What are the relevant differences between Asynchronous (ATS) and Credit Based (CBS) Shaper?

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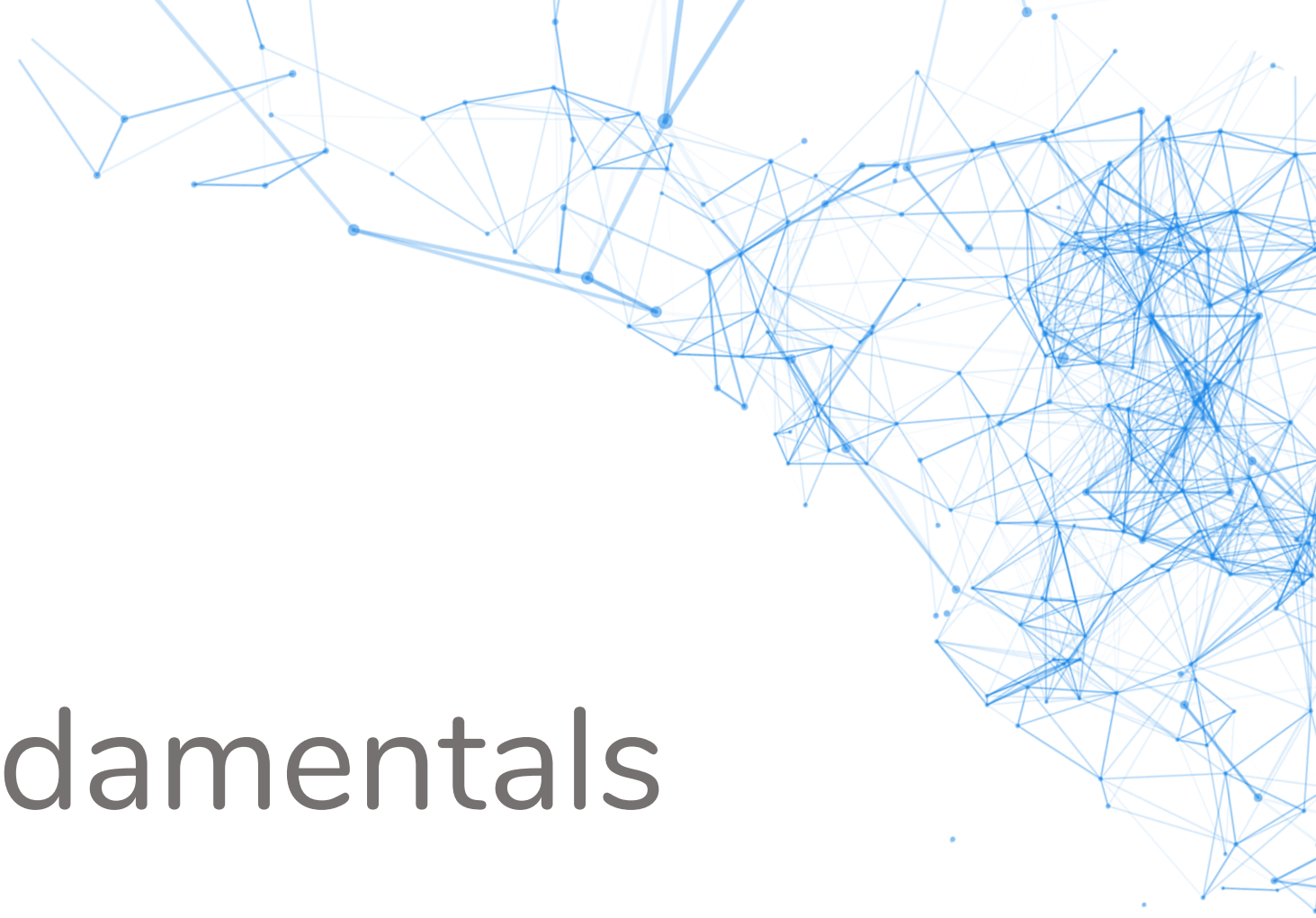


Shaping Fundamentals

Why do Shaping?

What can be expected from Shaping?

Shaping's Influence on Latency

- **Shapers can only delay frames**, i.e., the **general worst-case Latency will be increased** for the shaped traffic
- **Shaping high priority traffic**[1)] can **reduce Bursts** of high priority traffic, thereby increasing its Latency
- this will create temporal **Gaps for low priority traffic**, thereby **decreasing its average Latency**, but not reducing the general worst-case latency for the low priority traffic
- For a **specific topology** and **known traffic patterns** the network can be **engineered** to **reduce the specific worst case latencies for lower priority traffic**

[1)] Numerically high Traffic Class (TC) in IEEE Std 802.1Q

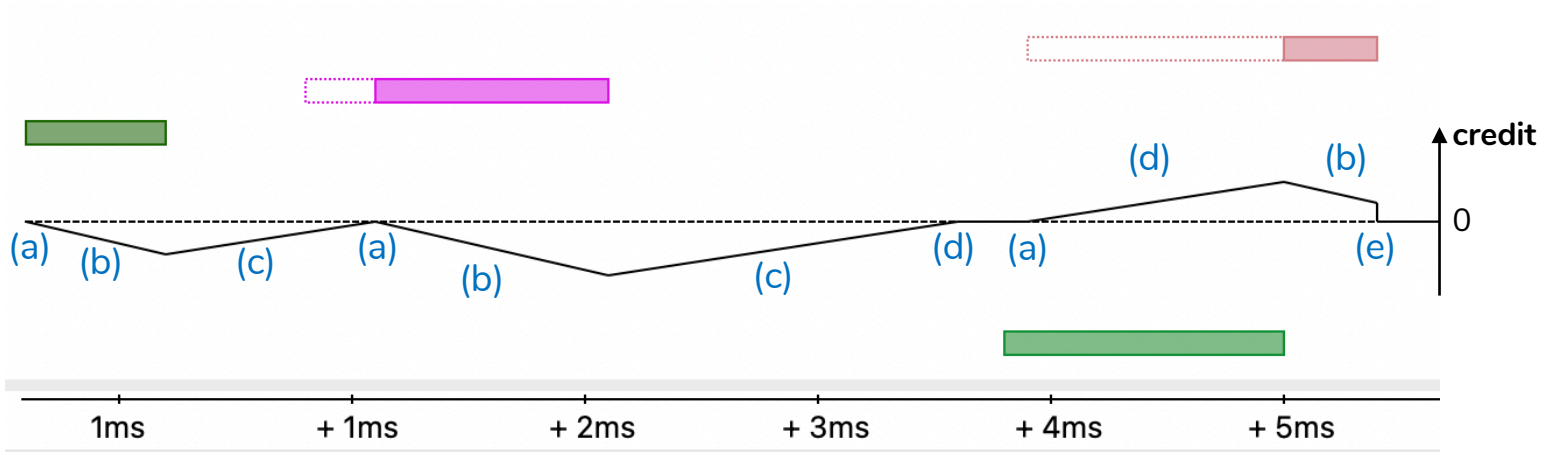
Credit Based Shaper (CBS)

aka Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)

Introduced for Audio/Video Bridging (AVB)

CBS Scheduling Rules

Credit Based Shaper (CBS)



In IEEE Std 802.1Q there is only one CBS instance per Traffic Class (TC)

a) Head of the queue frame becomes eligible as soon as credit ≥ 0.

b) During transmission credit decreases with sendSlope = idleSlope – lineRate.

c) While credit is negative, it increase with idleSlope.

d) While frames are waiting and no frame of the class is being transmitted, the credit increase with idleSlope.

e) If credit > 0, no frames are waiting, and no frame is being transmitted, the credit is reduced to 0.

Diagrams are not to scale!

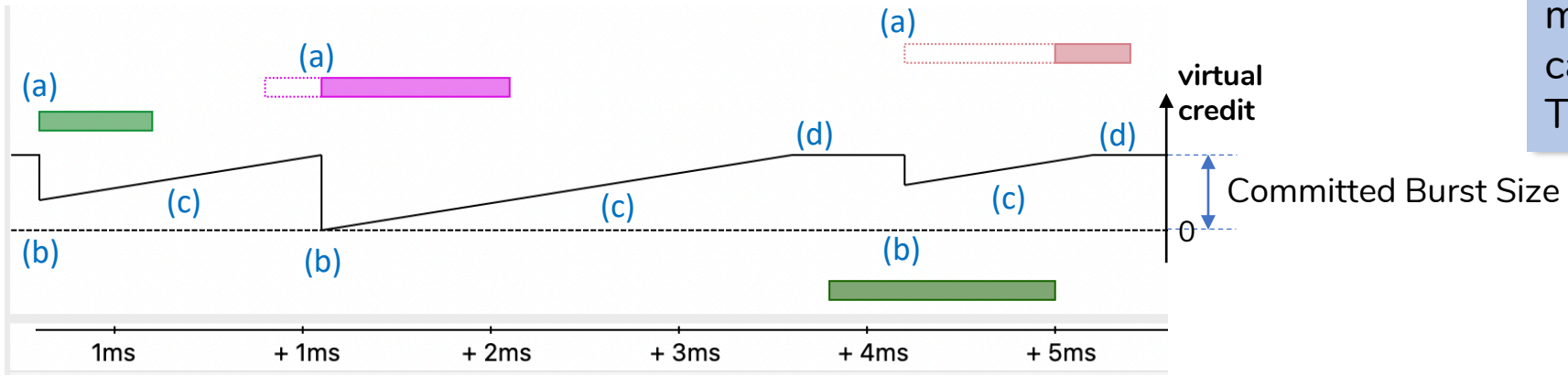
Asynchronous Traffic Shaper (ATS)

