Impact on credit freeze before gate closing in CBS and GCL integration into TSN

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Toulouse, France

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retour sur innovation

Outline

A (rejected) submission

Boyer and al.: "TSN behaves like *this*, then..."

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- The standart behavior is not the one proposed in previous studies.
- All performance analyses do assumption different from the standard.

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Questions

- Why this choice?

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Strange situation

- The standart behavior is not the one proposed in previous studies.
- All performance analyses do assumption different from the standard.

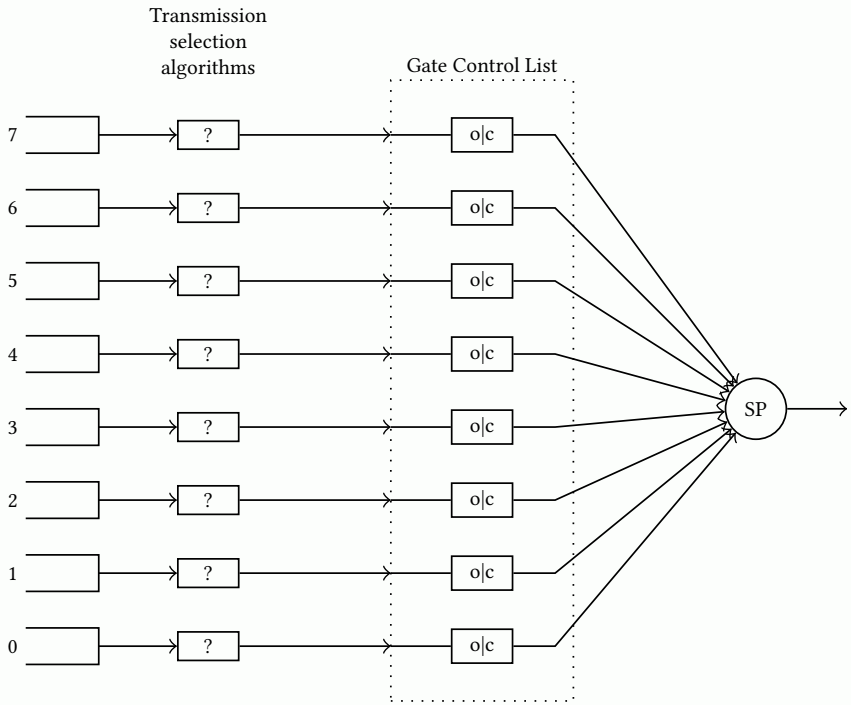
Questions

- Why this choice?
- What are the impacts on performances?

Outline

The Time Sensitive Networking IEEE working group

- Designing a new Ethernet-based real-time network
  - Extention of the work done on Audio Video Bridging (AVB)
- Focus of this study:
  - frame selection at output port
  - interactions between Credit Based Shaper (AVB) and Gate Control List



Outline

Credit-Based Shaper (CBS)

An algorithm to select the next frame when the link is idle.

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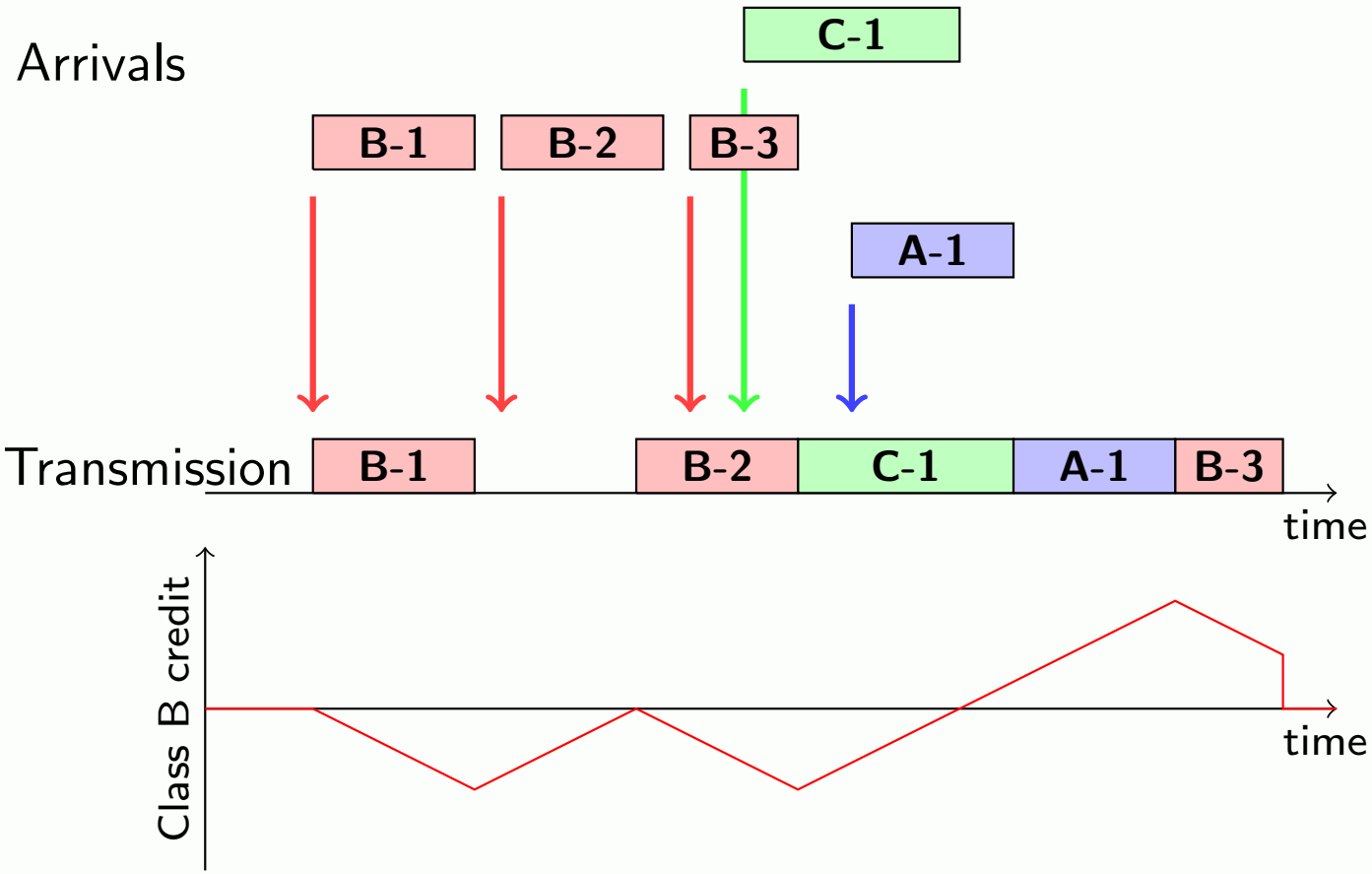
- each queue X as a credit c_X, initialised to 0, and a "idle slope" parameter $id_X \in [0, R]$, with R the link capacity

Credit-Based Shaper (CBS)

An algorithm to select the next frame when the link is idle.

