# Architecture to enable guaranteed Latency for Streams

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# Outline

- Recap: Industrial Automation Applications
  - Two different Industrial network systems
  - Requirements for the network
- TSN Streams
  - Handling of Streams in an AVB network
  - Extensions for TSN
- Summary – Missing Parts for using TSN

# Recap: Industrial Automation Applications

***Within industrial we have to differentiate two Systems:***

- **Closed Systems**
  Typical used for "Closed-Loop-Applications" like motion control system
  - Highest performance requirements
  - Engineered and highly optimized static network with TAS, CT and Preemption
  - Goal: lowest possible guaranteed latency (with "no" Jitter)

- **Open Systems**
  Typical used for "Control-Applications" like assembly lines
  - *Topology can change when applications are added , changed or removed at runtime*
  - *Guaranteed QoS & guaranteed low latency*
  - *Goal: Multiple automation applications share dynamically the network*

*BUT: Industrial networks can also consist of one Closed and multiple Open Systems*

# Recap: Latency

Worst-case effect of all Latency Sources must be considered

Sources of **Latency**

- Loss of Frames – Infinite End-to-End Latency
- Priority – Traffic from classes with higher priority
- Priority Inversion – Traffic from classes with lower priority
- In-Class Interference – Traffic from the same class
- Bridge Delay and other HW dependent effects

**Jitter**, because latency effects are not constant
(e.g. Influences from other traffic, ordering of streams, time sync, …)

**AVB / TSN** can avoid or limit the effect for Streams

# Recap: Overview of Mechanisms

**High Priority** for lower latency

**Reservation** to avoid congestion causing loss of frames

**CB** can avoid loss of frames in case of a failure

**Coordination** to influence congestion and in-class interference

**Preemption** to lower Frame Interference
(improve bandwidth usage in case of TAS)

**Shaper** influence Delay and Jitter

**Low Latency** and Shapers are converse requirements

But: **Robustness** in case of failures?
(robustness in case of failures – no additional delay in normal operation)

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# AVB Extensions for Streams

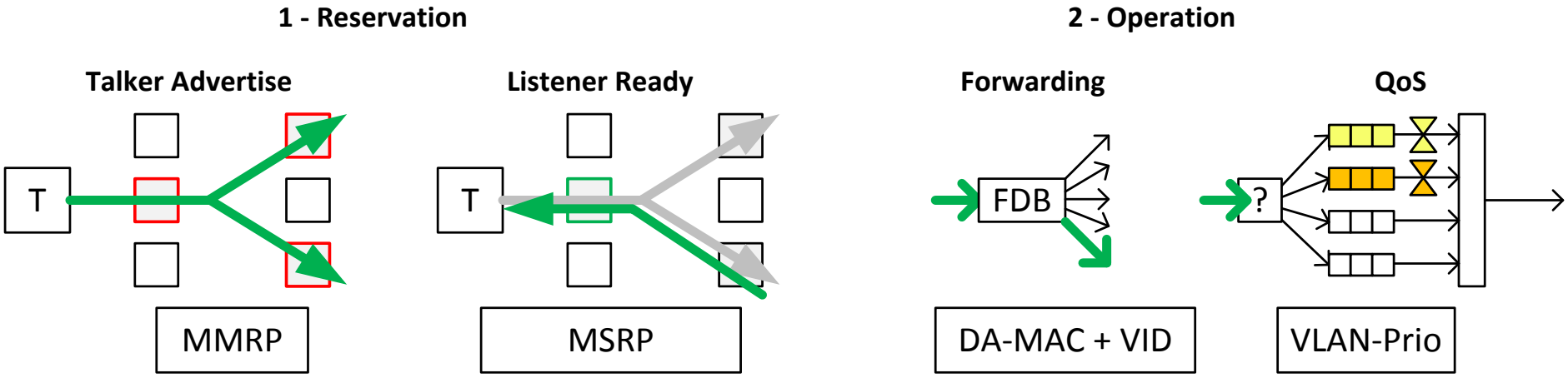
- AVB introduced QoS to Ethernet for AV Applications
  - Distinguished handling of Streams
  - Reservation to prevent “stream”-congestion
- AVB introduced high accurate timing
  - Enables the use of Ethernet with Jitter for synchronized Playback
  - Usable for other applications (e.g. Measurement)
- But: AVB doesn’t provide low latency with guarantees