The ATS algorithm and basic shaping scenarios

ATS Scheduling Rules

Asynchronous Traffic Shaper (ATS)

This credit curve[1] creates equivalent eligibility times as the algorithm of IEEE Std 802.1Q



In IEEE Std 802.1Q multiple ATS instances can feed into one Traffic Class (TC)

a) The head of the line frame **is set eligible**, as soon as the **virtual credit** ≥ frame's size

b) Virtual credit is **decreased at eligiblity time** by frame's size

c) Virtual credit increases continuously with **C**ommitted **I**nformation **R**ate

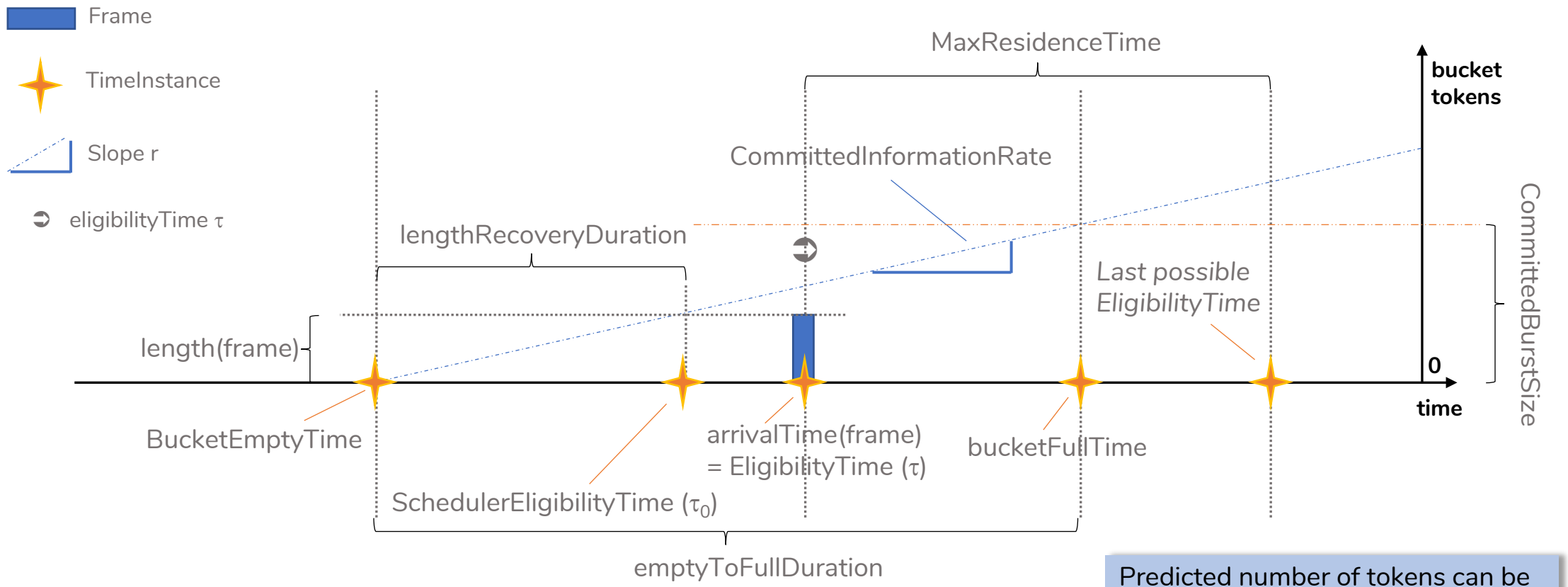
d) if the credit reaches the **C**ommitted **B**urst **S**ize, it is **pinned at Committed Burst Size**

Diagrams are not to scale!

[1] Marc Boyer. Equivalence between the theoretical model and the standard algorithm of Asynchronous Traffic Shaping. 2022. hal-03788302

ATS Algorithm Nomenclature

Asynchronous Traffic Shaper (ATS)



Diagrams are not to scale!

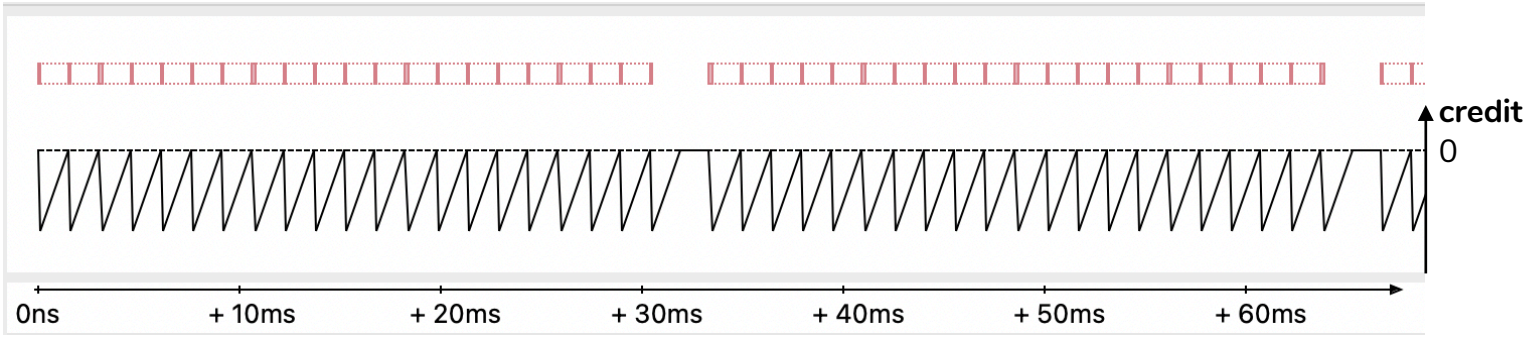
Predicted number of tokens can be greater than Committed Burst Size

Similarities

of ATS and CBS.

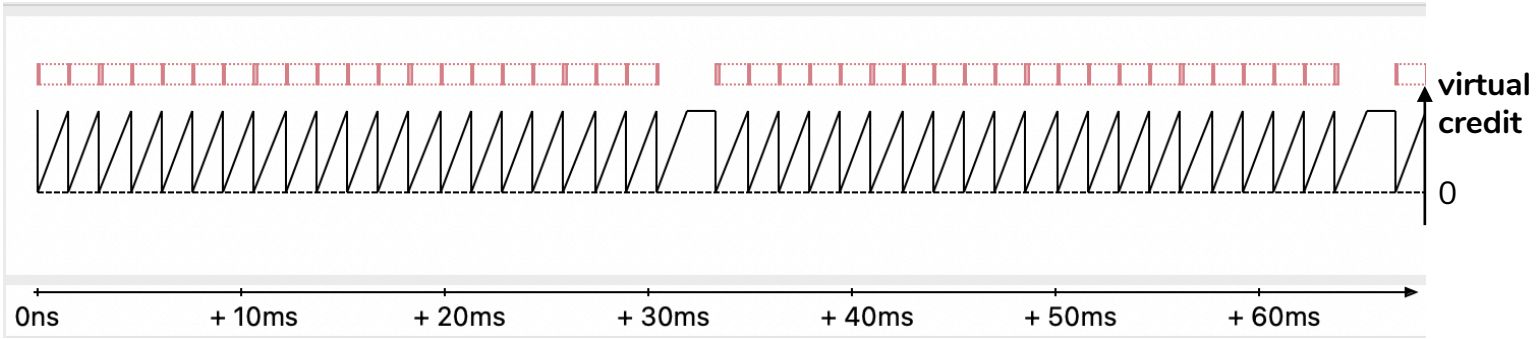
Same Behavior for a singular Stream of equal sized Frames

Credit Based Shaper (CBS)



