Joint ITU-T / IEEE Workshop on Next Generation Optical Access Systems

IEEE 1G and 10G EPONs: Factors that Influenced the Architecture and Specification

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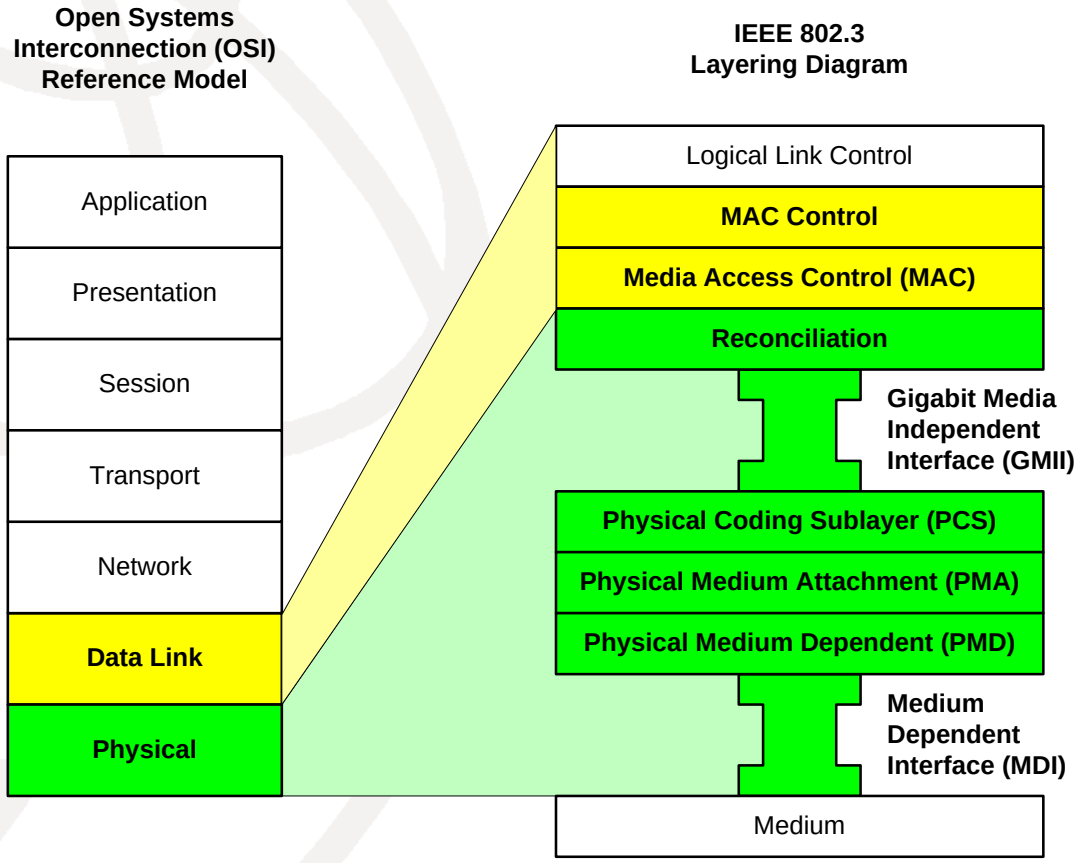
Higher and Lower Layers

- **Lower layers represent transport functions:**
  - Optics
  - PHY Framing Structure (GEM in GPON)
  - Line coding (scrambling, 8B/10B, 64B/66B)
  - Protocol (GEM or MPCP)
  - Forward-Error Correction
- **Higher layers represent system-level functions.**
  - DBA
  - Encryption
  - Provisioning
  - Protection
  - Service models
  - Management
  - **Higher layers determine PON performance and functionality**
- **This presentation will look at the development and evolution of lower-layer and higher-layer functions separately**

