An IEEE 802.1 TSN Timing Model

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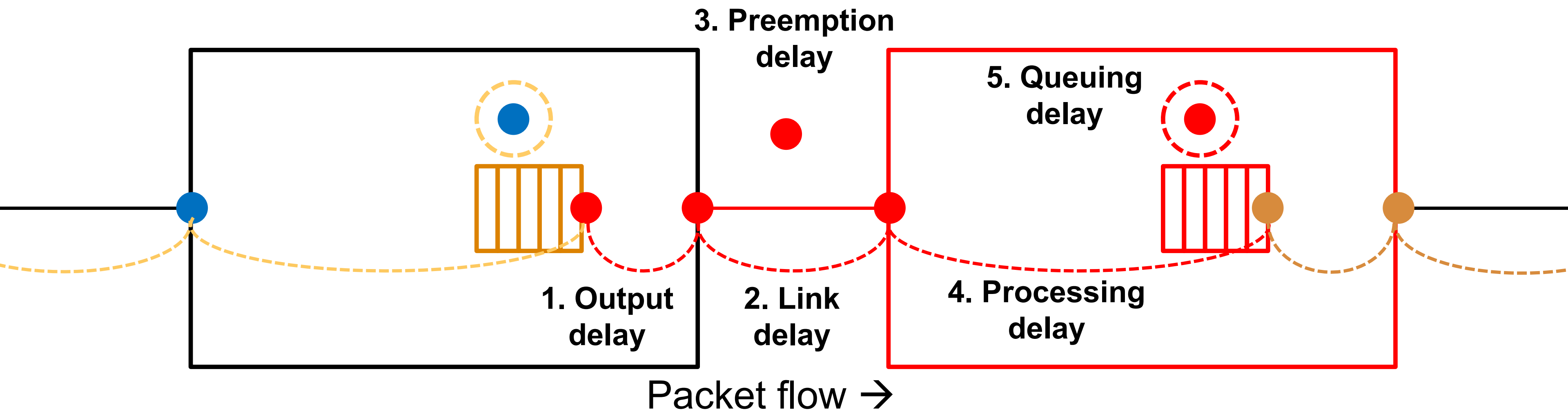
Disclaimers

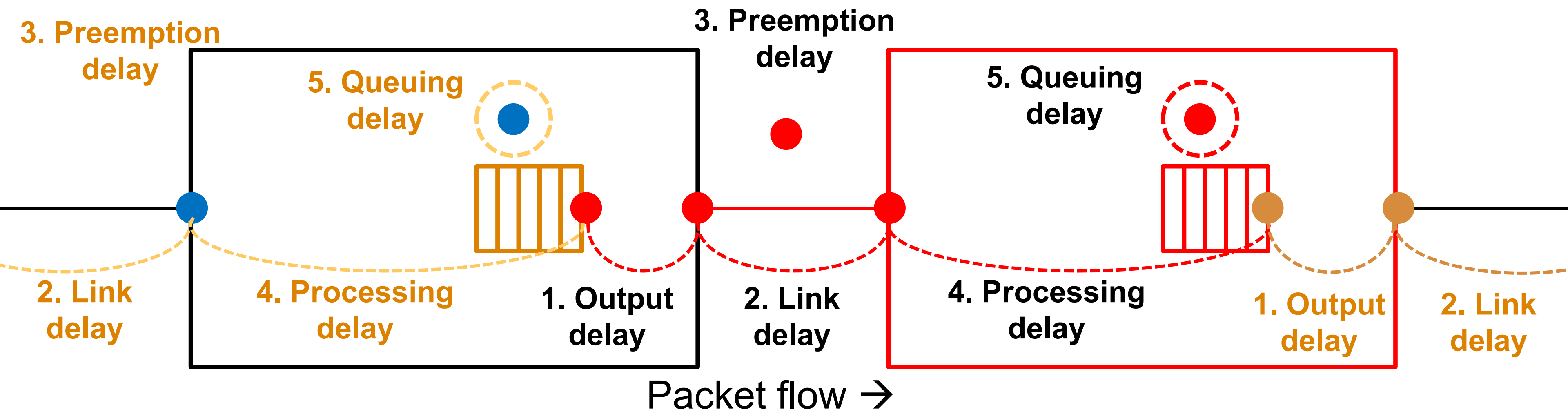
- I haven’t done the math required to prove the assertions made in this presentation.
- The specific names (processing delay, output delay, etc.) used here are not necessarily the same as in the academic literature, in IEEE standards or drafts, or in other presentations.

