

# EPON Scheduling Protocol Requirements

## A system-level perspective

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# Area of Application

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- Customer types:
  - Business subscribers
  - Residential subscribers
- Concentration schemes:
  - ONU serves single subscriber
  - ONU serves multiple subscribers
- EPON protocol must support
  - all customer types
  - various concentration schemes
  - combination of customer types and concentration schemes in the same EPON  
(EPON can be a combination of Fiber-to-the-Home, Fiber-to-the-MDU, and Fiber-to-the-Business)

# Control Parameters

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- SLA between Network Operator and subscriber include:
  - Minimum Rate (Guaranteed Bandwidth)
  - Maximum Rate (Excess Bandwidth)
  - Maximum Packet Loss Ratio
  - Maximum Packet Delay
  - (Delay Jitter can be controlled by Max. Delay parameter)
- SLA contract may include multiple services (i.e. voice, video, data). Each service would have different control parameters.

Example of SLA for  
subscriber A

	Voice	Video	Data
Min. Rate	128 Kbps	16 Mbps	0 Mbps
Max. Rate	128 Kbps	16 Mbps	40 Mbps
Max Delay	2 ms	8 ms	20 ms
Loss ratio	0.1%	0.1%	1%

# Why Rate Limit is Necessary?

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- Rate limit defines packet admission policy
- Without rate limit each user can generate data at full user-to-network interface (UNI) speed (10 or 100 Mbps)
- Packet loss ratio and packet delay will depend on number of active users

## **Example:**

- EPON serves 16 users with 100 Mbps ports => max Packet Loss ~ 40%
- EPON serves 32 users with 100 Mbps ports => max Packet Loss ~ 70%

# Minimum Rate (Guaranteed Bandwidth)

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- Defined as a minimum amount of data ( $W$  bytes) that subscriber will be able to send over interval  $\Delta T$  (regardless of network load)

$$\text{Min. Rate} = W / \Delta T$$

- If a subscriber has less than  $W$  bytes ready, the excess bandwidth may be given to other subscribers
- A particular SLA may specify  $\text{Min. Rate} = 0$

# Maximum Rate (Excess Bandwidth)

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- A busy subscriber may be given excess bandwidth (if other subscribers are idle or if EPON is under-subscribed)
- Max. Rate is the upper limit on excess bandwidth given to a subscriber

Min. Rate  $\leq$  Max. Rate  $<$  EPON line rate

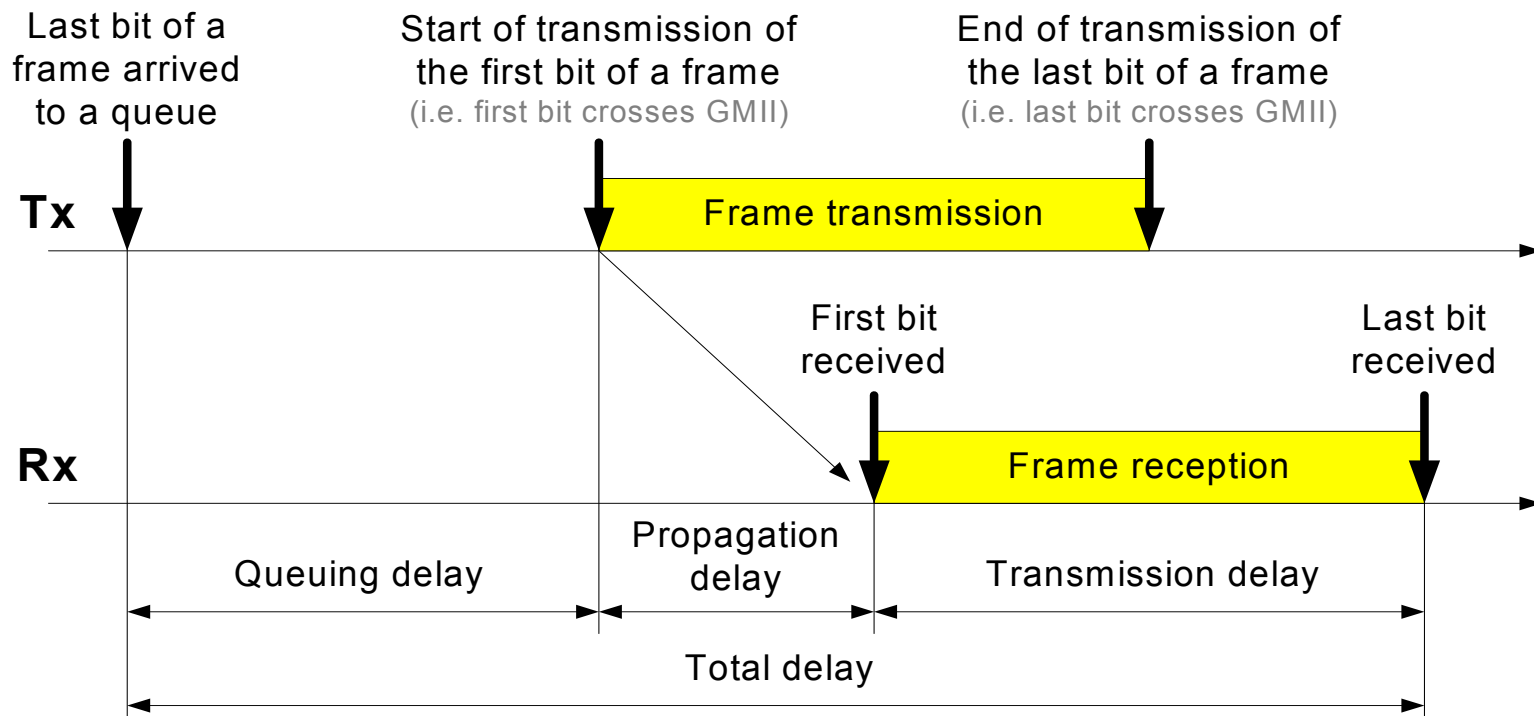
- Max. Rate is not guaranteed.

