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 (Guaranteed) Bandwidth (B_{MIN})
  - Maximum (Excess) Bandwidth (B_{MAX})
  - Maximum Frame Loss Ratio (L_{MAX})
  - Maximum Frame Delay (D_{MAX})
  - (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
B_{MIN}	128 Kbps	16 Mbps	0 Mbps
B_{MAX}	128 Kbps	16 Mbps	40 Mbps
D_{MAX}	2 ms	8 ms	20 ms
L_{MAX}	0.1%	0.01%	0.5%

Why Bandwidth Limit is Necessary?

- Minimum bandwidth B_{MIN} guarantees performance under heavy load. Subscribers (especially businesses) want to have fixed bandwidth available at any time (under any load).

- Maximum bandwidth B_{MAX} defines a frame admission policy. Without maximum bandwidth limit users may get better service than they entitled to.

Minimum (Guaranteed) Bandwidth

- Defined as a minimum amount of data (W_{MIN} bytes) that subscriber will be able to send over interval ΔT

$$B_{MIN} = W_{MIN} / \Delta T$$

- If a subscriber has less than W bytes ready, the excess bandwidth may be given to other subscribers

- Min. bandwidth should be guaranteed regardless of network load (should not be oversubscribed)

$$\sum B_{MIN} \leq EPON\ line\ rate$$

- A particular SLA may specify $B_{MIN} = 0$ (best effort)

Maximum (Excess) Bandwidth

- A busy subscriber may be given excess bandwidth if other subscribers are idle or if EPON is under-subscribed

- Defined as a maximum amount of data (W_{MAX} bytes) that subscriber will be able to send over interval ΔT

$$B_{MAX} = W_{MAX} / \Delta T$$

- Max. bandwidth is the upper limit on excess bandwidth given to a subscriber. During interval ΔT (s.t. queue is not empty during ΔT)

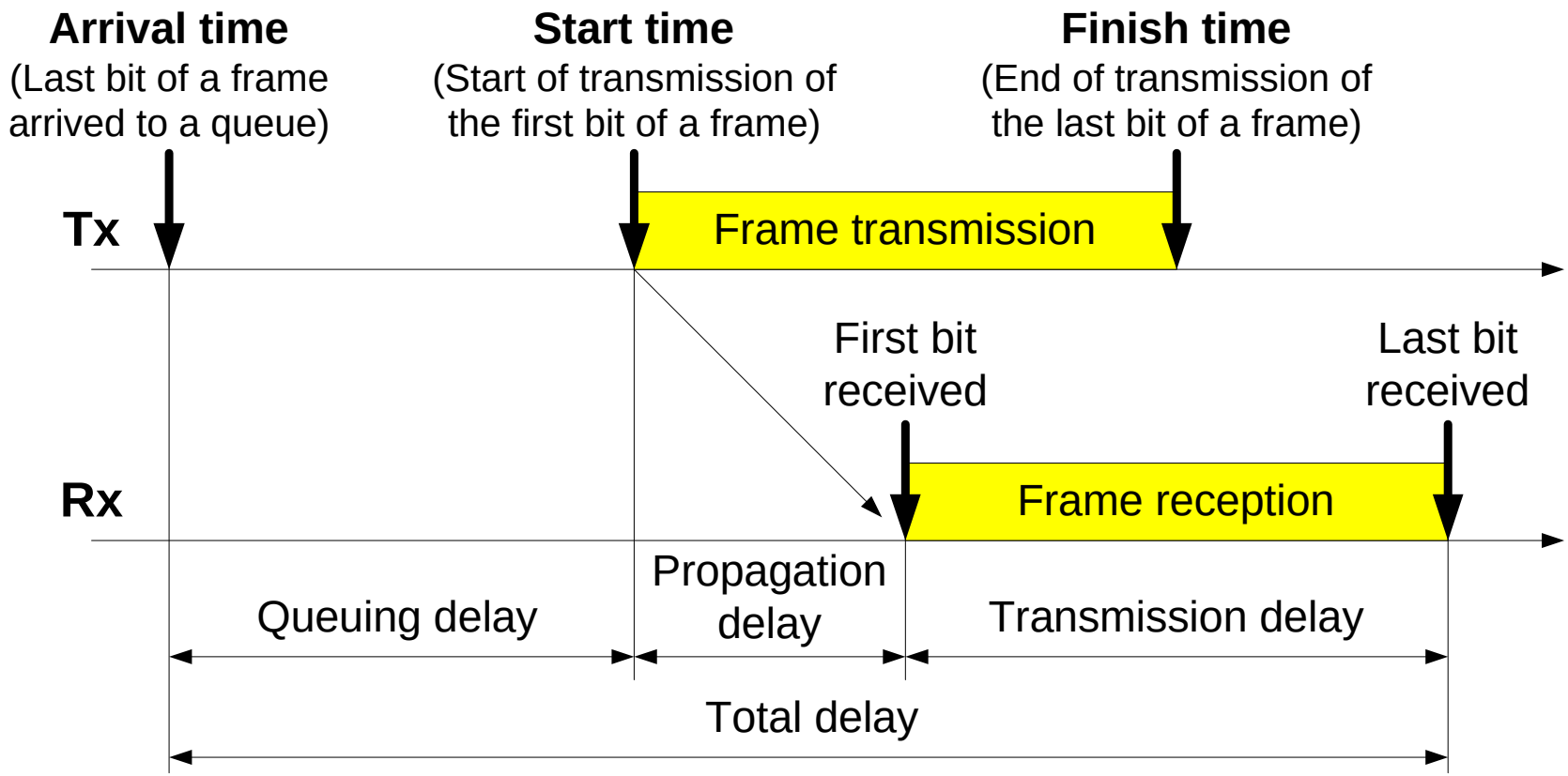
$$B_{MIN} \leq \text{subscriber's bandwidth} \leq B_{MAX}$$