comittedInformationRate = idleSlope
committedBurstSize = frameSize

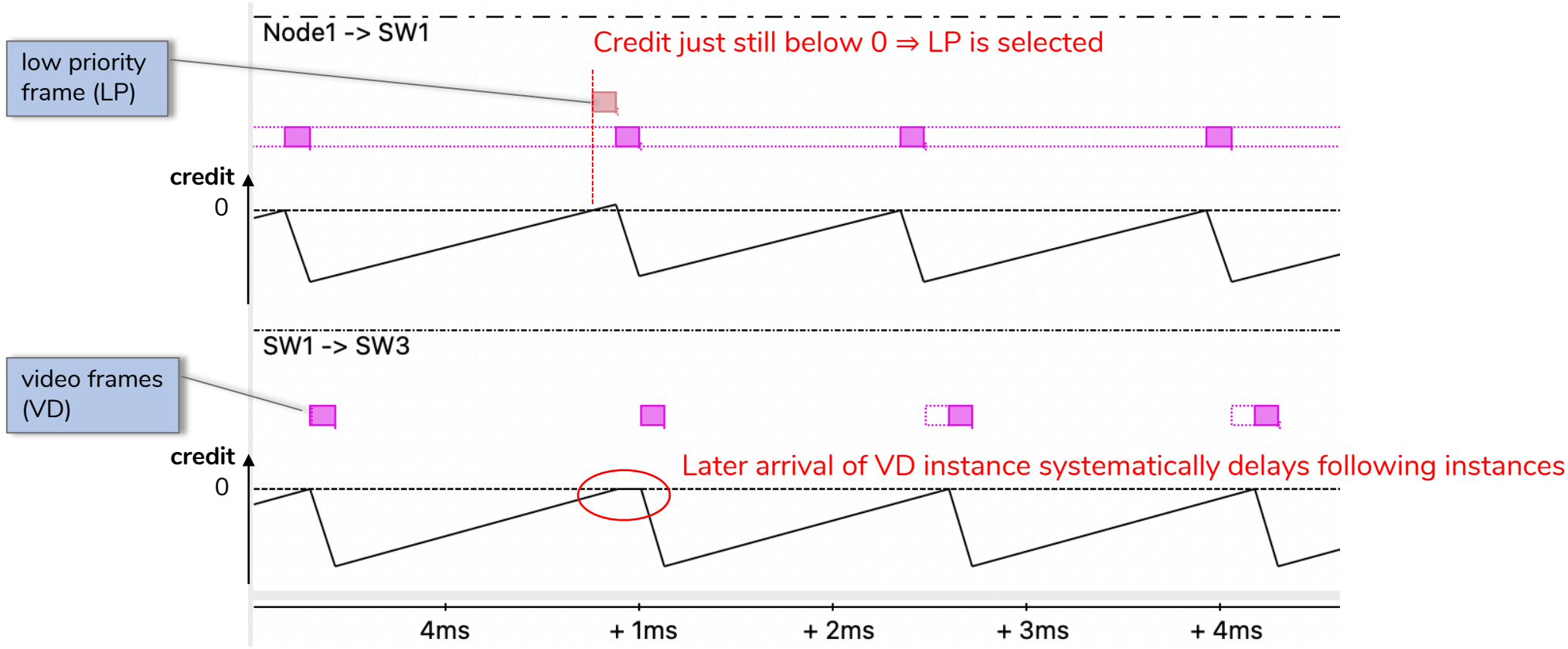
Asynchronous Traffic Shaper (ATS)



Diagrams are not to scale!

Lower Priority Interference can lead to Permanent Delay - CBS

Credit Based Shaper (CBS)



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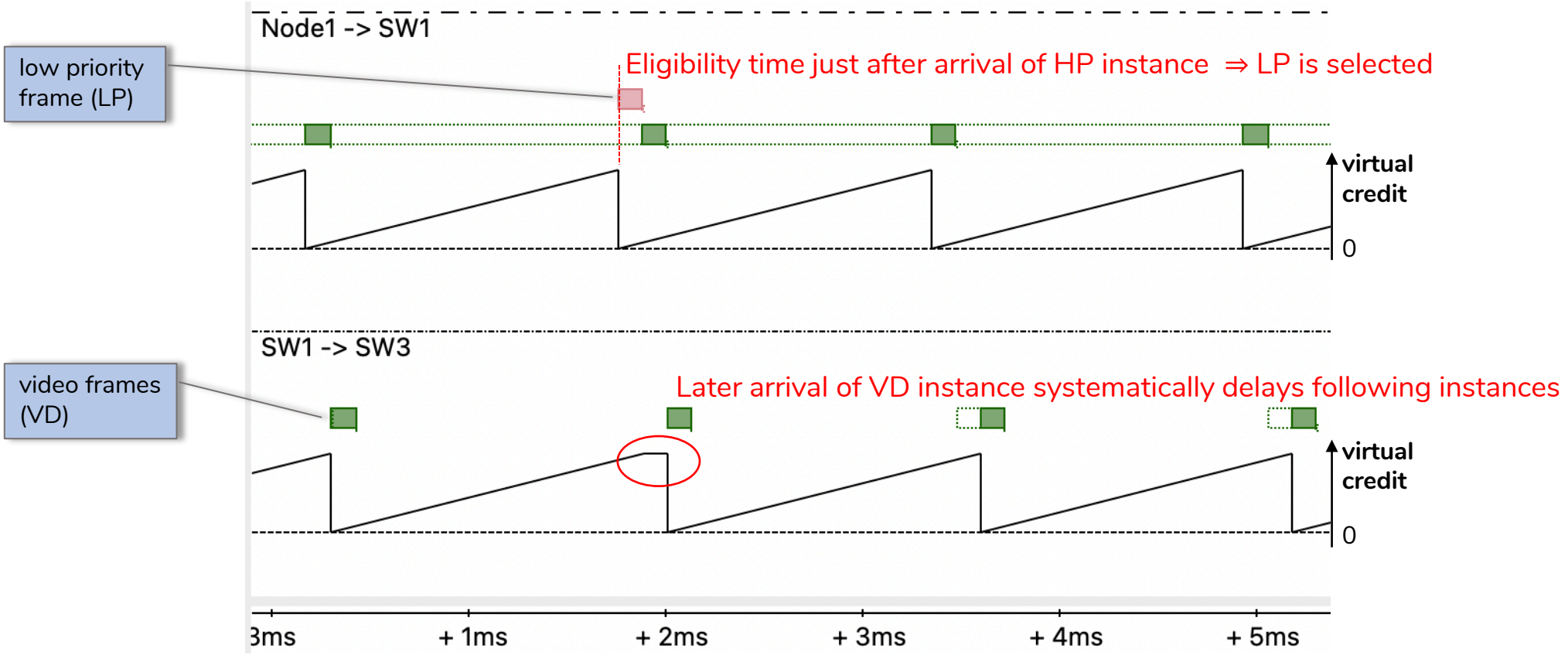
Lower Priority Interference can lead to Permanent Delay - ATS

Asynchronous Traffic Shaper (ATS)



Diagrams are not to scale!

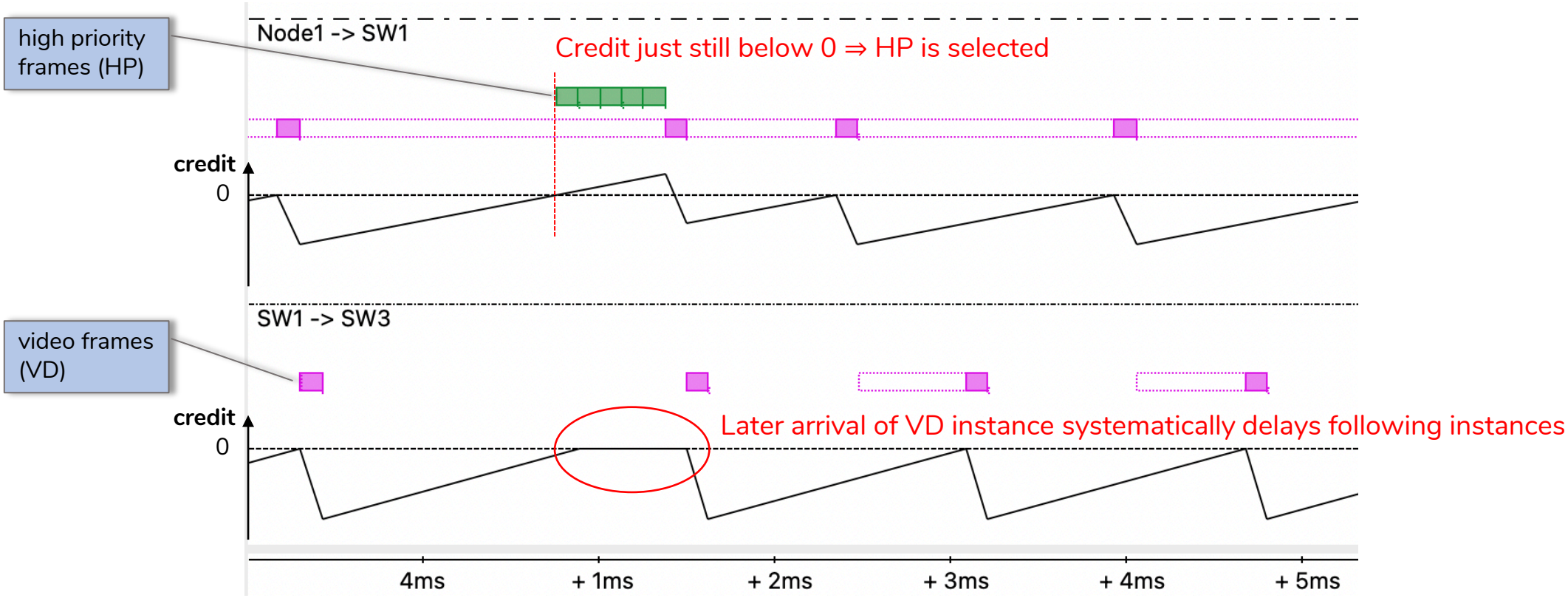
Priority for shaped Traffic

- Both ATS[1)] and CBS[2)] work best if they are configured in the numerically highest traffic class (TC) - i.e. highest priority.
- If the specific network topology and all characteristics of shaped and unshaped streams are known, the specific worst-case analysis allows to compute upper bounds on delays at any priority level. This allows to optimally configure[3)] shapers while verifying that latency constraints are met.
- For typical automotive use-cases we have seen that shapers may be efficient even if not used at the highest priority level, but their priority should not be too low, otherwise the interference from higher priority traffic may become too long (i.e., bursts) to allow any effective shaping.
- Changing network characteristics requires re-calculation of the configuration for a specific topology and configuration.
- Policing must be used to ensure compliance with assumed characteristics.

