Protocol Independent PHY Specific Sub-layer (PSS) for PON

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PSS Objectives

- PHY Bitstream Framing (e. g. frame format, bit/ byte/ frame sync, etc.) for continuous and burst mode operation, Link
- Encoding (e.g. 8B/ 10B vs Scrambling, etc.)
- Framing Protection (e.g. CRCs, BIP, BER methods, etc.)
- Ranging
- *Mechanism* for Upstream BW Allocation (e.g. Grants, BW- MAP, etc.)
- *Mechanism* for Security and Privacy (e.g. churning vs. encryption, etc.)
- *Mechanism* for Survivability (e.g. signaling systems like SONET (K-byte) or RPR)
- PHY layer Quality of Service (e.g. support for realtime and non-realtime traffic)
- PHY layer OA&M.

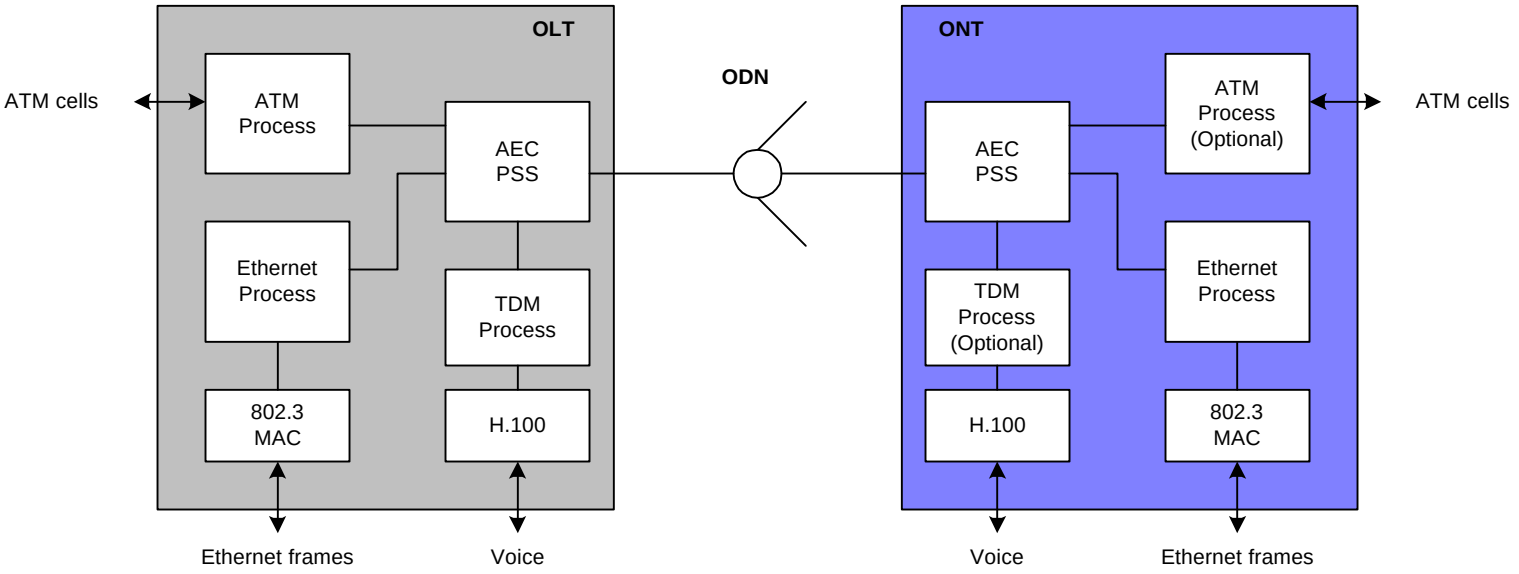
PSS Design Choices

- Line coding will be NRZ with scrambling.
- CRCs for framing protection and BIP to support BER estimation.
- Out-of-band control channel at PHY layer for OAM functions.
- Fragmentation and concatenation of data frames for BW efficiency.
- Upstream burst mode Preamble, including CDR, will not be long.
- Upstream BW allocation mechanism via slot assignments.
- Support for ONT ranging.
- Support for asymmetric line rate operation.
- Security and survivability integrated into the PHY layer.
- QOS supported at the PHY layer.

PSS Model

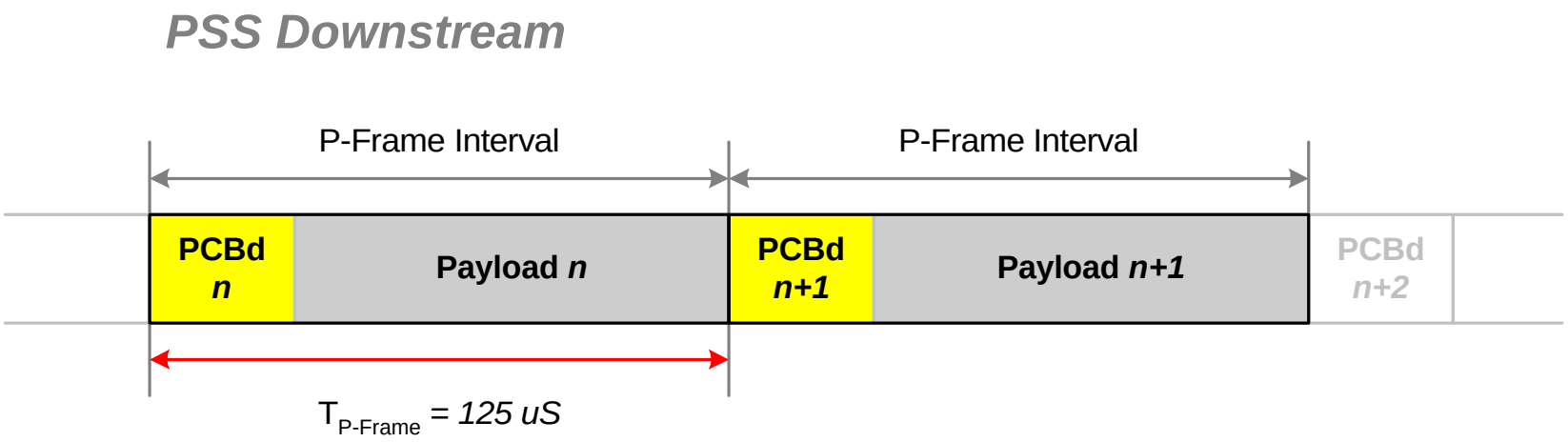
- PSS provides the physical layer transport service over PON.
- PSS is independent of traffic protocol (ATM, Ethernet, etc.).
- PSS **will** support Ethernet only traffic as EPON.
- PSS **can** also concurrently support ATM, TDM, MPEG2 and others.

