Deadline based Forwarding

draft-peng-detnet-deadline-based-forwarding-05

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Updates

- Buffer size design.
- Give an illustration of schedulabitliy conditions for leaky bucket arrival constraint function.
  - Initially describe the delay resource reservation.
- Further describe the conditions for on-time mode.
- Admission control on the ingress.
- Overprovision analysis.

Motivations

- To find a potential queuing mechanism to match the requirements for scaling deterministic networks.

- Issues of existing mechanisms:
  - TSN CBS and ATS come with a high latency variance, as the minimum latency is not affected by them.
  - TSN CQF is quite challenging because it requires time synchronization.
  - TSN Multi-CQF only requires frequence synchronization, but with complex admission control and low bandwidth resource utilization.
  - The widely used priority based queuing scheme may give better average latency, but with worst case latency.

- This document propose a variants of EDF (Earliest Deadline Forwarding) scheduling, to dynamically rotate the priority of each aggregated FIFO queue and uniformly provide bounded delay/jitter.

Overview

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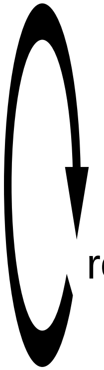
+--------------------------------+   +--------------------------------+
| Deadline Queue Group:          |   | Deadline Queue Group:          |
|    queue-A(CT=30us)            |   |    queue-A(CT=29us)            |
|      in-time sub-queue ######  |   |      in-time sub-queue ######  |
|      on-time sub-queue ######  |   |      on-time sub-queue ######  |
|    queue-B(CT=20us)            |   |    queue-B(CT=19us)            |
|      in-time sub-queue ######  |   |      in-time sub-queue ######  |
|      on-time sub-queue ######  |   |      on-time sub-queue ######  |
|    queue-C(CT=10us)            |   |    queue-C(CT=9us)             |
|      in-time sub-queue ######  |   |      in-time sub-queue ######  |
|      on-time sub-queue ######  |   |      on-time sub-queue ######  |
|    queue-D(CT=0us)             |   |    queue-D(CT=0us)             |
|      in-time sub-queue ######  |   |      in-time sub-queue ######  |
|      on-time sub-queue ######  |   |      on-time sub-queue ######  |
+--------------------------------+   +--------------------------------+

+--------------------------------+   +--------------------------------+
| Non-deadline Queue Group:      |   | Non-deadline Queue Group:      |
|        #################       |   |        #################       |
|        #################       |   |        #################       |
|        #################       |   |        #################       |
+--------------------------------+   +--------------------------------+

