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Time Sensitive Networking from a Tools Perspective

Tool Implications in TSN Networks

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Agenda

- **Introduction**
- Time Synchronization
- Queueing and Shaping
- Tool Perspective
- Conclusion

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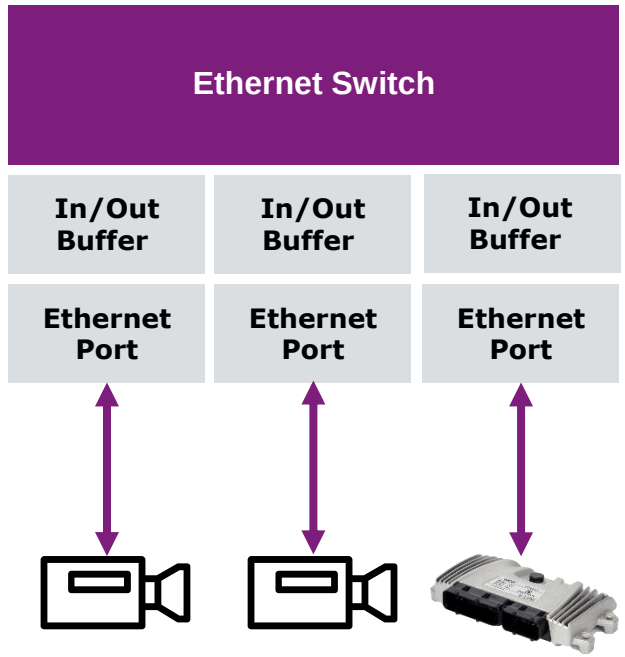
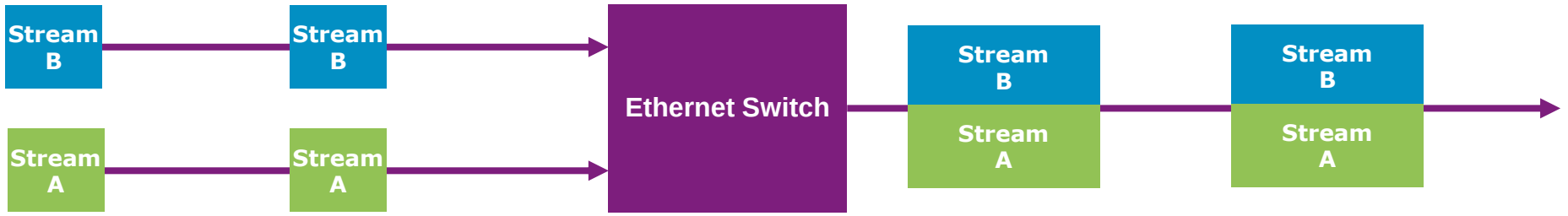
Challenges in traditional networks

- Example network without TSN
  - Two sources sending to one sync, may burst frame data at the same time
  - Temporary oversubscription
  - Packets must either be buffered or dropped in switch
  - Bursts are interleaved (best effort in switch)
- Unique challenges in Automotive Ethernet
  - Streams may be real time (e.g. Audio)
  - Streams may be critical and can’t be dropped
  - Network behavior must be predictable, ideally deterministic





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Solutions for time sensitive networks

- Time Synchronization
  - Provides mechanism for all network elements to have a common time base
  - Common terms: IEEE 1588, gPTP, IEEE 802.1AS
- Queuing and Shaping
  - Provides mechanism for network elements to schedule and prioritize traffic
  - Many options
    - basic VLAN priority
    - complex time aware and credit based shapers
  - Common terms: VLAN Priority, Time Aware Shaper, Credit Based Shaper, MSRP, IEEE 802.1Q, …

