

EPON Scheduling Protocol Requirements

A system-level perspective

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Area of Application

- 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

- 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.

	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%

Example of SLA for subscriber A

Why Rate Limit is Necessary?

- 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)

- Defined as a minimum amount of data (W bytes) that subscriber will be able to send over interval ΔT (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 **Min. Rate = 0**

Maximum Rate (Excess Bandwidth)

- 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

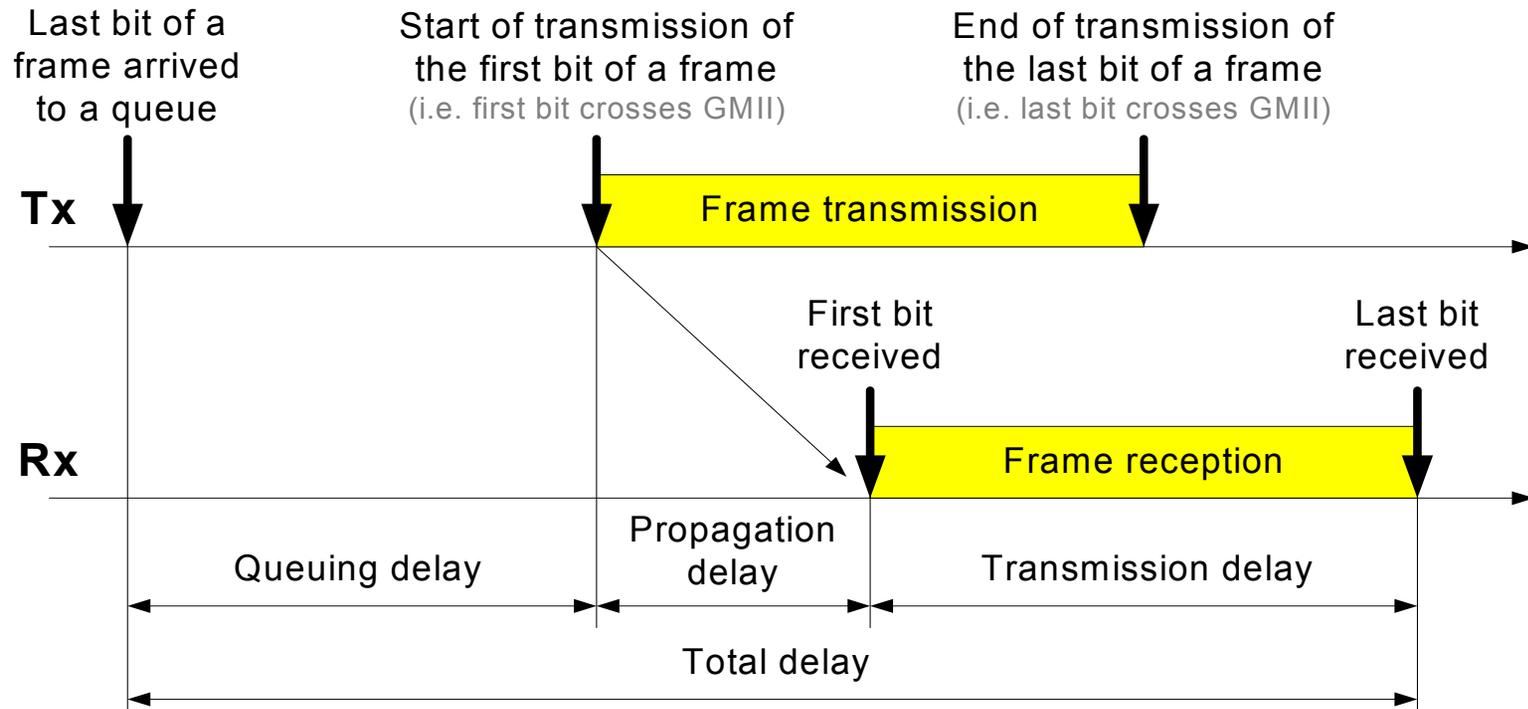
Min. Rate \leq Max. Rate $<$ EPON line rate

- Max. Rate is not guaranteed.

