PMD Burst Mode Dynamic Performance Requirement

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Outline

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  - Definition of relevant Burst Mode Terms
    - Optical Extinction Ratio
    - Optical "Off-State" Power
    - Optical Dynamic Range
- Benefit of Burst Mode (BM)?
  - Why do we need short Burst?
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    - Burst Efficiency as a function of transmission burst size
- PMD Upstream Dynamics for OLT Rx Path
  - Upstream Guard Time Requirement
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  - Upstream Overhead Byte Requirement
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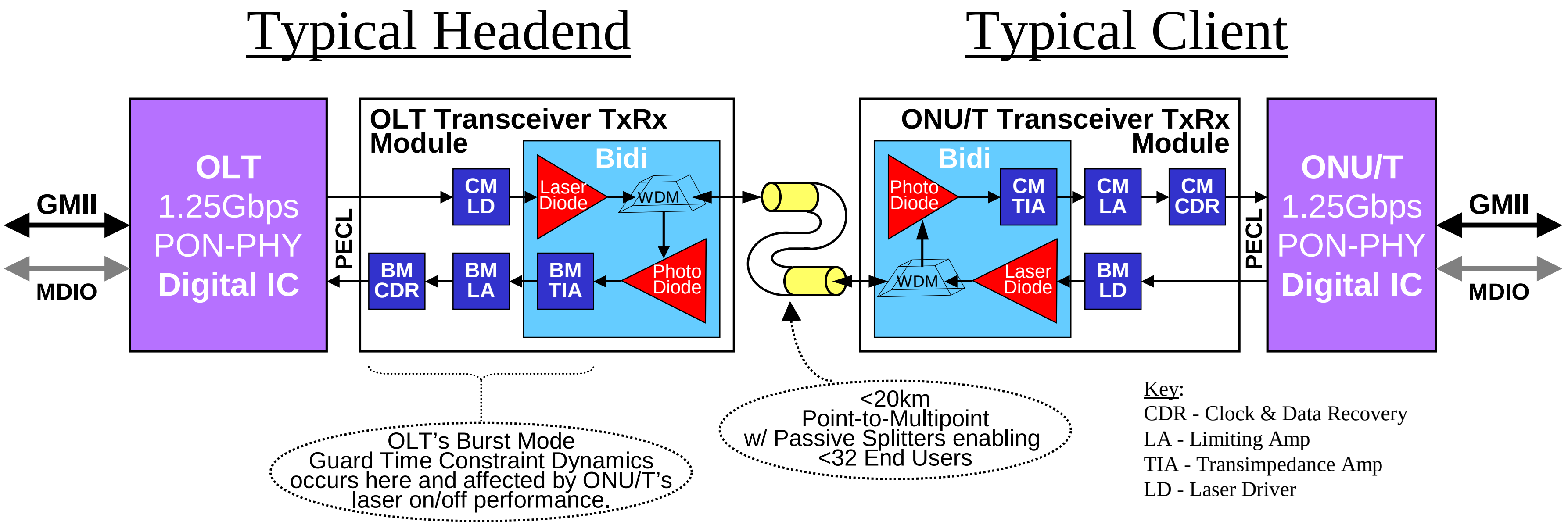
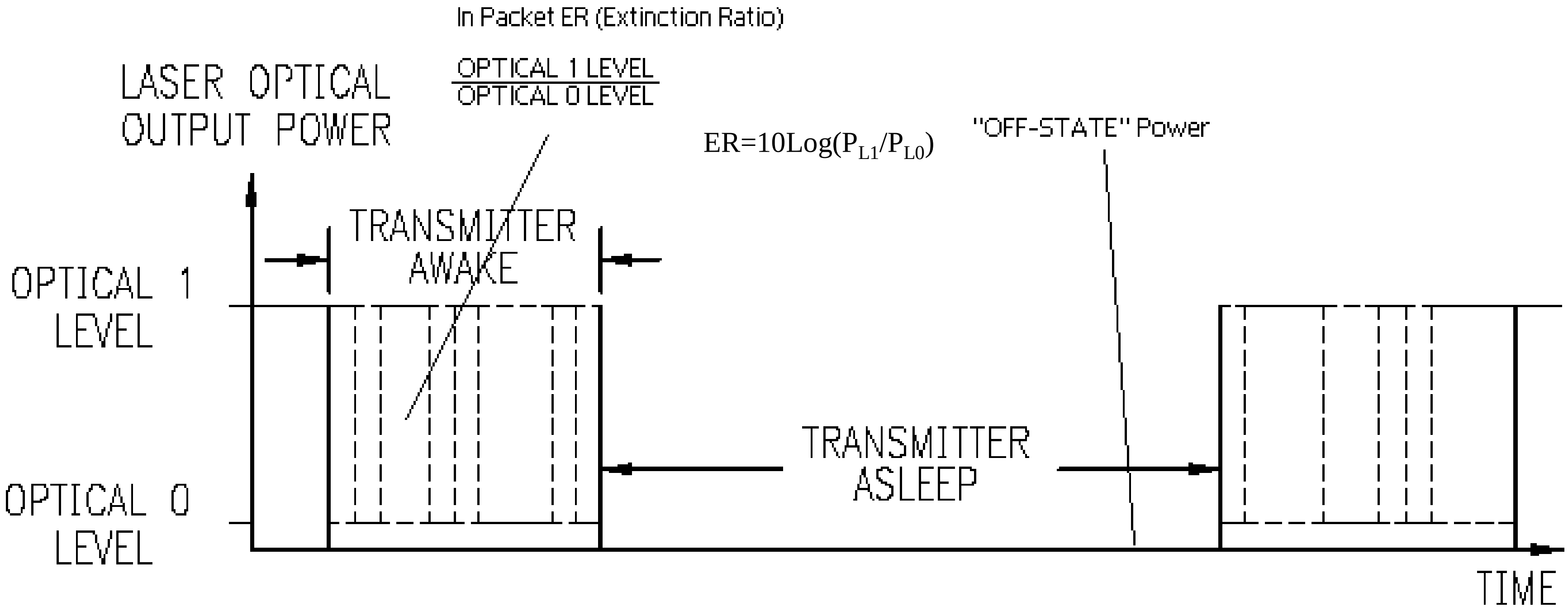
PMD's Burst Mode Analog ICs

