

- **EPON architecture is derived from existing specifications using small evolutionary changes**



- **Many logic components are common with existing deployed Ethernet devices and can be reused**
- **For example, 1G-EPON optics required only minimal modifications to point-to-point optics**
  - Relaxed on/off times
  - Relaxed Automatic Gain Control and Clock-Data Recovery times
  - No power level adjustments needed
  - Vendors were able to quickly re–purpose inexpensive high–volume 1Gb/s Ethernet transmitters for EPONs
  - Cost of 1G EPON optics approaches the cost of P2P optics
- **Ethernet volumes drive EPON cost down**

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EPON Protocol is Simple and Flexible

- **EPON uses Multi-Point Control Protocol (MPCP)**
- **No encapsulating framing**
- **Same full–duplex MAC as in any 802.3 device**
- **Everything is packet–based**
  - MPCP uses MAC Control frames (type 0x8808)
  - OAM uses "Slow Protocol" frames (type 0x8809)
  - TDM is implemented using circuit emulation (PWE3)
- **MPCP is designed to be flexible and accommodating of future development**
  - >32,000 logical links – capable of extended-split and per-flow QoS
  - MPCP does not introduce distance or split limitations
- **Going from 1G to 2G – no protocol changes**
- **Going from 1G or 2G to 10G – only minor changes**
  - Added new fields to two control messages to simplify coexistence of various ONUs (rates) on the same EPON
  - Modified some formulas to account for stronger stream-based FEC

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EPON is Easy to Design and Manufacture

No segmentation and reassembly buffers	➔	• **Lower memory requirements**
Processing complete packets instead of fragments	➔	• **Less packet processing** • **Easier queue management**
Data transfer and all protocols are packet-based (OAM, MPCP, TDMoE)	➔	• **Streamlined logic** • **No protocol conversion**
IEEE 802.3 rule: One solution for one problem	➔	• **Few options and implementation methods** • **Low silicon requirements**

- **Every single item above may be not critical, but together they make big difference**
  - **Highly integrated EPON ASICs can be built in smaller package**
  - **EPON ASICs consume very little power (1G/2G dual-mode ONU SoC ~ 725 mW)**

ONU integrated into an SFP module

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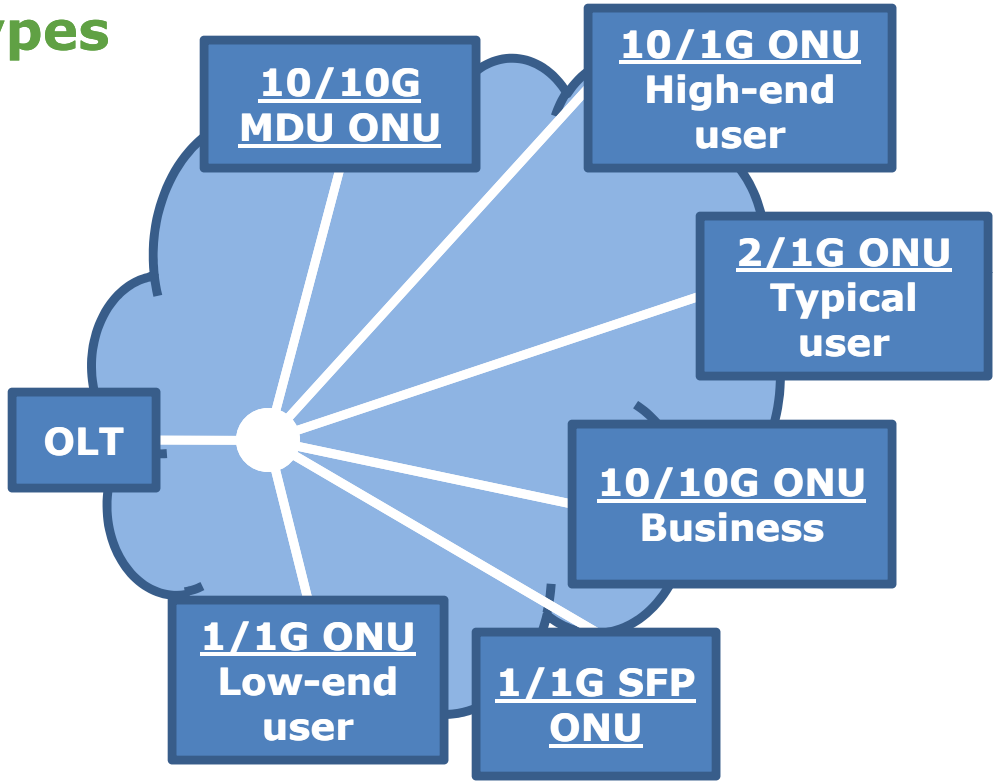
EPON is Evolving

