Stream Metering (Ingress Policing) for Industrial Control-Data Streams

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Contents

Assumptions
Industrial Control-Data Streams

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- End-station (talker)
  - periodic generation and transmission at talkers (like TAS)
  - each frame of one control-data stream has a fixed frame size
  - one transmission period per class for all talkers
  - fixed transmission order in a burst (topology dependent)
- Further constraints for control-data streams
  - maximal E-2-E delay must be less than one transmission period
  - maximal E-2-E delay below a defined threshold - guaranteed latency
- TSN bridges
  - shaper: Strict Priority (SP) with highest priority for control-data streams
  - pre-emption for highest priority queue (express traffic class)

Assumptions
Jitter Sources of Control Data-Streams

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- End-station (talker)
  - slight variations in transmission period
- TSN bridges
  - slight variations in bridge delays
  - pre-emption (~1 µs @GE)
  - Add/Remove Tag
  - change of transmission order (high number Fan-In and low number Fan-Out)
  - Jitter accumulates along transmission path (hop count)

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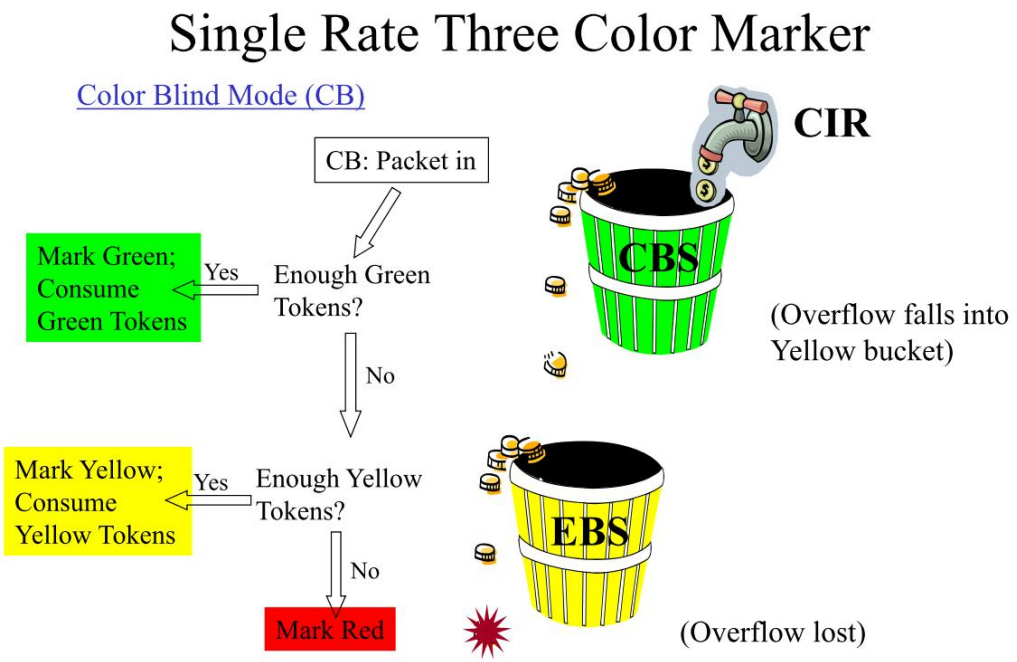
Why Ingress Policing is required for Control-Data Streams!

- Excessive traffic of faulty streams can break bandwidth and latency guarantees
  - replication of frames (at end-stations or bridges)
  - excessive transmission rate
  - longer frames (tagging, padding)
  - forwarding in wrong transmission queue
  - excessive bridge delay
  - babbling (talker, bridge)
  - …
- Ingress policing is a widely-used method for protecting network against overloading
  - detect excessive traffic
  - discard frames of non-conformant streams that exceed reserved bandwidth
  - prevent excessive traffic from propagating to egress ports and even spreading through the network

Ingress policing is required to guarantee latency for control data streams

Overview of Flow Metering in 802.1Q

- Flow metering specified in 802.1Q
  - is an ingress policing mechanism
  - minimally specified for maximum flexibility
- MEF bandwidth profile as recommended algorithms for flow metering
  - a Token Bucket based two-rate three-color algorithm
  - also possible as a single-rate three-color ***(SRTCM)*** *(see right fig.)* or two-color version
  - Operation in "*color aware*" or "*color blind*" (color is a global or local value)
  - handling of colored frames
    - G: let go;
    - Y: forward in best efforts;
    - R: discard



CTB - Committed Token Bucket
CBS - Committed Burst Size
CIR - Committed Information Rate
ETB - Excess Token Bucket
EBS - Excess Burst Size
EIR - Excess Information Rate

http://www.ieee802.org/1/files/public/docs2013/new-tsn-haddock-flow-metering-in-Q-0113-v01.pdf

Why an additional Stream Metering Scheme is needed for Control-Data Streams in TSN!