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IEEE Standards

- IEEE 802.1AS Timing and Synchronization for Time-Sensitive Applications (gPTP)
  - IEEE 802.1AS-Rev Timing and Synchronization for Time-Sensitive Applications
  - Reverences and defines usage of IEEE 1588 where applicable in the context of IEEE 802.1Q
- IEEE 802.1Q Bridges and Bridged Networks
  - IEEE 802.1Qav Traffic shaping for AV streams (FQTSS)
  - IEEE 802.1Qbv Enhancements for Scheduled Traffic (FQTSS)
  - IEEE 802.1Qbu Frame Preemption
  - IEEE 802.1Qca Path Control and Reservation (SRP)
  - IEEE 802.1Qat Stream Reservation Protocol (SRP)
  - IEEE 802.1Qcc Stream Reservation Protocol (SRP) Enhancements and Performance improvements
  - IEEE 802.1Qch Cyclic Queuing and Forwarding
  - IEEE 802.1Qci Per-Stream Filtering and Policing
  - IEEE 802.1Qcr Asynchronous Traffic Shaping
  - And more…

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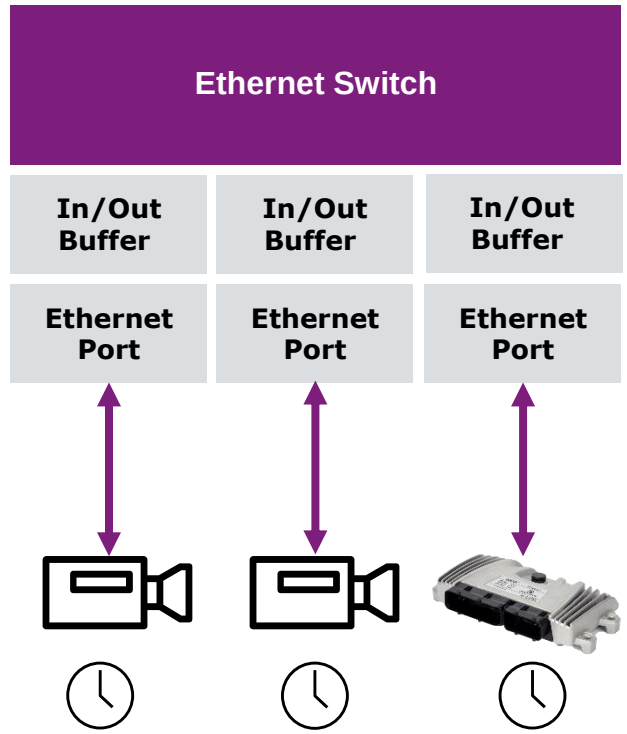
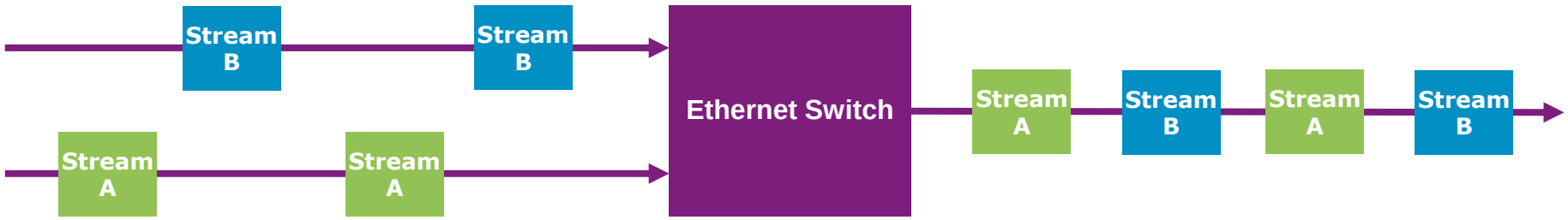
Time Synchronization