Simultaneous Ethernet, ATM & Voice Support Capability



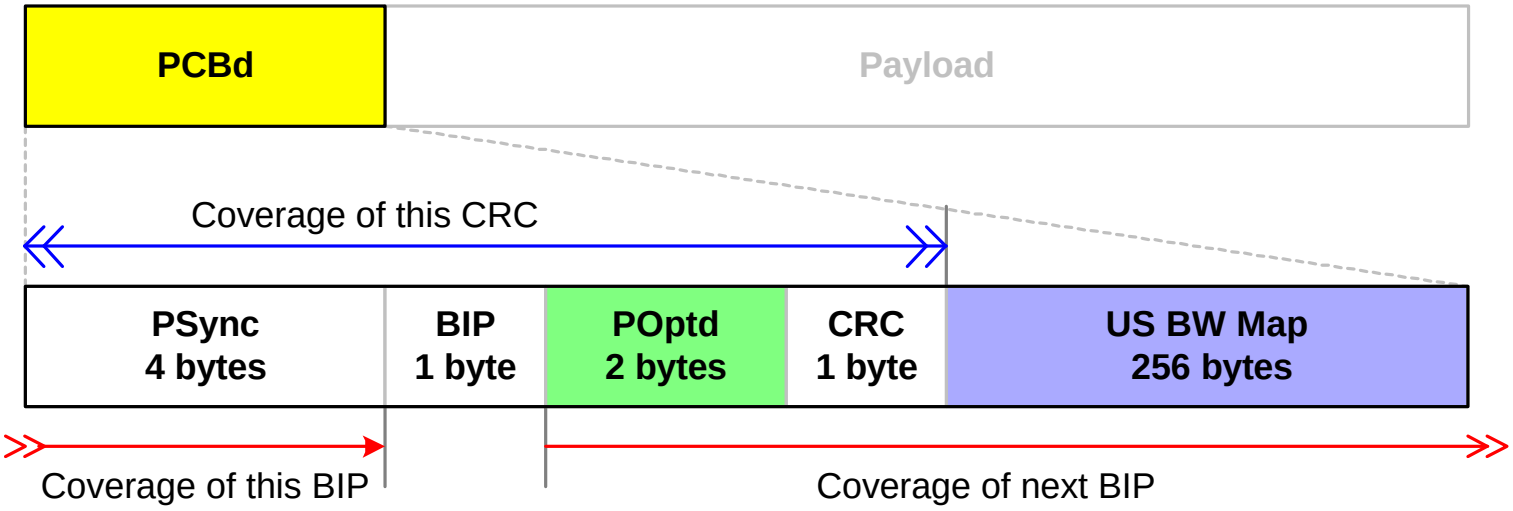
PSS Downstream

- Divide downstream into fixed size PSS Frames (P-Frames) of length 125 uS. This correlates to P-Frame intervals of 8 KHz.
- Each P-Frame is made up of a header (**PCBd**) and a Payload.
- No 8b/10b encoding is used since scrambling maintains line balance.



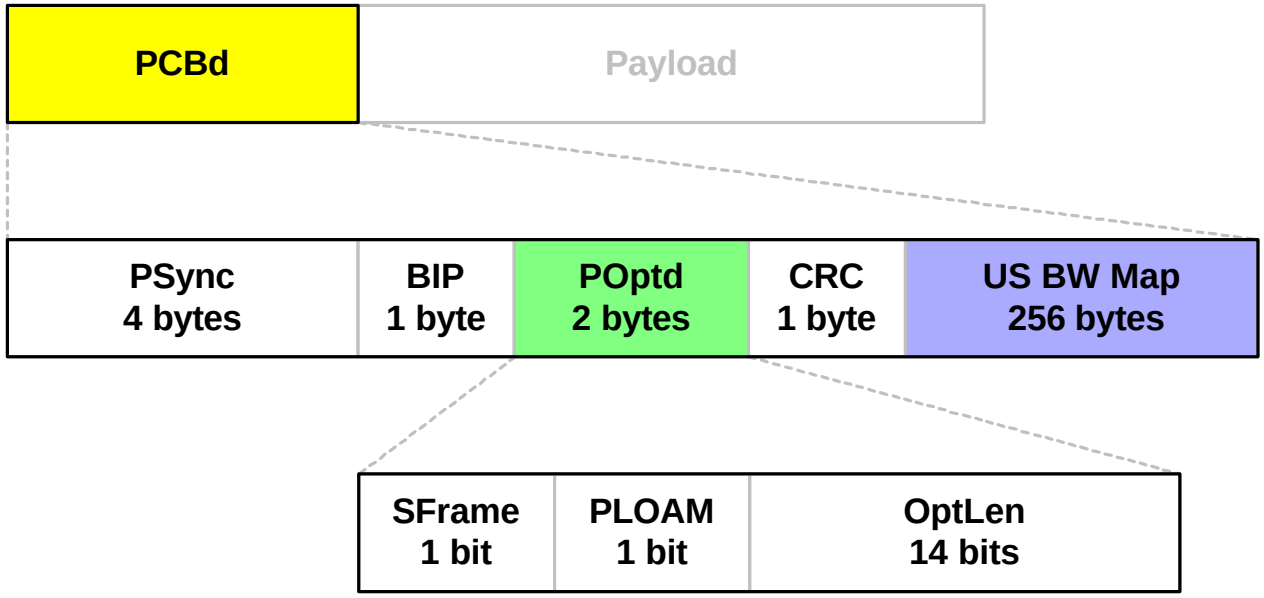
PCBd Downstream

- All ONTs must process downstream **PCBd**s.
- ONT uses **PSync** bytes for P-Frame delineation.
- Upstream **BW Map** controls ONT transmissions.
- **POptd** denotes presence of OAM and/or TDM partitions in Payload.
- **BIP** covers all downstream bytes since the previous **BIP**. Each of the bits of the **BIP** byte is the XOR of all the same-position bits in all the covered bytes. **BIP** is a good estimate of the real BER when BER < 10^{-4}.