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- 802.1 flow metering has no explicit support for TSN streams
  - how to identify TSN streams not specified
  - how to classify TSN streams (assign streams to meters) not specified

- MEF metering algorithms are NOT optimized for control-data streams

Metering Algorithms	MEF Bandwidth Profile	Proposed for Control-Data Streams
Interpretation of **ETB** with yellow tokens	Additional bandwidth for excessive traffic	additional bandwidth for temporal traffic overload caused by jitter in stream transmission
Consumed tokens for yellow frames *(see page 10)*	yellow frames consume only yellow tokens in **ETB**	yellow frames consume tokens in both **CTB** and **ETB**
Handling of yellow frames	transmitted in best efforts	must NOT be transmitted in other stream classes, because breaking guarantees for other classes
Optimization goals	bandwidth utilization	latency guarantee

Proposals:
Stream Metering Scheme for Control-Data Streams (1)

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- Stream-oriented flow metering – stream metering
  - explicit support for TSN streams
  - stream identification/classification (proposals of “Input Gates“ meant for this)

- Stream metering on every ingress port of all TSN bridges
  - faulty stream may arise anywhere along its transmission path
  - to ensure detection at places closest to failure sources and reaction at early stages

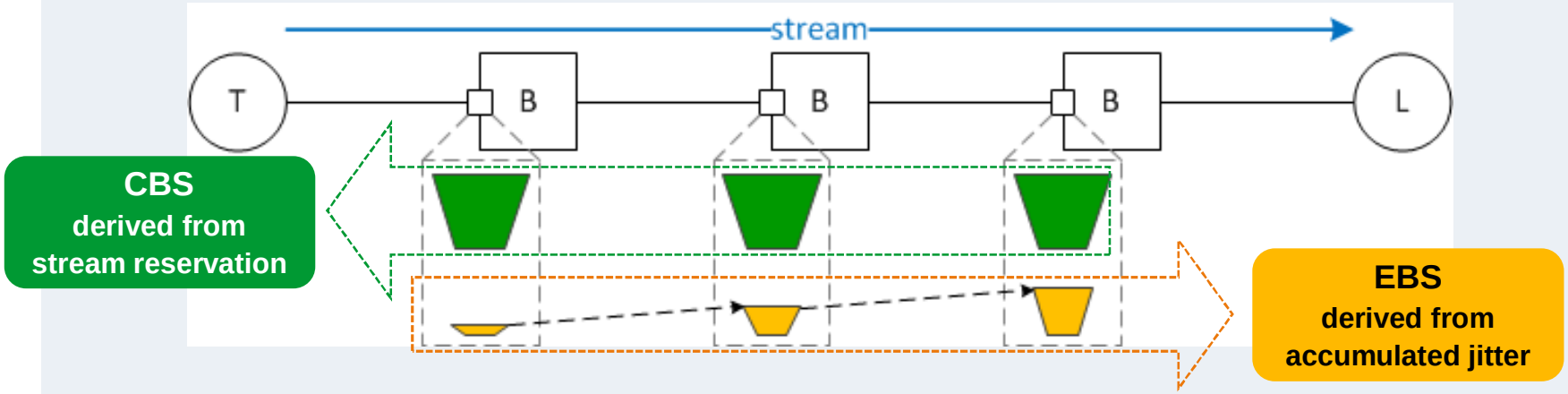
- Per-stream scheme policing
  - enable fault detection with accuracy down to stream level
  - avoid wrongly filtering out frames of other non-faulty streams that share the same class with the faulty streams

already discussed in http://www.ieee802.org/1/files/public/docs2013/tsn-jochim-ingress-policing-1113-v2.pdf

Proposals:
Stream Metering Scheme for Control-Data Streams (2)

- Threshold-enforcing
  - to restrict the load of a faulty stream while maintaining the stream connectivity
  - statistic counters for diagnostic and fault localization

- Jitter tolerance
  - jitter also causes temporally overloaded traffic
  - stream metering needs to distinguish between excessive traffic and jitter effects
    - on ingress ports, let jittered frames go through while dropping excessive traffic



Stream metering for the same stream at different ports should have the same CBS but different EBS

Proposed Metering Algorithm v.s. MEF SRTCM for Control-Data Streams with Jitter and Fault Cases