- **EPON is evolving to simultaneously support…**
  - **A mix of various user types**
    - ✓ Low-end users (1/1)
    - ✓ Typical users (2/1)
    - ✓ High-end users (10/1 or 10/10)
  - **A mix of various deployment scenarios**
    - ✓ FTTH
    - ✓ FTTC+MDU
    - ✓ FTTBusiness
    - ✓ Backhaul applications
    - ✓ DOCSIS over EPON



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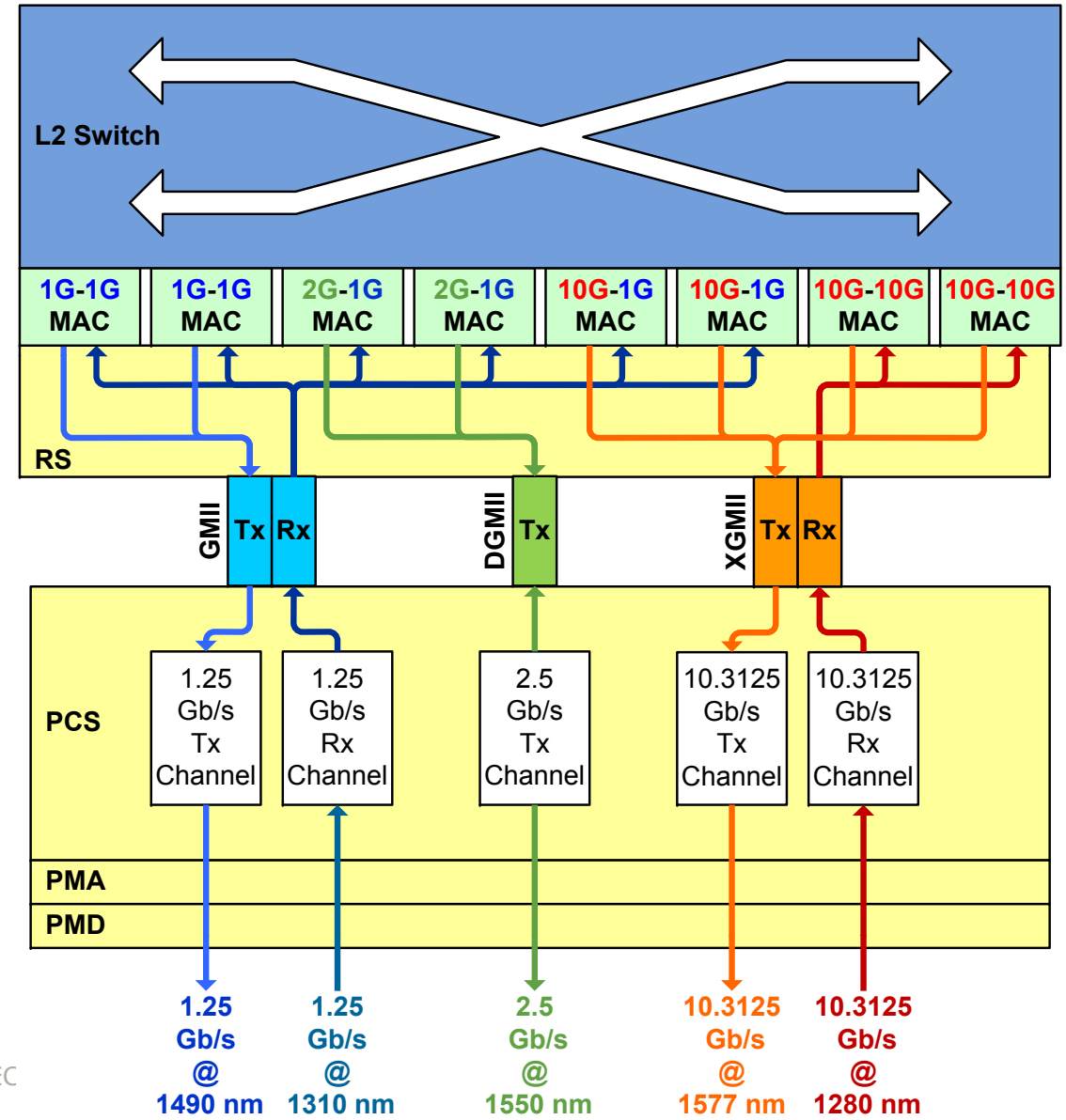
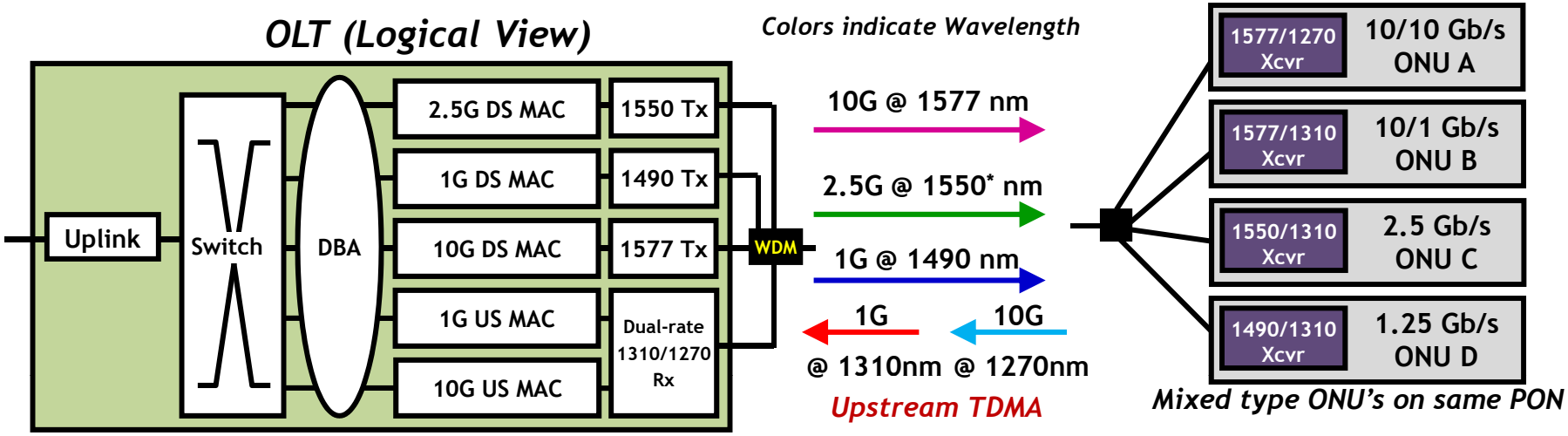
EPON OLT Supports 4 Types of ONUS