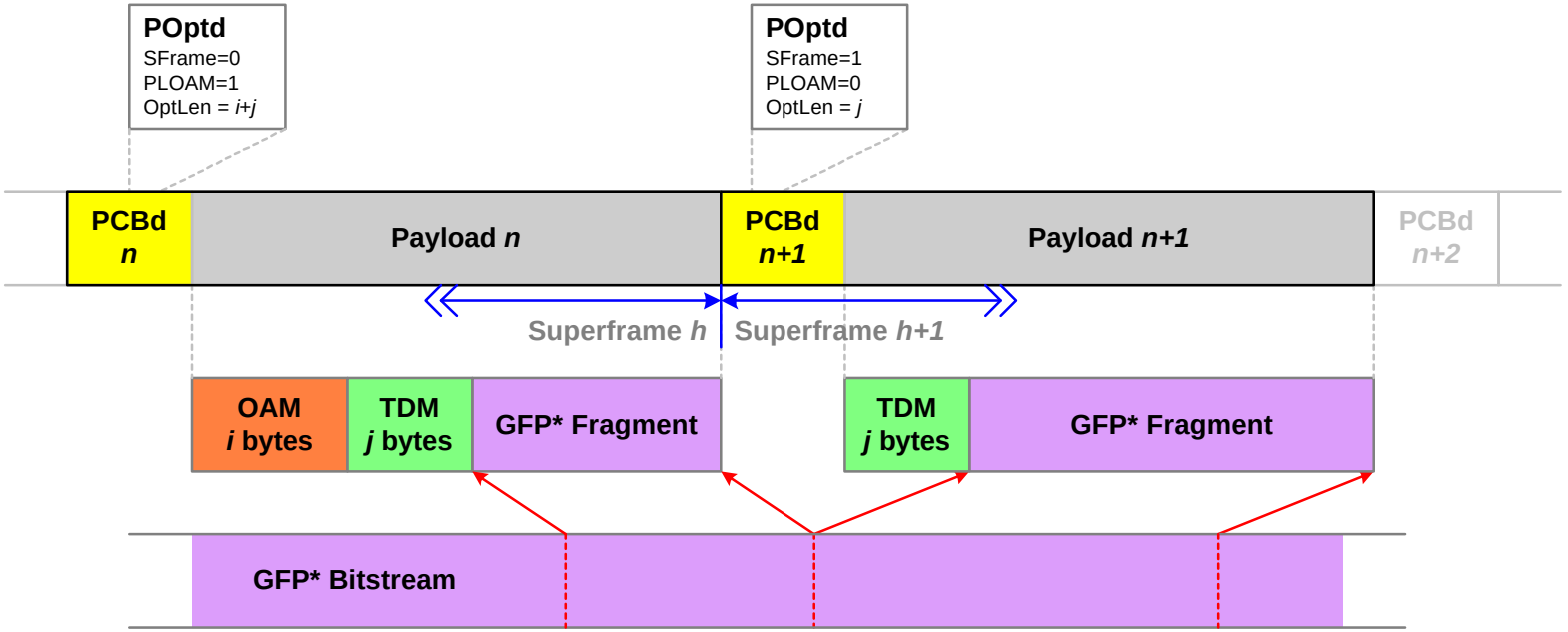
POptd in Downstream

- **POptd** denotes presence of OAM and/or TDM partitions in Payload.
- **SFrame** indicates superframe boundaries. It is '1' in the first P-Frame of a 16 P-Frame long superframe.
- **PLOAM** indicates the presence of a fixed length OAM message immediately following the PCB.
- **OptLen** is the total length of the optional partitions (OAM and TDM).