# TSN Extensions for Streams

- TSN further improves QoS for time-sensitive Applications
  - Improved handling of Streams with Preemption
  - Reservation to prevent “stream”-congestion
- TSN is working on redundant high accurate time synchronization
  - Important for time-based systems
- *IETF is starting work in detnet for a Layer3 solution*
  - *Usage of TSN HW mechanisms for e.g. IP / MPLS / …*
- But: TSN doesn’t provide low latency with guarantees
  - Network Latency can get increased by one misbehaving Stream

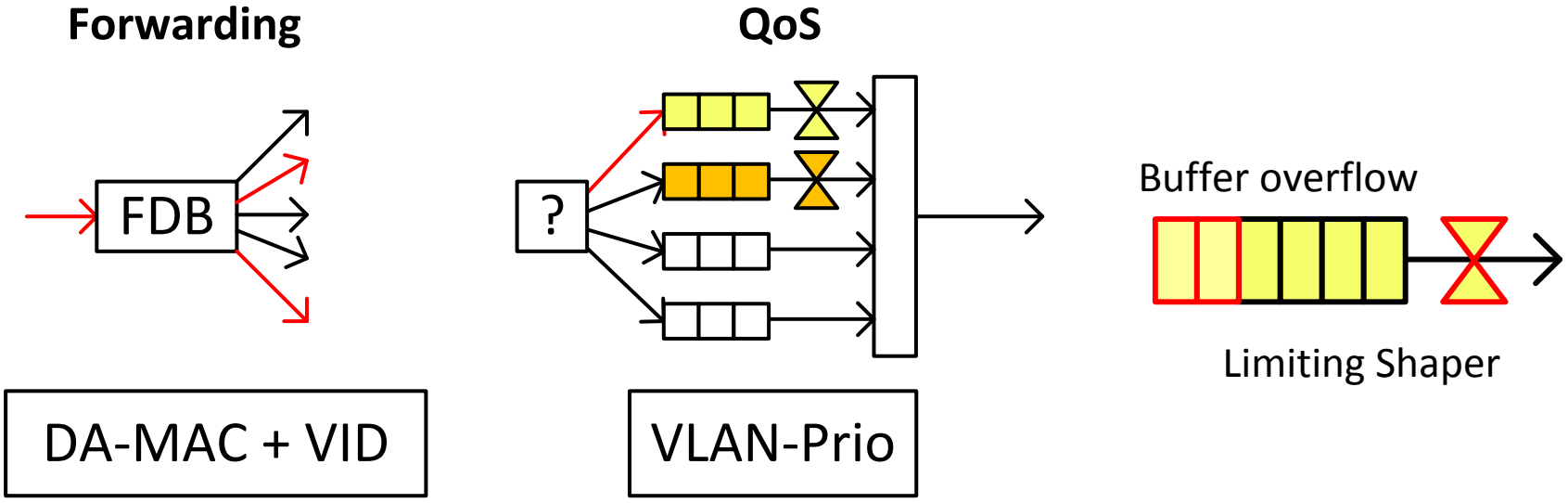
# Handling of Streams

- Steps from Stream Reservation to Operation
  - Advertisement of Stream Parameters using Talker Advertise (MMRP Talker Pruning can limit the forwarding Ports)
  - Reservation from Listener using Listener Ready (MSRP Reservation back to talker with path enabling)
  - Forwarding decision based on FDB Entry
  - QoS by VLAN Priority to Queue assignment
    Streams should use an exclusive queue!