Lower Layers of PON

Scope of IEEE 802.3 is on Lower Layers

- **IEEE 802.3 only covers Physical Layer…**
  - Physical Medium Dependent Sublayer
  - Physical Medium Attachment Sublayer
  - Physical Coding Sublayer
  - Reconciliation Sublayer
- **… and a portion of Data Link Layer**
  - Media Access Control (MAC)
  - MAC Control (contains MPCP)
- **IEEE 802.3 focus is on transport, not on the system**



How 802.3 Does It

- **IEEE 802.3 is very good at what it does**
  - In-scope functions are fully specified
  - “One solution for one problem”, no multiple options
  - Must demonstrate economic feasibility and broad market potential
    - Constant focus on finding the lowest cost solution
    - Broad representation (carriers, system vendors, ASIC vendors, PHY vendors, and optics vendors) ensures lowest total cost
  - Must demonstrate technical feasibility
    - Close tracking of technology evolution
    - Preference is given to reuse of existing specs
  - Each standard clause has a Protocol Implementation Conformance Statement (PICS) section
    - Standard compliance guarantees interoperability
- **1G and 10G EPON specs closely follow the above principles**

EPON PHY Spec

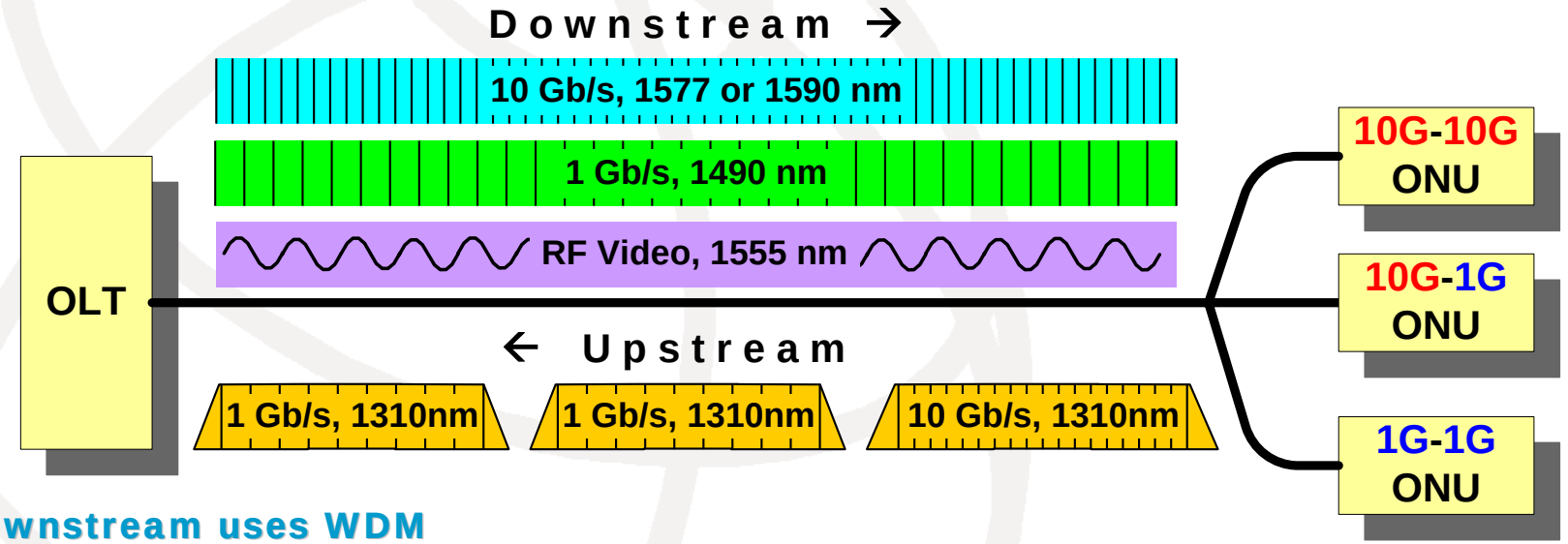
- **Minimal modifications to point-to-point transmitters**
  - Large on/off times
    - Adjustable in 10G EPON to accommodate emerging faster transmitters
  - No transmit power adjustments
    - Simpler optics control and interface
- **Minimal modifications to point-to-point receivers**
  - Relaxed burst lock timing to accommodate wider dynamic range of the signal
    - Adjustable in 1G and 10G EPONs to accommodate faster receivers
- **Vendors were able to quickly re-purpose inexpensive high-volume 1G Ethernet transmitters for EPONs**
  - Cost of 1G EPON optics approaches the cost of P2P optics