[1)] IEEE Std 802.1Q-2022 Annex V.1 a)
[2)] IEEE Std 802.1Q-2022 Annex L.1 d)
[3)] RTaW-Pegase

Higher Priority Interference can lead to systematic Delay - CBS

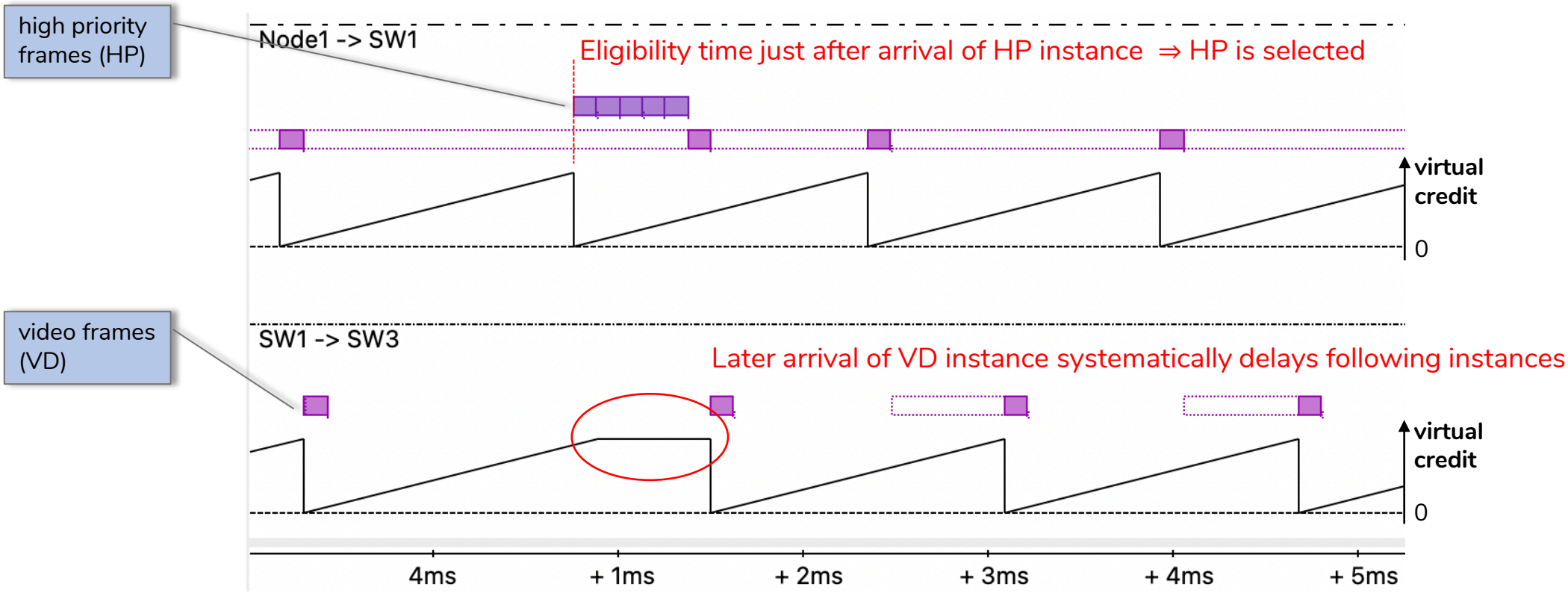
Credit Based Shaper (CBS)



Diagrams are not to scale!

Higher Priority Interference can lead to systematic Delay - ATS

Asynchronous Traffic Shaper (ATS)



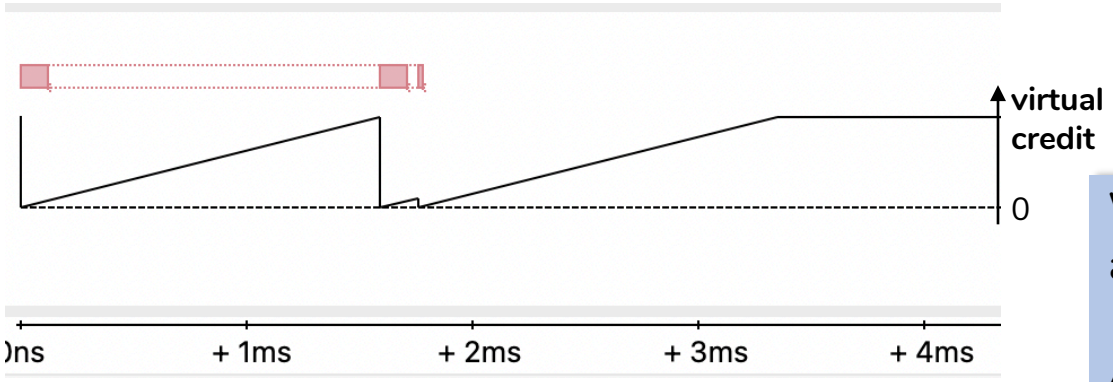
Diagrams are not to scale!

Differences

between ATS and CBS.

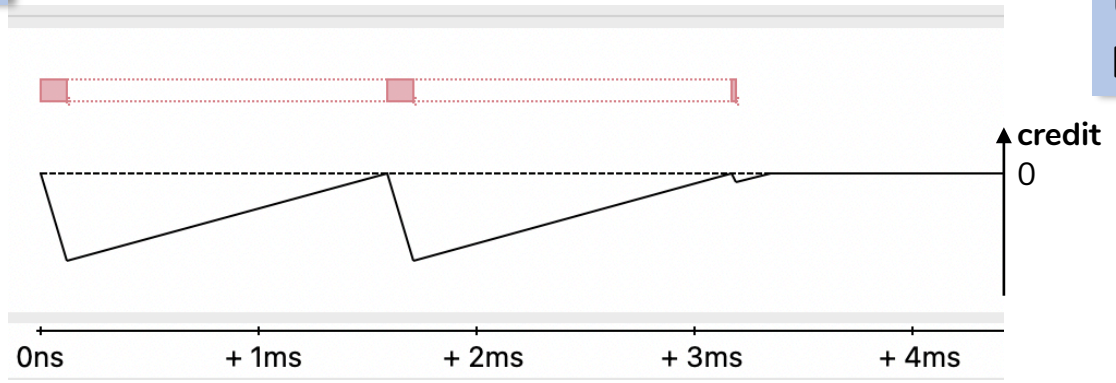
Scheduling of smaller Frames

Asynchronous Traffic Shaper (ATS)



Ingress Burst!

Credit Based Shaper (CBS)

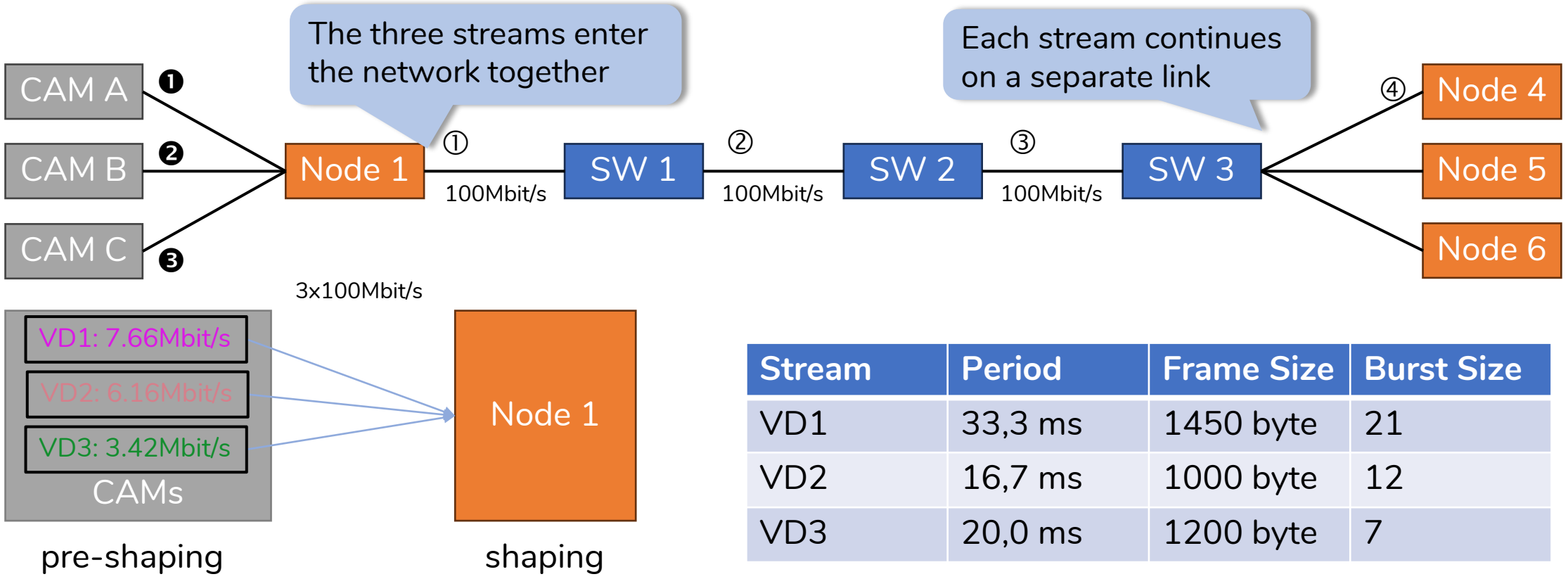


With ATS smaller Frames are scheduled earlier!

ATS needs enough virtual credit for the Frame to transmit, CBS needs to re-accumulate credit for the previously transmitted Frame.

Diagrams are not to scale!