- each queue X as a credit c_X, initialised to 0, and a "idle slope" parameter $id_X \in [0, R]$, with R the link capacity
- the head-of-queue frame can be selected for transmission only if
  - $c_X \geq 0$
  - no higher priority frame can be transmitted
- the credit evolution rules are
  - when a frame is waiting, increase with slope id_X
  - when a frame is transmitted, decrease with slope $id_X - R$
  - when the queue is empty and $c < 0$, increase with slope id_X up to 0
  - when the queue is empty and $c > 0$, reset $c = 0$

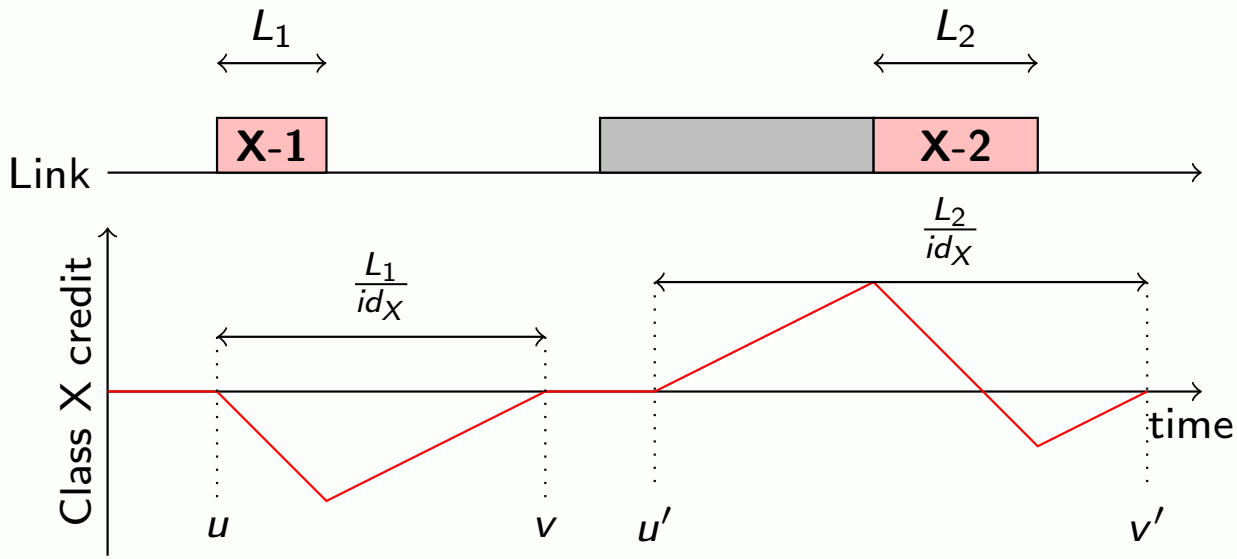
CBS illustration



Priorities: A > B > C

CBS is a shaper and bandwidth limiter

- The "idle slope" parameter is bandwidth allocation: value id_X allows throughput id_X



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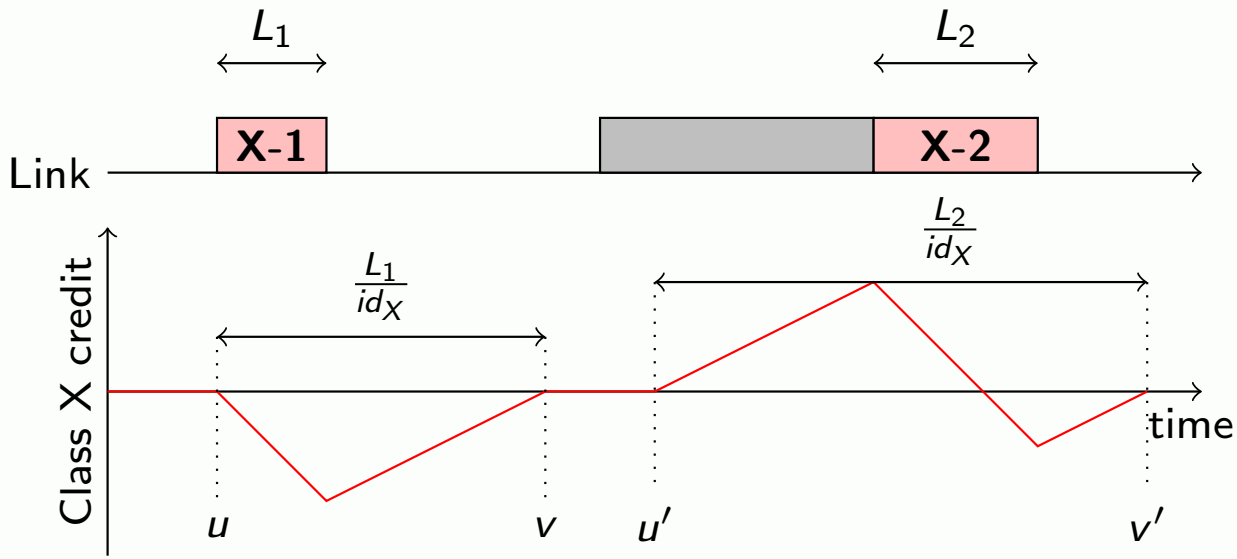
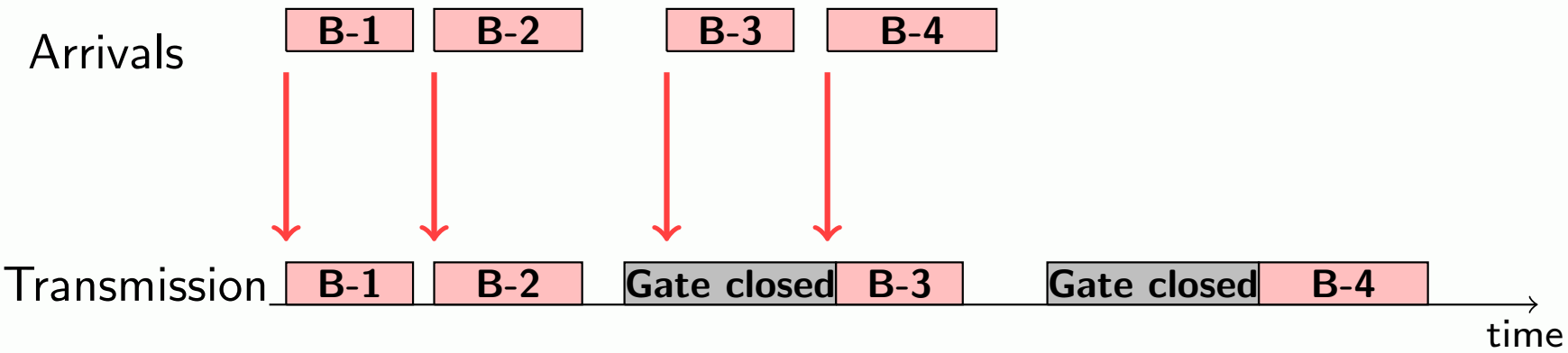


- Higher credit value leads to higher burst.

Outline

The gate control list

- each queue has a gate
- the gate is either open or closed
- a cyclic schedule defines per queue opening and closing time
  $\Rightarrow$ TDMA-like
- a frame can be selected only if
  - the gate is open
  - it can be transmitted up to completion before next closing (avoid encroaching)