- Max. bandwidth is not guaranteed.

Loss Ratio (LR)

- Loss ratio is defined (enforced) only for frames that are conformant (in-profile) with the minimum bandwidth limit.
- Frames that are out-of-profile may be dropped if no excess bandwidth is available to subscriber (time-varying condition).
- LR may be guaranteed or statistical:
  - Guaranteed: $Pr(LR > L_{MAX}) = 0$
  - Statistical: $Pr(LR > L_{MAX}) < \varepsilon$

Components of Frame Delay



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

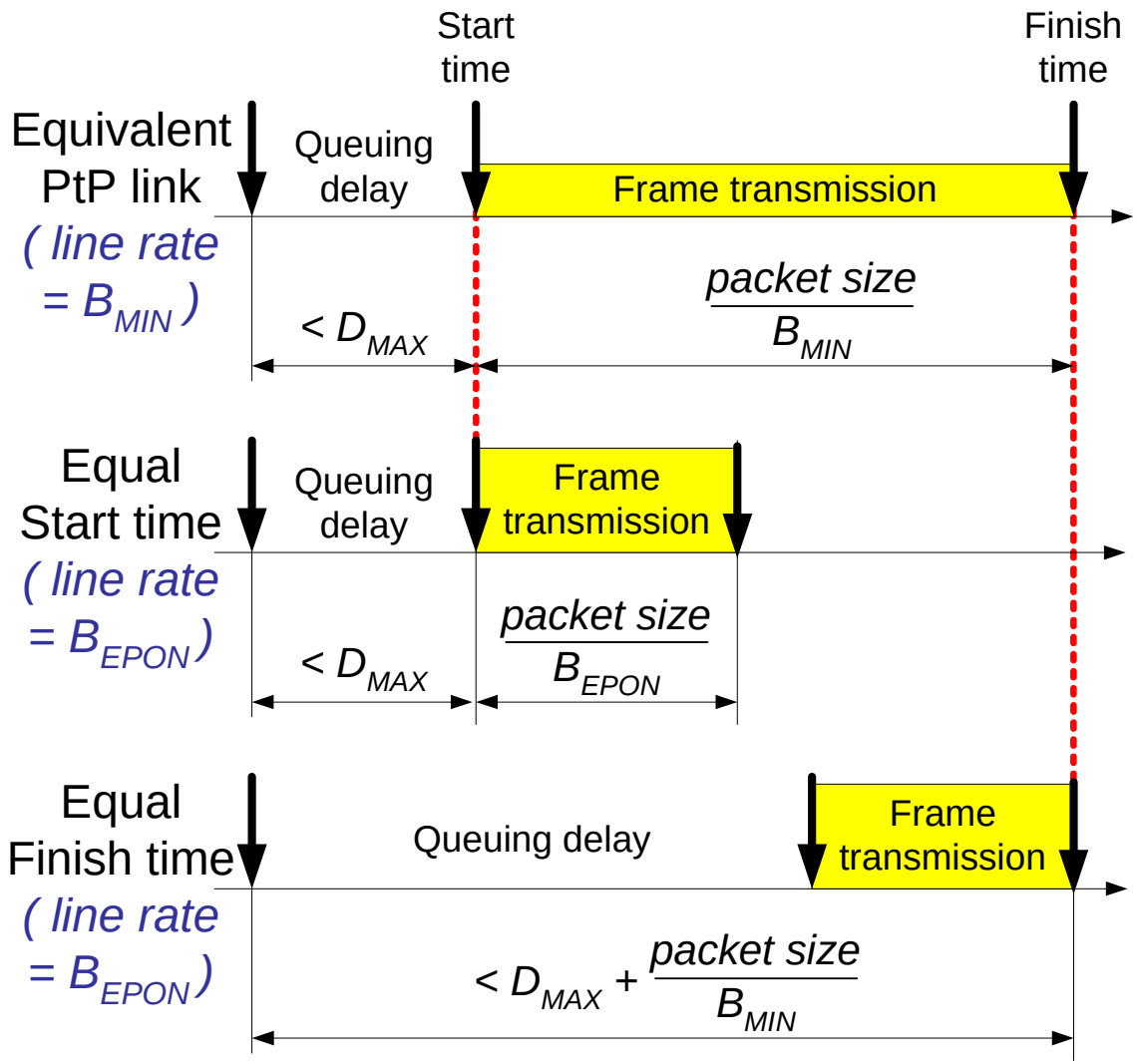