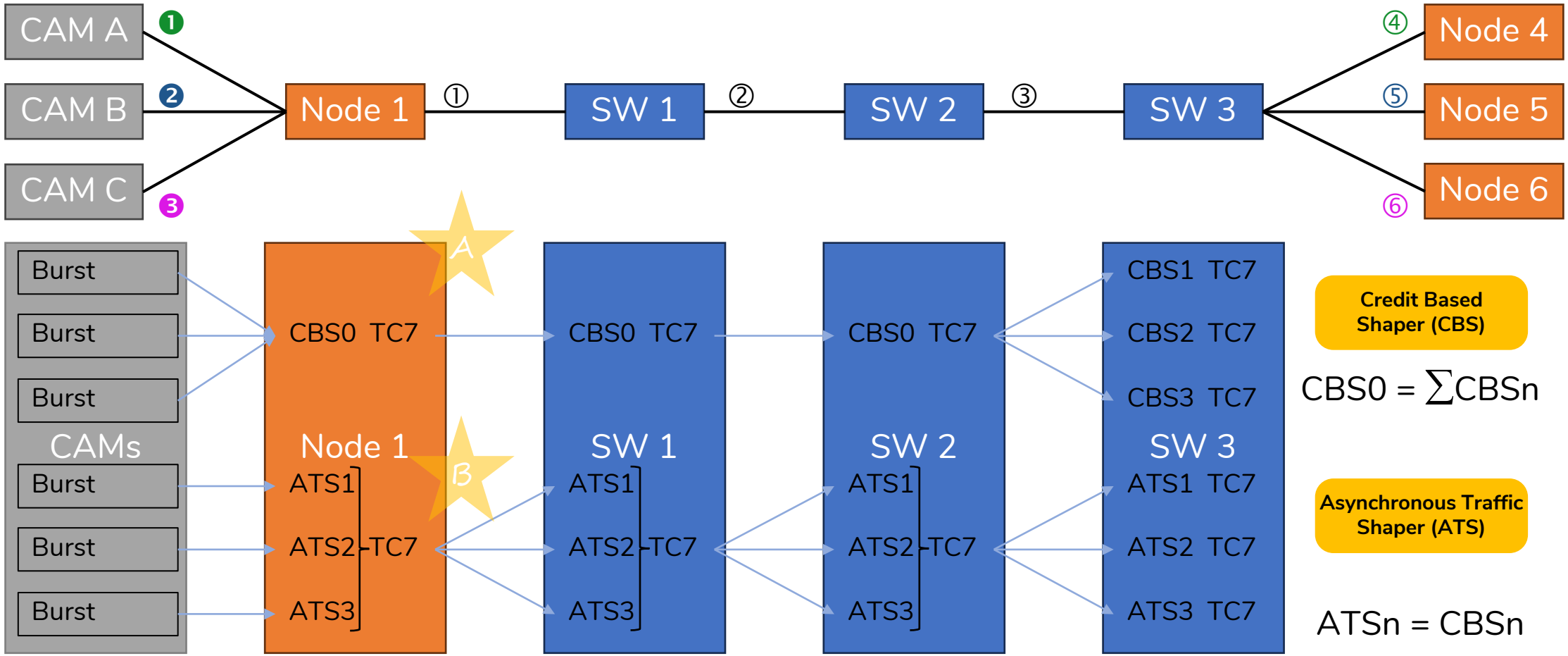
A Network Example



Stream	Period	Frame Size	Burst Size
VD1	33,3 ms	1450 byte	21
VD2	16,7 ms	1000 byte	12
VD3	20,0 ms	1200 byte	7

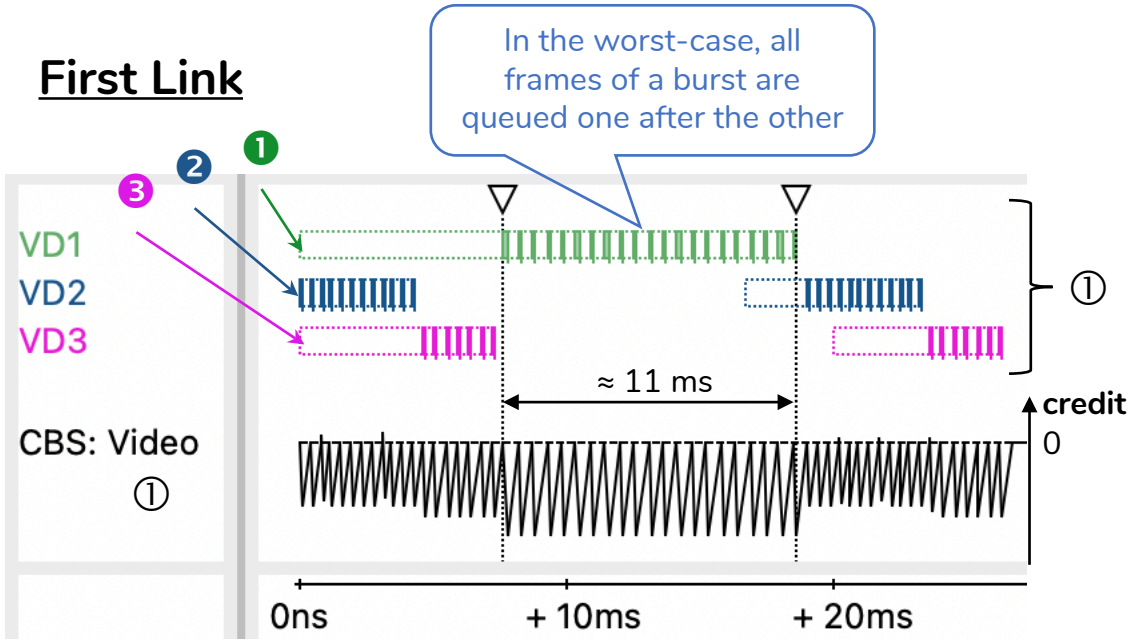
Note: ”Small” video streams to keep illustrations readable.

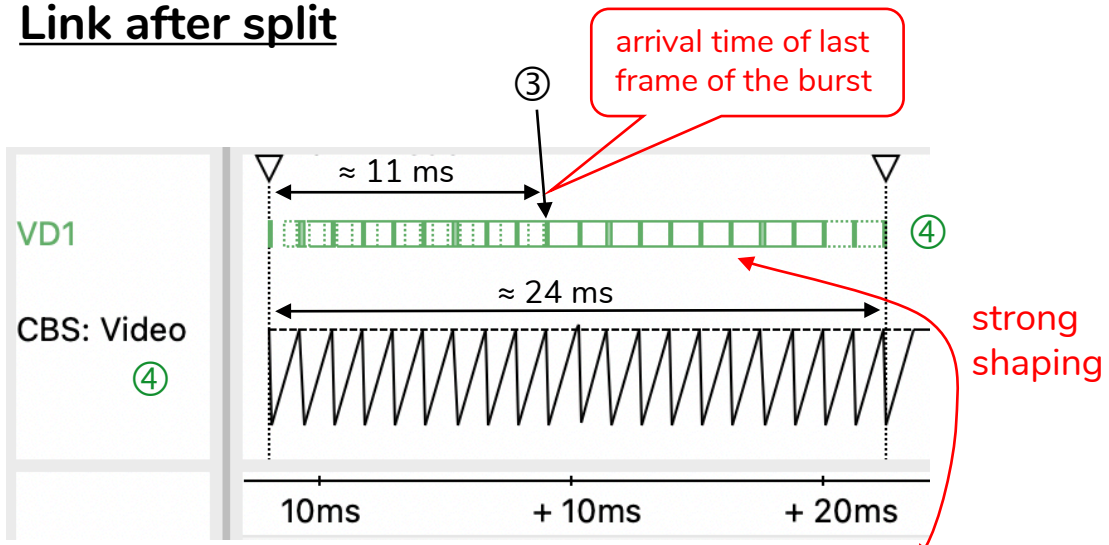
ATS vs. CBS with bursty input



CBS Default - without pre-shaping

Credit Based Shaper (CBS)