Outline

CBS and GCL integration

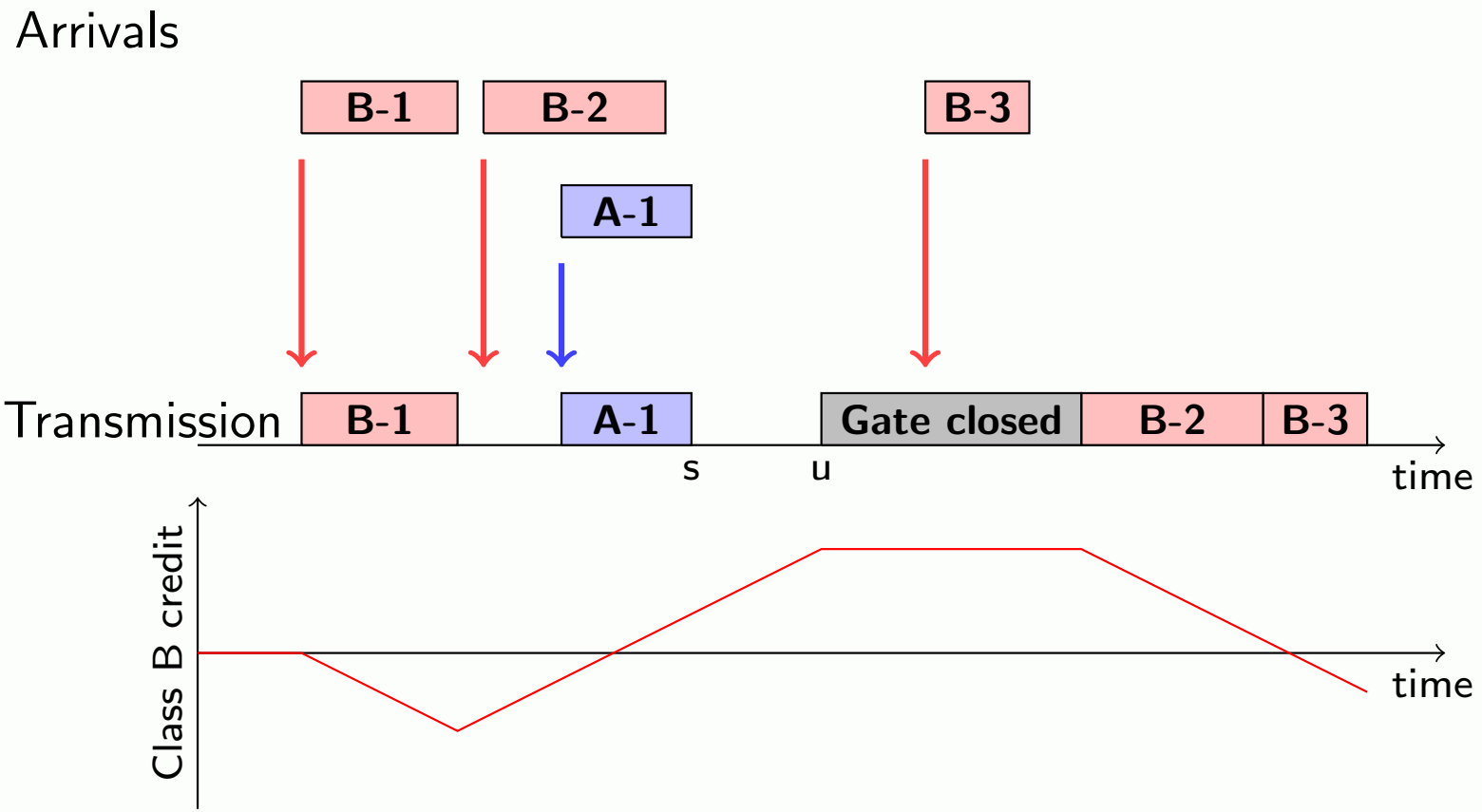
Main principles

- a frame can be selected only if
  - the CBS rules are satisfied ($c_X \geq 0$)
  - the gate is open (and no "near" closing event)
- the credit is frozen when the gate is closed
  - rational: avoid bursts after gate opening (?)

Question

What appends if a frame is blocked to avoid encroaching on next closed interval?

Integration illustration



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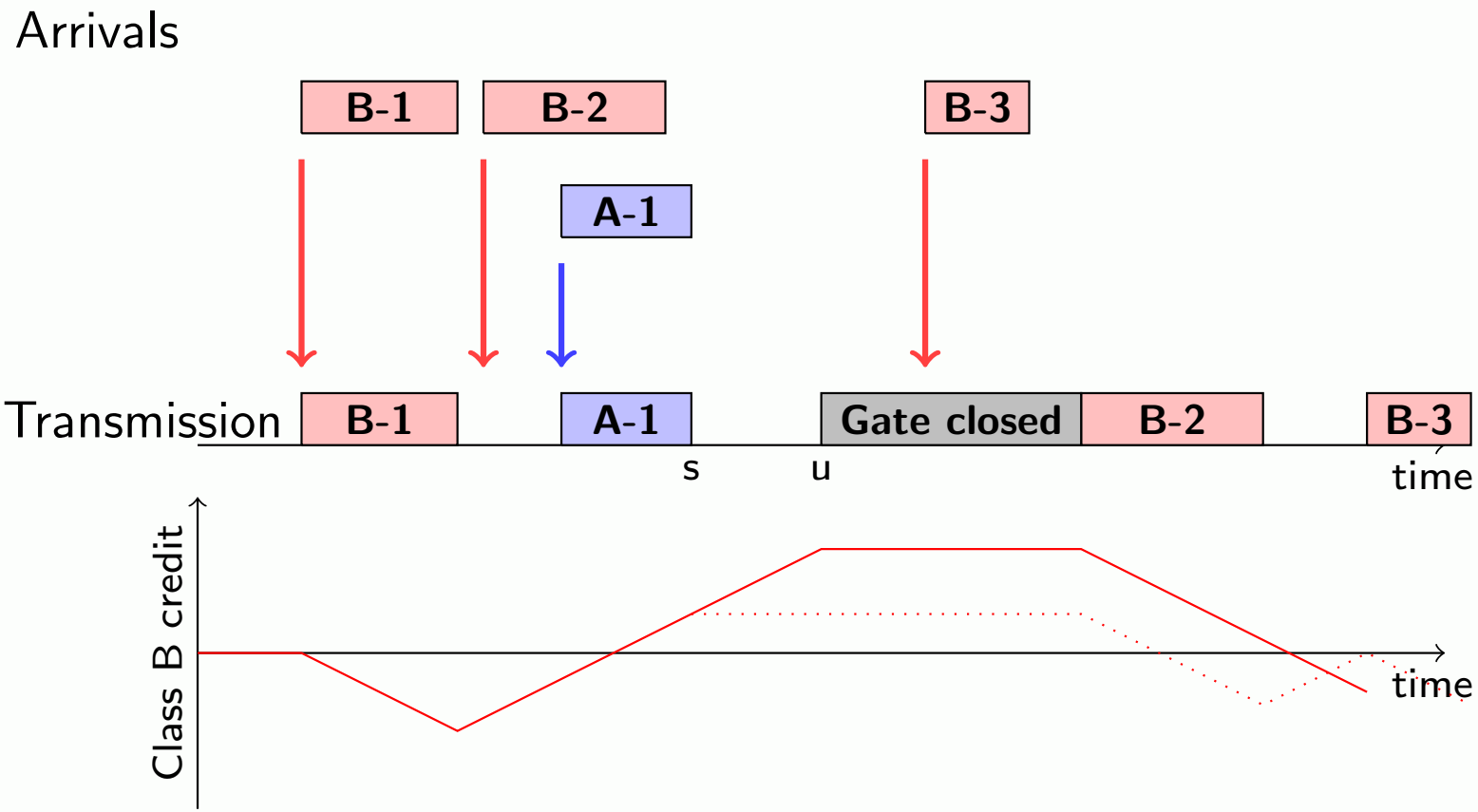
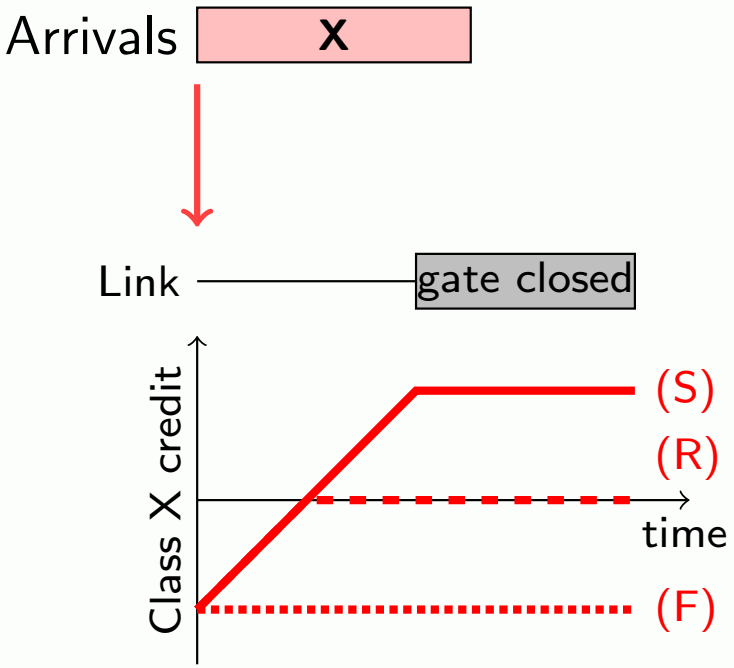


