Stream Metering for Guaranteed Low-Latency of Industrial Control-Data Streams

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Recap: Features and Requirements of Industrial Communication at Different Levels

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Features	Field-Level	Control-Level	Plant-Level
Link Speed	100 MBit or less	>= 1 GBit	
Max. Stream Bandwidth	< 50%	< 15%	?
Typical Traffic	Control-Data-Streams	slow Control-Data-Streams AV-Streams	AV-Stream for diagnostic and measurement
	… mixed with Synchronization, Network Control and Best-Effort-Traffic		
Transmission cycle **(TC)**	31,25 µs		10ms
Low latency	Closed-Loop-Applications **~ <= 20% of TC** Control-Applications **~ TC** *(Open Systems)*	Control-Applications **~ TC** *(Open Systems)*	Application dependent **~ 2.. 10ms**
Transmission modes	scheduled and coordinated or scheduled	periodical or scheduled	periodical
Max. frame size	64 byte		600 byte
Topology	simple topologies Daisy Chains or Rings (e.g. 64 2-Port devices)	more complex topologies e.g. combination with rings, coupled rings, trees and stars, …	
Flexibility	Closed Systems with less requirements on flexibility	High requirements on flexibility Add and remove of streams at runtime without any effect on established streams	
Seamless Failover	single Rings	ISIS-PCR for more complex topologies and flexibility	
Path reservation	**Closed-Systems** with Static path reservation		
	Open-Systems with dynamic path reservation at runtime		
Bandwidth & resource reservation	is required for guaranteed QoS		
	Closed-Systems with static configuration **Open-Systems** with dynamic configuration	**Open-Systems** with dynamic configuration	Dynamic configuration

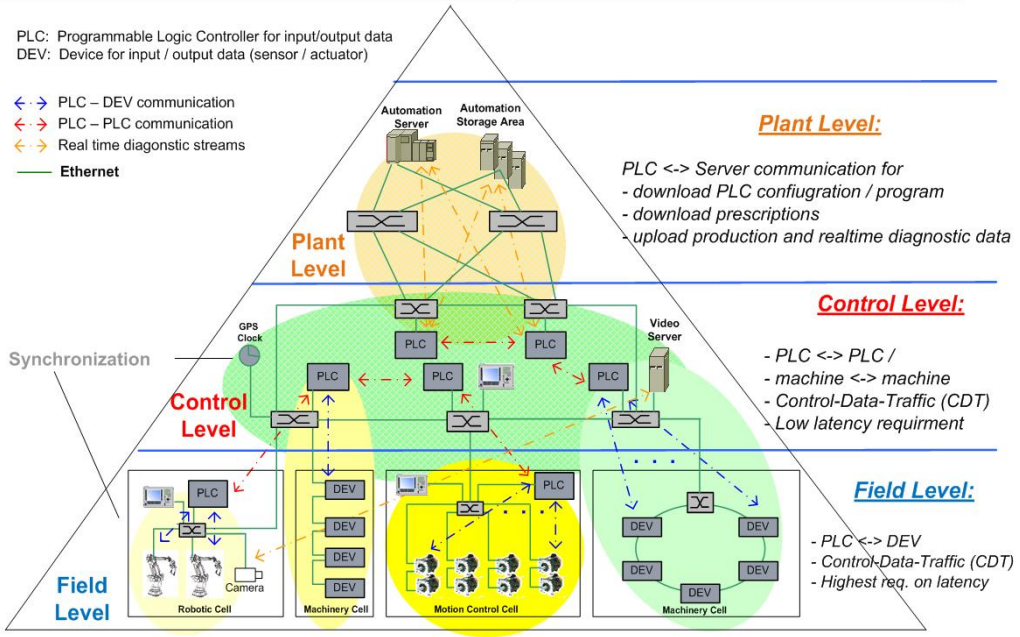
http://www.ieee802.org/1/files/public/docs2014/new-tsn-kiessling-Shaper-0714-v01.pdf