130% of stream load: IdleSlope=**9,959 Mbit/s**

130% of sum stream loads: IdleSlope=**22,412 Mbit/s**

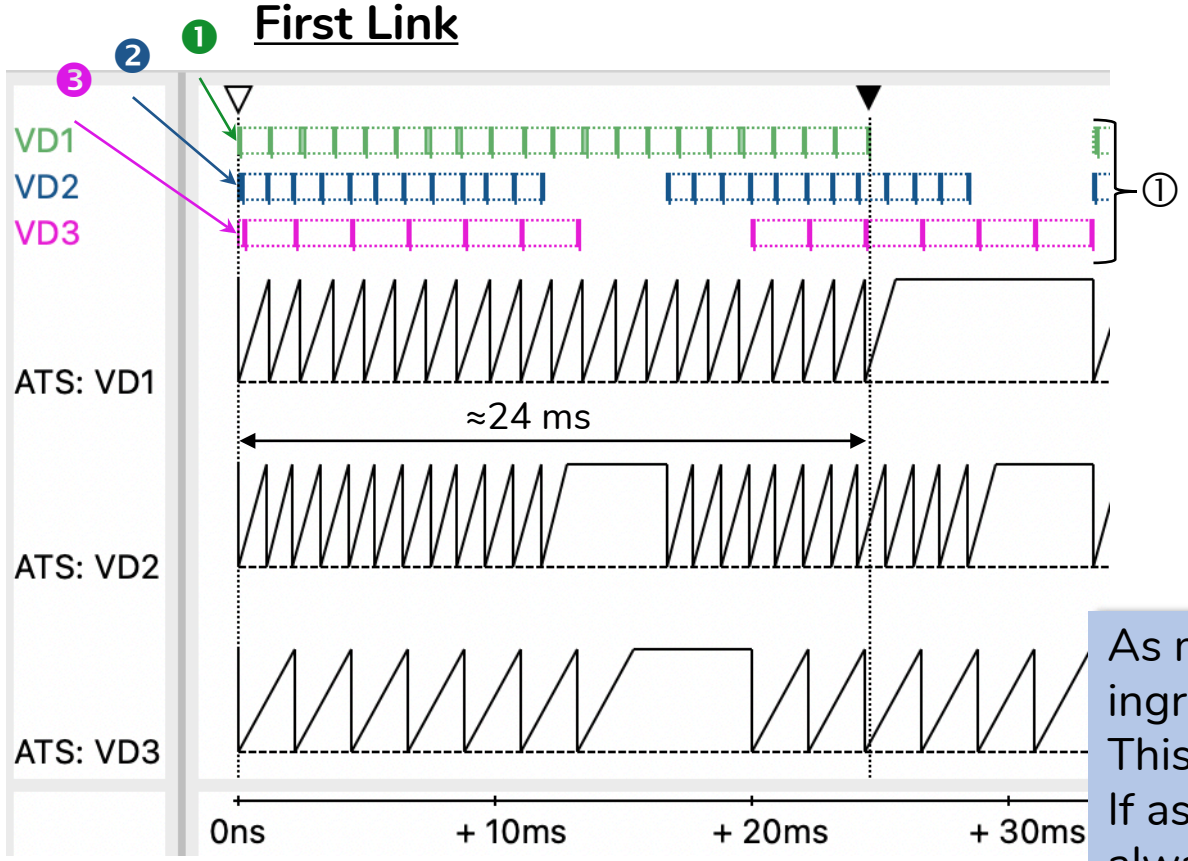
Shaping slopes based on stream loads guarantee that all shaped frames eventually go through …

… but in the last hop, the video streams may arrive with the class rate that is shaped down to the stream rate, which induces strong delaying!
⇒ more memory is required

ATS Default

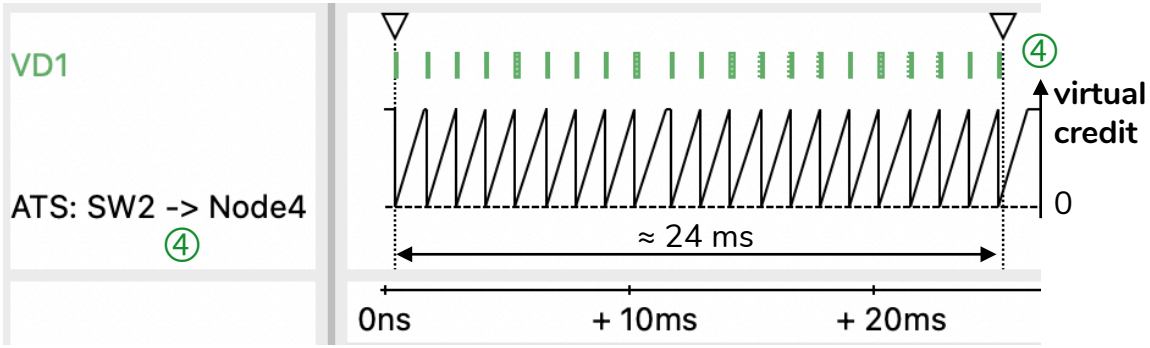
Asynchronous Traffic Shaper (ATS)

First Link



130% of stream loads: CIR=**9,959 Mbit/s**

Link after split



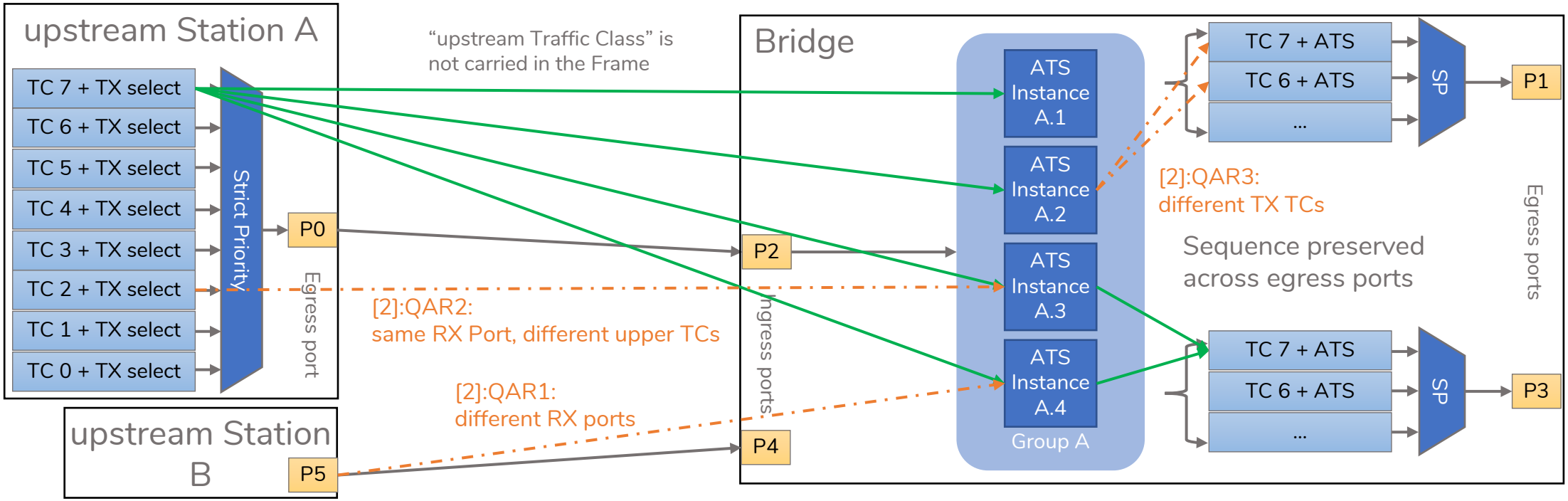
130% of stream load: CIR=**9,959 Mbit/s**

As multiple ATS instances are available, burst from different ingress ports get intermixed better on a single egress port. This will increase latency for the later frames in the burst. If assignment rules are followed, the worst case latency is always less than in the CBS case.

Preserve the grouping of Frames after being shaped together once

Asynchronous Traffic Shaper (ATS)

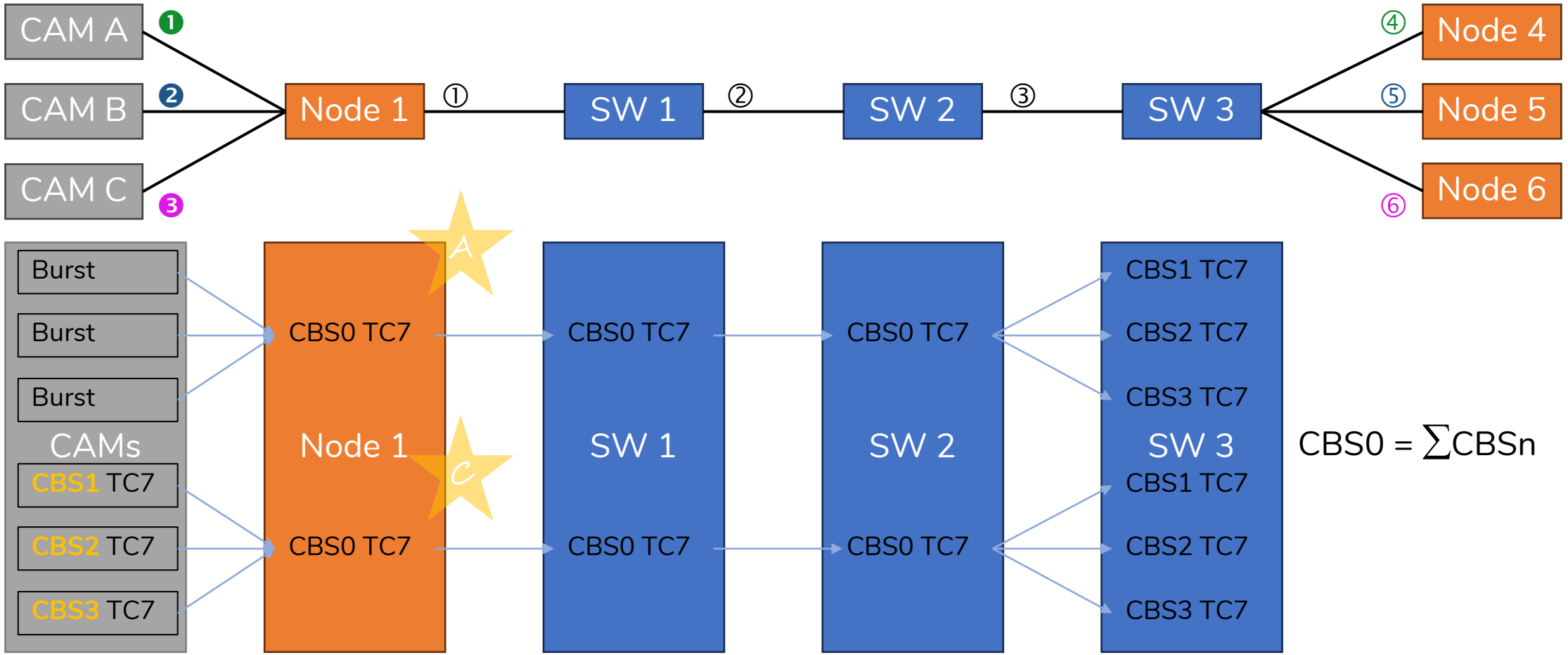
IEEE Std 802.1Q-2022 8.6.5.6: "*There is one ATS Scheduler Group per reception Port per upstream Traffic Class. All ATS schedulers that process frames from a particular reception Port and a particular upstream traffic class are in the respective ATS scheduler group.*"



