IEEE 802.1 Time Sensitive Networking TSN Profile for Aerospace Onboard Ethernet Communications

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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Time Sensitive Networking (TSN) Profile for Aerospace

- **Joint group between SAE AS-1A2 and IEEE 802.1 TSN in 2020**
  - Agreement to jointly develop the standard
  - IEEE Std 802.1DP™-2025/SAE AS6675-2025
- **Aerospace requirements**
- **Certifiability**
- **Interoperability**

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SAE International

- **Formerly Society of Automotive Engineers**
- **Founded in 1905, focused on two industries:**
  - Automotive and commercial vehicles
  - Henry Ford was a vice president
  - Aerospace
    - Purchase of Aeronautical Radio Inc. (ARINC) Industry Activities in 2014

- **Mission:**
  - Advance mobility knowledge and solutions for the benefit of humanity
- **Global association of more than 138,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle Industries**

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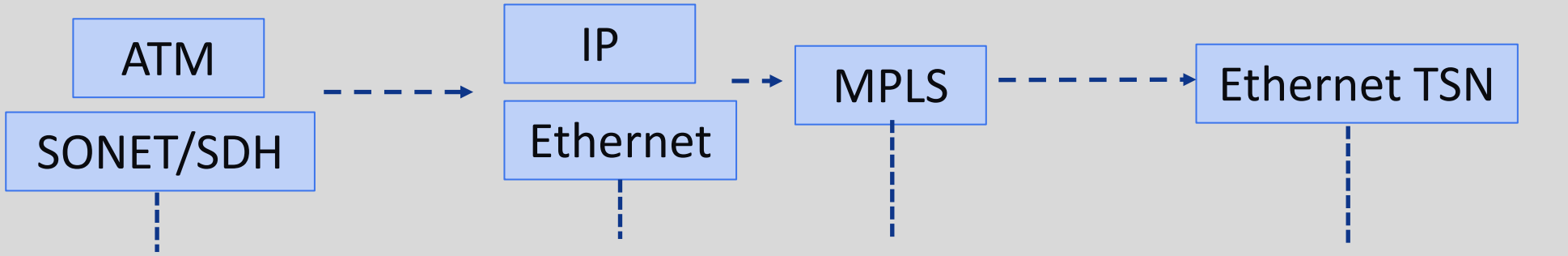
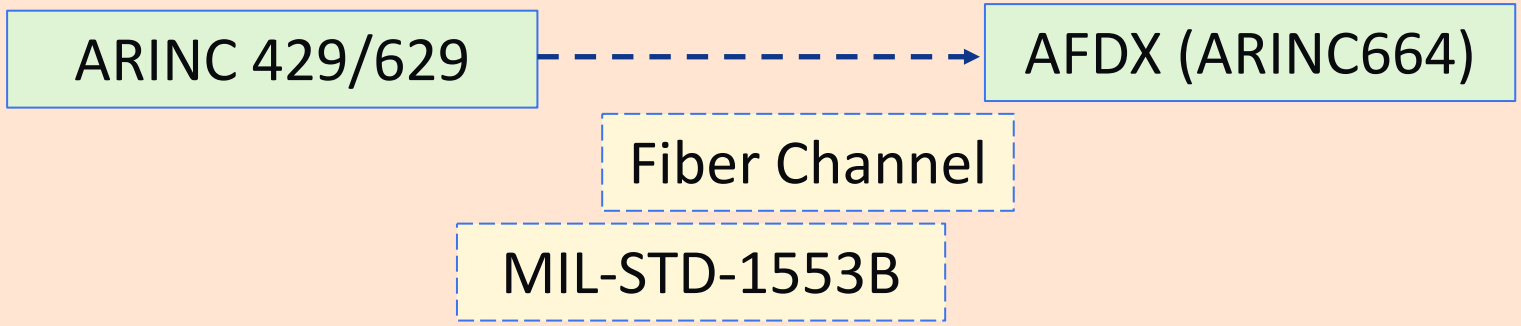
Deterministic Networking Technologies