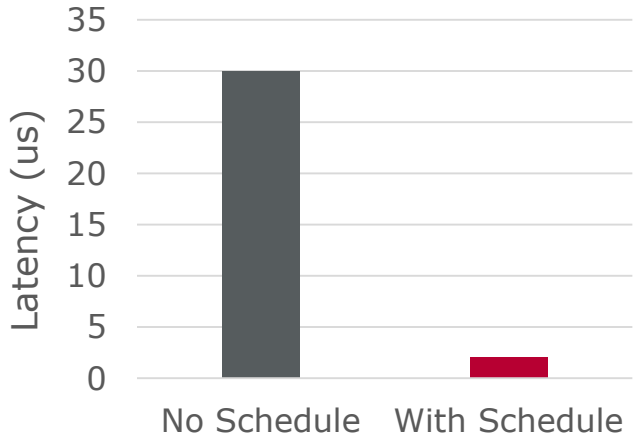
- First step towards a solution is to synchronize time across the network
  - Each network element contains a clock
  - Clocks are synchronized to common time base
- Applied to our simple example network:
  - Cameras and ECU synchronize clocks via switch
  - Cameras are programmed to start bursts at non-overlapping times
  - Packets are not buffered as they do not overlap

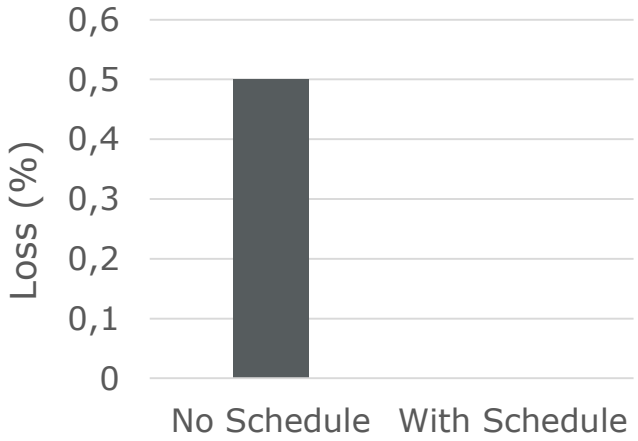




Network Performance with Synchronized Time

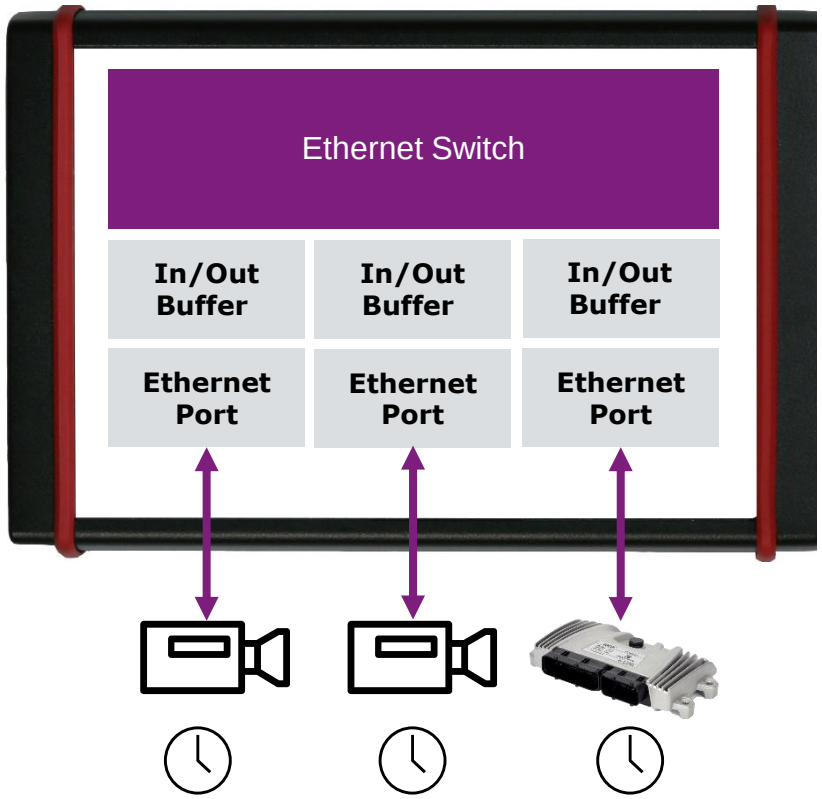
- Simple test with and without scheduled traffic
  - Using simple switch evaluation platform
  - In scheduled test the two streams are scheduled to not collide
- Overlapping streams:
  - Additional latency due to buffering (~30 us, depends on switch buffer size)
  - Packet loss due to temporary oversubscription / buffer overflow (0.5 %)
- Simple traffic scheduling:
  - Latency variation reduced to (2 us)
  - Packet loss eliminated (0%)