Desired Solutions for Industrial Control Applications on Different Levels

Features	Field-Level	Control-Level	Plant-Level
TSN solutions for industrial control systems with predominant requirements	Closed Systems: TAS (802.1 Qbv) **+ Ingress Stream Metering** for guaranteed lowest latency and low jitter	Open Systems: **SP + Stream Metering** for guaranteed low latency	Open Systems: SQF **+ Ingress Stream Metering** for guaranteed latency and low jitter
	Open Systems: **SP + Stream Metering** for guaranteed low latency		

How to guarantee low-latency for control data streams in industrial open systems

- transmit control-data streams with highest priority (no shaping applied)
- apply stream metering (policing) on both ingress and egress ports
  - limit receiving and transmitting rates by discarding non-conformant frames
  - detect misbehavior and prevent failure propagation
  - enable diagnostics



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A Overview of Flow Metering in 802.1Q

- 802.1Q specifies flow metering (in sub-clause 8.6.5)
  - is an ingress policing mechanism (located after filtering before queues)
  - only minimally specified for maximum flexibility (just a framework)
    - assignment of frame to meters (flow classification) left open
    - the metering algorithm not specified
    - how to deal with colored frames in queue management very loosely specified
- MEF bandwidth profile algorithm is referenced and recommended in 802.1Q
  - is a Token Bucket based two rate three color algorithm
    - color interpretation (G: committed; Y: excess; R: non-conformant)
  - can be configured to be a single rate three (or two) color version
  - operates 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)

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

http://www.avnu.org/files/static_page_files/90CCC9EF-1D09-3519-AD34763EC820D48D/AVnu%20AAA2C_Ingress%20Policing_Rodney%20Cummings.pdf

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Stream Metering in TSN

In AVB/TSN, we focus primarily on streams, such as AV-Streams and Control-Data-Streams, which are a subset of flows with known characteristics or requirements

(unidirectional from one talker to one or more listeners, typically periodic data, requiring e.g. low-latency, shaping, bandwidth reservation, seamless redundancy …) .

- Bandwidth reservation for streams but jitter in their transmission may form temporary overload
- Stream metering must distinguish between reserved bandwidth and additional bandwidth which is required to compensate jitter, and excessive use of bandwidth
- Stream metering will enable overload detection in failure situation caused by e.g. misbehaved talkers or bridges
- When stream metering detects an overload situation, non-conformant frames must be discarded to prevent failure propagation
- Stream metering helps to improve error localization
- Stream metering may be applied on ingress or egress
- To guarantee low latency for Control-Data-Streams or AV-Streams each network component along the path has to support stream metering.

Industrial Requirements for Streams Metering in TSN
1. Why Stream Metering is Needed at Ingress Ports

Stream metering per stream (or aggregate) at ingress port

Need to consider streams as a basic unit of stream metering in TSN, i.e. using a meter for one single stream or an aggregation of streams in order to:

- detect overload at earliest time before switching
- discard non-conformant frames (bandwidth, frame size, unreserved streams/frames, …) to prevent failure propagation to egress ports:

  passing a faulty stream (typically overloaded with an excessive burst size) may exhaust resources in transmission queues, causing delay or drop of other streams (possibly received from other ingress ports) in the same stream class.
- improve error localization down to single stream

Earlier presentation on ingress policing for TSN streams:

http://www.ieee802.org/1/files/public/docs2014/tsn-chen-ingress-policing-0714-v1.pdf

Industrial Requirements for Stream Metering in TSN
2. Why Stream Metering is Needed at Egress Ports?

Stream meters at egress ports measure transmission rate of outgoing frames of stream classes

- Shaping is not suitable for Control-Data-Streams with low-latency requirements, because it delays frames. SP serves low-latency better for control-data streams of highest priority.
- Egress metering performs jitter compensated bandwidth control for Control-Data-Streams by discarding non-conformant frames on a per-class base.

Why do we still need stream meters at egress ports, if already having them on ingress side?

Independent stream metering at ingress ports can cause overload for the stream class at egress port. If this overload is not locally detected, interference with other reserved classes can occur. Therefor also stream metering per class on egress ports is required.

Concept of Stream Metering for TSN
1. Leaky bucket or token bucket?