Definition(s) of Frame Delay

Providing guaranteed bandwidth B_{MIN} to a subscriber should be equivalent to providing a dedicated PtP link with line rate ≥ B_{MIN}

Def 1: Start time of frame transmission should not exceed start time in an equivalent PtP link

Or

Def 2: Finish time of frame transmission should not exceed finish time in an equivalent PtP link



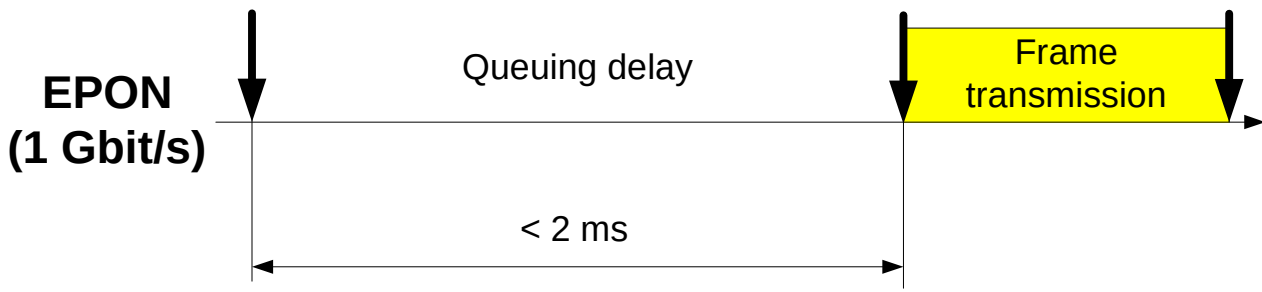
Delay Definition 1 (Based on start time)

- EPON protocol guarantees delay bound D_{MAX} if frame queuing delay does not exceed D_{MAX}.