Three rules: S,R,F



- Three rules
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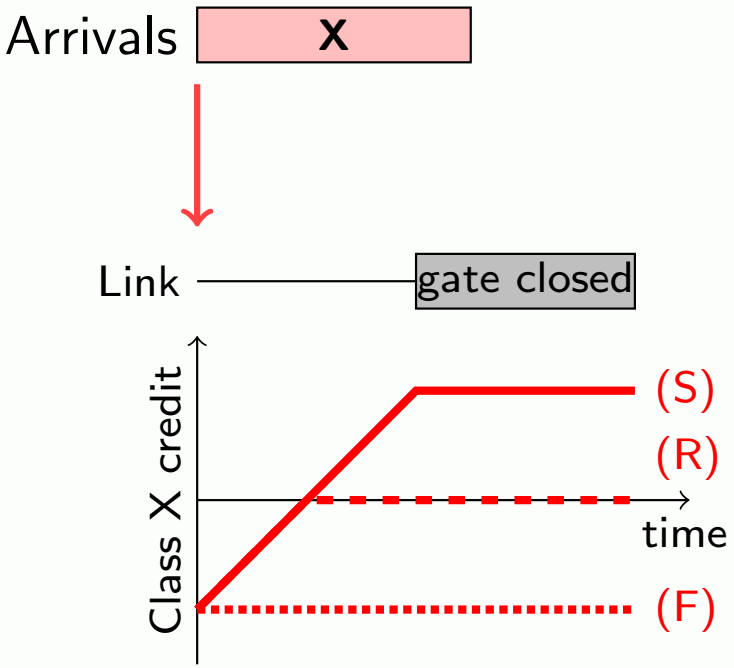
  - F: frozen
  - R: return to zero

Three rules: S,R,F



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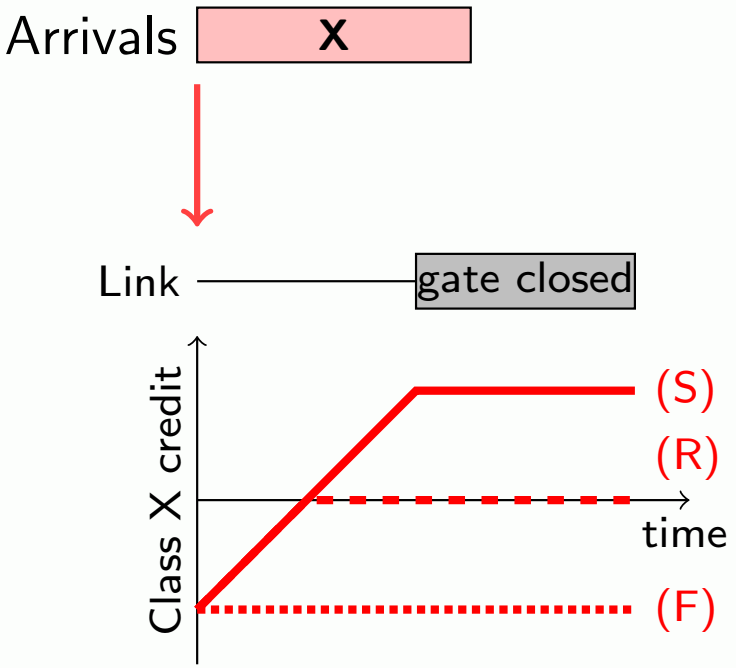

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- Can we quantify the differences?
  - on worst case delays

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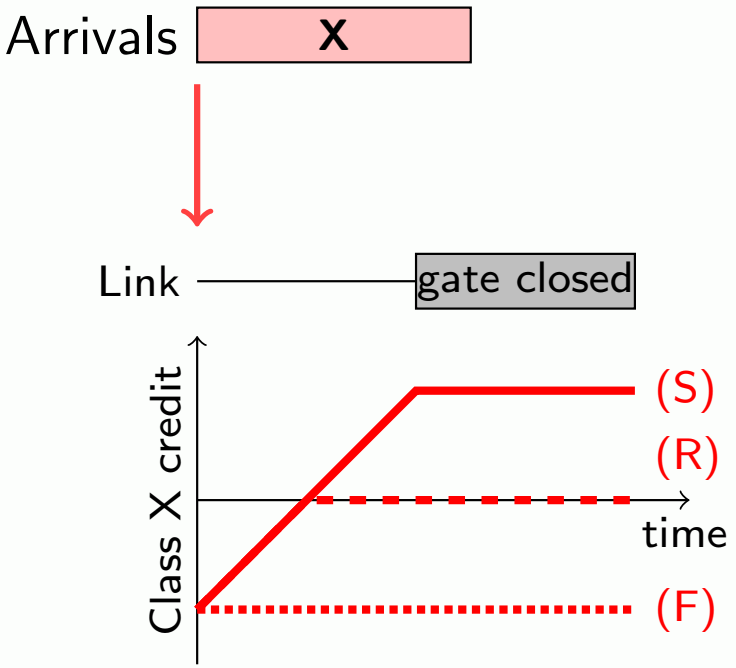

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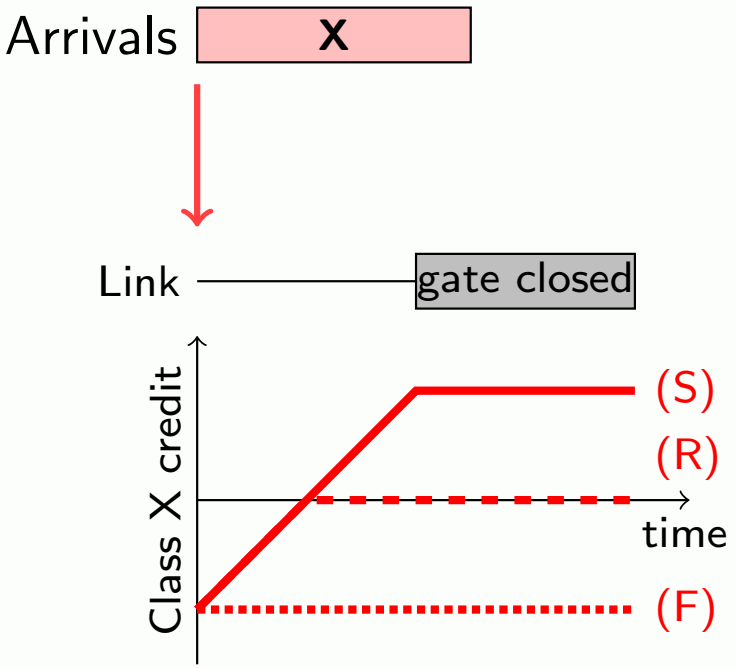

- Three rules
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  - on mean delays

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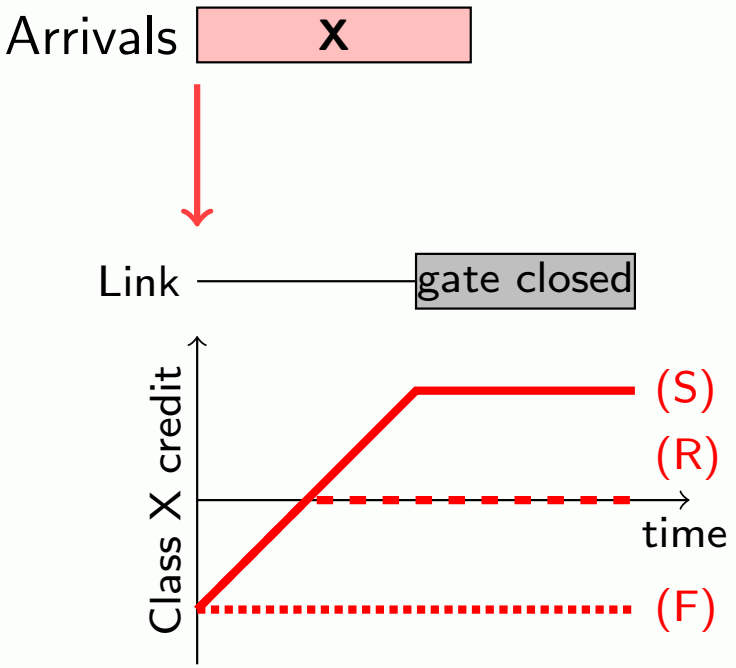

- Three rules
  - S: standard
  - F: frozen
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- Can we quantify the differences?
  - on worst case delays another paper
  - on mean delays simulations

