Lessons from ProAV: How MILAN Shows the Path to Scalable TSN Adoption Across Markets

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RELIABLE SYNCHRONIZED NETWORKING

Outline

- TSN Standards & Profiles
- ProAV Requirements
- MILAN
- Deployments
- Lessons for Scaling TSN

Base TSN Standards & Profiles

- Base standards define the "tools in the TSN toolbox" with flexible protocols and capabilities
- Profiles specify required features and constraints for implementations to meet domain-specific requirements.
  - ➢ Defining strict requirements, reducing optional features and ambiguity are critical for multi-vendor system interoperability

	IEEE 802.1BA AVB	IEEE 802.1DG	IEEE/IEC 60802	IEEE 802.1DP
TSN Profiles* (Examples)	Pro AV	Automotive	Industrial	Aerospace
Base TSN Standards* (Examples)	IEEE 802.1AS IEEE 802.1Qbv	IEEE 802.1Qav IEEE 802.1Qbu	IEEE 802.1Qcc/Qdj Many other tools/standards …	

* Not a comprehensive list. Refer to https://1.ieee802.org/tsn/ for a complete list.

Professional Audio & Video (ProAV) Converged Network and Deterministic Requirements

Networked ProAV devices are present in all kind of buildings and industrial context

- Live performances is often seen as core ProAV market, but it is just 'visible tip of the iceberg'
- Strong need for convergence with other protocols in installations

ProAV requirements:

- Working Clock and Global Time
- Guaranteed latency
- Zero congestion loss
- Well-defined resources and APIs
    - → similar requirements as other applications!!!
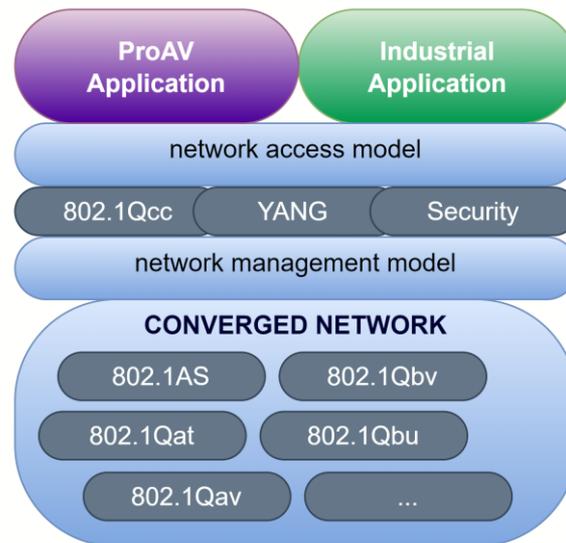
MILAN – TSN for Professional Audio and Video

Avnu Alliance's Milan (Media-Integrated Local Area Networking) Specification builds on the IEEE 802.1BA (Audio Video Bridging Systems) TSN profile and other IEEE standards (IEEE 1722 and 1722.1) to meet ProAV requirements for media networking over Ethernet.

The Avnu Alliance maintains the Milan specification*, certifies compliant devices, and promotes interoperability based on TSN standards.

TSN Profiles

Pro AV

IEEE 802.1BA-2011 – Audio Video Bridging

Base TSN Standards

IEEE 802.1Q-2014 – Bridge and Bridged Networks
IEEE 802.1AS-2011 – Timing and Synchronization for Time Sensitive Applications
IEEE 1722-2016 – Transport Protocol for Time-Sensitive Applications in Bridged Local Area Networks
IEEE 1722.1-2021 – Device Discovery, Connection Management, and Control Protocol for IEEE 1722(TM) Based Devices

* Milan Specification – Avnu Alliance is available for free. No membership required.

Milan TSN Capabilities

Network Synchronization & Flawless Media Playback

Accurate time synchronization (based on 802.1AS) is crucial for aligning audio streams in real time

Deterministic Data Transport & Mixed-criticality

Milan ensures predictable data delivery for AV streaming through bandwidth reservation (802.1Qat / SRP) while coexisting with best-effort traffic (802.1Qav / CBS)