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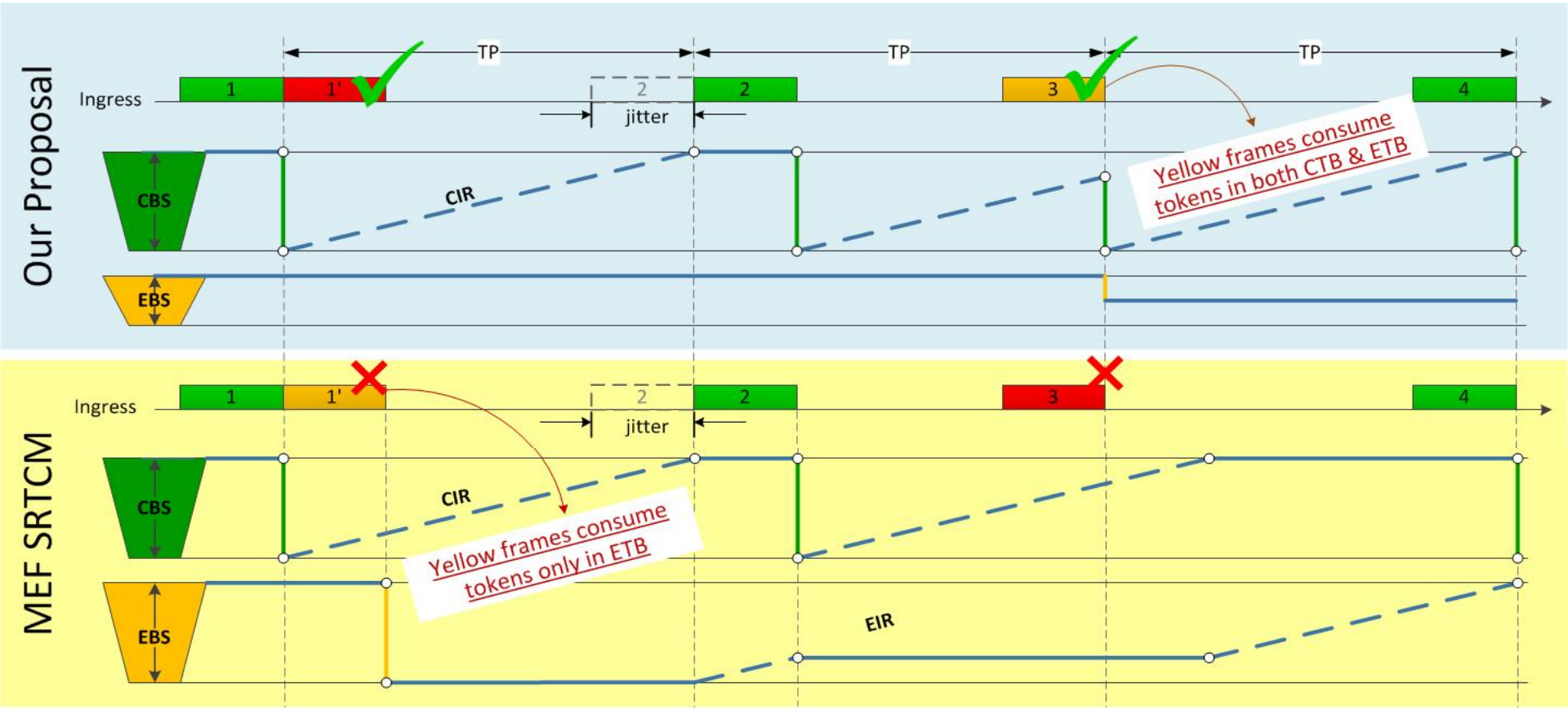