# Forwarding of Streams

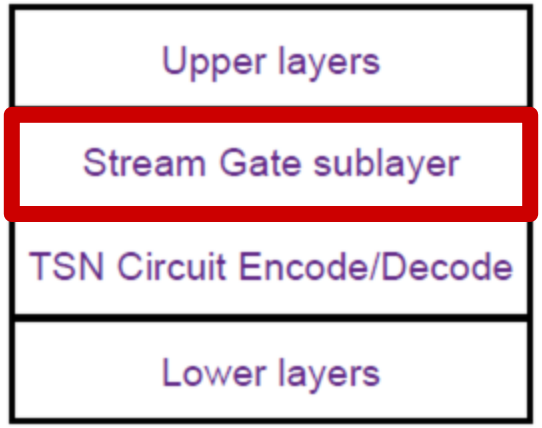
- No guarantees for low forwarding Delay
  - Shaper limits the forwarding rate
  - Queue can get filled due to Failures
  - Latency of the Stream Class increases
    (infinite Latency in case of dropped frames due to congestion)
- All Streams in the class/queue are affected



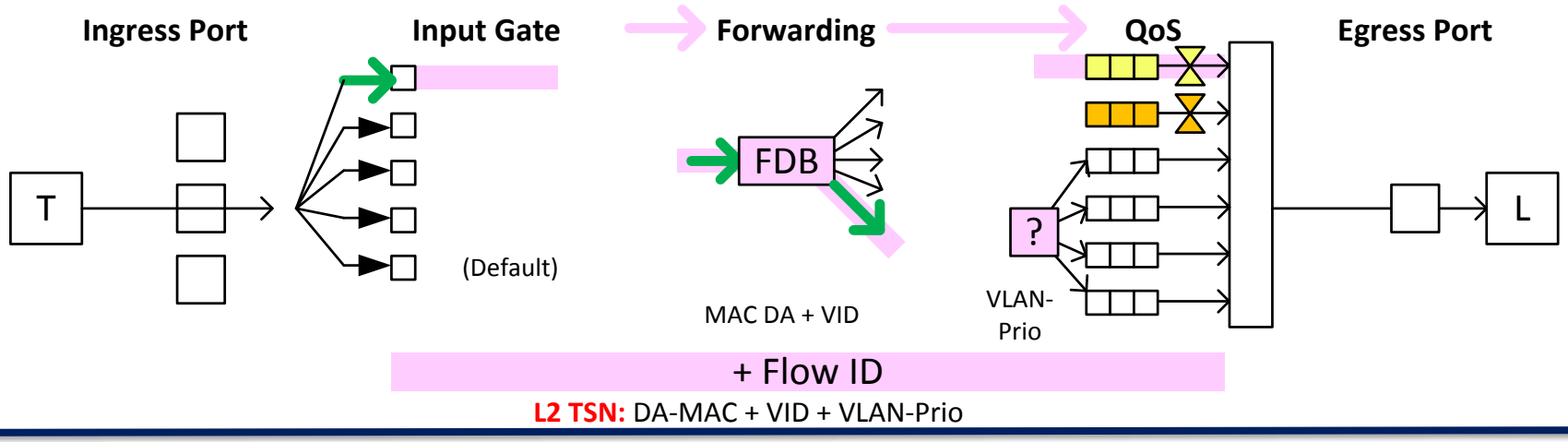

- The Connection between Stream and Queue is missing …

# Input Gates for TSN Streams

- Streams should use one exclusive class for transmission
- Gates can identify specific traffic (Streams)
  - L2 TSN: Based on DA-MAC and VID and VLAN Priority