EPON Data Link Spec

- **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 very flexible, easy to implement**
  - Uses 5 types of messages (each message is a MAC Control frame)
  - ONU reports multiple packet boundaries, OLT grants on a packet boundary
- **Leads to simplified packet processing, queuing, and monitoring**

1G and 10G EPON Coexistence

The new draft standard supports coexistence of symmetric 10G ONUs, asymmetric 10G/1G ONUs, symmetric 1G ONUs, and RF video overlay on the same ODN



- **Downstream uses WDM**
  - 1Gb/s ONUs already have filters to block the C- and L-bands
  - 10Gb/s ONUs will have filters to block the C- and S-band
- **Upstream is dual-rate burst mode:**
  - All ONUs transmit in the O-band (1260-1360)
  - 1Gb/s ONUs send bursts using 8b/10b @ 1.25 Gb/s
  - 10Gb/s ONU send bursts using 64b/66b @ 10.3125 Gb/s

IEEE P802.3av Project Status

- **Released Draft 1.802**
- **Modified Clauses**

  Clause 1: Introduction

  Clause 30: Management

  Clause 45: Management Data Input/Output (MDIO) Interface

  Clause 56: Introduction to Ethernet for subscriber access networks

  Clause 66: Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport

  Clause 67: System considerations for Ethernet subscriber access networks

- **New Clauses**

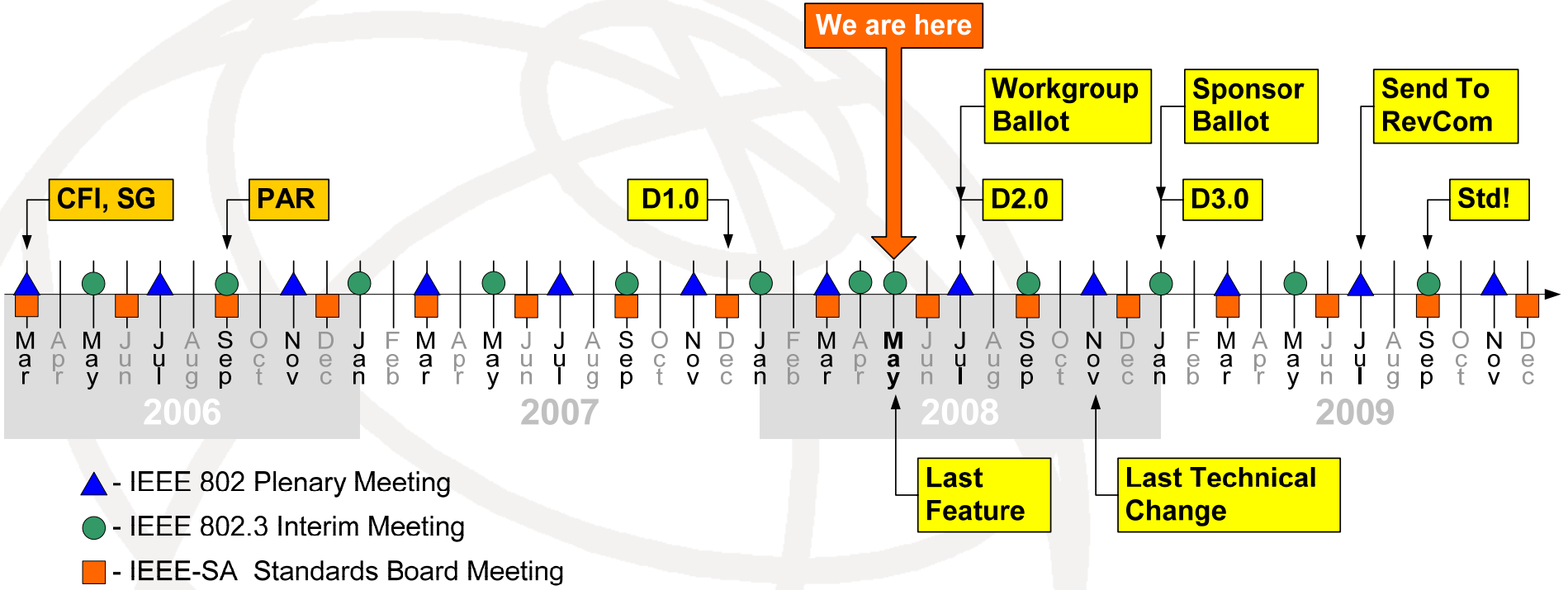
  Clause 91: Physical Medium Dependent (PMD) sublayer and medium, type 10GBASE–PR (symmetric 10 Gb/s long wavelength passive optical networks) and 10/1GBASE–PRX (asymmetric 10 Gb/s downstream, 1 Gb/s upstream long wavelength passive optical networks)