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Deployed as a meter, leaky bucket or token bucket are simply mirrored process in their basic algorithms.

Interpretation	Leaky Bucket	Token Bucket
Reserved bandwidth e.g. a rate of A bits/s	removing token at a rate of A	adding token at a rate of A
Consumed bandwidth e.g. receive or transmit B bytes	adding token of B bytes	removing token of B bytes
Overload indicator	adding B bytes causes bucket overflow or exceeding a specified max level	no enough token for B bytes left in the bucket

More important is to defined a metering scheme (based on leaky/token bucket) with functions that meet meet our requirements

e.g. CBSA is typically regarded as a special case of leaky-bucket algorithm by setting max_level to 0 (no burst allowed in normal case) and allowing positive credits for accumulating credits during an ongoing transmission of interfering traffic.

Concept of Stream Metering for TSN
2. What Kind of Metering Scheme do We Need?

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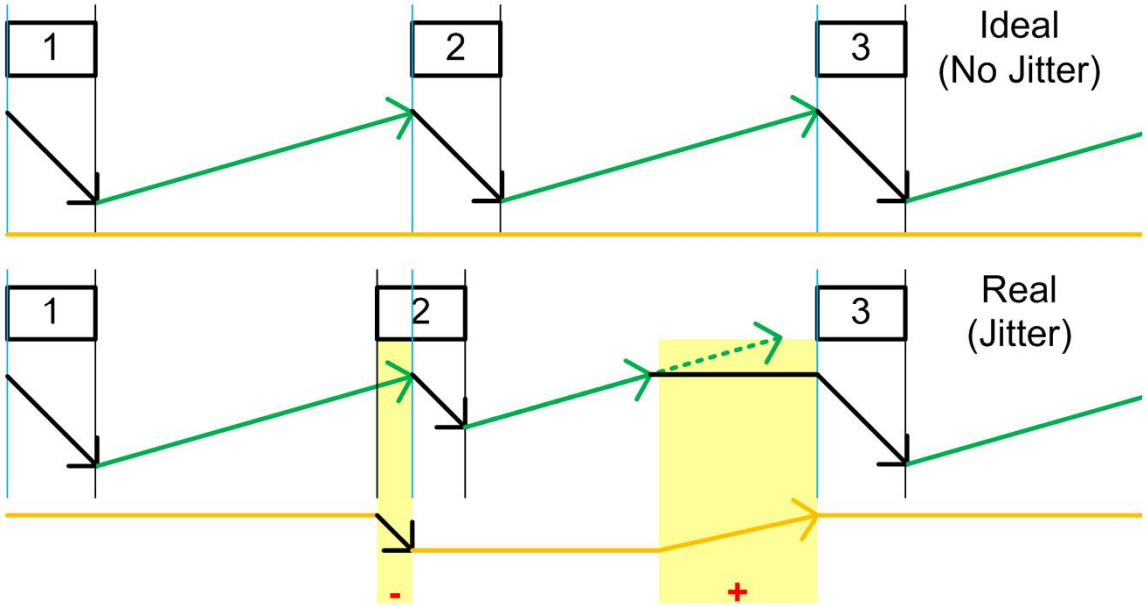
- Stream metering in combination with strict priority for Control-Data-Traffic is needed for both ingress and egress ports.
  - on ingress ports: per stream policing is desired and needed for control-data streams, can be also be applied to other streams like AV-streams
  - on egress ports: per-class policing scheme for Control-Data class
- Coloring scheme
  - color blind, i.e. color is valid only locally on ports, not propagated from ingress to egress and also not to next station
  - three-color (G, Y, R) scheme can be deployed
    - MEF defines that Y frames are transmitted with “Best efforts” (lowered priority), which is not desired for control-data streams, because doing that will overload best efforts traffic
    - Y may be used to indicate frames received or transmitted using extra bandwidth reserved for purpose of jitter tolerance.
    - to support jitter tolerance, a new metering algorithm is needed

Concept of Stream Metering for TSN
3. Example of Metering Algorithm

- two buckets algorithm (one for reserved bandwidth, one for jitter)



Thank you for your attention!

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