Telecom



Aerospace/ Defense



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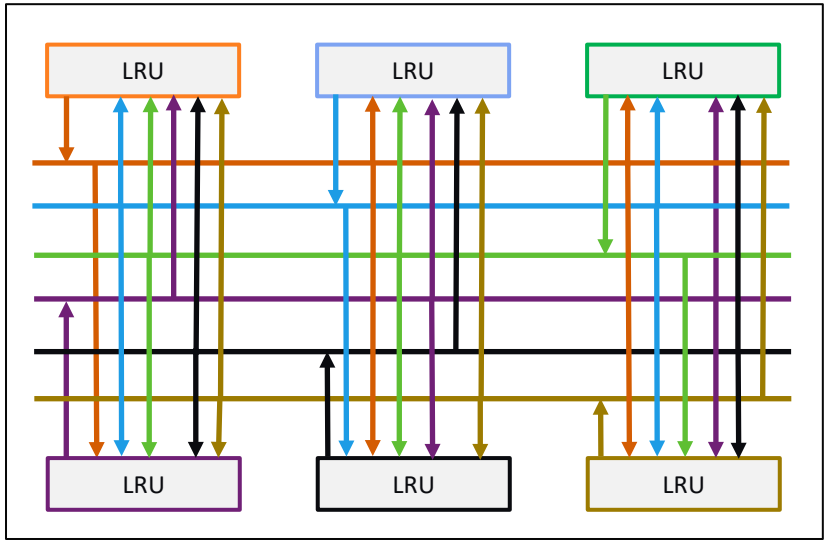
Avionics Deterministic Networking Technology

ARINC 429

- **Boeing 737, Boeing 757**
- **Avionics digital bus developed in 1977**
  - Flight management, air data computer, radio, altimeter, GPS sensor
- **Simplex network architecture**
  - Unidirectional buses for each direction (simplex) - 1 transmitter and 20 receivers
  - Serial twisted pair wire
  - Message consists of start of transmission signal and 253 data words and end of transmission signal
  - Star or bus topology
  - Bandwidth: 12.5 kbps to 100 kbps
  - Maximum 20 receivers
  - Custom proprietary hardware



Boeing

Cyber def. mag.

globalair

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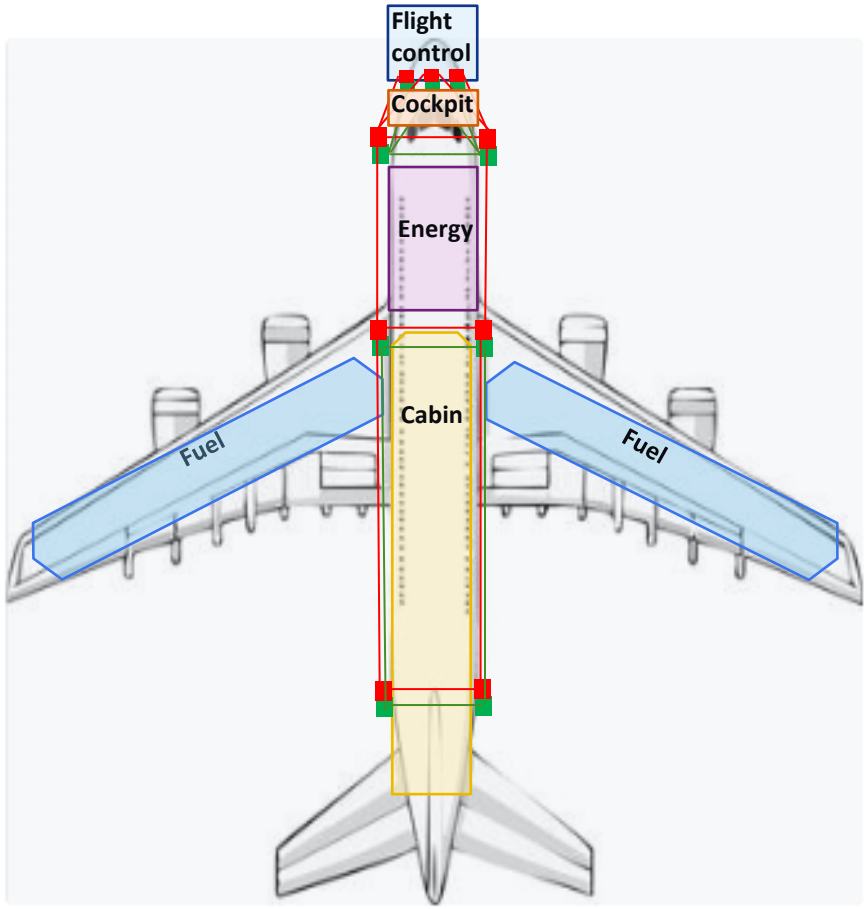
Avionics Full-Duplex Switched Ethernet AFDX