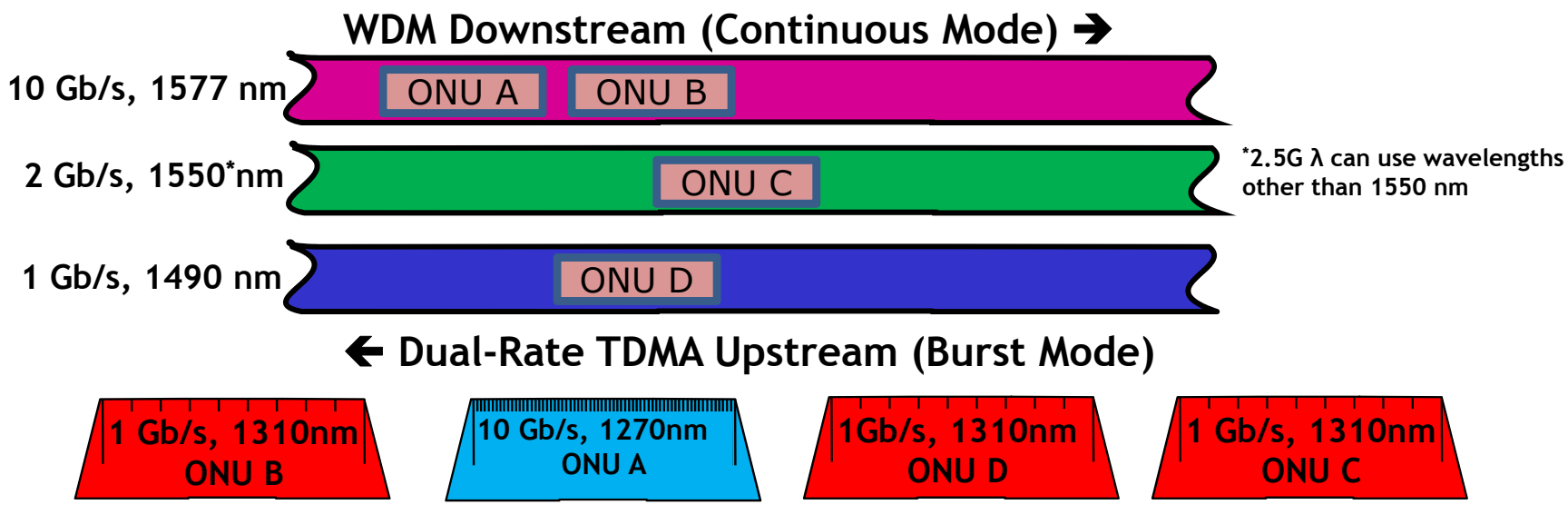
- EPON OLT built for coexistence can support 4 types of ONUs simultaneously:
  - 1G/1G
  - 2G/1G
  - 10G/1G
  - 10G/10G