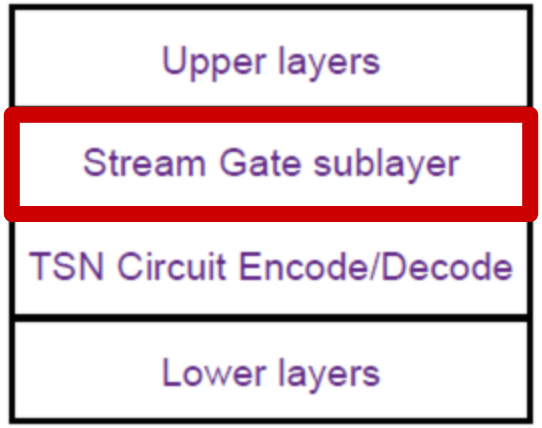


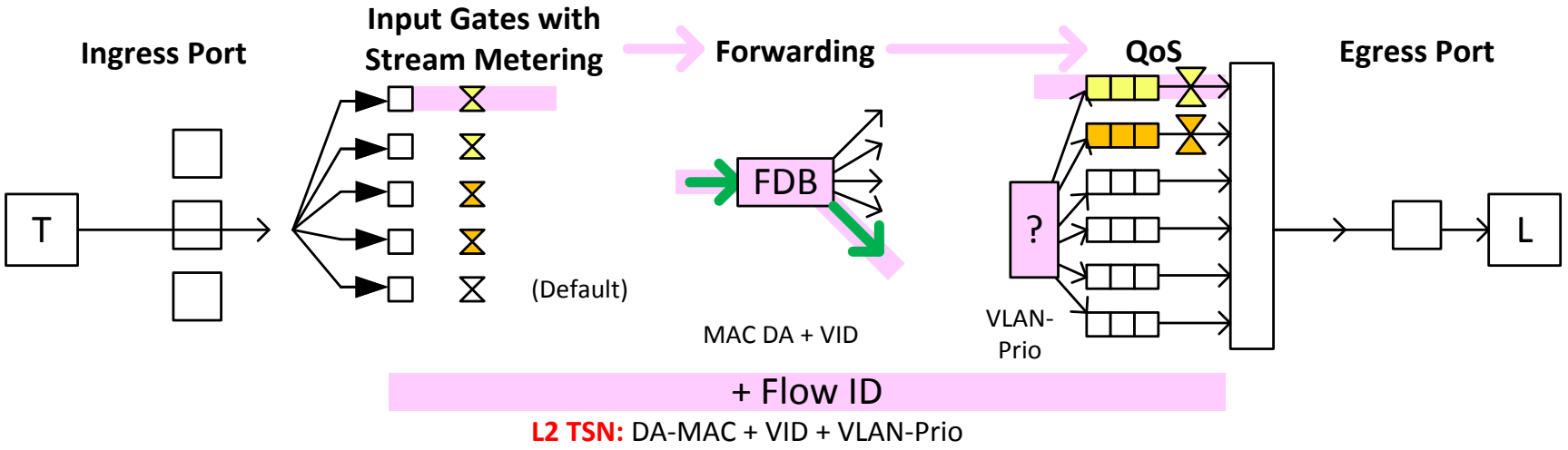

- Using the Input-Gate concept:
  http://www.ieee802.org/1/files/public/docs2014/cb-nfinn-input-gates-0914-v01.pdf



# Mechanisms for Input Gates

- Streams should use the exclusively class for transmission
- Gates can identify specific traffic (Streams)
  - Stream Metering can be assigned to a Gate
  - TAS mechanism to open/close Input Gates
    - *A possible way to define CQF*
- **cb-nfinn-input-gates-0914-v01.pdf**



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# Important Projects for guaranteed Latency

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## Current Status:

**Qbv TAS** for engineered, high performance systems

**UBS** for multiple traffic types

**Qch CQF** *as improved AV Shaper*

*(Naming: peristaltic shaper –> Scheduled Queuing and Forwarding -> Cyclic Queuing and Forwarding)*

**Q SP (Strict Priority)** with highest priority for Streams

~~Policing~~ **Stream Metering** requirement from automotive and industrial automation for **guaranteed** latency

- For TAS to **guarantee** "lowest" latency (engineered behavior)
- For UBS/CQF to **guarantee** latency (protection for streams)
- For SP to **guarantee** latency (protection for lower priority traffic)

# Basic Considerations for Policing

- **TAS Systems**
  Ensure that the right traffic is forwarded in the right (configured) time
  **Guarantees** for the scheduled traffic
- **UBS Systems**
  Limit the error propagation – don't affected other Applications
  **Guarantees** independently for every Application
- **SP Systems**
  **Guarantees** independently for every Application
  Jitter makes accurate bandwidth measurement difficult

**Primary Goal:**

*Guaranteed Latency not only in fault-free conditions*

*This is very important in multi-service networks*

Measurement per stream/class to limit the effect of failures