Outline

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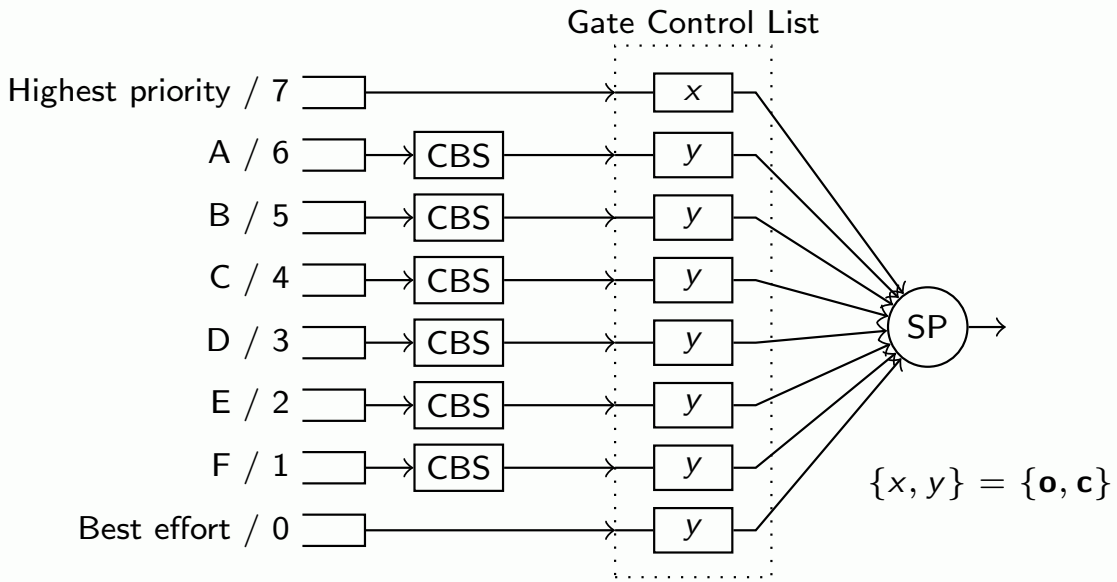
Simulated system

Single TSN/CBS+CCL port

- a high-priority queue, without shaper
- 3 CBS queues, A, B, C
- one best-effort queue (lower priority, no shaper)
- exclusive gating:
  - when the high-priority gate is open, all others are closed
  - when the high-priority gate is closed, all others are open



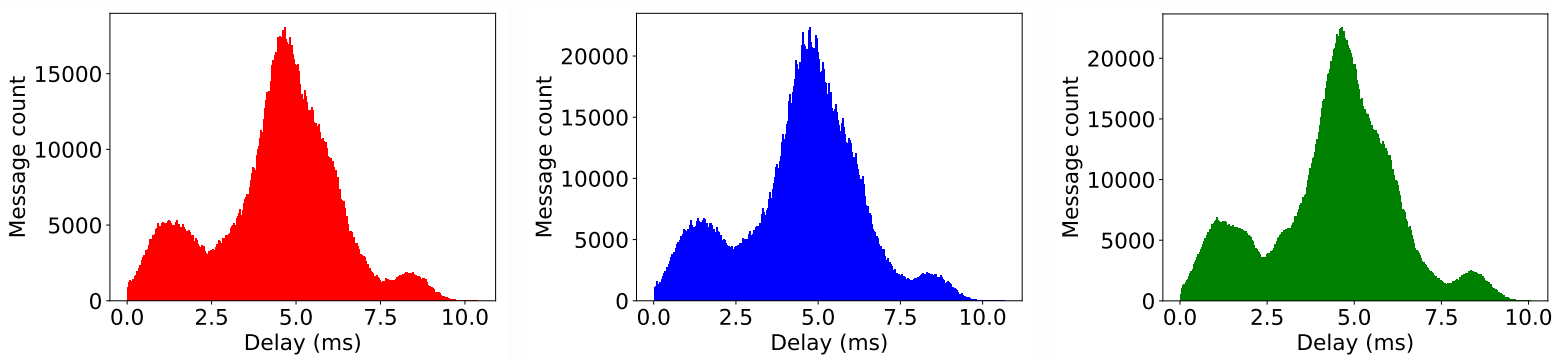
Simulation parameters

- port bandwidth: 100Mb/s
- gate cycle: 1s
- CBS gates closed 20% of the time with two policies
  - random: 1000 intervals, with duration 0.2ms each, randomly set (without overlaping)
  - uniform: one closed interval each ms
    - 400 with duration 0.1ms
    - 400 with duration 0.2ms
    - 200 with duration 0.4ms
- each CBS queue is shared by 20 periodic flows of 1Mb/s throughput each
  - 50 simulations of duration 5s
  - random offset for each flow for each simulation
- the best-effort queue is always ready to send a frame

Outline

Same distribution for all queues A, B, C

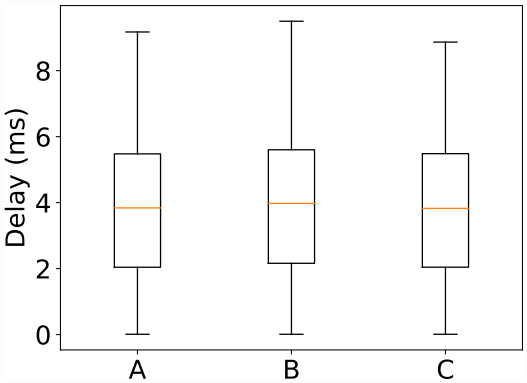
The delay distribution shape is independent of the class.
$\Rightarrow$ good quality of CBS shaping
$\Rightarrow$ only min/max/average/Q1/Q3 in next figures



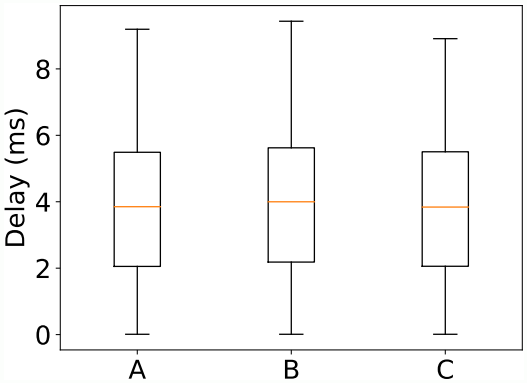
(a) Class A (b) Class B (c) Class C

Per class frame delay distribution for policy S, random gate closing.

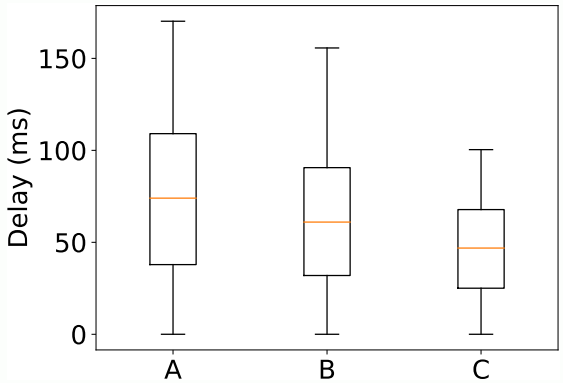
Uniform (a,b,c) and random (d,e,f) gate closing