  Clause 92: Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 10GBASE-PR and 10/1GBASE-PRX for multipoint links and forward error correction

  Annex 92A: FEC Frame Encoding example

  Clause 93: Multipoint MAC Control for 10Gb/s EPON

IEEE P802.3av Project Timeline



- Timeline approved on November 15, 2007
- Expected standard approval – September 2009

Evolution of Lower Layers

- Within the layers that are in-scope for IEEE 802.3, the functional or performance differences between EPON and GPON are not significant
- Evolution of the lower layers is governed mostly by technological capabilities
- **General trend: Be generous with the abundant resource (bandwidth) in order to conserve the limited resource (money)**
  - Higher overhead is OK if it saves costs

Higher Layers of PON

Current Business Realities

- **Network Infrastructure Owners (Telcos, Cablecos) are losing revenues to over-the-top (infrastructure-less) service providers**
  - Price-per-bit is decreasing, ARPU is falling
  - Over-the-top services (Skype, Joost, YouTube, etc.) are low cost, innovative, flexible, and agile.
- **Carriers want to add revenue by selling services, not just the pipe.**
  - **Application awareness** to handle each type of traffic in a way that does not harm user experience
    - Example: IPTV is sensitive to packet loss and jitter, VoIP is sensitive to latency
  - **Service isolation** ensures that one service does not affect another service
    - Sending or receiving big file should not affect video or voice service performance
    - Watching video should not affect voice or data performance
- **Carriers require similar functions, regardless of the flavor of the lower layers (GPON or EPON)**

Power Saving Mode?

- **There were many presentations on power saving requirements for PONs. Let's calculate:**
  - Typical US household standby power consumption: ~75 W/hr
  - Typical US household average power consumption: ~930 W/hr
  - ONU power consumption 2-6 W/hr (loaded)
  - Even if ONU is made to not consume any power at all, that saves 0.2-0.7%.
- **Mind the Amdahl's Law!**

Source: http://standby.lbl.gov/HomeTours/HTmeier99/HTmeier99.ppt

	Watts
Desktop computer	1.5
Monitor	6.9
Notebook computer	6.2
Cell phone	0.3
Compact stereo	3.1
Television	6.4
VCR	12.0
Clock radio	3.2
Cordless phone (x3)	8.7
CO sensor	1.6
Baby monitor (x2)	2.0
Modem	7.1
Answering machine (x2)	4.6
Battery charger (x2)	5.1
Radio	0.6
Portable vacuum	1.2
Microwave oven	3.0
Portable heater	0.9
Total Leaking	74.4
% of average household load	**8%**