- **AFDX (ARINC 664 part 7)**
- **Ethernet Frame (1518 bytes)**
  - Packet switching (IP/UDP)
  - Switch: 20-24 ports
- **Bandwidth:** 100 Mbps (up to 1 Gbps)
- **ATM token bucket concept**
- **Unidirectional logical paths**
  - Virtual Link (VL)
  - Multicast: one transmitter and several receivers
- **Loose synchronization**

Airbus



■ Switch Network A

■ Switch Network B

Boeing 787/737-MAX
Airbus 220/350/400M
Sukhoi Superjet 100
COMAC ARJ21/C909
AgustaWestland AW101

Boeing

Boeing

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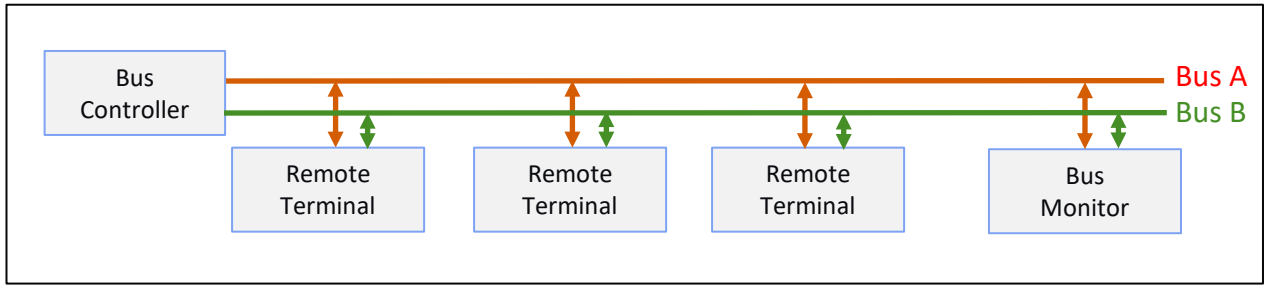
Avionics Deterministic Networking Technology

MIL-STD-1553B (Milbus)

- **Adopted by US Force, NATO, UK MoD, NASA, ESA**
- **Military Aircrafts/Vehicles/Weapons**
  - Air Force:
    - B-1, B-2, F-15, F-16, AWACS, F-35A, MQ-1 Predator, French Rafale
  - Navy/Marine:
    - F-18, F35B/C
  - Army:
    - H-64 Apache helicopter, CH-47 Chinhook helicopter, H-60 Black Hawk, M1A2 tank,
    - M2A3 Bradley fighting vehicle, Abrams M1A2, German Leopard 2
  - Weapons:
    - Tomahawk Long-Range, FMG-148 Javelin Anti-Tank Missile
  - Submarines:
    - Virginia-class SSN, Vanguard-class SSBN
- **Space**
  - International Space Station, James Webb Space Telescope, Space Shuttles, Ariane 5, Gallileo
- **Bidirectional architecture**
  - Bidirectional shared serial bus (twisted pair wire), TDM data bus
  - Bandwidth: 100 Mbps and maximum of 31 remote terminals