# Packet Loss Ratio (PLR)

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- PLR is defined only for packets that are in-profile for Min. Rate.
- Packets that are out-of-profile may be dropped if no excess bandwidth is available to subscriber (time-varying condition).
- PLR may be guaranteed or statistical:
  - Guaranteed:  $\Pr( \text{PLR} > X ) = 0$
  - Statistical:  $\Pr( \text{PLR} > X ) < \epsilon$

# Definition of Packet Delay



- Delay consists of
  - Queuing delay (variable)
  - Transmission delay (depends on packet size)
  - Propagation delay (constant).



# Specification of Packet Delay (Ver. 1)

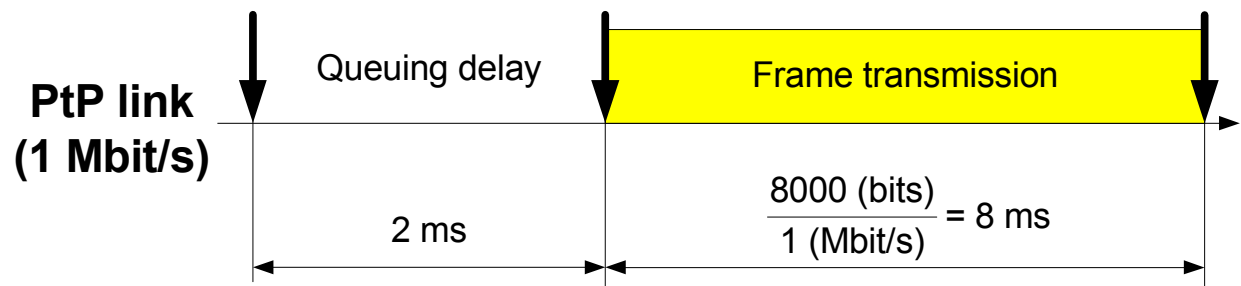
- EPON protocol guarantees delay bound  $D$  if a total of packet queuing delay and packet transmission delay does not exceed a delay that same packet would encounter in a point-to-point link with capacity = Min. Rate and queuing delay  $D$ .