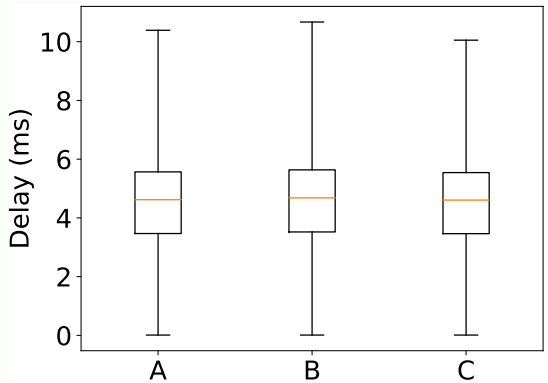
(a) Policy S



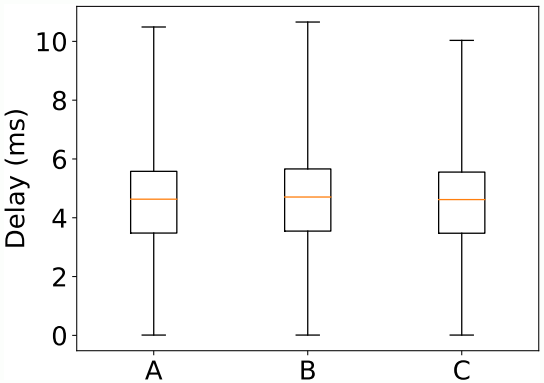
(b) Policy R



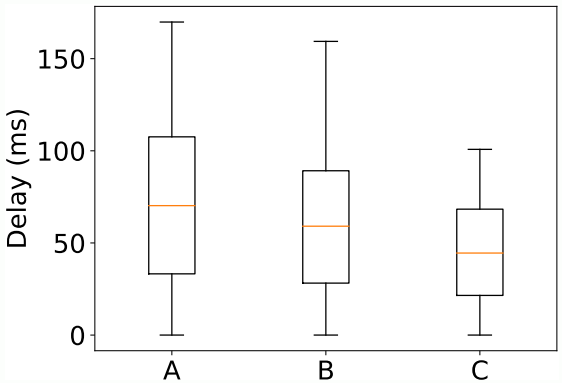
(c) Policy F



(d) Policy S



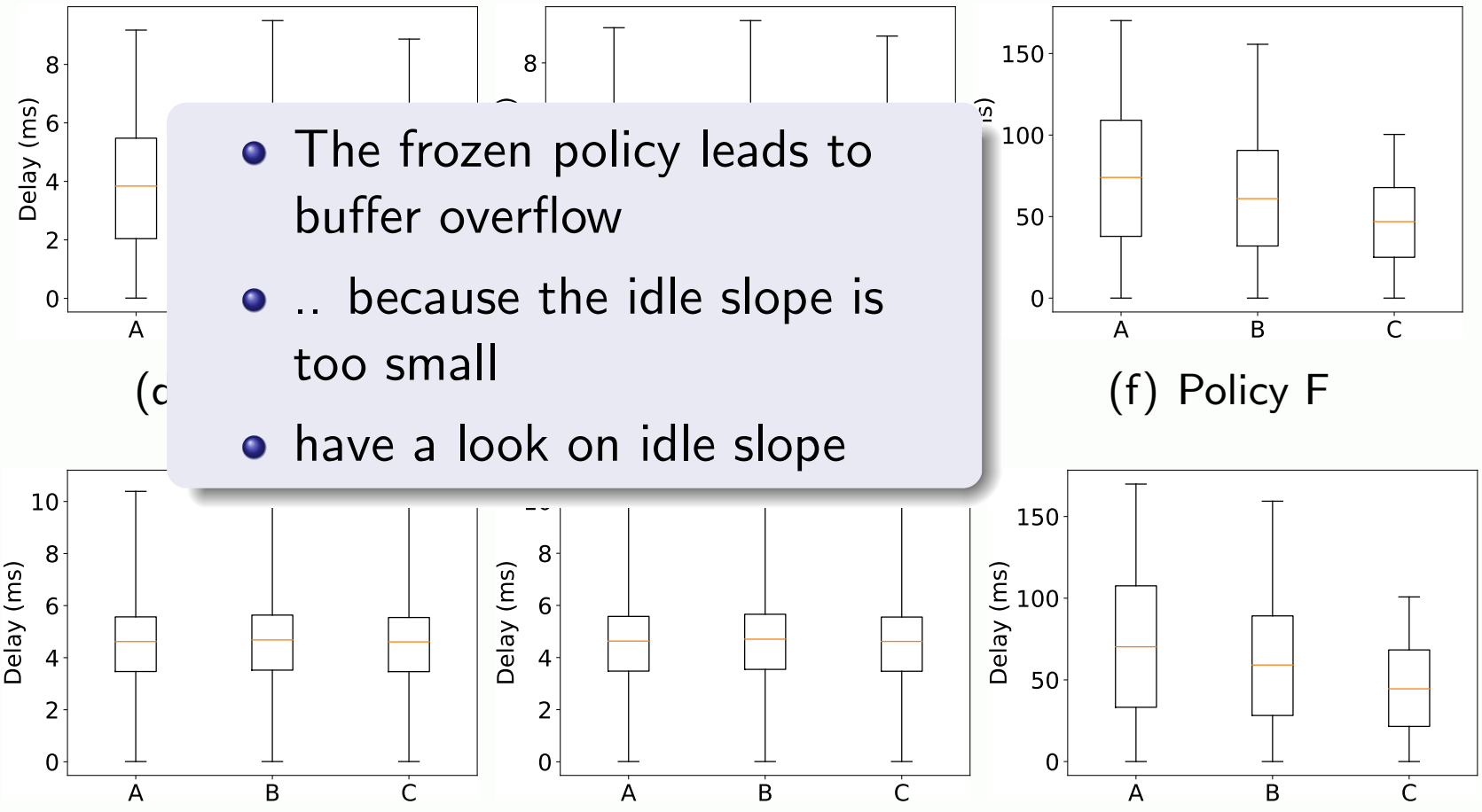
(e) Policy R



(f) Policy F

Plotting mean (red), min, max, Q1 and Q3 delays

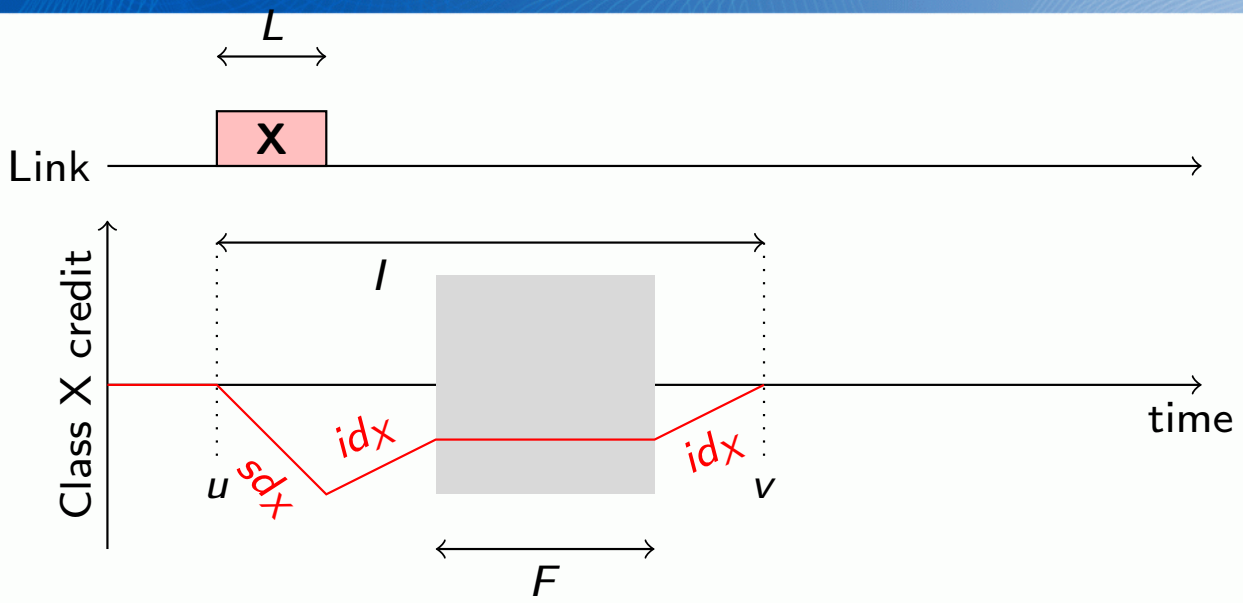
Uniform (a,b,c) and random (d,e,f) gate closing



- The frozen policy leads to buffer overflow
- .. because the idle slope is too small
- have a look on idle slope