Packet Loss Ratio (PLR)

- 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)

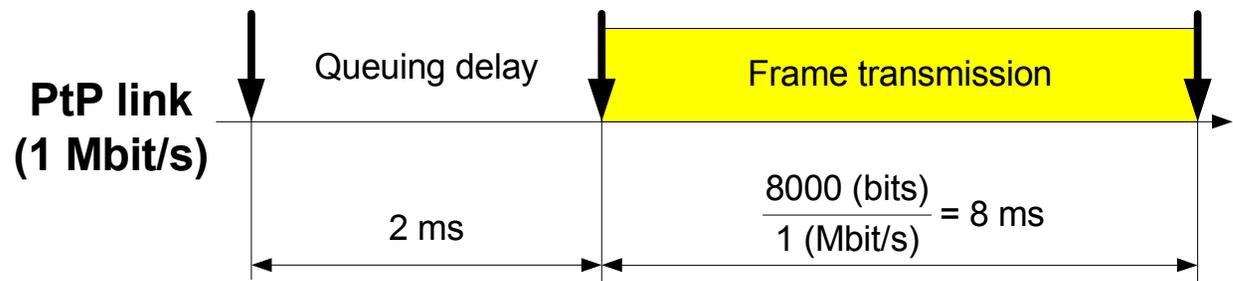
- EPON protocol guarantees delay bound D if a total of packet queuing delay and packet transmission delay does not exceed a delay that same packet would encounter in a point-to-point link with capacity = Min. Rate and queuing delay D .

Example:

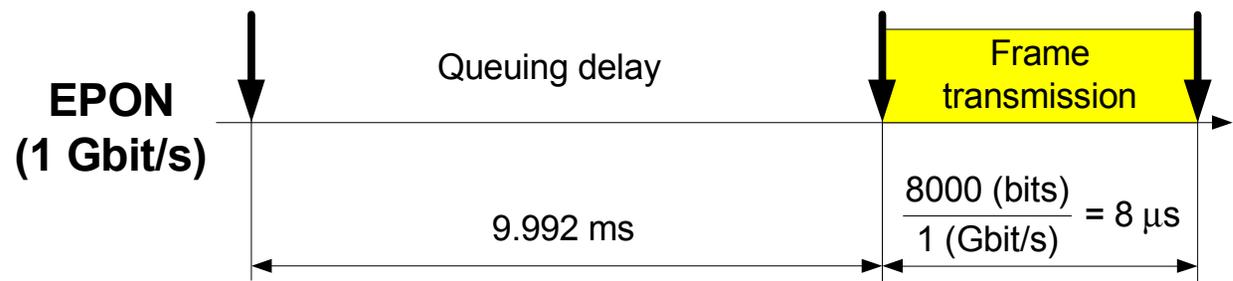
Min. Rate = **1 Mbit/s**

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:

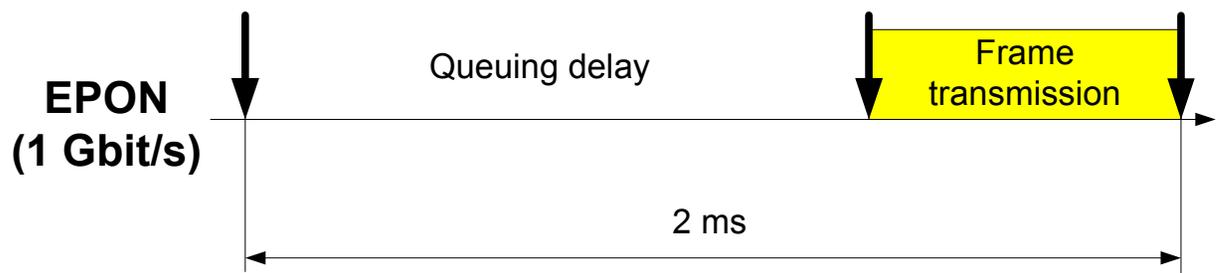
Min. Rate = **1 Mbit/s**

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

- Delay may be guaranteed or statistical:
 - Guaranteed: $\Pr(\text{delay} > D) = 0$
 - Statistical: $\Pr(\text{delay} > D) < \epsilon$
- 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 ≤ 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?

- 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 ONUs × 64 subscribers per ONU × 3 classes of traffic per subscriber = 6144 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.