- What is Burst Mode?
  - P2MP PONs employ short bursts of data packets upstream instead of continuous data packets used in Continuous Mode (CM) P2P applications. Hence the term Burst Mode (BM).



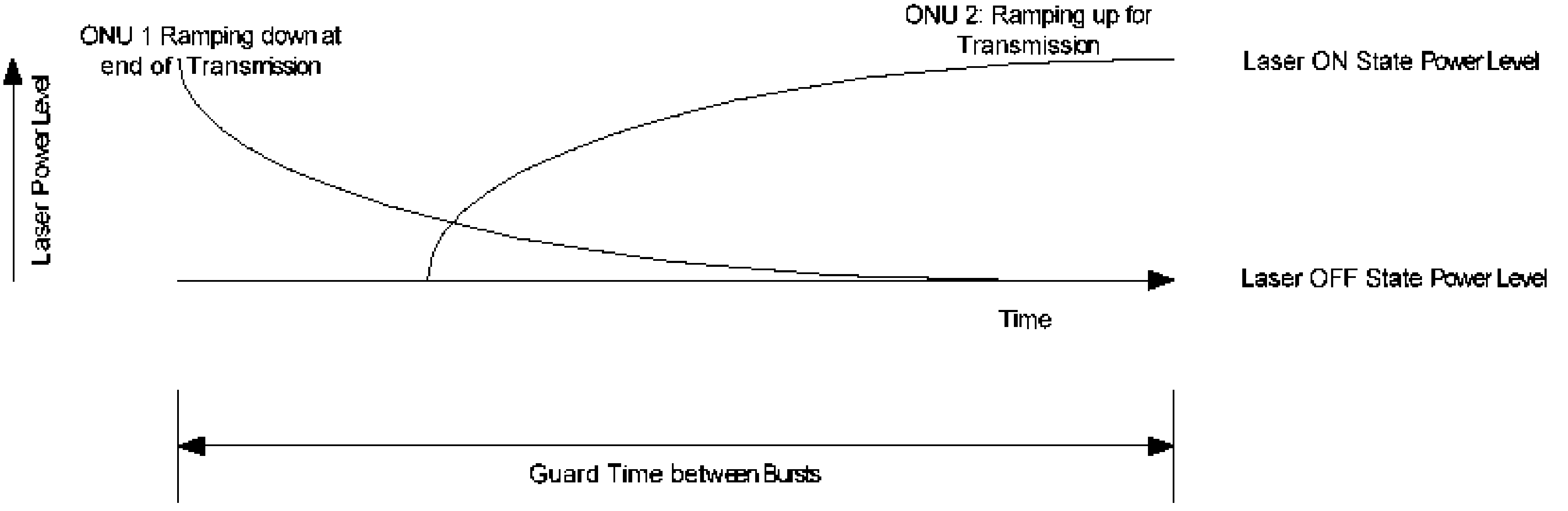
What is ER & “Off-State” Power?

- ER refers to the Extinction Ratio, which is the ratio of Optical Power transmitted by ONU for logic one & zero levels during an upstream packet burst. (ER > **10**dB per ITU-T G.983.1)
- “Off-State” Power refers to how much the ONU is polluting Upstream when Laser is powered off. (Off-State Power < **-45**dBm)
- ER & “Off-State” Power numbers as seen by OLT.



Why do we care about ER & "Off-State" Power?