Plotting mean (red), min, max, Q1 and Q3 delays

Duration of frozen intervals and idle slope

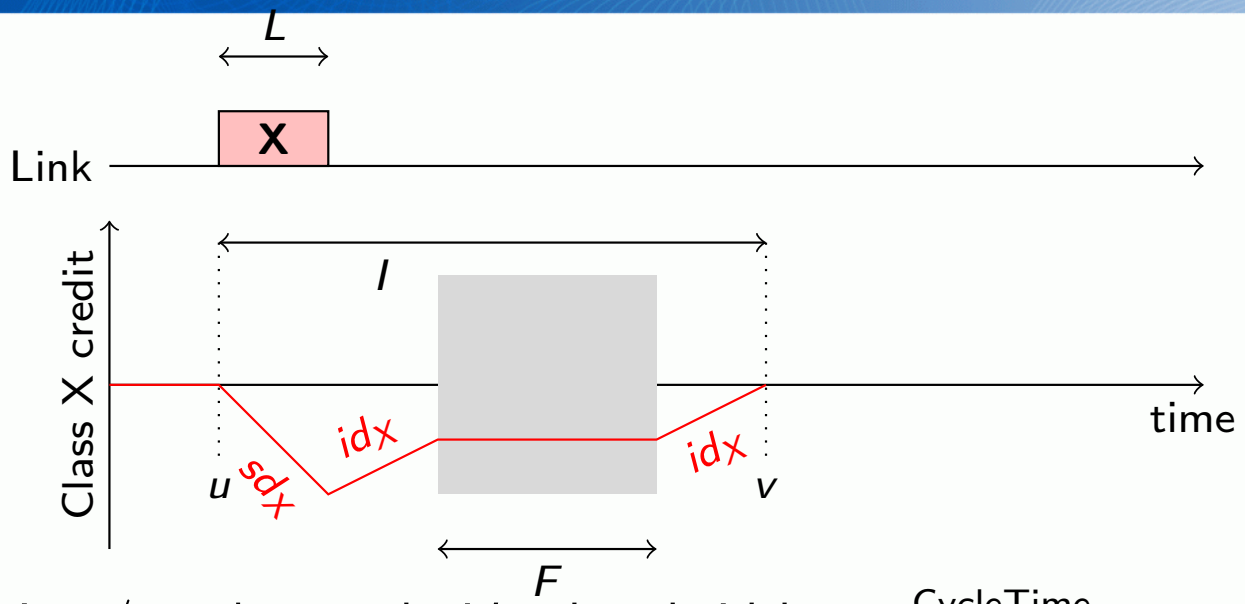


Problem

- Credit freezing reduces credit refuelling opportunities

$\Rightarrow$ Freezing reduces throughput

Duration of frozen intervals and idle slope



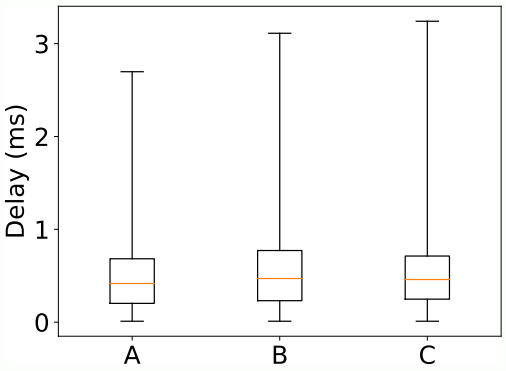
- Solution / workaround: $id = \text{bandwidth} \times \frac{\text{CycleTime}}{\text{CycleTime} - F}$
- S: F is known, $F = \text{CloseTime}$,

$$id_S = \text{bandwidth} \times \frac{\text{CycleTime}}{\text{CycleTime} - \text{CloseTime}}$$

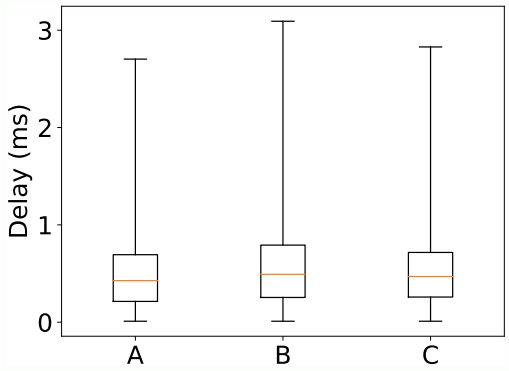
- F,R: F is dynamic, $\text{CloseTime} \leq F \leq \text{CloseTime} + n\frac{L^M}{R}$

$$id_{F,R} = \text{bandwidth} \times \frac{\text{CycleTime}}{\text{CycleTime} - \text{CloseTime} - n\frac{L^M}{R}}$$

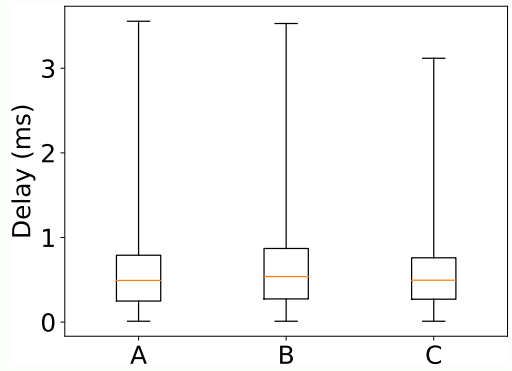
Same experiment with larger idle slope $id_{F,R}$



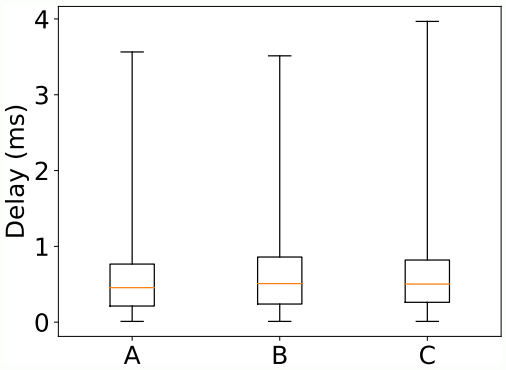
(g) Policy S



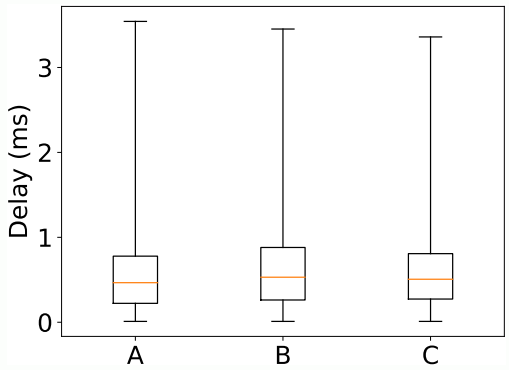
(h) Policy R



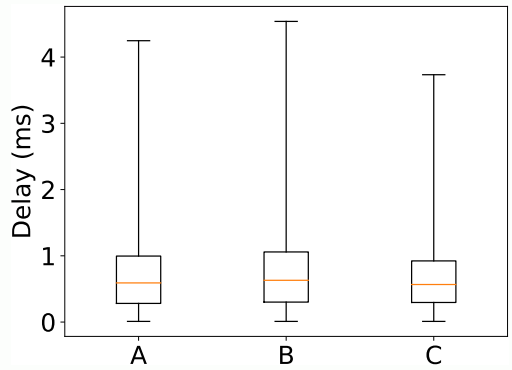
(i) Policy F



(j) Policy S



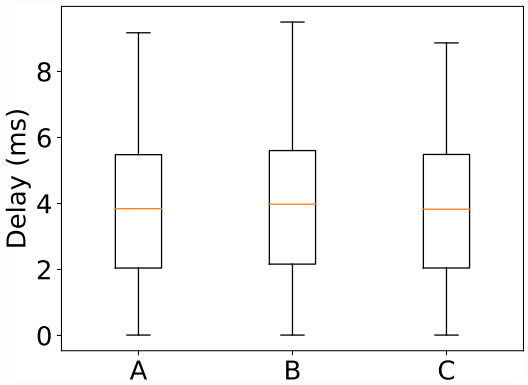
(k) Policy R



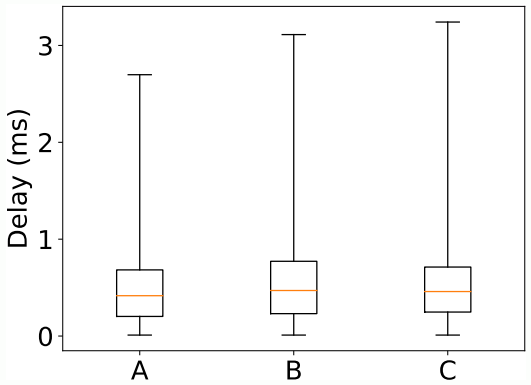
(l) Policy F

Plotting mean (red), min, max, Q1 and Q3 delays
Closing interval distribution: uniform (d-e-f), random (g-h-i)