Tool Implications for Time Synchronization

- Time synchronization runs between switch endpoints
- The tool needs to be transparent to this time synchronization
  - Switch latencies are not constant, this interferes with time synchronization between endpoints
- IEEE 1588v2 transparent clock resolves this
  - Switch is transparent to clock synchronization
  - Implication - endpoints see adjustment field changes



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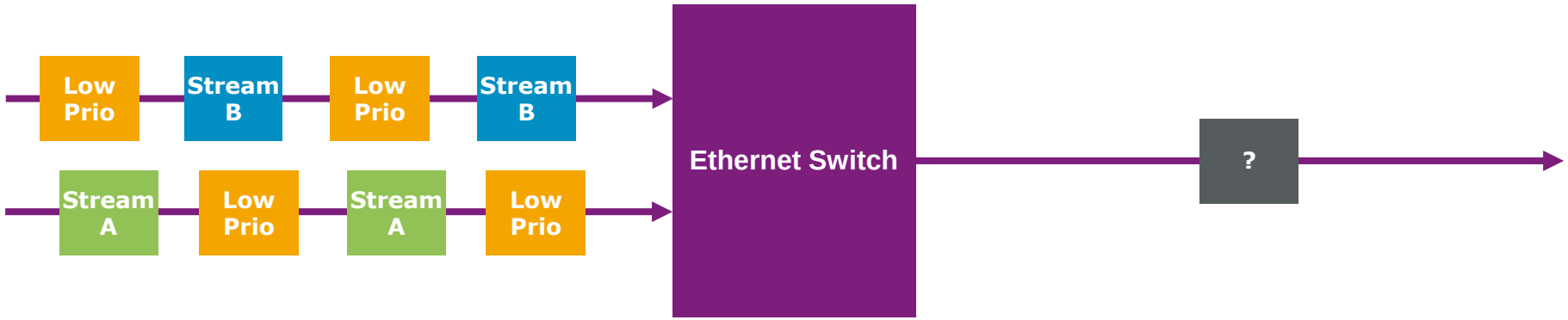
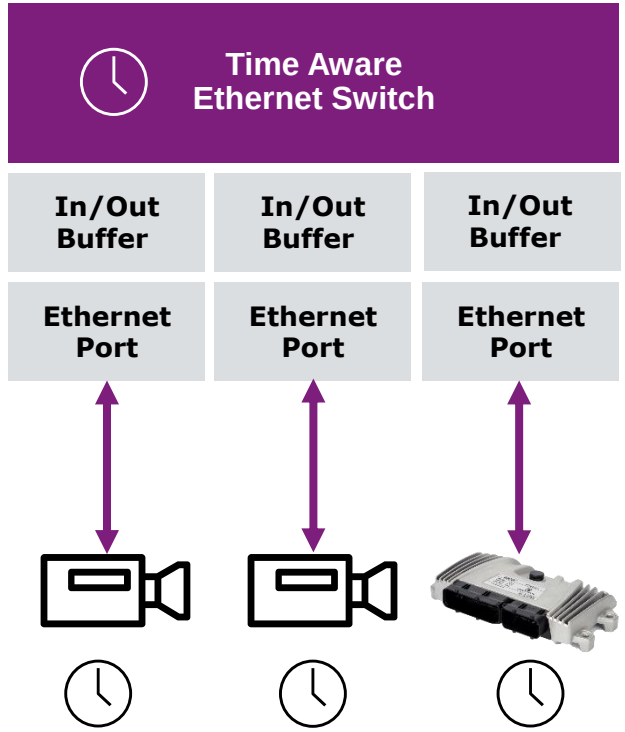
Queueing and Shaping