Example:

D_{MAX} = **2 ms**

Frame transmission should begin no later than 2 ms after its arrival.



Delay Definition 2 (Based on finish time)

- EPON protocol guarantees delay bound D_{MAX} if a total of frame queuing delay and transmission delay does not exceed a delay the same frame would encounter in a point-to-point link with line rate $\geq B_{MIN}$ and queuing delay $\leq D_{MAX}$

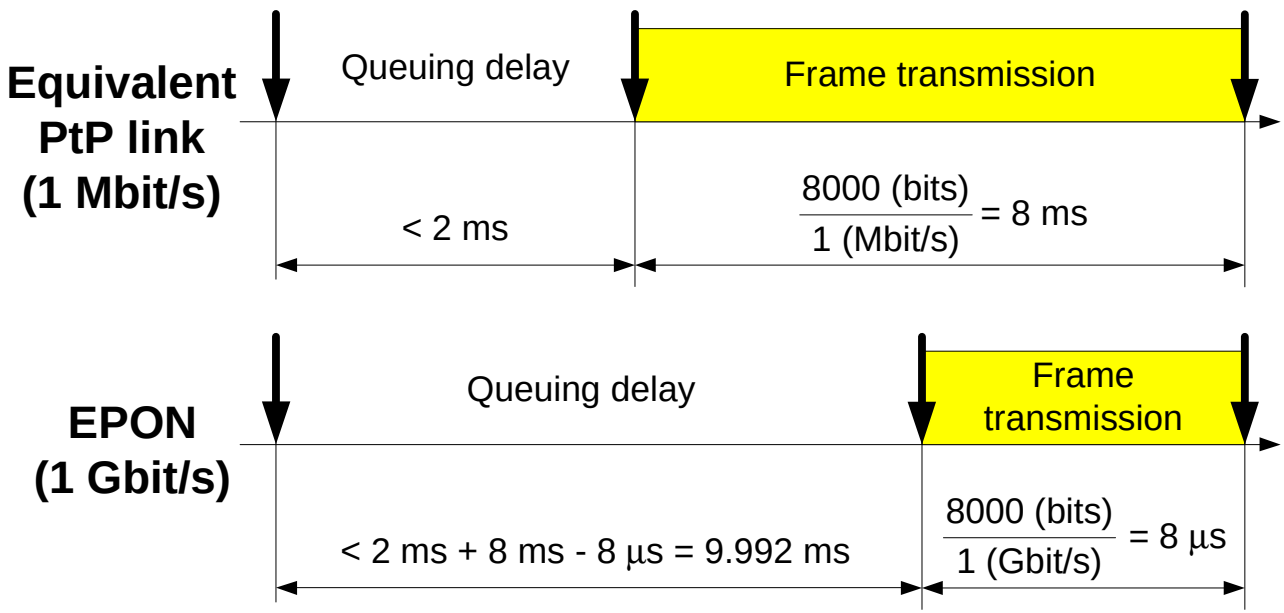
Example:

B_{MIN} = **1 Mbit/s**

D_{MAX} = **2 ms**

Frame size = **1000 bytes**

Frame transmission should begin no later than 9.992 ms after its arrival



Packet Delay

- Delay may be guaranteed or statistical:
  - Guaranteed: $Pr(delay > D_{MAX}) = 0$
  - Statistical: $Pr(delay > D_{MAX}) < \varepsilon$

- Which delay definition (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 protocol be able to support 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	B_{MIN}	B_{MAX}	Equal Share	Equal Fraction of B_{MIN}	Equal Fraction of B_{MAX}
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.

Questions

1. Should we demonstrate that it is possible to use MPCP with “some basic” allocation/scheduling algorithm and guarantee min. and max. bandwidth, delay and loss bounds?

2. Which delay definition should we use: based on start time or based on finish time?

3. Should we guarantee 1.5 ms max. delay for voice traffic?

4. Should we set a limit on total number of queues (individual SLAs) supported by one EPON system?