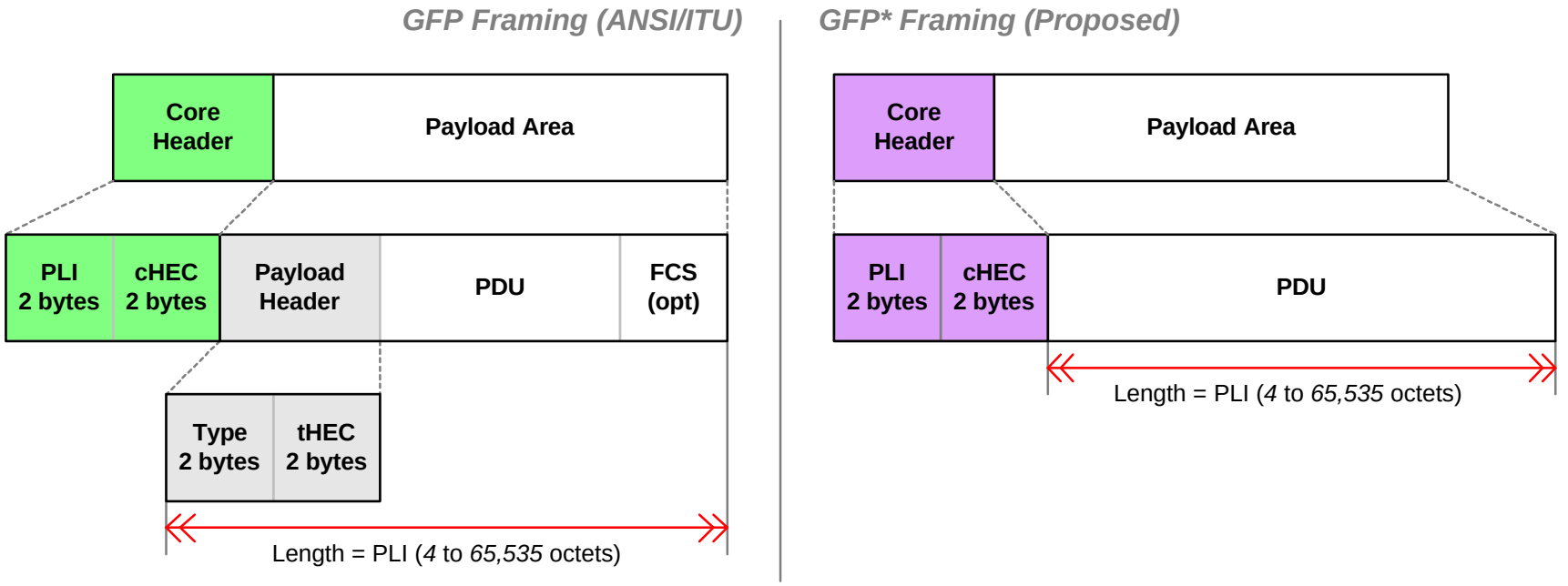
Payload Downstream

- The Payload area is always fixed in length since the P-Frame Interval is constant; e.g. **PCBd**s are periodic.
- The Payload is divided into 3 regions: fixed size **OAM** (optional), variable size **TDM** (optional) and fragments of a **GFP*** encapsulated bitstream.
- **POptd** in the **PCBd** denotes presence of **OAM** and/or **TDM** partitions.



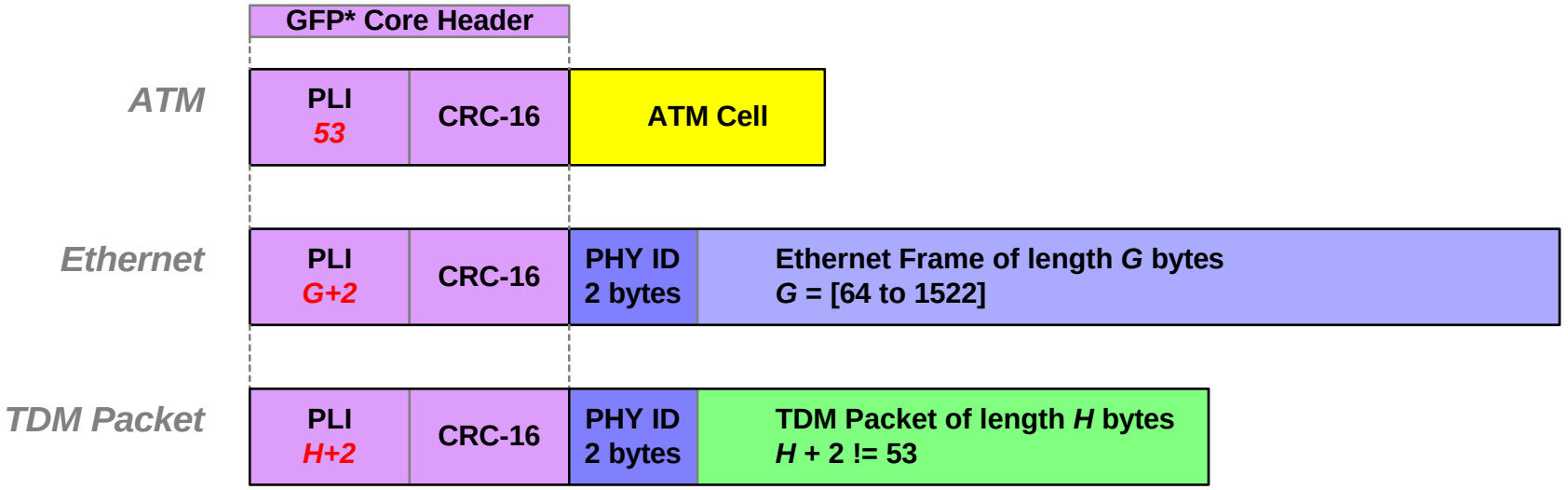
GFP* Framing

- **GFP*** is similar to ANSI/ITU GFP: same Core Header.
- **GFP*** does not have the Payload Header. The PDU type is decoded by **PLI** since cells yield **PLI** = 53 and frames/packets yield **PLI** ≠ 53.



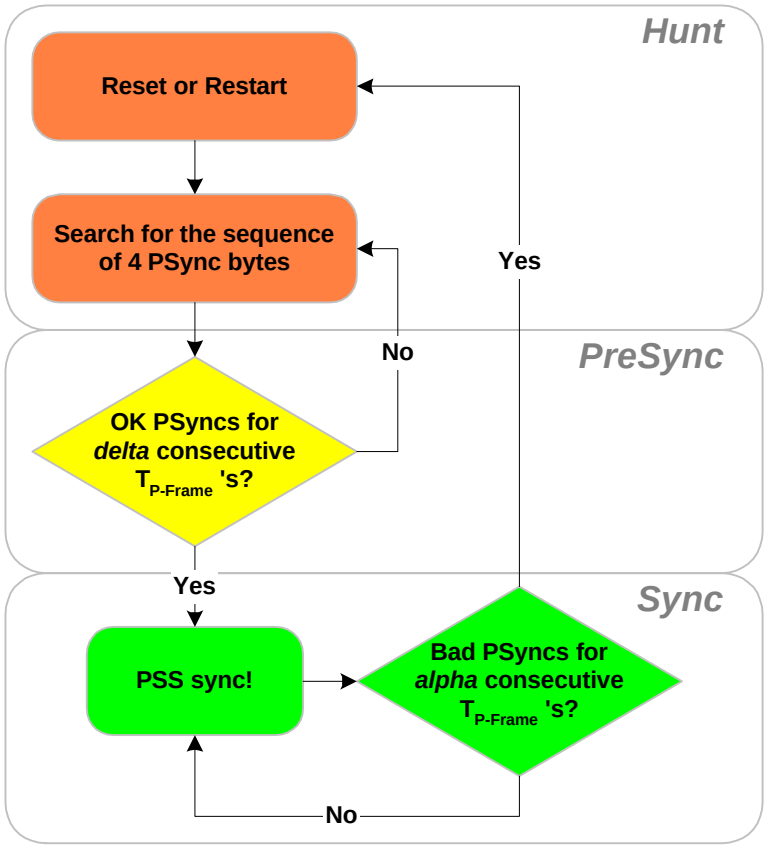
GFP* PDU Support

- **GFP*** concurrently supports ATM cells, Ethernet frames and other PDUs.
- **GFP*** Core Header's **PLI** identifies cells from frame PDUs.
- **PHY ID** label identifies PDU type and destination/source ports.
- **GFP* Core Headers + PHY ID** are smaller than Ethernet's 8 byte Preamble + SFD.