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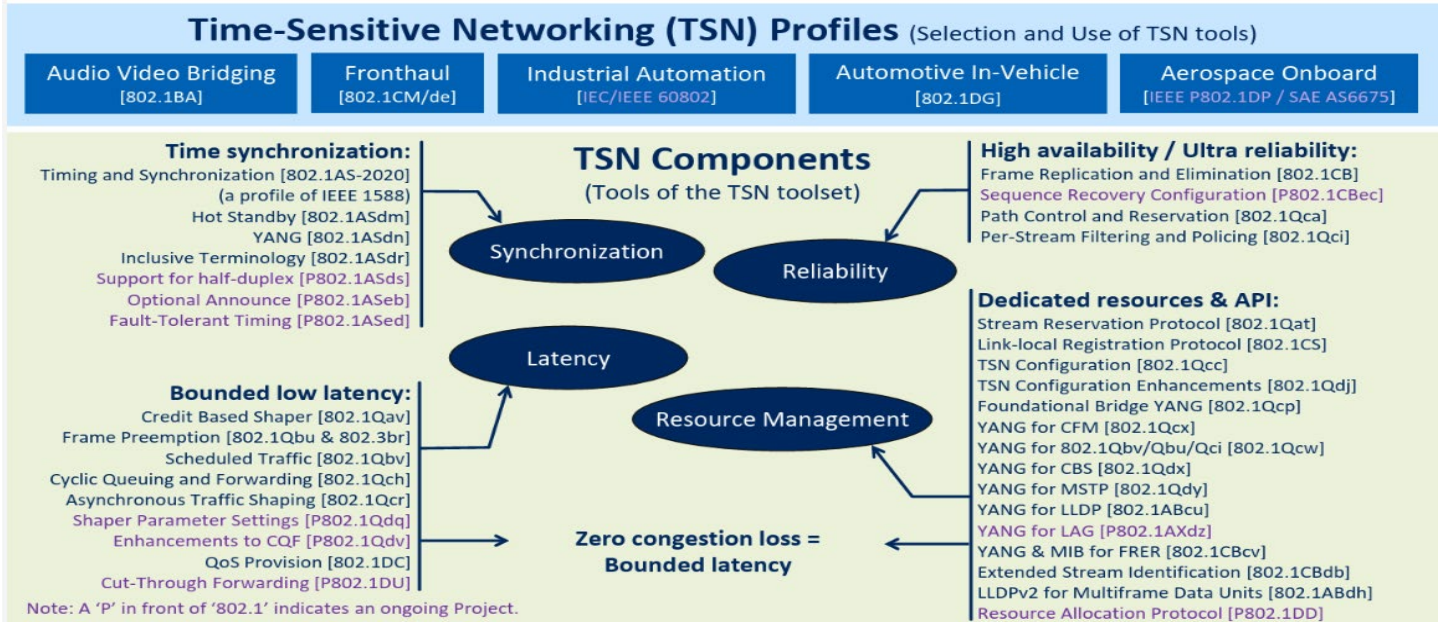
Time Sensitive Networking Profile

- Time Sensitive Networking
  - Applications that require bounded latency, synchronization, reliability, and high availability

- IEEE TSN Profile
  - Features
  - Options
  - Configurations
  - Protocols
  - Procedures



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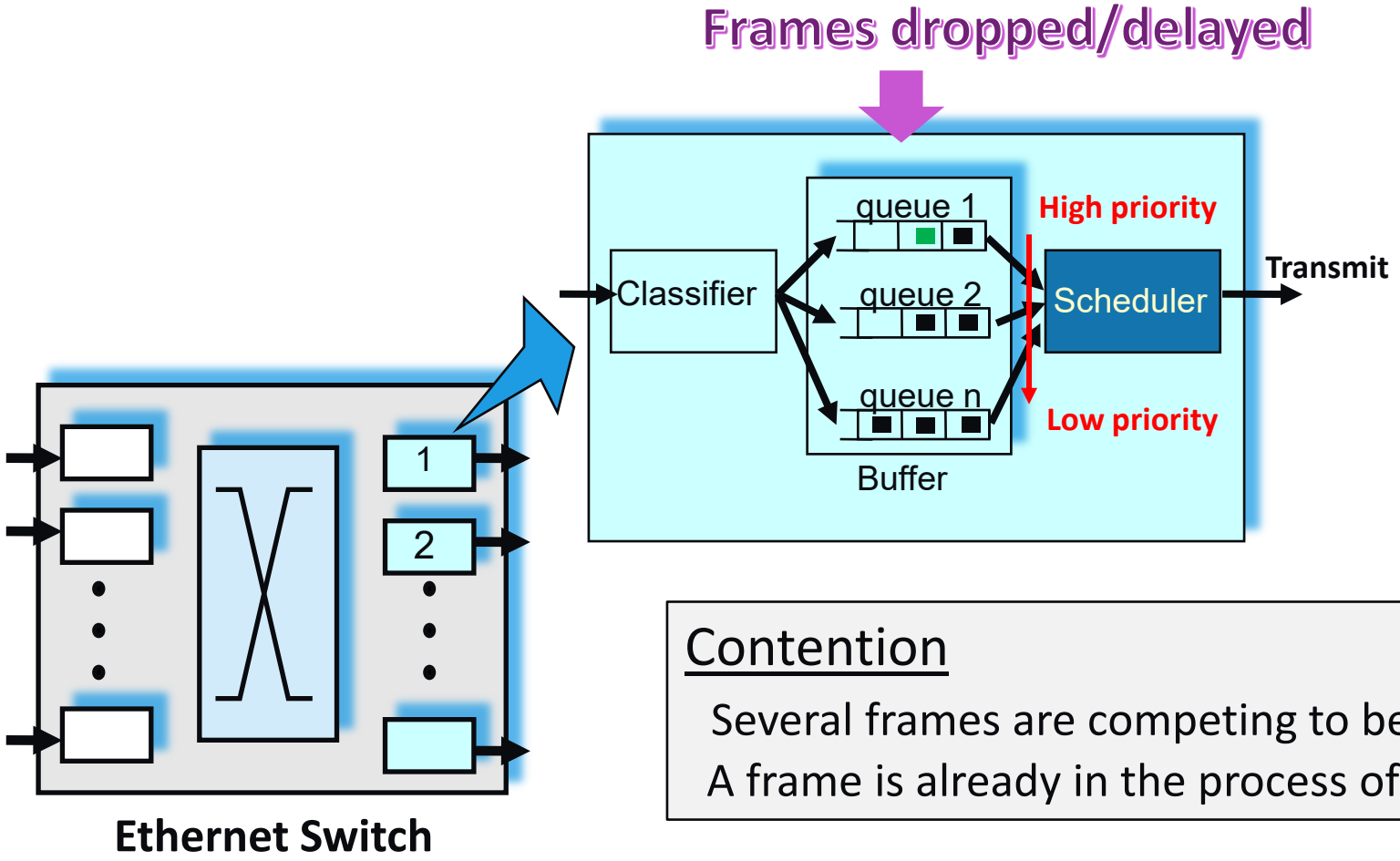
IEEE Time Sensitive Networking (TSN)