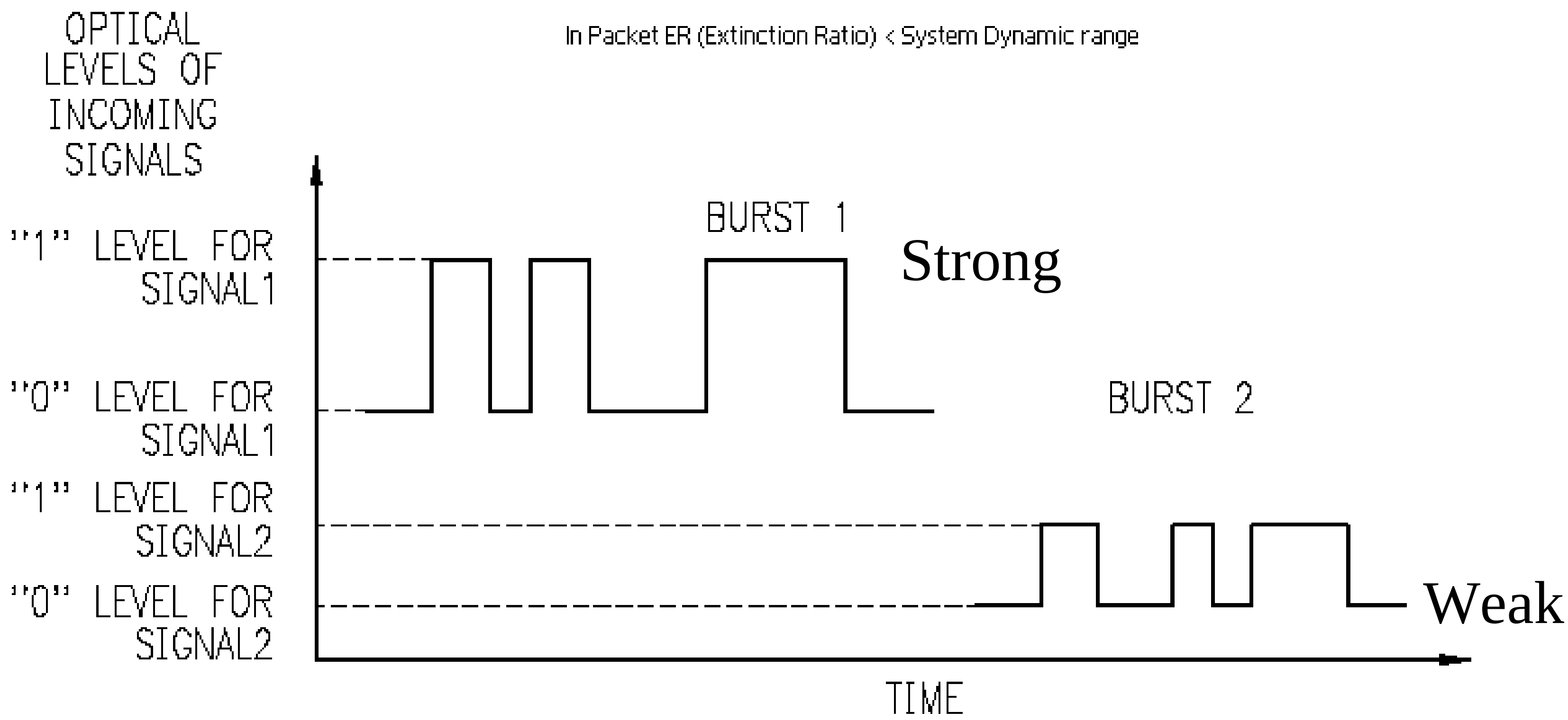
- Helps to define performance for transition region between burst.
- Tradeoffs are captured within Guard Time bits fields.
- Upstream aggregated throughput performance impacted.



What is the PMD's Optical System Dynamic Range?

- Dynamic Rage is related to ratio of Strongest to Weakest Optical Signal seen by OLT.

10Log(Strong/Weak) = System Dynamic Range > **23**dB example.