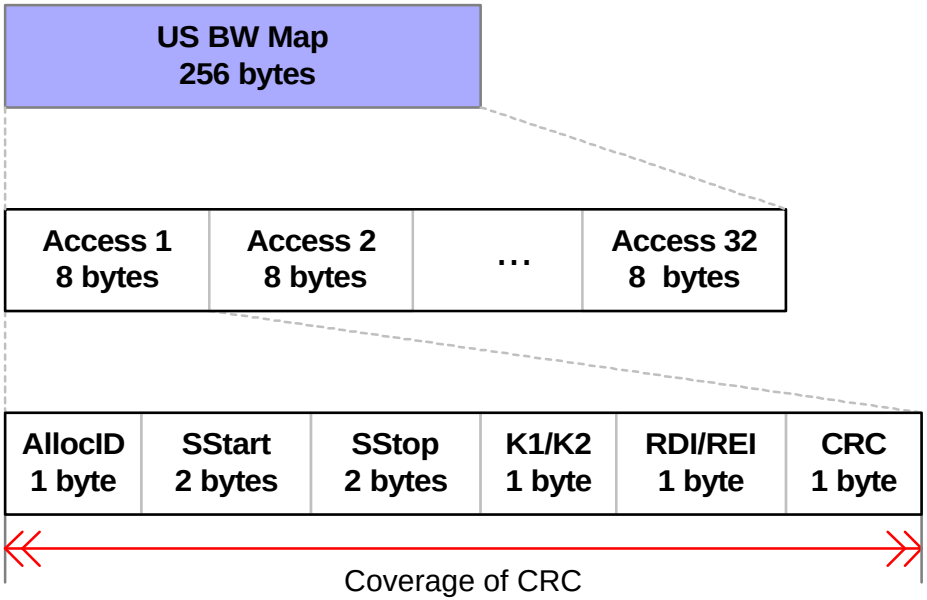
Downstream Byte/Frame Synchronization

- P-Frames are periodic so frame sync is achieved by locking on **PCBd**s.
- Each **PCBd** starts with 4 **PSync** bytes. ONTs search for this periodic, 4 byte sequence to locate a **PCBd**. If ***delta*** consecutive **PCBd**s are found, then DS frame sync has been achieved.
- If the **PSync** header is incorrect ***alpha*** consecutive times, then the process of searching for **PCBd**s is restarted.
- Bit synchronization is performed by **PMD** layer **CDR** function.



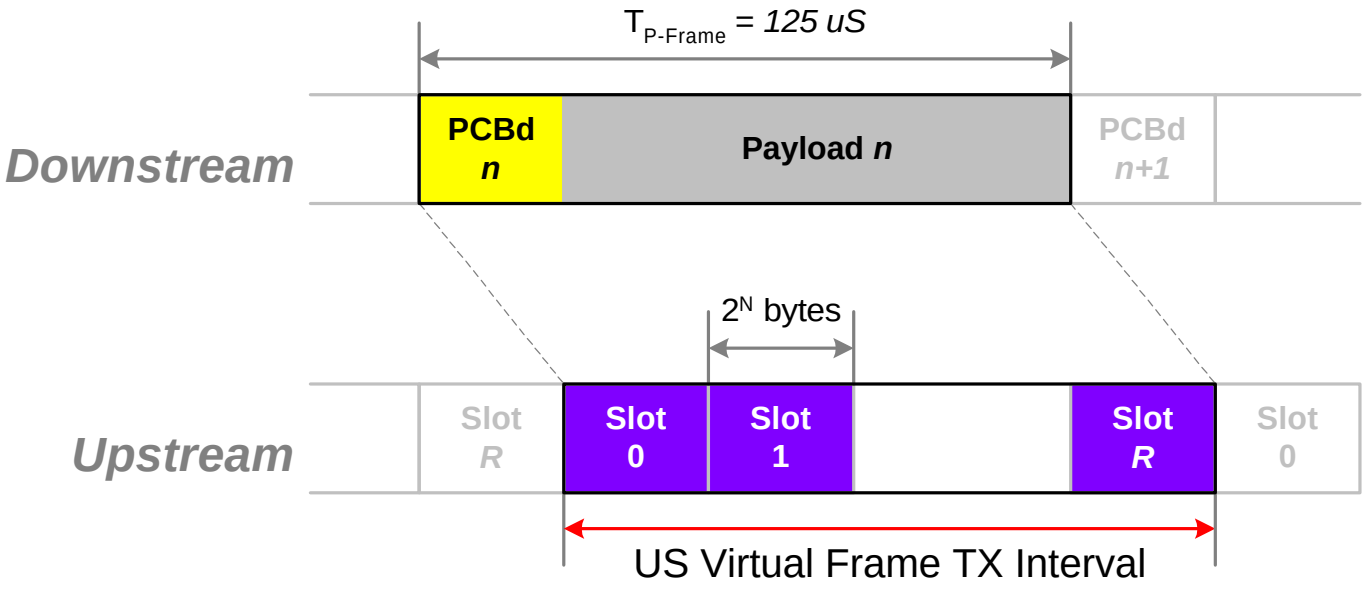
US BW Map

- The **BW Map** contains 32 **Access** structures. Each **Access** structure grants an US transmission window.
- Allocation IDs (**AllocID**) are assigned to the ONT by the OLT. An ONT may contain multiple **AllocID**s. Well known **AllocID**s are reserved for special windows, i.e. activation, ranging, etc…
- **K** bytes are for survivability and protection switching.
- **RDI/REI** are for Remote Defect/Error Indication.
- US pointer mechanism allow dynamic configuration of the guard times.
- Each **Access** structure is protected by its own **CRC**.