## Example:

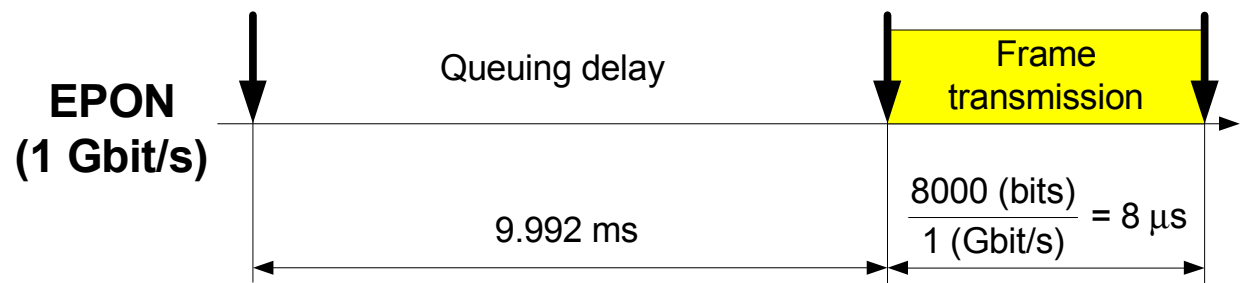
Min. Rate = **1 Mbit/s**

Delay bound = **2 ms**

Packet size = **1000 bytes**



**Packet transmission should begin no later than 9.992 ms after its arrival**



# Specification of Packet Delay (Ver. 2)

- EPON protocol guarantees delay bound  $D$  if a total of packet queuing delay and packet transmission delay does not exceed  $D$ .
- After sending a packet of size  $S$  bytes, protocol may not serve same queue (if load is high) for time interval  $t$

$$t = \frac{S}{\text{Min. Rate}}$$

## Example:

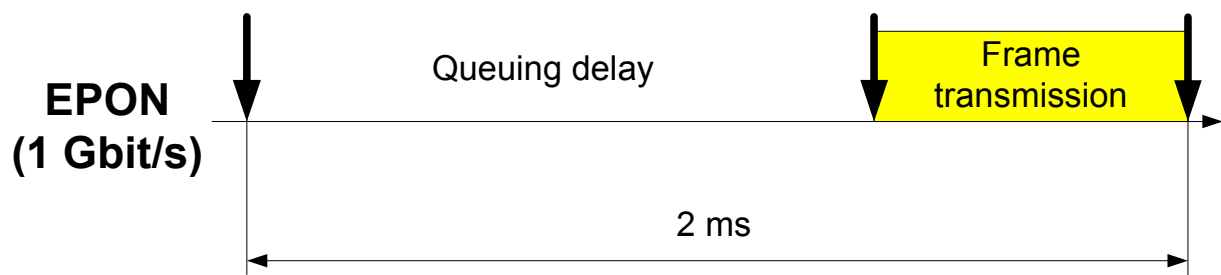
Min. Rate = **1 Mbit/s**

Delay bound = **2 ms**

Packet size = **1000 bytes**

**Packet transmission should begin no later than 1.992 ms after its arrival.**

**Protocol may not serve the queue for 8 ms.**



# Packet Delay

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- Delay may be guaranteed or statistical:
  - Guaranteed:  $\Pr(\text{delay} > D) = 0$
  - Statistical:  $\Pr(\text{delay} > D) < \varepsilon$
- Which delay specification (1 or 2) should we use? For interoperability ONU and OLT should assume the same scheme.
- ITU-T G.114 recommends max. one-way delay in access network  $\leq 1.5$  ms. Should we adopt 1.5 ms delay bound for voice traffic?

# Fairness

- Excess bandwidth must be divided between busy subscribers in a fair manner. Network operators may have different fairness policies.

**Example of dividing 120 Mbps of excess bandwidth between 4 busy subscribers**

Subscriber	Min. Rate	Max. Rate	Equal Share	Equal Fraction of Min. Rate	Equal Fraction of Max. Rate
A	1 Mbps	50 Mbps	30 Mbps	8 Mbps	20 Mbps
B	4 Mbps	50 Mbps	30 Mbps	32 Mbps	20 Mbps
C	4 Mbps	100 Mbps	30 Mbps	32 Mbps	40 Mbps
D	6 Mbps	100 Mbps	30 Mbps	48 Mbps	40 Mbps

- Protocol should allow excess bandwidth redistribution within ONUs as well as between ONUs.

# Why this presentation?

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- Need to consider what EPON SYSTEM MUST BE ABLE to do, even if a particular vendor decides that its product only needs a subset of that .
- Protocol design is affected by these decisions

Example:

$32 \text{ ONUs} \times 64 \text{ subscribers per ONU} \times 3 \text{ classes of traffic per subscriber} = 6144 \text{ queues per EPON}$

- GATE and REPORT message per queue or per user
  - May not be possible to meet delay requirements, scalability
- GATE and REPORT message per ONU
  - May not be possible to fairly share excess bandwidth.