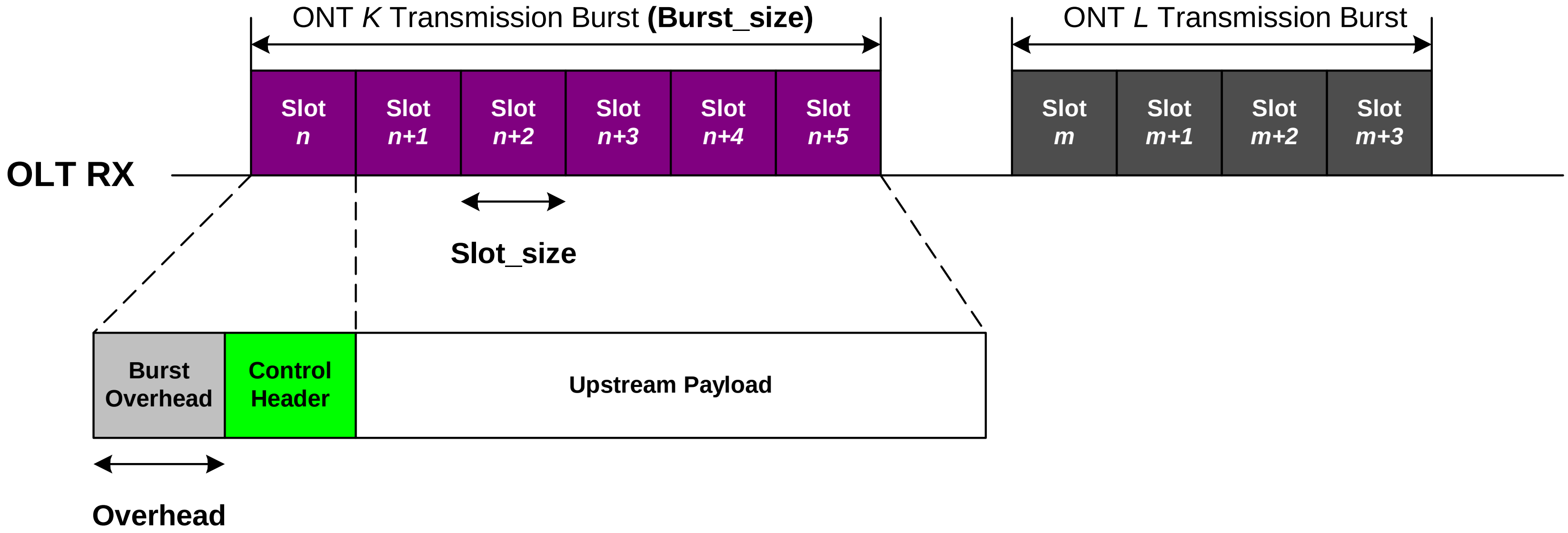


PMD's Burst Mode Benefits

- Why we need Burst Mode?
  - Improves the efficiency of PON's upstream data bit stream.
  - Cost comparable with Continuous Mode (CM) ICs
  - Saves ONU power by allowing ONU to power off TX path.
    - Typical saving range between 50% to 90% compared to CM.
- What are the Dynamic relationships within BM ICs?
  - Clock synchronization and clock recovery.
  - Proper delineation of received data called Delimiter.
  - Time between data packets is called Guard time.
  - Guard time is strongly dependent on Power Ratio of back-to-back data packet bursts.
  - Photodiodes can be designed to minimize residual carrier effects without adding cost
    - Doping or masking the fringing field solves this problem

Upstream Burst Efficiency

- Typical Bit-Stream Usage:
  - Upstream (US) transmission burst is divided into slots,
  - Each ONU/T is granted a group of consecutive slots for US burst of data,
  - Each ONT transmission burst is lead by the Overhead Bytes.
- Small slot size enables high US grant granularity and is desirable for overall US throughput efficiency.
- Most US bursts are relatively small due to nature of access networks (Examples are small 64 byte US Ethernet packets ACK's for DS data).



Upstream Burst Efficiency Equation

- Based on 3 variables: **Slot_count**, **Slot_size** & **Overhead**.
- **Slot_count** is data dependent, but the **Overhead** to **Slot_size** ratio **R**, can be bounded to a small set of values. We cannot find the optimal **Overhead** or **Slot_size**, but graphing **Efficiency** based on several carefully chosen values for **R** should yield some insight.

US Burst Efficiency Equation

$$\textbf{Efficiency} = \frac{\textbf{Burst\_size - Overhead}}{\textbf{Burst\_size}} \quad (1)$$

Since **Burst_size** = **Slot_count** * **Slot_size**

$$\textbf{Efficiency} = \frac{\textbf{Slot\_count} * \textbf{Slot\_size - Overhead}}{\textbf{Slot\_count} * \textbf{Slot\_size}} \quad (2)$$

Rearrange

$$\textbf{Efficiency} = \frac{\textbf{Slot\_count} - \dfrac{\textbf{Overhead}}{\textbf{Slot\_size}}}{\textbf{Slot\_count}} \quad (3)$$