-o-----------------------------------o------------------------------->
 T0                                  T0+1us                       time
```



rotation

- Each deadline queue has **CT** (Count-down Time) that is decreased by **TI** (rotation timer interael), and **AT** (Authorization Time) that is for sending duration.
- A packet with Allowable Queuing Delay **(Q),** computed by Planned Residence Time **(D)** and Accumulated Residence Variation **(E)**, will put to a deadline queue, meeting CT ≤ Q < CT+AT.

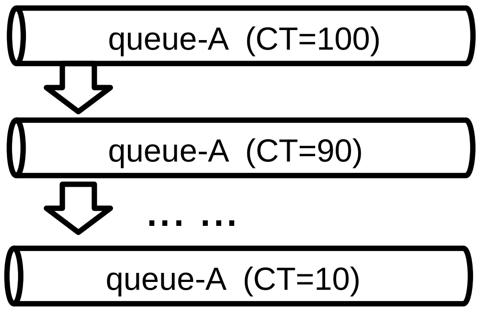
Update-1: Buffer size design

- Each deadline queue is not bound to a fixed delay level (d_i), and it will actually store all levels of traffic during its CT decrement process.

  e.g:
  - At T0, d_{100} traffic arrived and inserted to queue-A with CT = 100
  - At T0+10us, d_{90} traffic arrived and inserted to the same queue-A with CT = 90

    ... ...
  - At T0+90us, d_{10} traffic arrived and inserted to the same queue-A with CT = 10

  That is, each level (d_i) of traffic arrived is r_i * AT, where r_i is the averaged bandwidth of level d_i, AT is 10 us.



- Considering the stability condistion $\sum r_i \le C$, then buffer size is designed to C*AT -M, where r_i is the bandwidth resource of level d_i, C is the service rate of the deadline scheduler, M is the maximum interference packet size.

  The burst resource of any level must be less than the full-value, i.e., C*AT - M.

  However, the burst resource of each level will be more small if the bandwidth of other higher priority level can not be negligible.

  When the concurent burst of all levels are received, during the period of maximum level (dn), all bursts can be sent one by one before their deadline.

Update-2: Conditions for Leaky Bucket Constraint

- For the case that n types of planned residence delay levels (d_1, d_2,..., d_n) is supported, and each level d_i has the leaky bucket arrival curve $A_i(t) = b_i + r_i * t$, we have the following conditions:

$$b_1 \le C*d_1 - M$$

$$b_1+b_2 + r_1*(d_2-d_1) + r_2*AT \le C*d_2 - M$$

$$b_1+b_2+b_3 + r_1*(d_3-d_1)+r_2*(d_3-d_2) + (r_2+r_3)*AT \le C*d_3 - M$$

... ...

$$\sum b_i + r_1*(d_n-d_1)+r_2*(d_n-d_2)+...+ r_{n-1}*(d_n-d_{n-1}) + (r_2+...+r_n)*AT \le C*d_n - M$$

- For each level d_i of the link, the parameters (b_i, r_i) is called its delay resource pool that can be reserved by the service.

Update-3: Conditions for On-time Mode

- The on-time mode does not cause the arrival curve to exceed the expected traffic constraint function, however, it is non-work-conserving and waste the opportunity to send packets, cause that some packets may exceed their deadline in the extreme case, e.g, each concurrent b_i is full value (i.e., C*AT - M) .
  - suggest in-time mode for low delay service.