OLT Layering Diagram



Dual-Rate TDMA Upstream: Combined 10G+1G DBA





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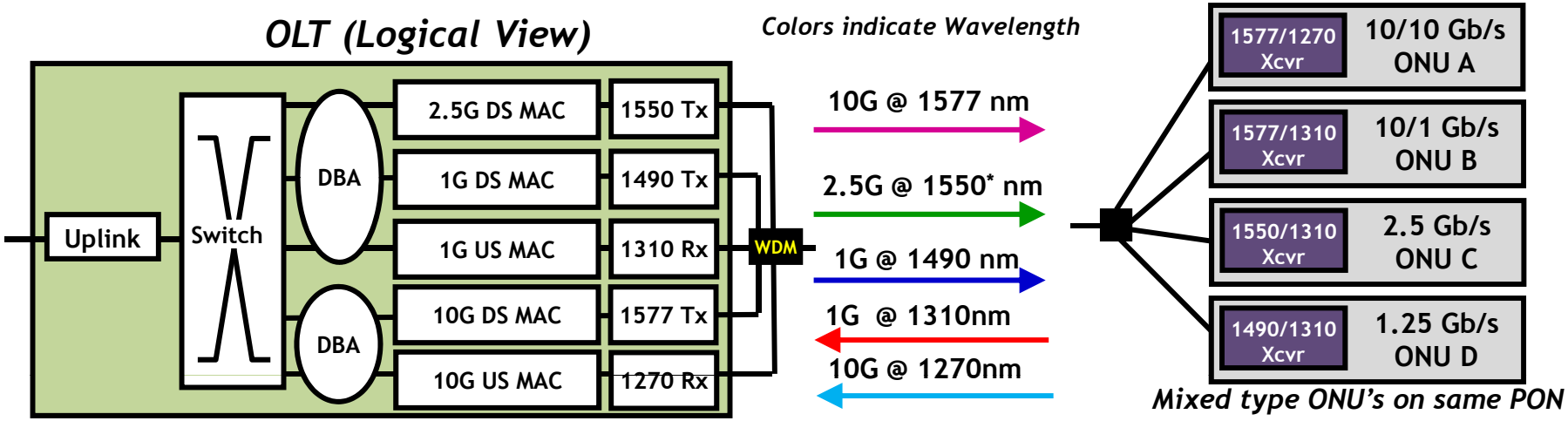
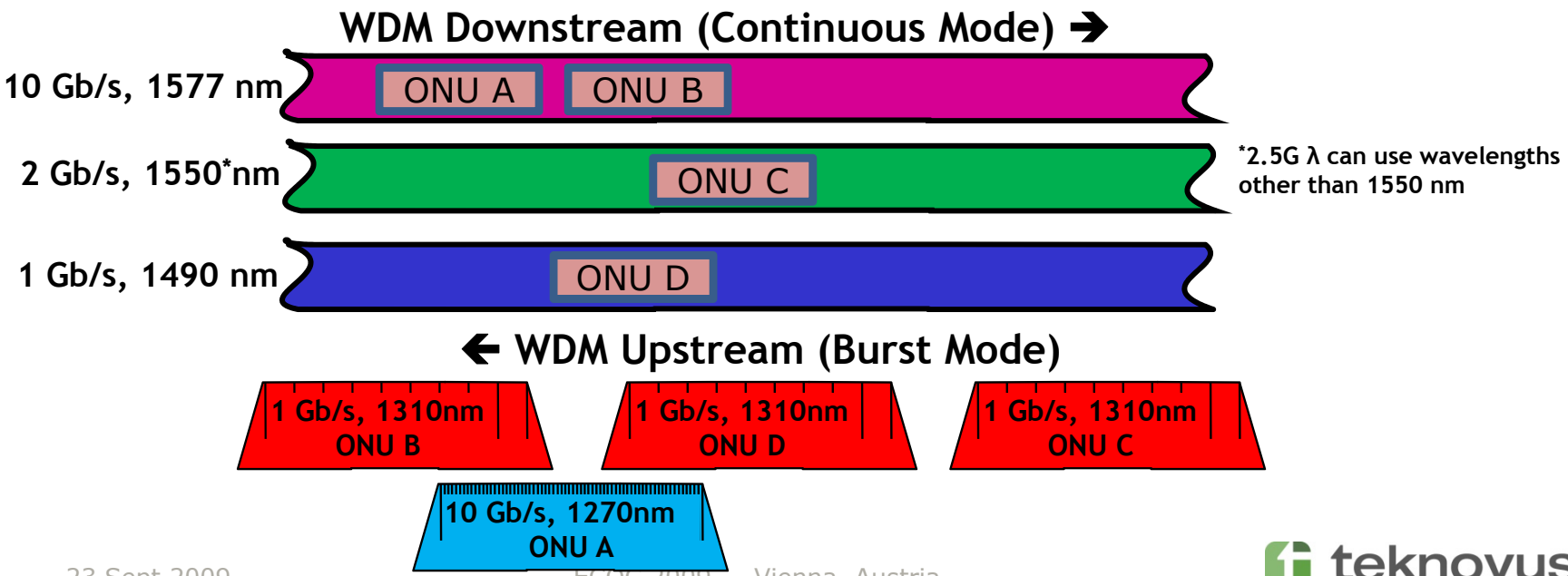
WDM Upstream – Separate 10G and 1G DBA