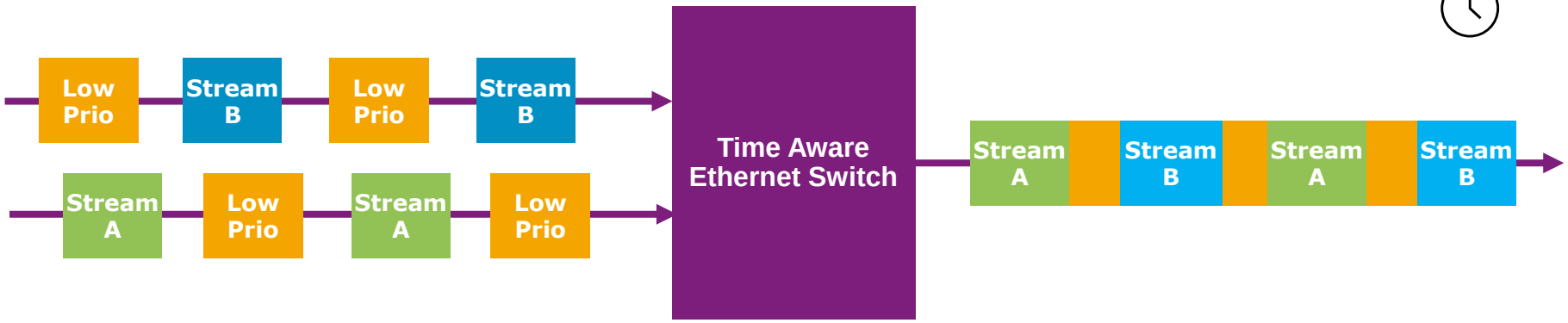


- Drivers for queueing and shaping
  - Non time aware network traffic (e.g. TCP/IP, etc.) interferes with our simple solution
- Queueing and Shaping allows us to partition network timeslots
  - best effort data does not impact time sensitive data

Queueing and Shaping

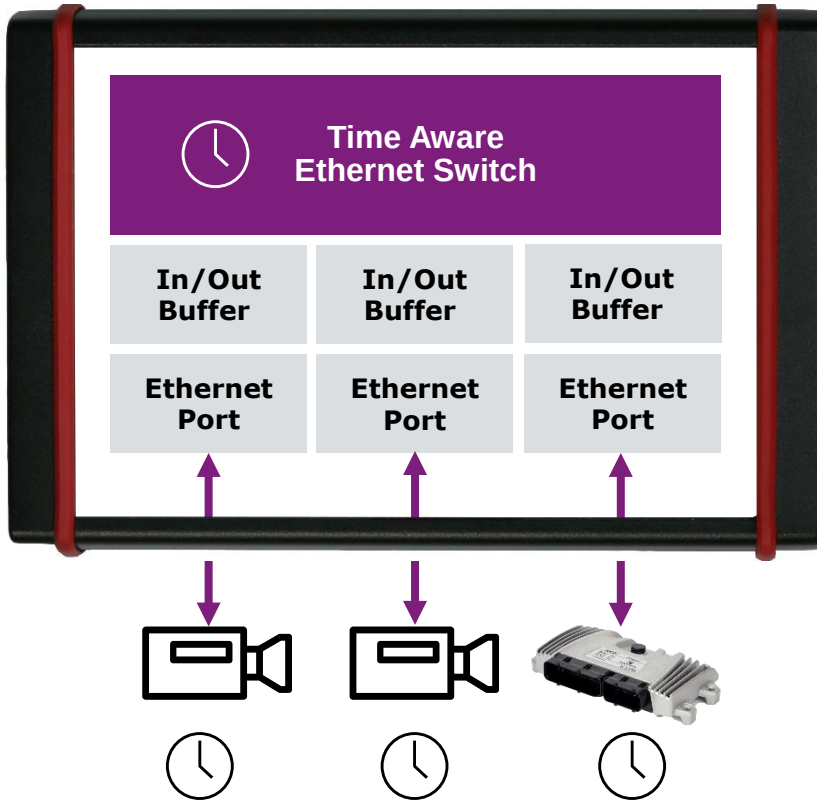
- Additions
  - Switch contains a synchronized clock
  - Switch contains queueing and shaping
- Result
  - Streams are placed in allocated time slots
  - Non time aware traffic fills gaps





Tool Implications for Queuing and Shaping

- Replace time aware switch with tool
- Implications for tool:
  - Time synchronization
  - Traffic identification and prioritization
  - Shaper Support (time aware, credit based, etc.)
  - Configuration interface to match simulated network



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Which Standards Need Support?