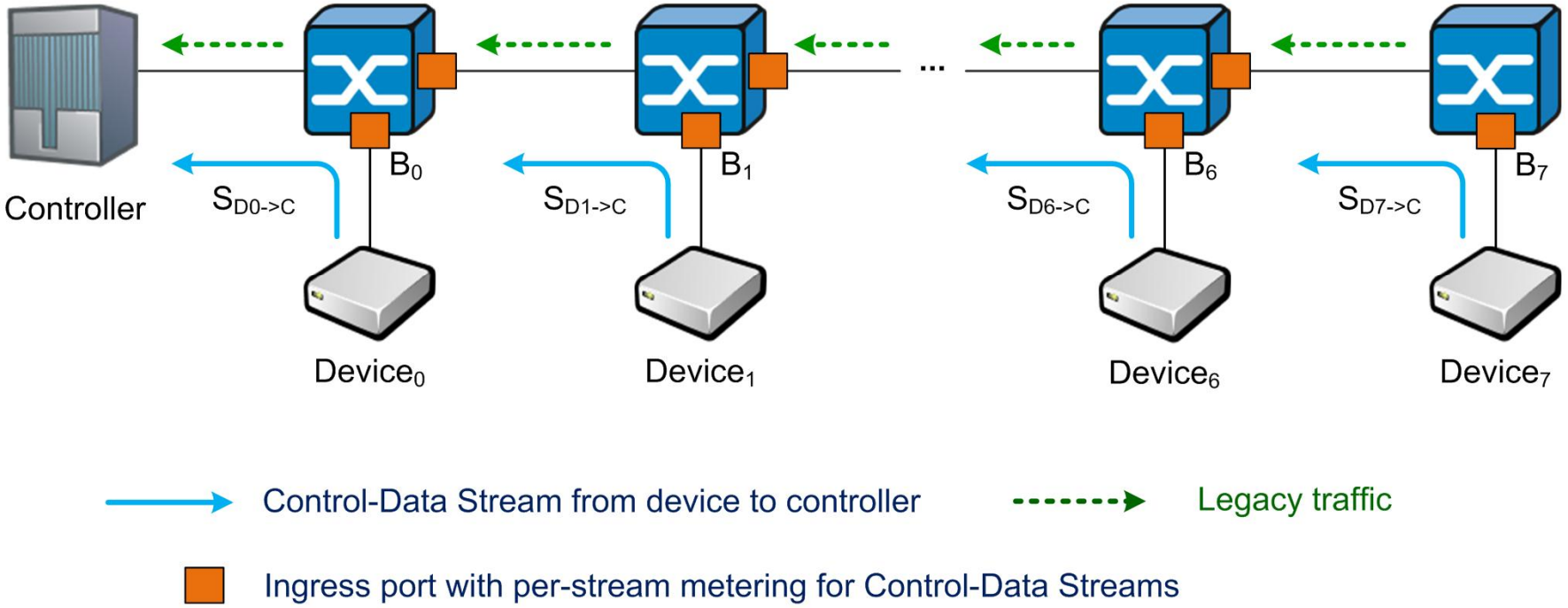
✓ expected handling

X unexpected handling

1' Is a duplication of 1, which must be marked as a non-conformant RED frame

2 is jittered, thus its distance to 3 is smaller than a TP, causing a temporal overload. Such overload situation must be marked as yellow.

Test Bench:
8 Devices -> 1 Controller in a Comb Topology



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Simulation Settings

Network settings	
Bit-rate	1 Gbps
Link delay (incl. PHY delays)	fixed for each link, random between 300 ns ~ 750 ns
Control-data streams talkers (devices)	
Synchronized, transmission period: **125 µs**, frame size: **100 bytes**	
Legacy traffic talkers (interfering traffic)	
100% traffic load, frame size distribution (25% 1536 bytes, 25% 64 bytes, 50% mean = 750B)	
Bridge settings	
Shaper	strict priority (control-data streams higher than legacy traffic)
Forwarding mode	store & forward
Switching delay	random between 50 ns ~ 500 ns
Pre-emption	control-data stream is preemptive over legacy traffic
Faulty stream generator (only at talkers of control-data streams)	
Traffic pattern of faulty streams	Babbling (repeating transmission of the same frame for 1~5 times randomly) fault probability (independent for each talker): 10%

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Simulation Results

Control-data-streams	Stream Metering Settings			Results		
	CBS	EBS*	CIR=EIR	max. end-2-end delay	excess ratio	drop ratio
w/o faulty streams	960 bits	1%	960 bits/125 µs	19.24 µs	0%	1.77%
		2%		19.32 µs	0%	0.82%
		4%		19.38 µs	0%	0.35%
w/ faulty streams		1%		19.36 µs	29.24%	31.06%
		2%		19.24 µs		30.03%
		4%		19.35 µs		29.59%
	disabled			27.43 µs		0%

* EBS is configured to be *(percentage of CBS) x (num of hops away from the talker for the targeted stream at that ingress port)*

- w/o faulty streams:

  drop ratio is slightly above zero due to inaccurate estimation of accumulated jitter for configuring EBS, which can be lowered by increasing the EBS (more jitter buffer)

- w/ faulty streams:

  - w/ stream metering: drop ratio slightly higher than excess ratio indicates that all excessive traffic is dropped, thus the max. E2E delay is not affected

  - w/o stream metering: no guaranteed latency (max. E2E delay will further increase if faulty streams of higher traffic load occur)

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Summary

- Stream metering is required for industrial control-data streams to
  - detect faulty streams with excessive traffic timely (on each ingress port) and precisely (per-stream scheme)
  - protect non-faulty streams from excessive traffic to guarantee latency
  - also protect other lower stream classes

- Requirements on stream metering algorithm for control-data streams
  - jitter tolerance
    - MEF algorithm is not sufficient for distinguish excessive traffic in faulty streams and jitter effects
  - threshold-enforcing
  - handling of yellow frames: must NOT be transmitted in best efforts

Thank you for your attention!

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