Deterministic Services



Contention

Several frames are competing to be transmitted

A frame is already in the process of being transmitted

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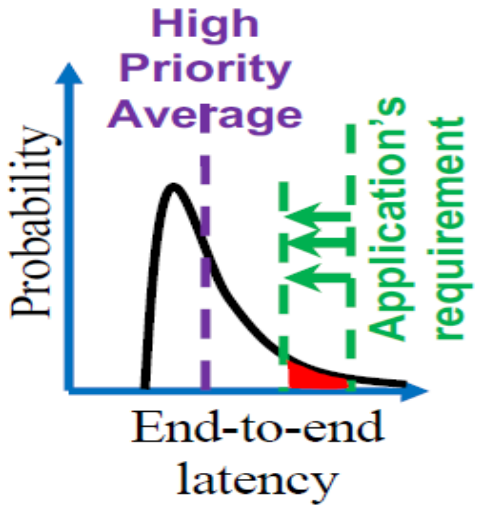
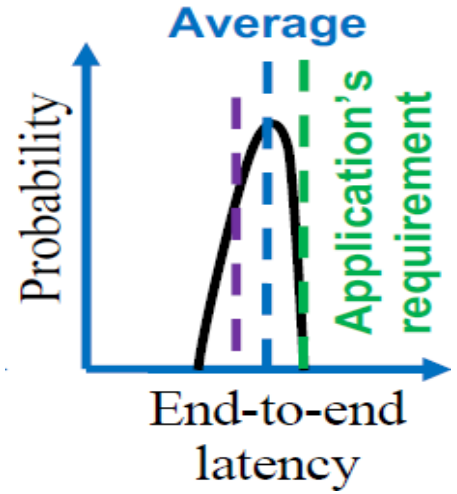
IEEE Time Sensitive Networking

Deterministic Services

- **Bounded low latency**
  - No overprovisioning
- **One-way latency**
  - High degree of time synchronization between the two end points



Overprovisioning



Deterministic
Service

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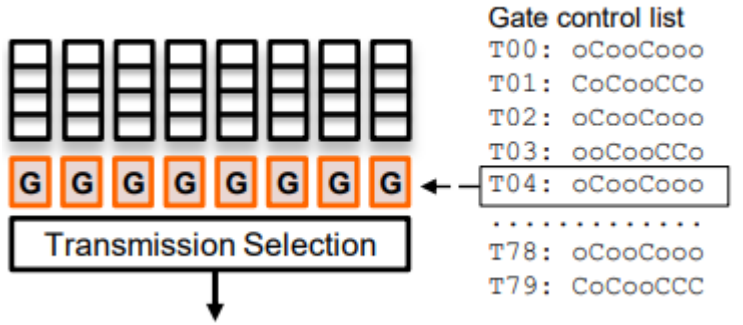
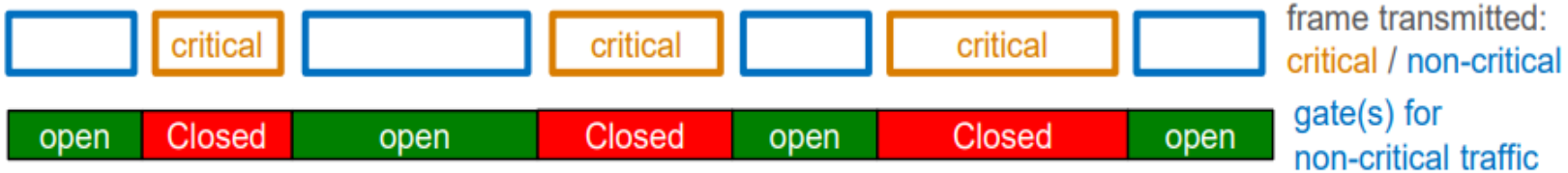
IEEE Time Sensitive Networking