Green Services

- **However, PON's capabilities to reduce the CO^2 footprint are huge. This reduction comes from modified user behavior**
  - Convenient and personalized news feeds allow many users to give up newspaper subscriptions.
  - High-quality video streaming eliminates trips to video stores to rent DVDs. ONU+HGW consume less than DVD player.
  - Telecommuting eliminates auto commuting.
  - Telepresence eliminates business trips
  - There are many other examples where today we carry mass where all we need is to carry information.
- **Carriers should focus on enabling services that are known to modify user behavior in the right direction**

Common Carrier's Requirements

- **Traffic engineering functions**
  - Flexible (programmable) user-data classification
  - Admission control
  - Shaping/policing
- **QoS to support multiple services (known and not yet known)**
  - Bandwidth guarantees
  - Latency guarantees
  - Packet loss guarantees
  - Fairness of resource allocation
- **Encryption**
- **Management**
  - Managing PON devices
    - PLOAM or OAM is an internal implementation, the NMS interface is similar
  - Managing home gateways/applications
    - Pass-through using PON-independent protocols (like TR-069 or derivatives)

EPON System-Level Spec

- IEEE 802.3 spec enables various system-level features or functions, but some formal specifications are out-of-scope for IEEE 802.3
  - Exact DBA algorithm
  - Exact number of queues
  - Exact number of LLIDs
  - Exact packet classification rules
  - Encryption (specified in IEEE 802.1AE)
  - Protection (?)
- It was assumed that other SDOs would standardize system-level parts
- Because no system-level spec existed when the 1G-EPON transport spec (IEEE 802.3ah) was completed, carriers created their own system specs and interoperability testing plans.
- China took it further and created a country-wide EPON system-level standard (standardized in CCSA).

EPON Standards by CCSA

See http://www.ccsa.org.cn/english/list_std.php

Document #	Title	Publication Date	Status
YD/T 1526.2-2007	Technical Specifications of Single Fiber Bi-Directional Triplexer Optical Transceiver for Access Network; Part 2: Single Fiber Bi-Directional Triplexer Optical Transceiver for EPON ONU	2007-09-29	In force
YD/T 1664-2007	Technical Specification for Ethernet Passive Optical Network (EPON) Management Interface	2007-07-20	In force
YD/T 1531-2006	Test Method for Access Network Equipment——Passive Optical Network Based on Ethernet (EPON)	2006-12-11	In force
YD/T 1475-2006	Technical Requirements for Access Network——Passive Optical Network Based on Ethernet (EPON)	2006-06-08	In force
YD/T 1419.2-2005	Technical conditions of Triplexer optical assembly for access network; Part2: General characteristics of Triplexer optical assembly for Ethernet passive optical network (EPON) optical network unit (ONU)	2005-12-26	In force

Potential SDOs for NG-EPON Spec

- **FSAN / ITU-T**
  - Probably the best candidate because of experience with PONs and similarity of goals
- **MEF**
  - Many of the specs on carrier-grade services are applicable to NG PONs
- **DSL Forum**
  - Now specifying service and management models for PON-based access networks
- **CCSA**
  - The 1G-EPON CCSA spec is under consideration by multiple carriers outside China
  - High incentive to be the first with 10G-EPON system-level spec and test plans

Why Work on Higher Layer Functions is Needed

- Convergence of Communications, Computing, and Entertainment is happening faster than anybody anticipated.
- To survive, carriers need to become service providers, or revenue streams will bypass them.
- Carriers and vendors need to study how to support large-scale IP video in PON access networks (DBA issues, scalability, management).
- This work is needed for all NG PON technologies, regardless of which transport layer is used (EPON or GPON).