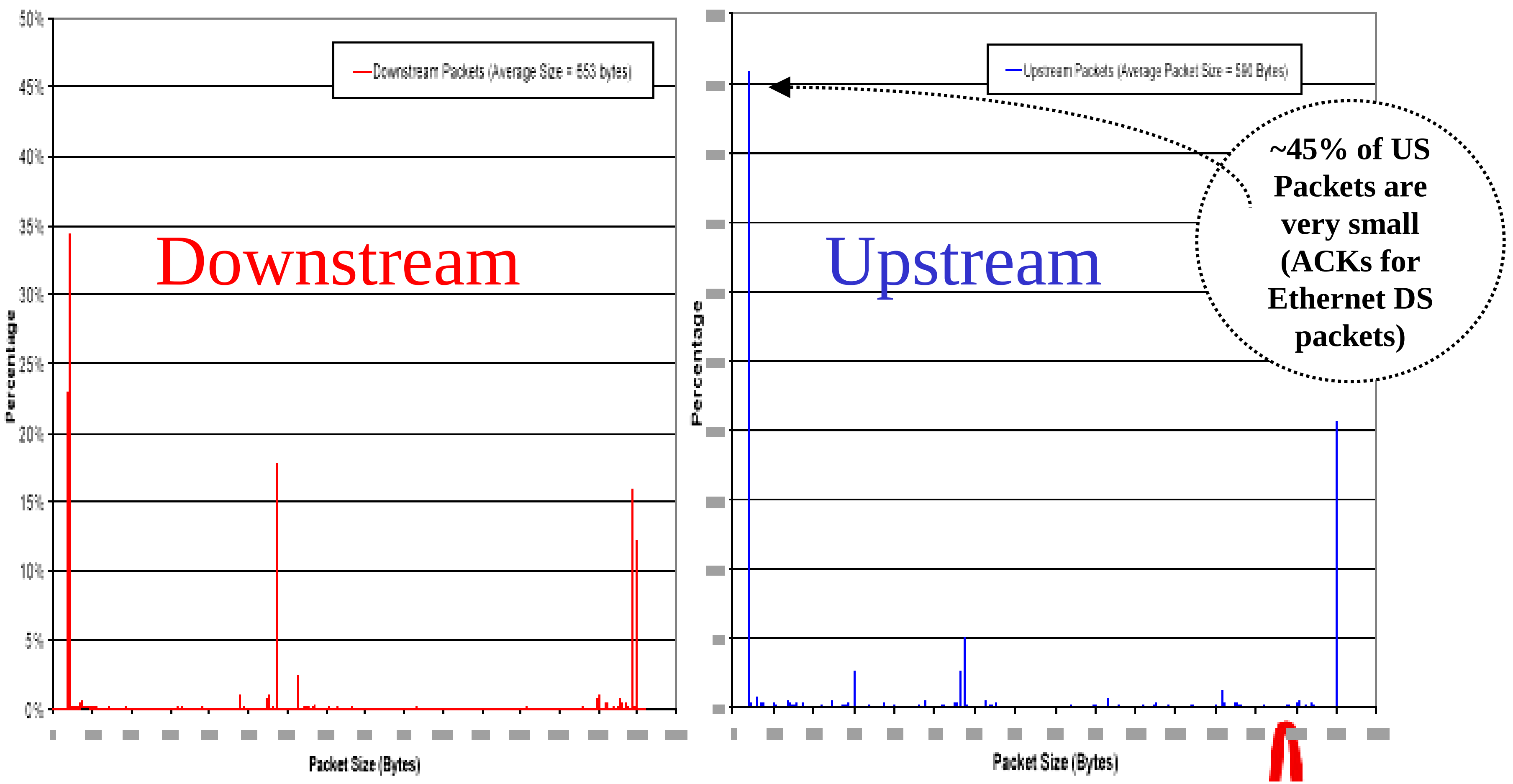
Let **SC** = **Slot_count** and **R** = $\dfrac{\textbf{Overhead}}{\textbf{Slot\_size}}$

$$\textbf{Efficiency} = \frac{\textbf{SC - R}}{\textbf{SC}} \quad (4)$$

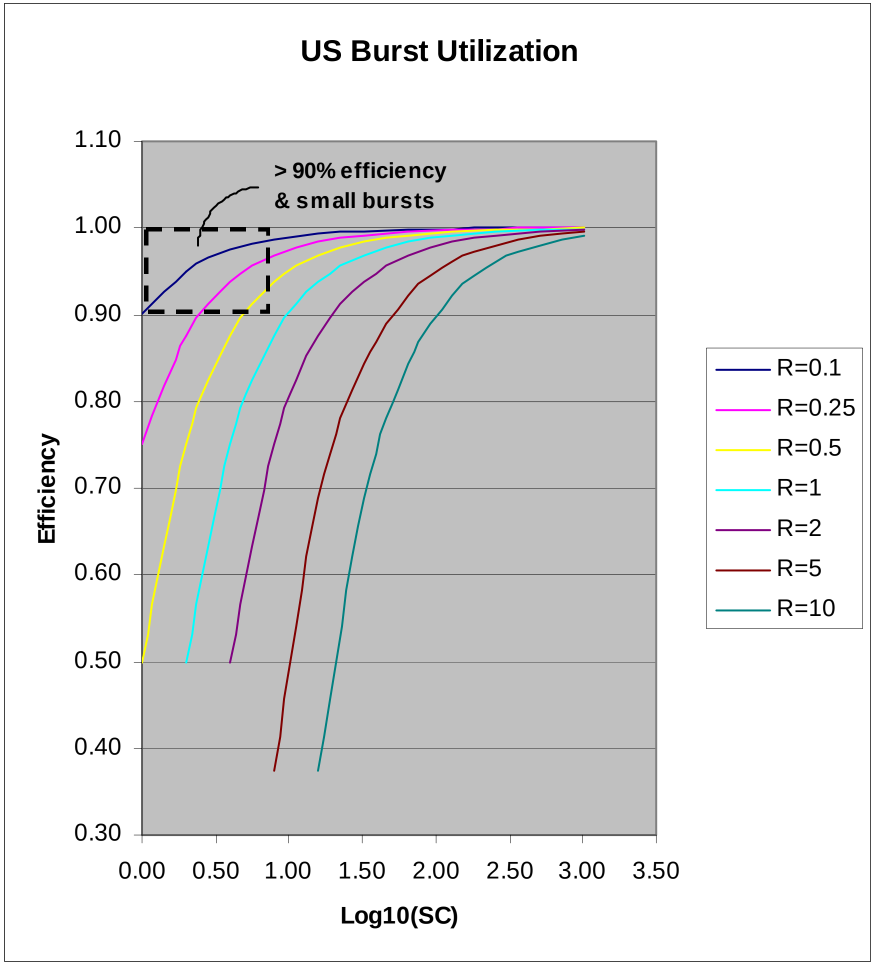
From EFM's July Meeting in Portland, we can see the US Packet Distribution.