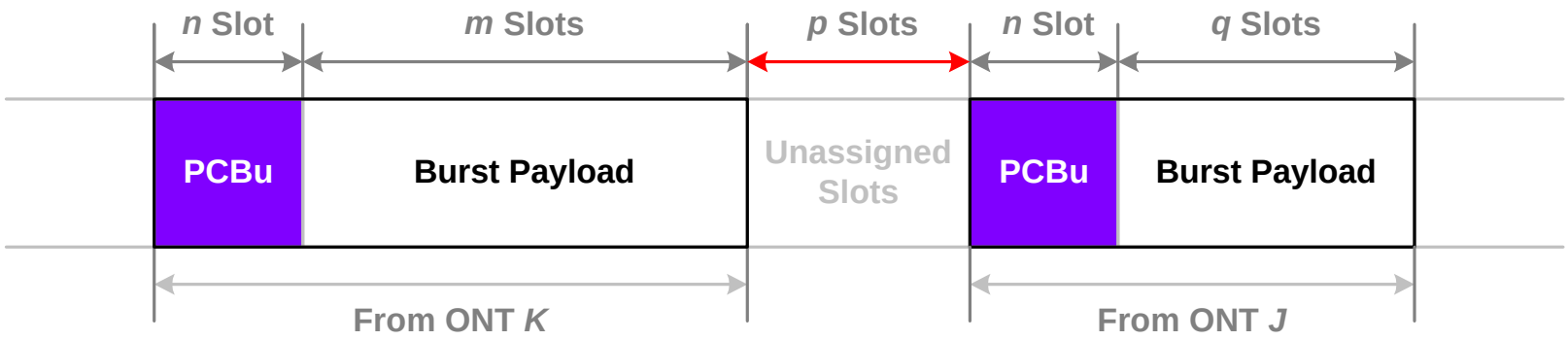
PSS Upstream Overview

- Pointers mechanism to control ONT US transmissions.
- Pointers are carried in **BW Map** in the DS **PCBd**s.
- Pointers are 16 bits yielding ~64K max slots per correlated US virtual frame transmission interval.
- Divide upstream into slots of $\mathbf{2^N}$ bytes where N depends on PON bit rate.



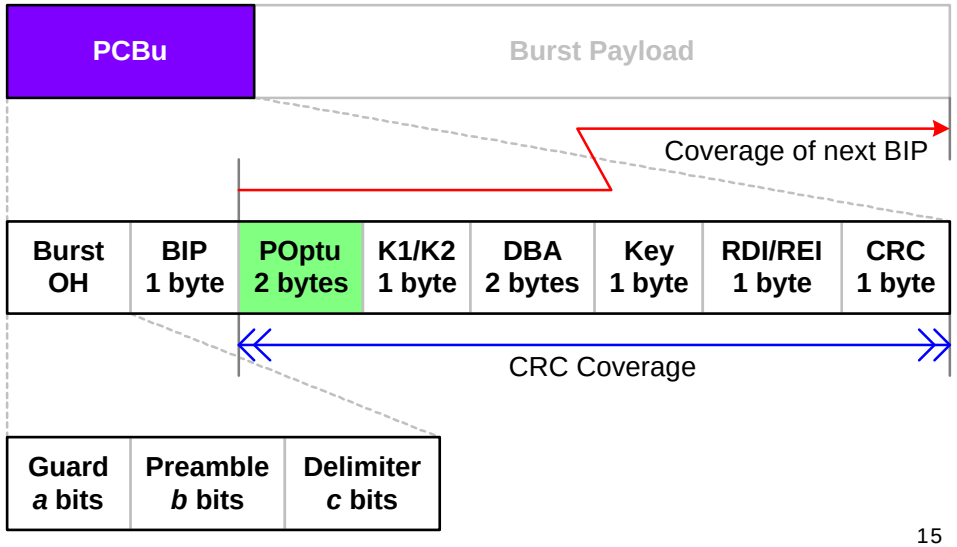
PSS Upstream Transmission Bursts

- Each US Burst consists of a **PCBu** and the Burst Payload.
- Each ONT must be given a minimum number of slots per ONT burst grant. The minimum US burst is the **PCBu** only (*n* slots in figure).
- The Burst Payload contents are determined by the **AllocID** value in the DS **BW Map**.
- The total Payload length is based on granted US transmission slots, so it is variable.



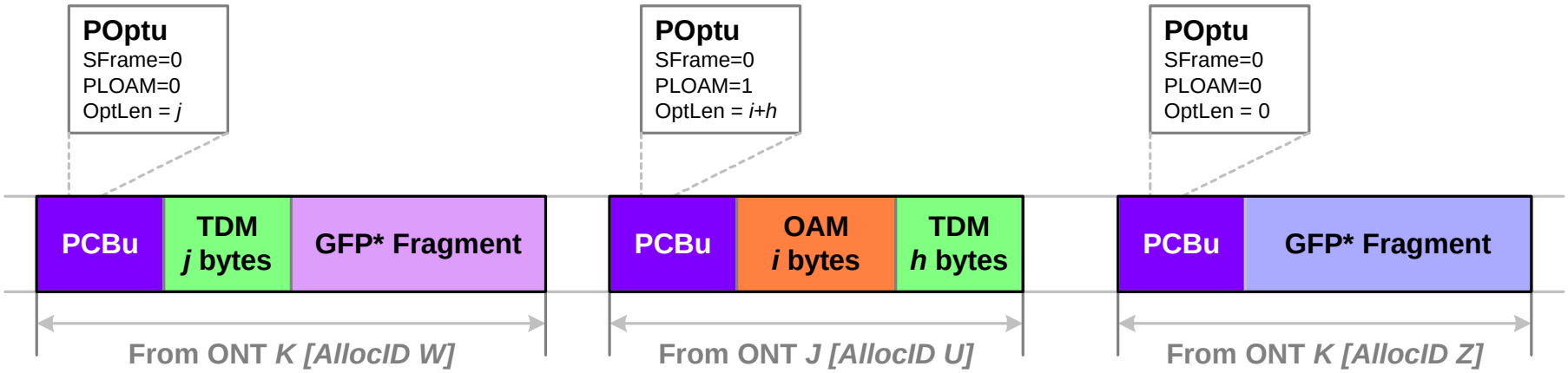
PCBu Upstream + Bit/Byte Synchronization

- Separate **BIP** from each ONT. The **BIP** includes all bytes sent by the ONT since the last **BIP** with the exception of the Burst Overhead bytes.
- **POptu** indicates presence of OAM and/or TDM partitions in the Payload. Format is exactly the same as the downstream **POptd**.
- **K** bytes are for survivability and protection switching.
- **DBA** reports ONT buffer status to DBA mechanism in OLT.
- **Key** carries the upstream churning key one byte at a time.
- **Guard**: between consecutive bursts to avoid collisions.
- **Preamble**: bit synch and amplitude recovery.
- **Delimiter**: byte sync.
- **RDI/REI**: Remote Defect/ Error Indicators.