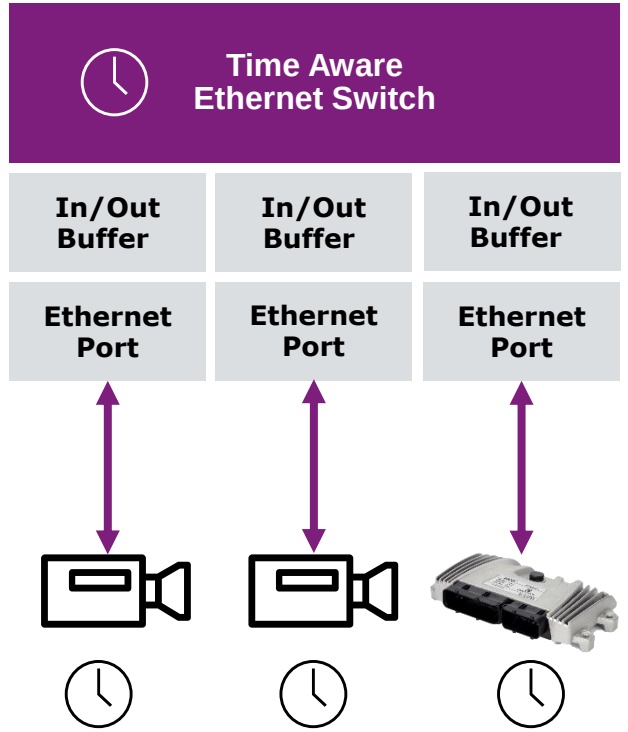
- TSN defines a large variety of scheduler and shaper solutions
  - Target markets include Automotive, Industrial Ethernet, Pro AV, and others
  - Tools need to support our customer needs without being overly costly or complex

- Highlighted Technologies:
  - 802.1AS Timing and Synchronization
    - Transparent Clocks
    - Boundary Clocks
  - 802.1Q VLAN priority queuing
    - 8 queues based on VLAN priority tag
    - Improves reliability but latency and buffering variation still occur on multi-hop networks
  - 801.1Qbv Time Aware Scheduler
    - Improves upon VLAN priority queueing by applying time slots
    - With proper configuration can bound jitter and latency in network
  - 802.1Qav Credit Based Shaper
    - Removes bursts in traffic to generate a constant bit rate
    - Avoids frame loss