[2] J. Specht & S. Samii, "Urgency-Based Scheduler for Time-Sensitive Switched Ethernet Networks," in *2016 28th Euromicro Conference on Real-Time Systems (ECRTS)*, Toulouse, France, Jul. 2016, pp. 75–85

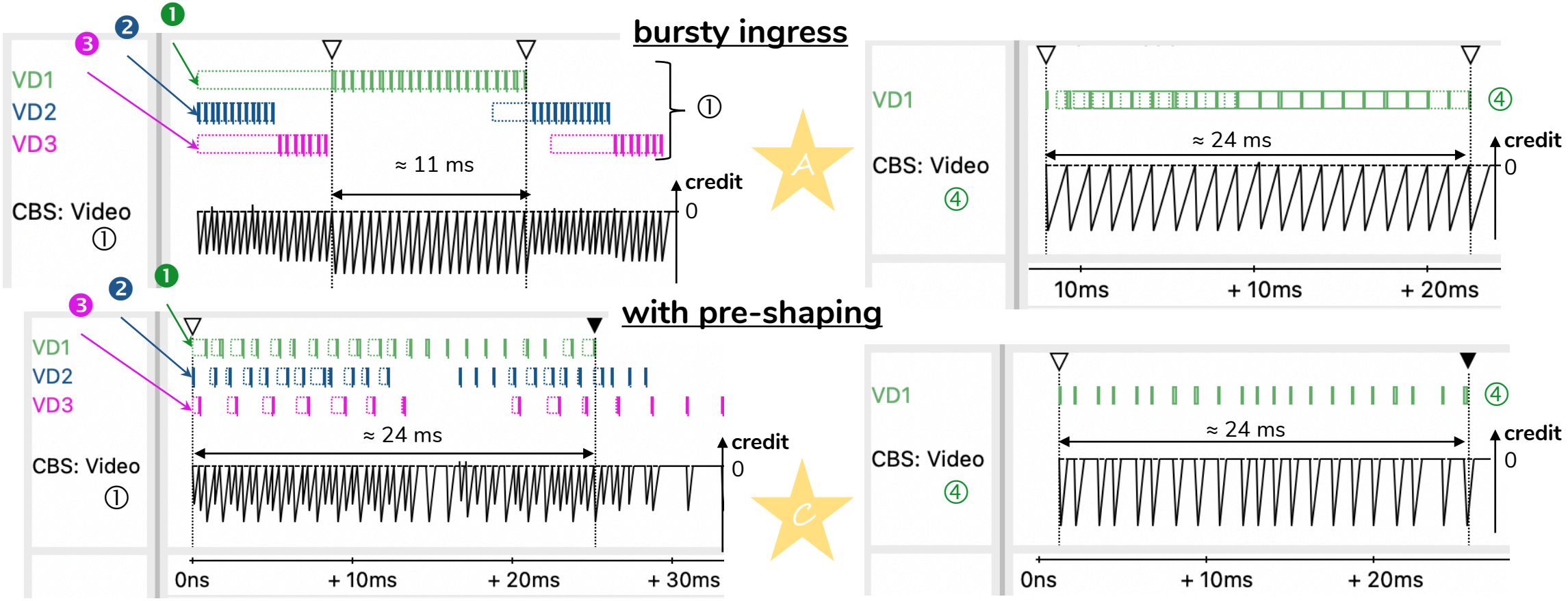
CBS pre-shaping

Credit Based Shaper (CBS)



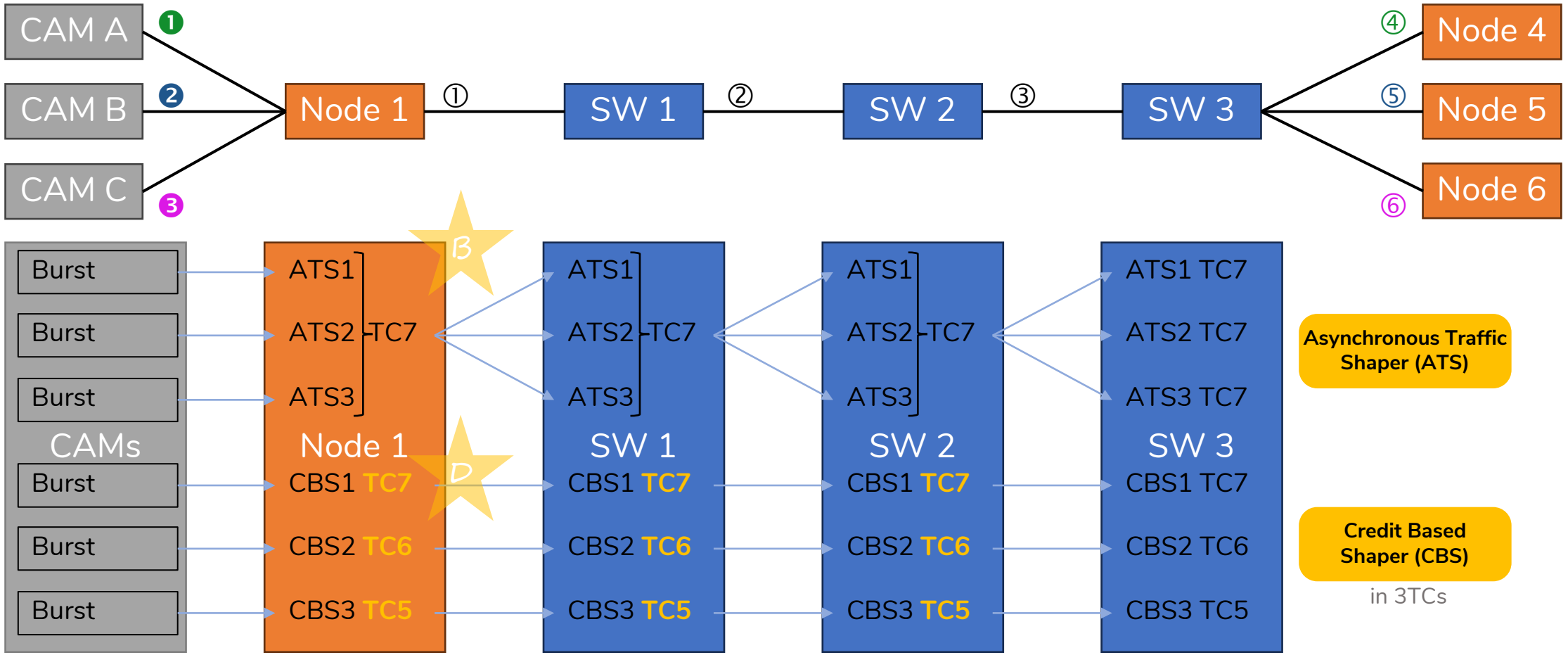
CBS with and without pre-shaping

Credit Based Shaper (CBS)

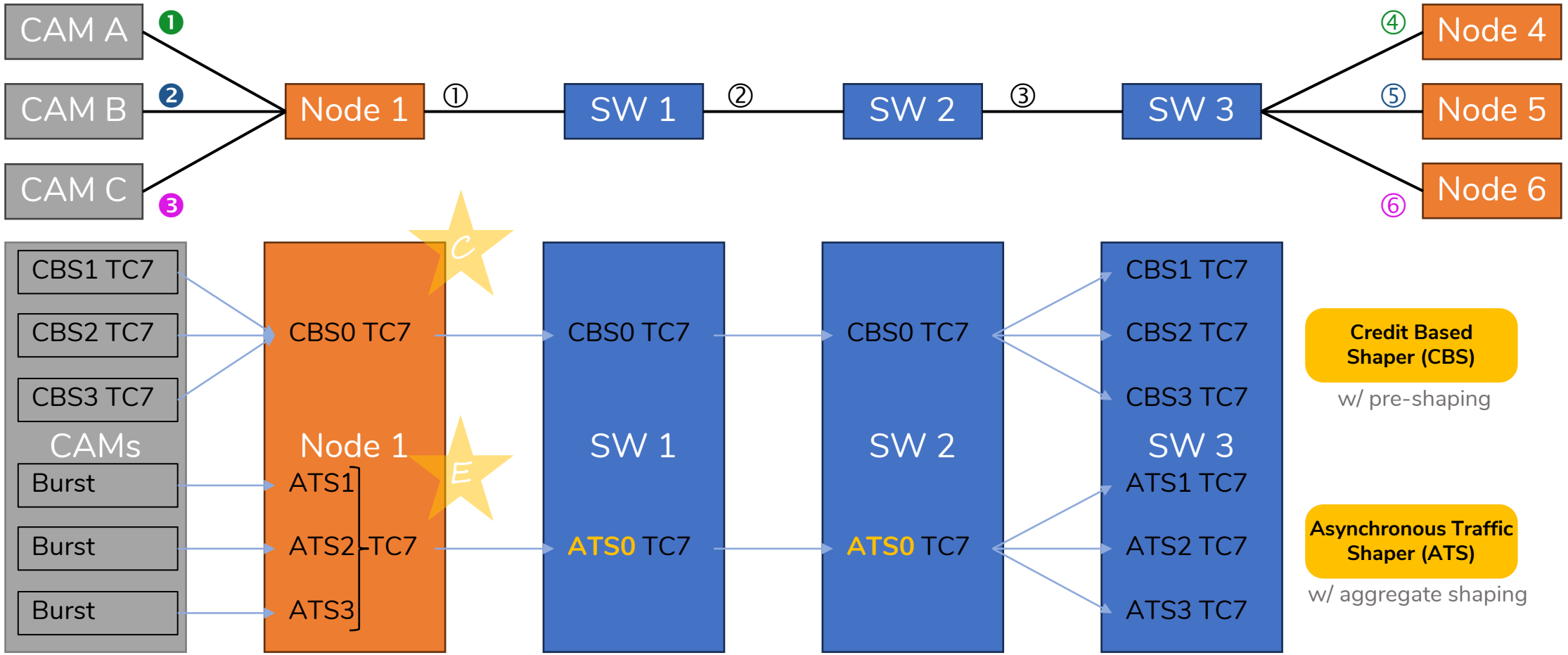


Pre-shaping allows to achieve “nice” multiplexing … but is it always possible (hardware limitations)?