IEEE 802.1Qbv Time-Aware Scheduler - QoS

- **Low latency data pattern**
  - Small bursts at known regular intervals (40 usec burst every 125 usec)
  - Delay start of non-critical frames before start of burst window

- **Fixed length, repeating time cycles (time-sync schedule controls all queues)**
  - Different time slices can be configured and assigned to one or several of the eight Ethernet priorities (TDMA)
  - **All clocks on all Ethernet switches and end devices are synchronized using IEEE 802.1AS**
  - Identical schedule on each device
  - A guard band in front of every time slice carries time-critical traffic
    - During this guard band time, no new Ethernet frame transmission may be started





Note: gate of non-critical data can be closed in advance to protect critical data

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TSN Aerospace Profile Synchronization

Synchronization Features

- **IEEE Std 802.1AS-2020 (IEEE Std 802.1AS-2025)**
- **Static engineered network**
  - GMs and time distribution tree is predetermined
  - No Best timeTransmitter Clock Algorithm (BTCA) function
- **Fault tolerance mechanisms**
  - 802.1ASed-2026 Fault-Tolerant Timing with Time Integrity
    - Multiple time domains
    - Multiple Grandmasters (GMs)
    - Multiple time distribution trees
    - Multiple PTP instances per physical port in bridges and end stations

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TSN Aerospace Profile Use Cases

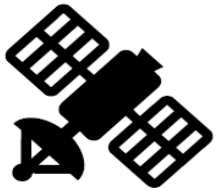
IEEE Std 802.1DP™-2025/SAE AS6675-2025

Commercial/Civil Aircraft
- Aircraft Control Domain Network (ACD)
  small and large passenger aircraft
- Cabin Network (ACD, AISD, PIESD)
  large passenger aircraft

Fixed Wing Military Aircraft
- Mission Network (small, combat, large)
- Flight Network (VMS)
- Fiber Channel over TSN (convergence)

Rotary Wing Military Aircraft
- Mission Network
- Flight Network

Unmanned Military Aircraft Network



Satellite
- Platform Network
- Payload Network

Ground Vehicles
- Vehicle Electronics

IEEE 802.1

Long lifecycle (20 to 50 years), small topologies, small number of use cases

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TSN Aerospace Profile Use Cases Topologies

Requirements

Characteristics	Aerospace profile	Most restrictive use cases
Number of nodes	500	Large Passenger Aircrafts
Physical topology	Hybrid-Ring and Star	Switched star: Large Networks Ring: Military
Number of hops	15-30	Large Passenger Aircrafts
Max number of streams per switch	4096	Large Passenger Aircrafts
Data rates	100 Gbps	Large Military Networks
Media type	Fiber for higher data rates	All Aircrafts
Network redundancy	Independent A/B networks	Independent A/B networks

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TSN Aerospace Profile Traffic Characteristics

Requirements

Characteristic	Current tightest bound	Aerospace profile (tightest bound)	Use cases driving tightest bound
Periodicity or cycle time	<1 ms	100 usec	Flight critical controls, sensors, weapons systems
Latency mode guarantee value	1 ms	100 usec	High criticality asynchronous events
Delay variation/Jitter	<1 usec	<1 usec	Fly-by-wire, synchronous sensors
Tolerance to loss	0	0	Flight control, weapons release
Payload size	2112 bytes	2112 bytes	Fiber Channel over TSN

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Summary

- **TSN Aerospace Profile marks a transformative milestone for the aerospace industry**
  - Ethernet is an open-standard, ever-evolving with huge vendor based (cost effective)
  - Aerospace industry already uses packet-based technology and the ethernet frame format
- **TSN Aerospace profile adopted by the defense industry**
  - US Army Aviation Architecture Framework requires IEEE Std 802.1DP
  - US Army Ground Vehicles requires IEEE Std 802.1DP
  - NATO Generic Vehicle Architecture (NGVA) adopted TSN

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Thank You