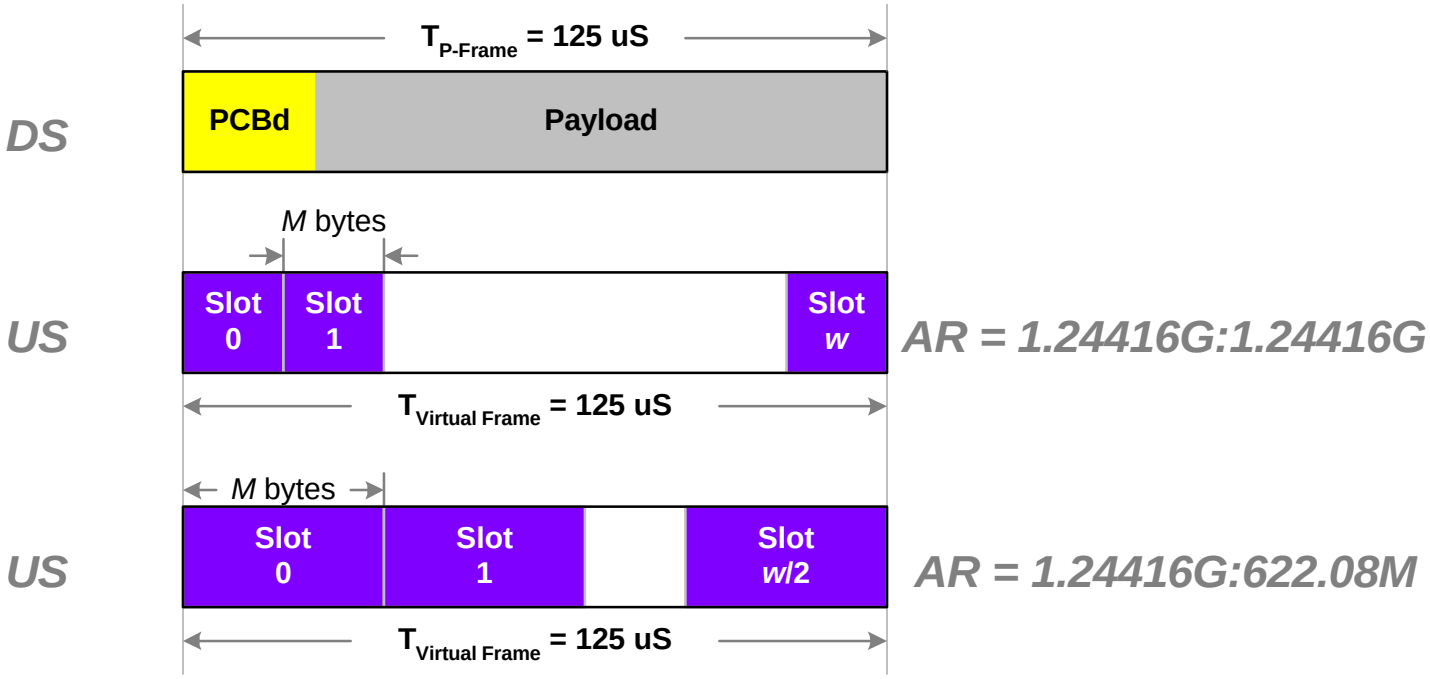
Upstream Burst Payload

- The Burst Payload is divided into 3 regions: fixed size **OAM** (optional), variable size **TDM** (optional) and fragments of a **GFP*** framed bitstream.
- **POptu** in the **PCBu** denotes presence of **OAM** and/or **TDM** partitions.
- An ONT sets **SFrame** every 16th burst to indicate the US superframe.
- An ONT may be assigned multiple **AllocID**s. Consequently, an ONT may source multiple, distinct US **GFP*** bitstreams.
- The US **GFP*** framing format is identical to that of the DS.



PSS Asymmetric Data Rates

- Asymmetric data rates are easily supported by judicious utilization of the **BW Map**.
- The asymmetric ratio (**AR**) is defined as (DS rate):(US rate)
- The slot size is fixed for all **AR**. Each **BW Map** must only assign enough slots to satisfy the US BW. If **AR** = 1.24416G:622.08M, then the **BW Map** should only assign the first 1/2 of the available slots.



PSS Scrambling

- In the DS, the **PSync** bytes are not scrambled and the scrambler is reset immediately following the **PSync** bytes.
- In the US, the **Burst Overhead** is not scrambled and the scrambler is reset immediately following the **Burst Overhead**.
- **Scrambling objectives**:
  - Randomizing the data in the information field for possible improvement of the transmission and EMI performance
  - No error detection and no special code groups
  - ***Advantage: No overhead***
- **8b/10b code objectives**:
  - Sufficient number of transitions in every symbol: High transition density (between 3-8 transitions) makes clock recovery easier
  - Error detection
  - Special code groups: Distinct and easy recognizable bit patterns
  - ***Disadvantage: 20% overhead***

PSS Layer BW Efficiencies

- Excluded are data dependent overheads, i.e. **GFP* Core Header + PHY ID**, which is smaller than the traditional 8 byte Ethernet **Preamble** and **SFD**.

Downstream

	P-Frame Size (Bytes)			*Throughputs (bits/s)*			*Efficiency*
	PCBd	OAM	Payload	PCBd	OAM	Payload	
1.24416G/'OC-24'	264	0	19,176	16.9M	0	**1.227G**	98.64%
	264	16	19,160	16.9M	1.0M	**1.226G**	98.56%
2.48832G/OC-48	264	0	38,616	16.9M	0	**2.471G**	99.32%
	264	16	38,600	16.9M	1.0M	**2.470G**	99.28%

Upstream

	US Burst Size (Bytes)			*Throughputs (bits/s)*			*Efficiency*
	PCBu	OAM	Payload	PCBu	OAM	Payload	
1.24416G/'OC-24'	13	0	595	26.6M	0	**1.219G**	97.94%
	13	16	579	26.6M	32.8M	**1.186G**	95.31%
2.48832G/OC-48	13	0	1203	26.6M	0	**2.464G**	99.01%
	13	16	1187	26.6M	32.8M	**2.431G**	97.70%

Notes

[1] The Burst Overhead is assumed to be 4 bytes total.