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Various upgrade scenarios

- **WDM for 1G and 10G upstream**
  - Independent DBA for 1G and for 10G
  - Total upstream bandwidth is 11 Gb/s (10+1)
  - 10G OLT may be added as a separate line card or as single line card combining 1G and 10G
- **Dual-rate TDMA upstream**
  - One OLT port can serve all types of ONUs
  - Provides highest subscriber density
  - Conserves power and saves CO rack space
- **Most important: existing 1G and 2G-EPON investments are protected**
  - Either upgrade method allows all existing ONUs to remain in operation
  - Carrier can selectively upgrade subscribers who are willing to pay for premium services and higher data rates

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Organizations Endorsing 10G-EPON

Excerpt from joint press release:

Piscataway, NJ, September 11, 2009 - Today, more than 40 companies and organizations that supported or participated in the IEEE P802.3av 10 Gb/s Ethernet Passive Optical Network (10G-EPON) Task Force are celebrating completion of IEEE Std. 802.3av™-2009, also known as Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks. <…> The following companies have expressed their support for the approved standard: Alloptic, Anritsu Company, ARRIS, B-DeltaCom, Bright House Networks, Cambridge Industries Group, China Mobile Communications Corporation, China Telecom – STTRI, China Unicom – Beijing, Corecess, Cortina Systems, CyOptics, Dasan Networks, Dongwon, Enablence Technologies, ETRI, FiberHome, Fujitsu, H3C, Hisense Broadband, Hitachi, Huawei Technologies, Kawasaki Microelectronics, KDDI R&D, KT, Ligent Photonics, Mitsubishi Electric, NEC, NTT Corporation, OF Networks, OneChip Photonics, PMC-Sierra, Shanghai Luster Teraband Photonics Co., Sumitomo Electric, Teknovus, Telekom Malaysia R&D, Ubiquoss, Vitesse Semiconductor, and ZTE. The China Communications Standards Association (CCSA), the Ethernet Alliance, the Optical Access (FTTx) Industry Alliance (OAIA) of China, and the Taiwan Optical Communication Industry Alliance also endorse the 10G-EPON standard.

(reviewed and approved by every listed organization)

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