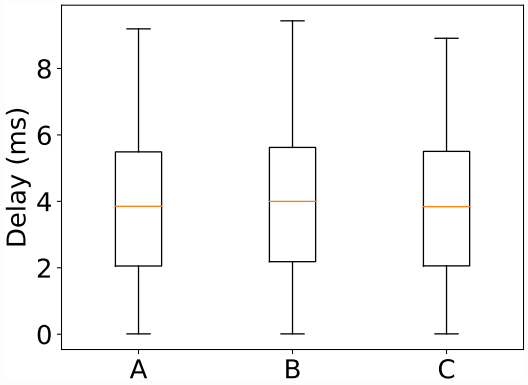
Comparing impact of the idle slope



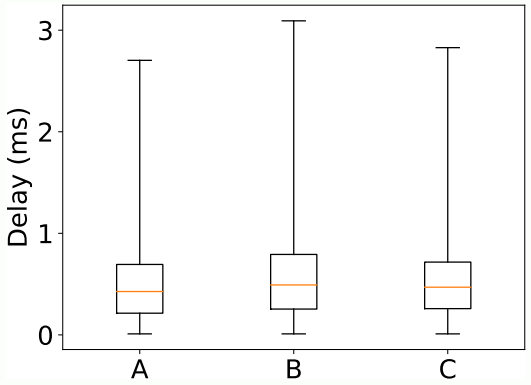
(m) Policy S, $id = 25\text{Mb/s}$



(n) Policy S, $id = 27.78\text{Mb/s}$



(o) Policy R, $id = 25\text{Mb/s}$



(p) Policy R, $id = 27.78\text{Mb/s}$

Outline

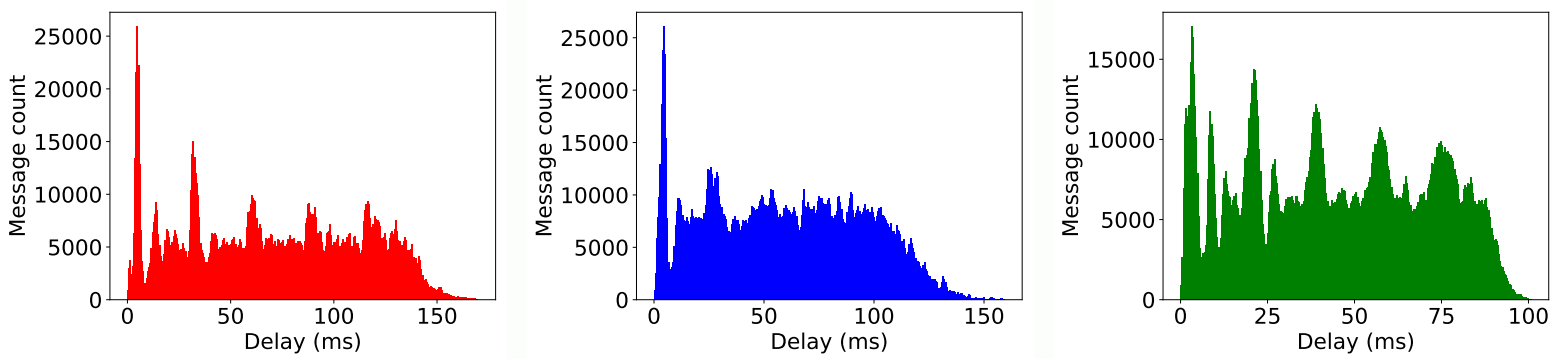
Conclusion

- The ratio "throughput/idle slope" has strong influence on delays.
- The "frozen" rule requires modification of the idle slope.
- The expected benefits of "frozen" rule are not visible on theses simulations.
- A new rule (return to zero) is proposed.
  - trade-off between both
  - looks slightly better than standard on simulations
- Evaluation on worst case delay is coming.

Outline

More figures

Same distribution for all queues A, B, C (F, *id*, random)



(q) Class A (r) Class B (s) Class C

Figure: Per class delay distribution for policy F, idle slope *id*, random gate closing.

Same distribution for all queues A, B, C (S, *id*, uniform)

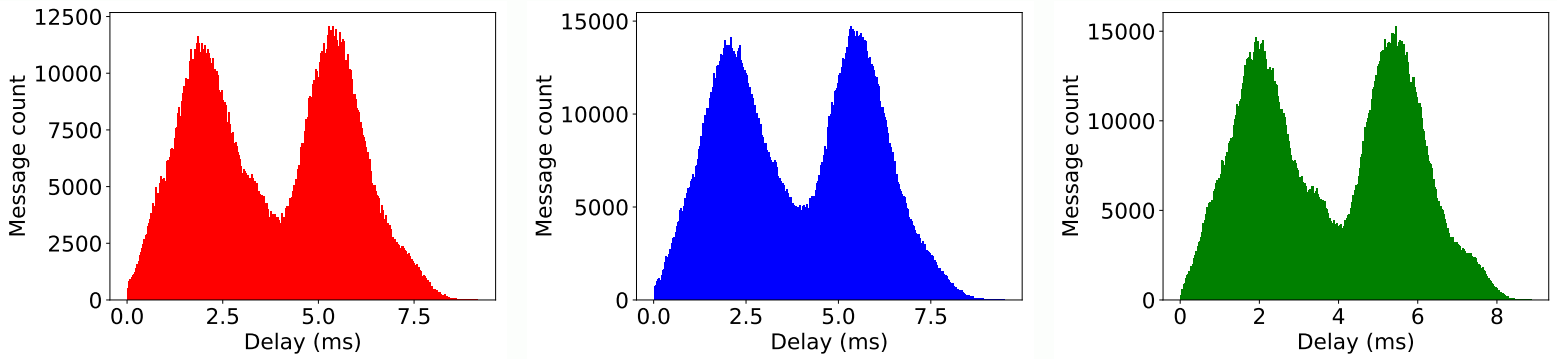


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Figure: Per class delay distribution for policy S, idle slope *id*, uniform gate closing.

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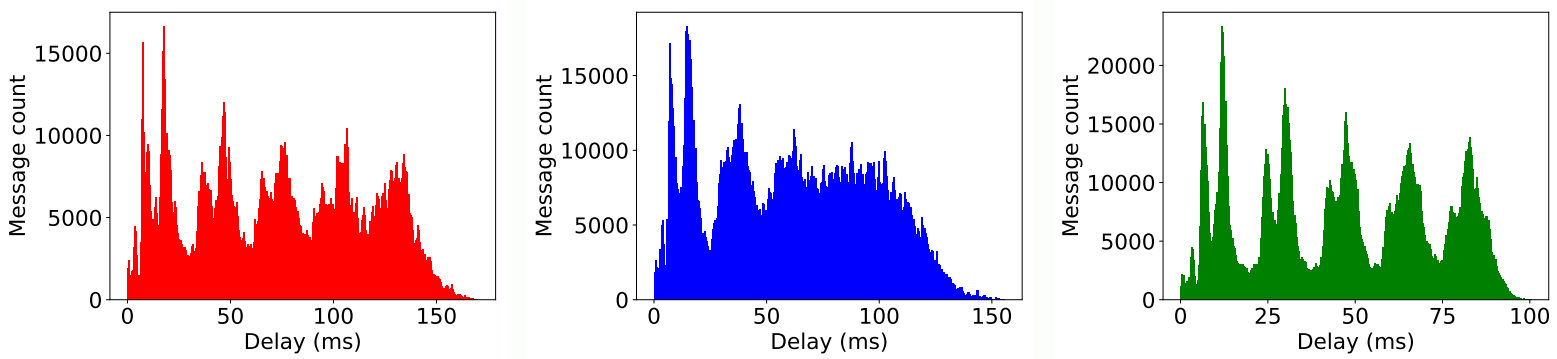

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