  - Let’s consider an example

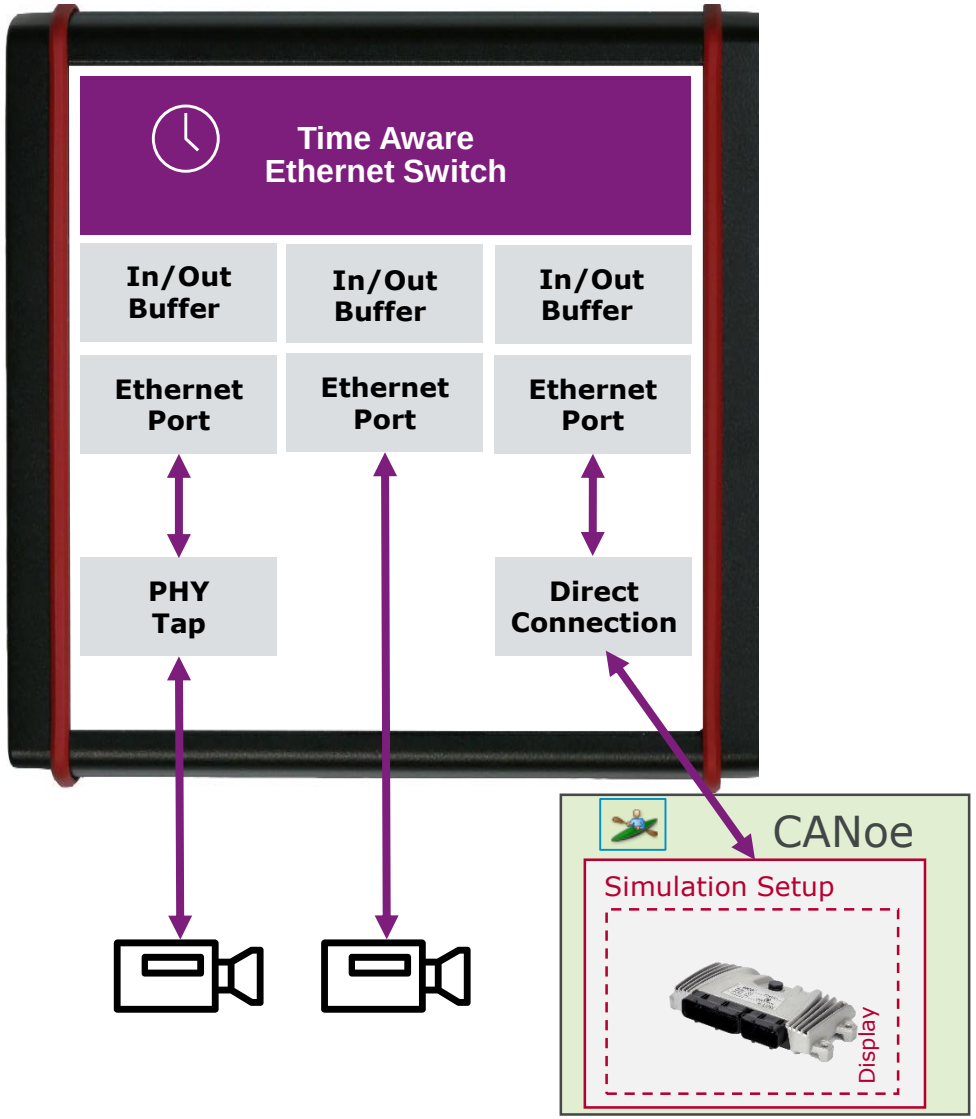
Example Network

- Basic Network
  - Two cameras
  - One Switch
  - One ECU
- Desired Measurement setup
  - Record camera data
  - Simulate Switch
  - Simulate ECU



Example Network

- 3 Tool Connection types used
  - PHY Tap
    - Allows recording of Camera data
  - Direct Connection
    - Allows CANoe to connect to network via switch for simulation
  - Switch
    - Allows devices to interconnect at wire speed with simulated devices



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Tool Implications for Different Connection Types

- PHY Tap
  - No special support is required, fixed latency
  - Transparent in test setup (minor latency impact)
- Direct Connection
  - Hardware timestamps the transmit and receive messages for software
  - Simulation environment can correlate itself to real-time and operate in a time sensitive simulation
- Switch
  - Time synchronization
    - Transparent Clocks
    - Boundary Clocks
  - Queuing and shaping
    - VLAN Priority, Time aware shaper
    - May or may not be required depending on complexity of network

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Summary

- Standards Support
  - The right standards need to be supported without creating a tool that is overly complex or expensive
  - Understanding customer use models is critical
- Transparency
  - Tool needs to be as transparent as possible when inserted in network
  - Tool influences on network need to be understood by customer
- Tool must support interaction with Simulation and Stand Alone Modes
  - Tool needs to work seamlessly with simulations (e.g. CANoe) to permit accurate modeling, testing and measuring of TSN networks
- Tool must provide an appropriate level of configuration and complexity
  - needs to be as automatic as possible
  - needs to be enough to support use cases
- Tracing and Debugging
  - The standards are complicated, thought needs to be given to debugging solutions

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