Current Residential Traffic

(Data collected at a cable head-end)



Upstream Burst Efficiency Results



- Plot of **Burst Efficiency** for several reasonable **R** value (Overhead/Slot_Size)

Results

- Assumptions:
  1. Upstream bursts tend to be small in size with typical Slot_Count < 10.
  2. > 90% efficiency desired.
- Graph suggests **R** ≤ 0.5

Scenario Example

If ~45% of US packets are ~64bytes, then to obtain ~94% efficiency:

Burst_Size = 72 bytes,

Slot_Count = 9 & Slot_size = 8,

means Overhead ≤ 4 bytes

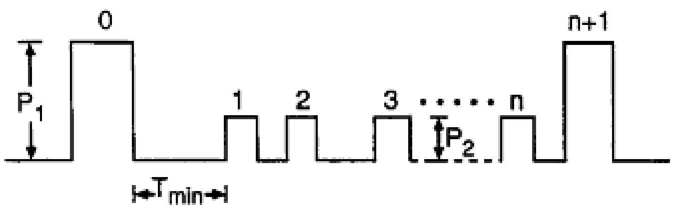
Conclusion

- Hence small Slot Sizes are desirable, and Overhead should also be small.

Guard Time Dynamics

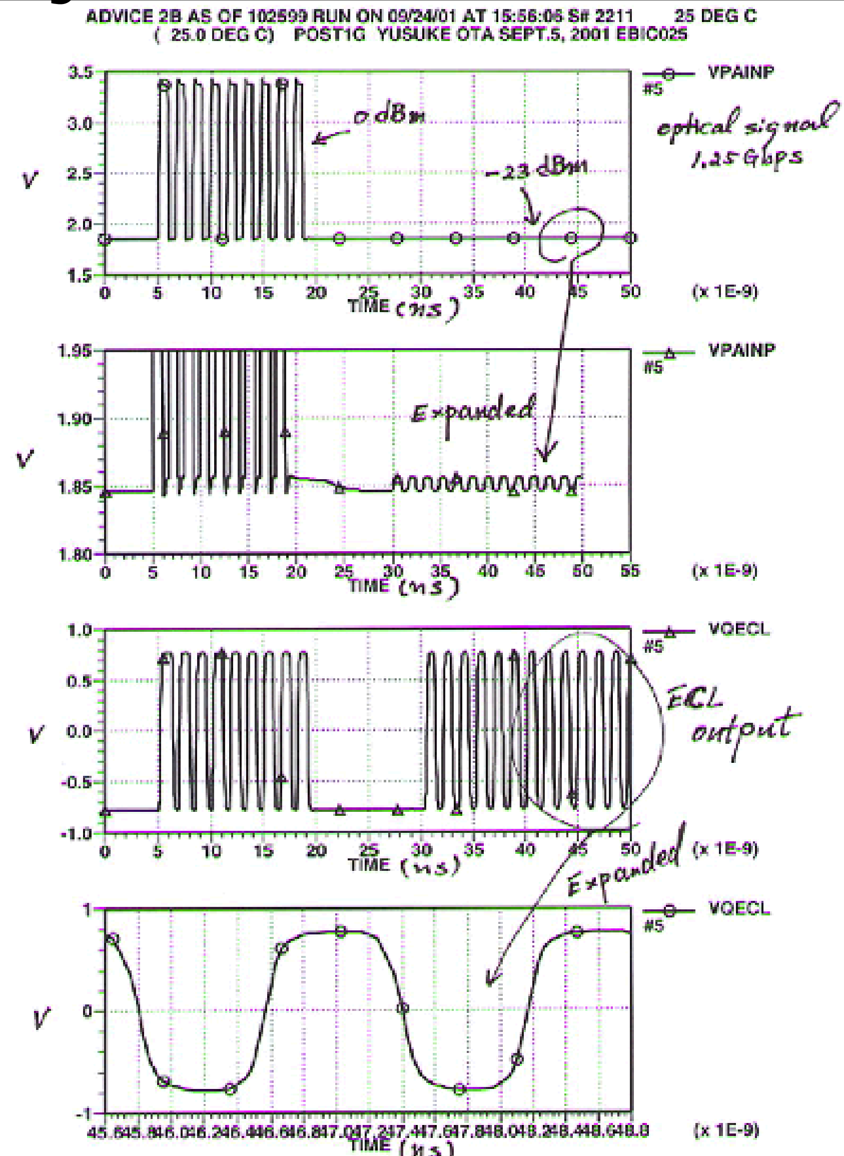
<u>Guard Time Constraints are:</u>

- Strongly dependent on both Optical Power P1 and P1/P2
- Strong to weak Optical Power (>23dB dynamic range)
- Independent of the bit rate.
- When P1/P2 < 3db, Guard Time ≅ 0(regardless of P1)



- P is the Optical Power of each Packet
- P1/P2 is the Ratio of the Optical Power
- T**min** is called the Guard Time between packets and is the minimum packet spacing required to properly recover the first bit in the second packet