  - suggest in-time or loose on-time mode applied on the transit nodes, and strict on-time on the egress, for low delay jitter service.

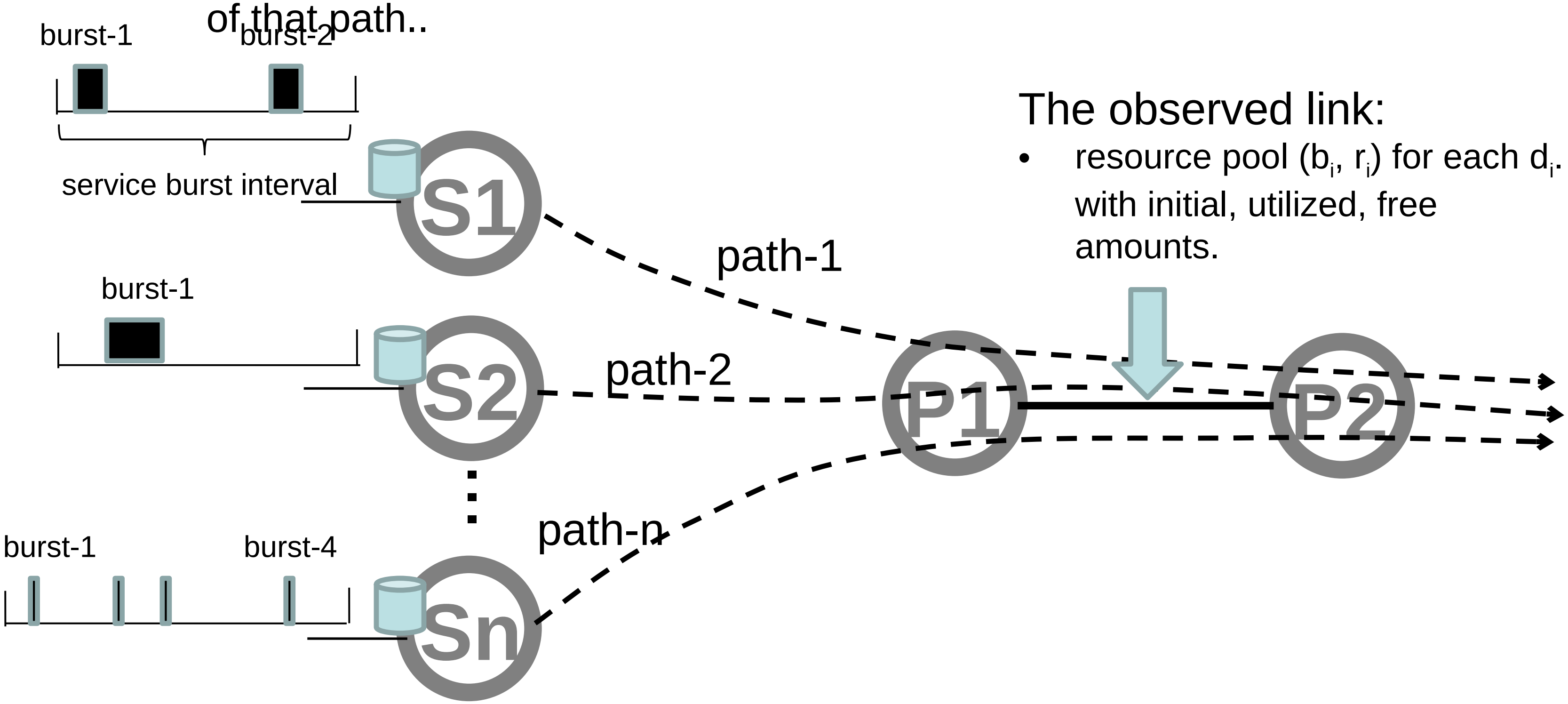
when sum(all b_i) equals to C*AT - M (traffic well-distributed)

when each b_i equals to C*AT - M

in-time	loose on-time	strict on-time
before deadline	before deadline	near deadline, ±AT
before deadline	before deadline	partially exceed deadline
before deadline	partially exceed deadline	exceed deadline, AT~d_n

Update-4: Admission Control on the Ingress

- Traffic regulation on the imcoming port of the ingress node.
  - Leaky bucket depth is set to cover the reserved burst resource.
  - Leaky bucket rate is set to cover the reserved bandwidth resource.
- All path j through the link allocate delay level d_i resources, $\sum(b_{ij}, r_{ij})$, is less than the delay resource pool (b_i, r_i) of that link's delay level d_i.
  - all service k of delay level d_i over path j contribute the reserved resources (b_{ij}, r_{ij}) of that path..

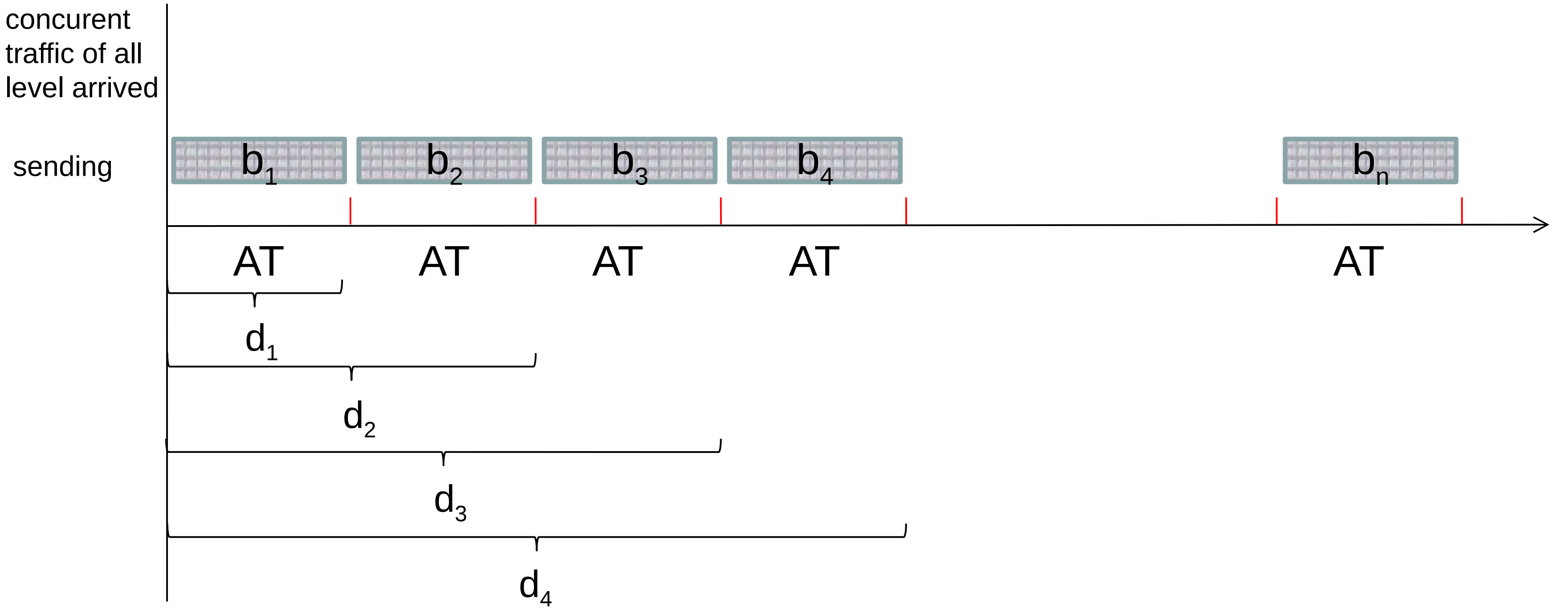


The observed link:

- resource pool (b_i, r_i) for each d_i. with initial, utilized, free amounts.

Update-5: Overprovision Analysis

- According to the schedulability condition, each delay level d_i has its own resources pool (b_i, r_i).
  - In the extreme case, each b_i can be the full value, i.e., C*AT - M, the scheduling procedure maybe like:



  - However, each level does not require the overprovision bandwidth b_i / AT. The bandwidth resource of each level is separate from the burst resource.
    - The requirece bandwidth of service is still according to the burst size per burst interval.

Matching Evaluation of Requirements

- Checklist

Requirement items	Evaluation
3.1. Tolerate Time Asynchrony	Need no time synchronization.
3.2. Support Large Single-hop Propagation Latency	Not affected by link propagation dely.
3.3. Accommodate the Higher Link Speed	Each link sets AT independently according to its speed.
3.4. Be Scalable to The Large Number of Flows	No states per flow on the transit nodes. No overprovision issues.
3.5. Prevent Flow Fluctuation from Disrupting Service	Distinguish fluctuation flow by latency compensation.
3.6. Tolerate Failures of Links or Nodes and Topology Changes	No relationship with queueing mechanism...
3.7. Support Enhancement of Queuing Mechanisms	In-time mode for low latency, on-time mode for low jitter.
4.1. Support Aggregated Flow Identification	Defined delay level (d_1, d_2, ..., d_n)
4.2. Support Information used by Functions ensuring Deterministic Latency	Defined delay resource for each level, protocl extensions to advertise and reserve resource (TBD).
4.3. Support Redundancy Related Fields	No relationship with queueing mechanism...
4.4. Support Explicit Path Selection	No relationship with queueing mechanism...

Next step

- Any questions and comments ?

Thank you!