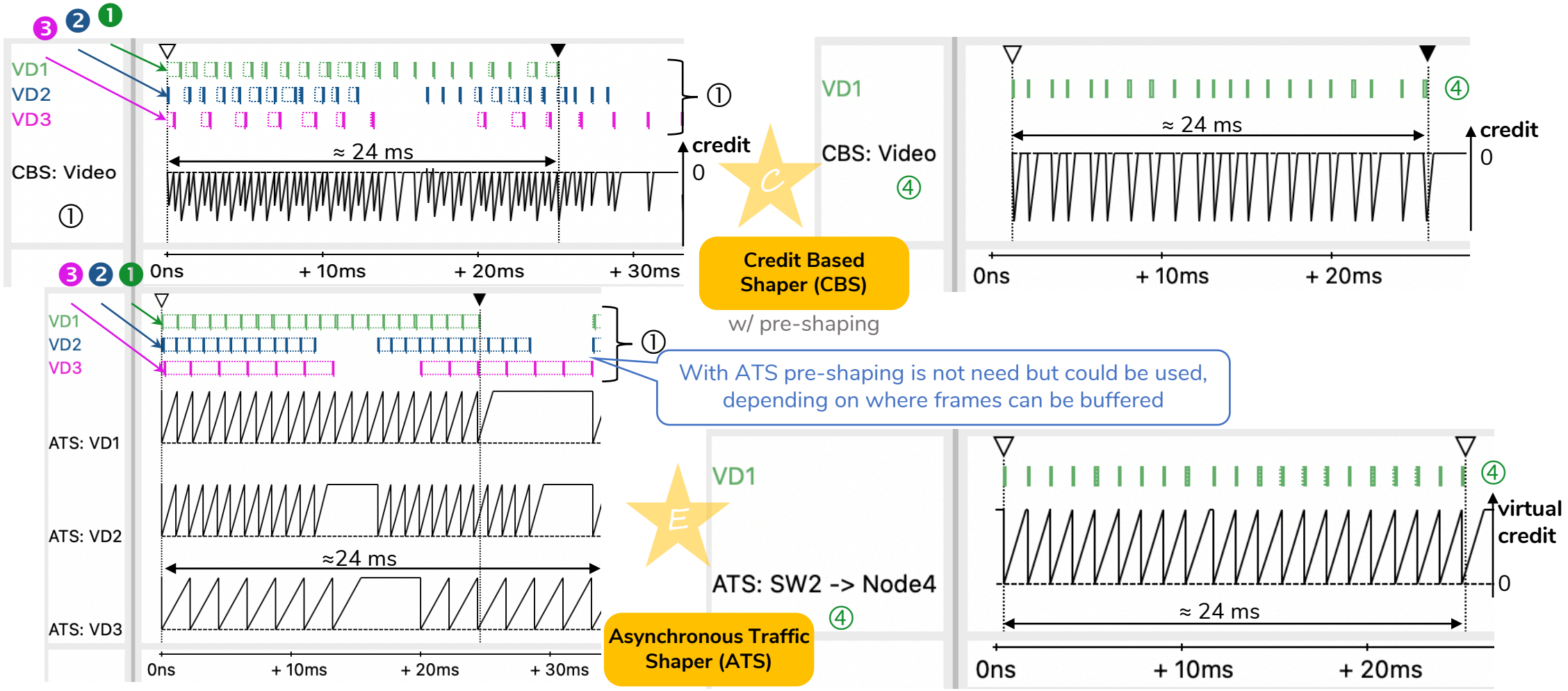
CBS per TC can mimic ATS



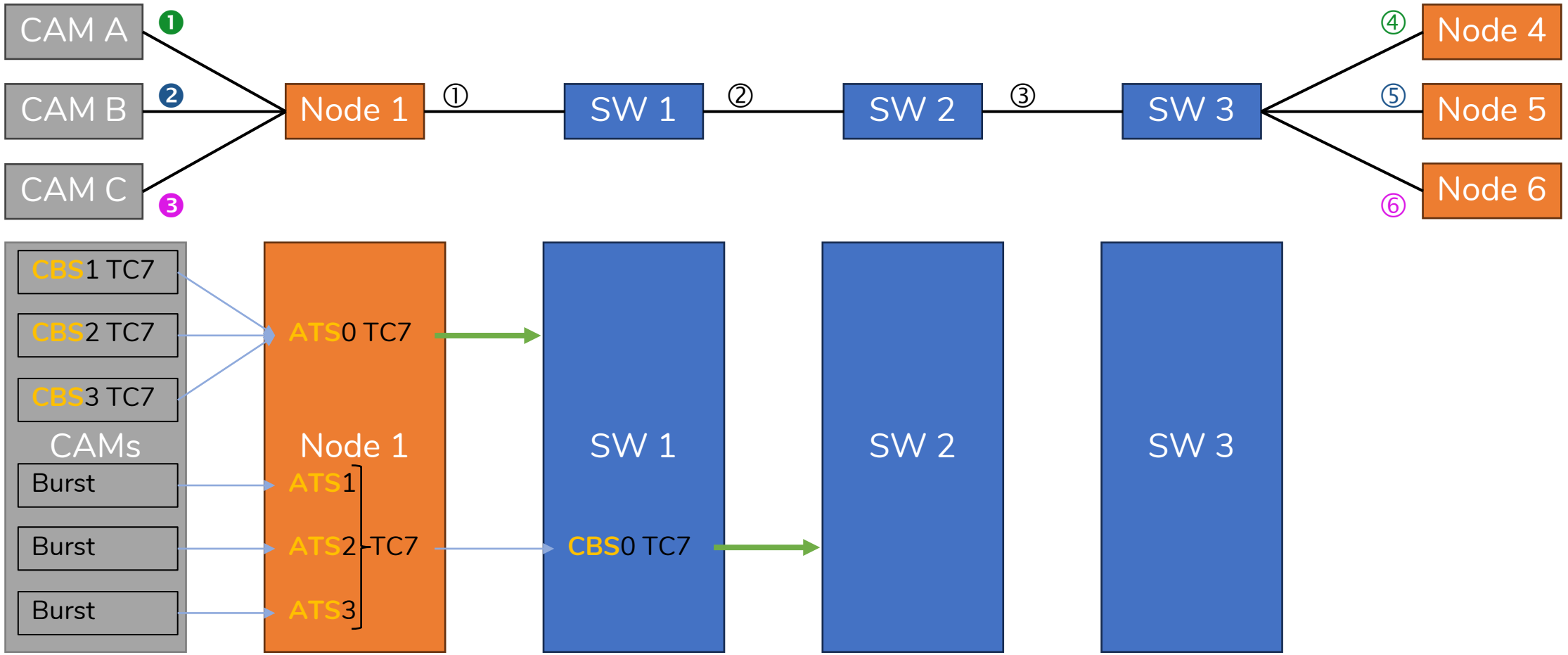
ATS can mimic CBS with pre-shaping



ATS can mimic CBS with pre-shaping



Combining CBS and ATS



Conclusions - Part I

- **ATS and CBS** can achieve **similar** effects, depending on the exact context and with different efforts (pre-shaping, several traffic classes, …)
- **Differences** between ATS and CBS are driven by the **number of shaper instances per TC**, not by the actual shaping algorithm!
- **ATS** is designed to provide a **network wide** path for some traffic
- **CBS** is viewed as a more local **per hop** shaper configuration
- **Assignment** of Frames to **ATS** shaper instances must follow **strict rules**[2] in order to achieve the improved characteristics - these are **not given in IEEE Std 802.1Q**!

[2] J. Specht & S. Samii, "Urgency-Based Scheduler for Time-Sensitive Switched Ethernet Networks," in *2016 28th Euromicro Conference on Real-Time Systems (ECRTS)*, Toulouse, France, Jul. 2016, pp. 75–85

Conclusions - Part II

- **Combinations of ATS and CBS are possible** under certain topological conditions, potentially allowing for a simpler configuration
- If one has to choose a single Tool, **ATS is more flexible**, as it can mimic all CBS behaviour, incl. simple per TC configuration
- Numerical **Traffic Class Priority** need **NOT** always **match the Importance or Urgency** of the Traffic, if numerically high TC traffic is strongly shaped (higher latency) to allow for numerically lower TC traffic to use the gaps (lower latency)
- Without **strict policing of all traffic**, latency guarantees can only be given for the numerically highest TC due to potential burst accumulation

Thank you very much for your attention!

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