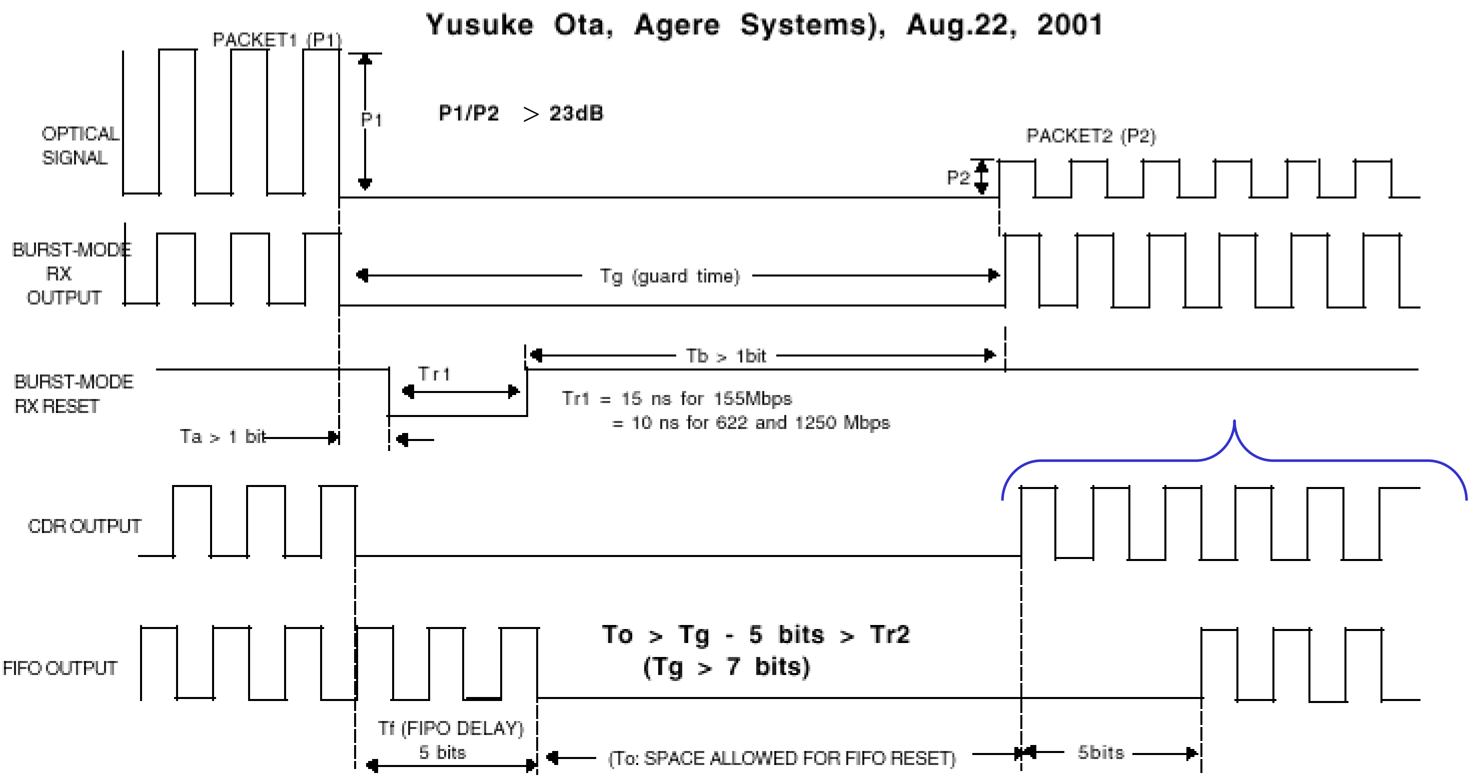
Definition of Guard Time Dynamic Terms



Example 1.25G Burst Mode Rx Path Trace Diagram

Why do we need Delimiter or Preamble?

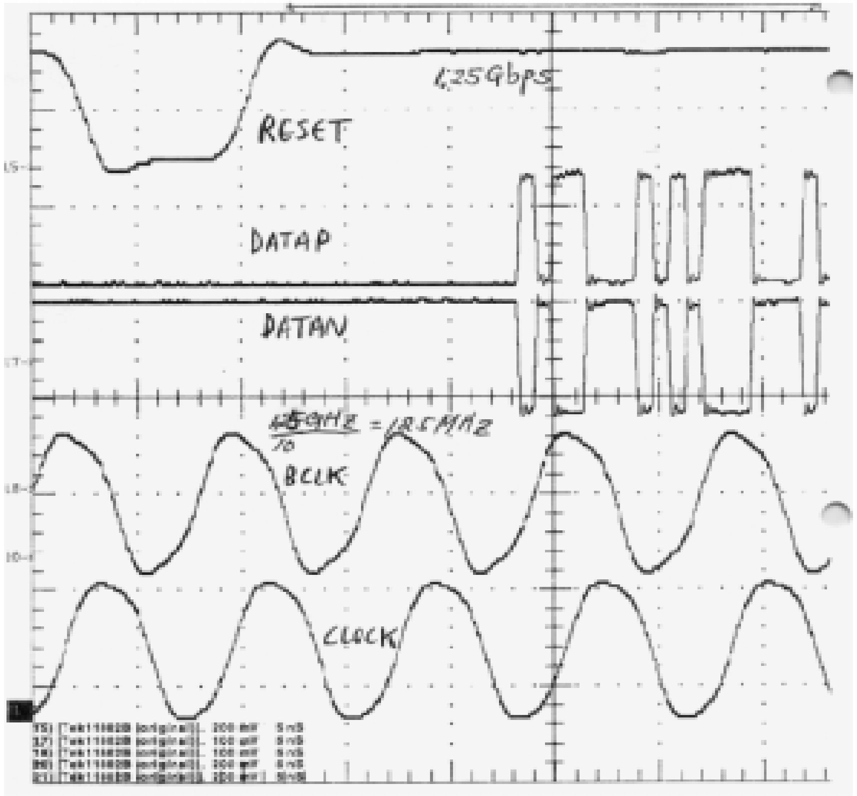
- Start of each Upstream Burst Packet must include known pattern to recover both clock and data correctly, which are referred to as Delimiter & Preamble bits.
- Delimiter bits are used to delineate the start of a valid burst.
- Preamble bits are used for phase locking and may not be required.
- Bit values for Delimiter & Preamble bits vary per implementation and are captured within ITU-T G.983.1 Overhead Bytes field.