Overall picture



1. Output delay: Selected for transmission to PTP transmit time.
2. Link delay: PTP transmit time to PTP receive time (both are at the start of the frame).
3. Preemption delay: Time taken by preempting frames and overhead.
4. Processing delay: PTP receive time (start of frame) to ready for selection for transmission.
5. Queuing delay: Ready for selection to selection for transmission.

Overall picture



- Note that any variation in Output delay (1), Link delay (2), and Processing delay (4) all affect the number of buffers needed in **next** queue.
- In particular, note that variations in Output delay (1) require buffers in the next-hop's queues, not the queues in the system in which the Output delay variation occurs. That is why we need to separate Output delay (1) from Processing delay (4).

Processing delay and cut-through

- In order to separate preemption delays and cut-through issues, the (frame size) * (link data rate) (often called “transmission delay”) gets factored into the processing delay (4) of the receiving hop.
- Thus, if no cut-through, processing delay varies with packet size and input link data rate.
- If cut-through is enabled, processing delay varies with input link data rate ((link rate) * (minimum header size for processing)), but not frame size. With cut-through, frame size does not affect per-hop latency.
- The last-hop transmission time of the last part of a cut-through frame (or any other frame) is included in the receiving end system’s “processing time”.

Computing required buffer sizes

The amount of buffering needed in a given queue is a function of:

1. The interaction between the worst-case gaps and bursts of the previous-hop queue(s) and the given queue.
2. The difference between the best- and worst-case sums of times 1-4.

- The reason that 1-4 are separated at all is that they come from different sources:
  - Output delay is an input ultimately obtained from the previous hop.
  - Link delay is measured (PTP) and very constant.
  - Preemption delay may or may not be controlled.
  - Processing delay is local to the queue affected (plus link speeds).

Computing worst-case latency

- We want to compute the worst-case latency independently per hop, not on a dynamic, multi-hop basis. This makes the calculation feasible in a large, dynamic network.
- Worst-case latency is based on the steady state of the queues in every hop. That steady state is reached when there are enough frames in each queue to ensure that, when it is time to transmit a frame, there is always one to transmit.
- Worst-case latency = sum(worst-case Queuing delay from interactions of queuing algorithms) + sum(worst-case times for Output delay, Link delay, Preemption delay, and Processing delay).

  [Here is where some good math would be very helpful.]

Worst-case latency and preemption

- With a suitably rate-limited (or better yet, scheduled) high-priority preempting TSN streams, it should be possible to compute their worst-case effect on lower-priority preemptable TSN streams.
- The term for Preemption delay (3) presented here may work for this purpose.
- This is for future study.

A note on end-to-end latency

- In my opinion, the measure of end-to-end latency that is useful to an applications designer (but which cannot necessarily be measured) is:
  - From ready-for-transmit selection in the transmitting station, which pretty much equals ”time sent by the application process”,
  - To ready-for-transmit selection in the receiving station, which means “packet received and can be sent up the stack”.
- Note that the transmitting end system requires some average number of frames buffered in its queue for the same reasons as in a relay node. This means that end-to-end latency includes Queuing delay (5) in the transmitting end system.

Actions to be taken

- This or some other timing model for TSN should be incorporated into IEEE 802.1Q (or, if we get ambitious, into a queuing model document).
- Each queuing discipline should be then described in terms that incorporate it into the selected timing model. In particular, the calculation of latency due to last-hop/next-hop queue interactions needs to be described for each allowed pair of queuing disciplines.

Thank you