[2] Assume US virtual frame is divided into 32 equal sized TX windows.

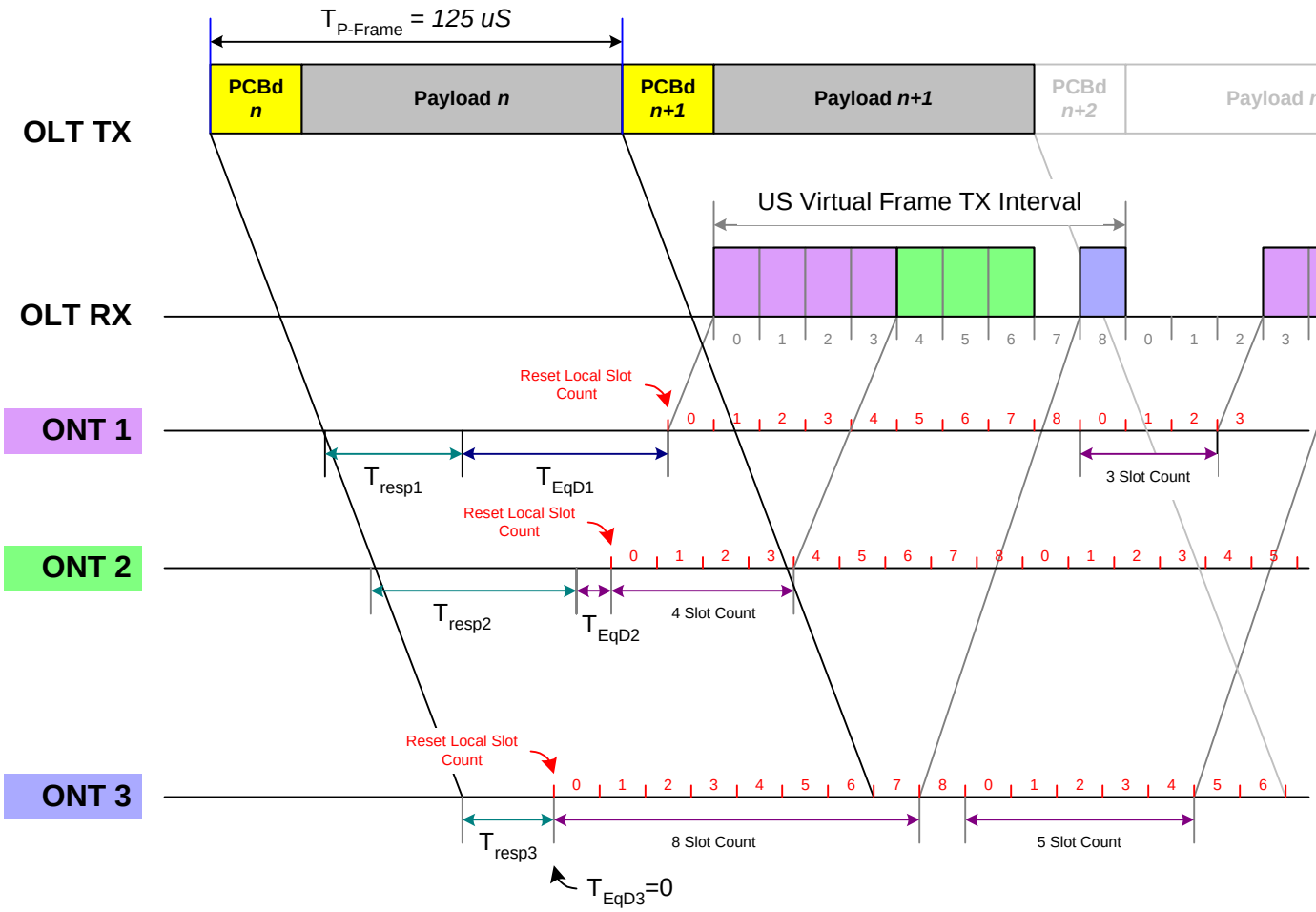
[3] Efficiency only represents the PSS layer (i.e. PCBx and OAMs overheads).

PSS Upstream Transmission Access

- OLT assigns start/stop pointers in the **BW MAP** for when ONTs can TX.
- OLT must always measure ONT **RTD** through a ranging window.
- ONTs will implement the Equalization Delay mechanism, like APON.
- All ONTs reset their local slot count only upon receiving the **BW Map**. An ONT transmits when its local slot count reaches its start pointer value.
- The ONT activation (initial ONT response to OLT) will be either with Collision Avoidance via Back-off or the Binary Tree Mechanism.

PSS Upstream Example

US Transmission with Pointers and Local ONT Eq Delay



PCBd *n*		
AllocID	SStart	SStop
ONT 1	0	3
ONT 2	4	6
ONT 3	8	8

PCBd *n+1*		
AllocID	SStart	SStop
ONT 1	3	4
ONT 3	5	8

*** Assume ONT response times are not all identical.**

PSS Summary

- Very efficient BW utilization. User data throughput easily exceeds 1Gb/s in both US and DS.
- PHY layer OAM is out-of-band and secure. Additional frame-based in-band OAM may still be provisioned.
- Built in continuous link BER performance monitoring
- Highly efficient, no overhead transport of native TDM traffic (T1, E1, DS3, E3, Nx64Kb/s POTS).
- Scalable framing structure for 1.244Gb/s to 2.5Gb/s and beyond as well as asymmetric rates.
- BW MAP supports allocation of both guaranteed BW as well as non-guaranteed BW in the US.
- DBA, Security, Survivability/Protection, and QOS infrastructure are built in.
- PHY layer transport is protocol independent, allowing data and telecom convergence.

>>Thank You!<<