Definition of Guard Time Dynamic Terms

PMD Upstream Overhead Byte Requirement

- Overhead Bytes are used at the beginning of every packet burst.
- ITU-T G.983.1 Defines:
  Overhead Bytes (OH) =
  Guard Time + Preamble
  + Delimiter = 3 bytes
- 1.25G Prototypes show 3 Bytes of Overhead is possible.
- RESET signal prior to packet acquisition provided by OLT PHY is implementation specific.



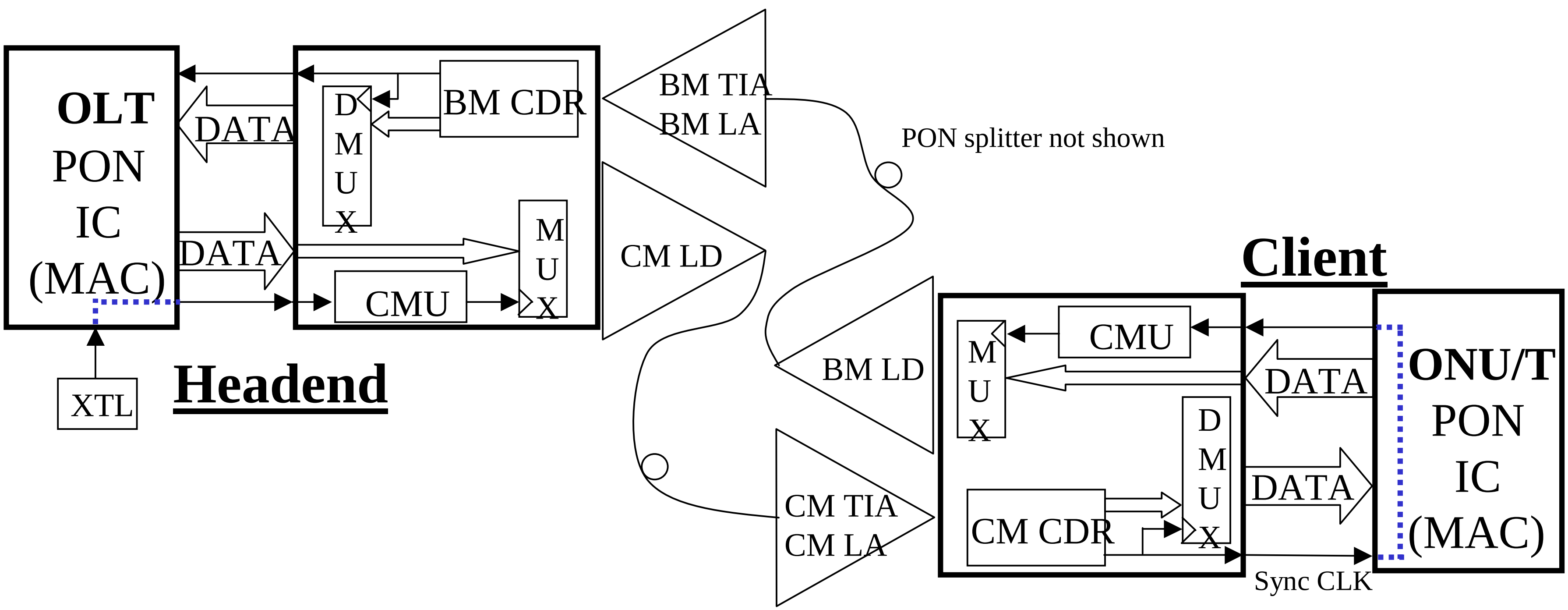
Example Lab Trace for 1.25Gbps CDR

System CDR Synchronization

- Clock and Data Recovery (CDR) performed using bits within the Overhead Byte field.
  - First n-bits may be lost in this process
- ONU CDR synchronizes frequency/phase and bit alignment to the continuos downstream data from OLT.
- OLT BM CDR reacquires lock, phase and bit alignment between each upstream burst (i.e. new phase acquired for each burst.).

System CDR Synchronization

- Upstream transfer clock is derived from Downstream transfer, which means PON system synchronized to OLT transmitter.



Thank You