Redundancy and Failover Mechanisms

Multiple network paths to provide redundancy and automatically switch to backup network paths to maintain continuous media transport
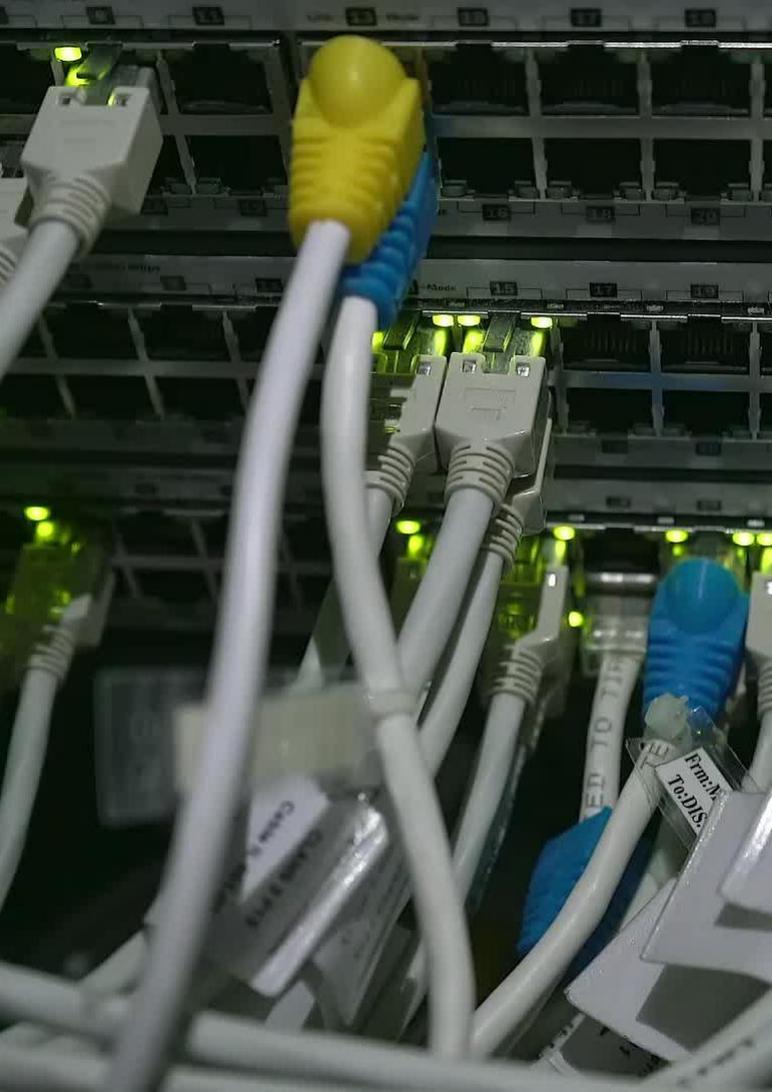
Ensuring Milan Interoperability and Plug-and-Play

Strict Interop Requirements

The Milan specification (the profile)* sets mandatory features to ensure devices from multiple manufacturers work seamlessly. The requirements include

- Media formats
- Time synchronization capabilities
- Redundancy and control plane requirements

Testing & Certification

Avnu provides open/collaborative testing opportunities (via interop events/Plugfests) and clear certification requirements that Milan device vendors must meet

* Milan Specification – Avnu Alliance is available for free. No membership required.

From Conformance to System Interoperability
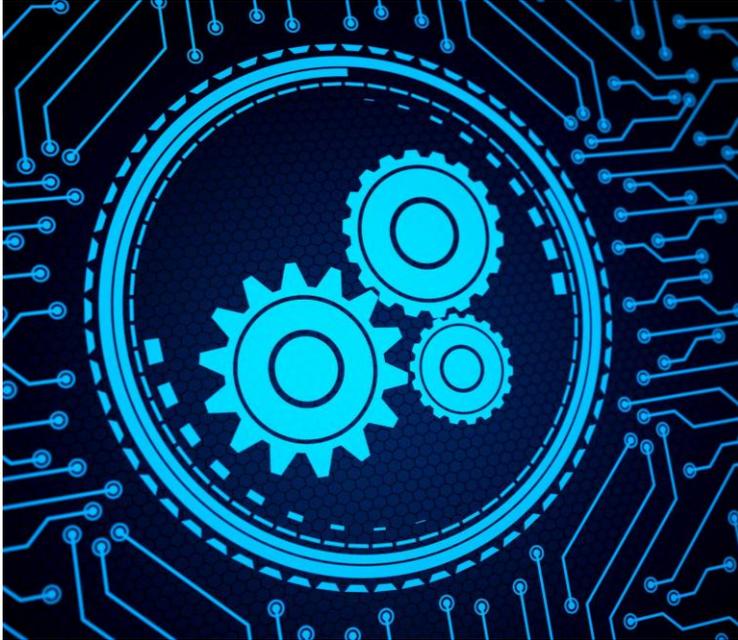
Conformance vs Interoperability

Conformance alone does not guarantee system-level interoperability across different vendors and implementations.

MILAN Certification Program

MILAN pairs constrained profiles with formal testing and certification to validate protocol compliance and interoperability.

Importance of Testability

Testability and certification readiness are crucial for profiles to scale and ensure consistent implementation across vendors.

Reinforcing Standards Intent

Certification enforces consistent interpretation and implementation of standards as a technical mechanism, not just market activity.

Avnu TSN Switch Certification: Milan-AVB Switch

Profile Agnostic Testing for common features

The plan leverages the existing Avnu profile agnostic test plans for MRP, MSRP, MVRP, CBS and gPTP
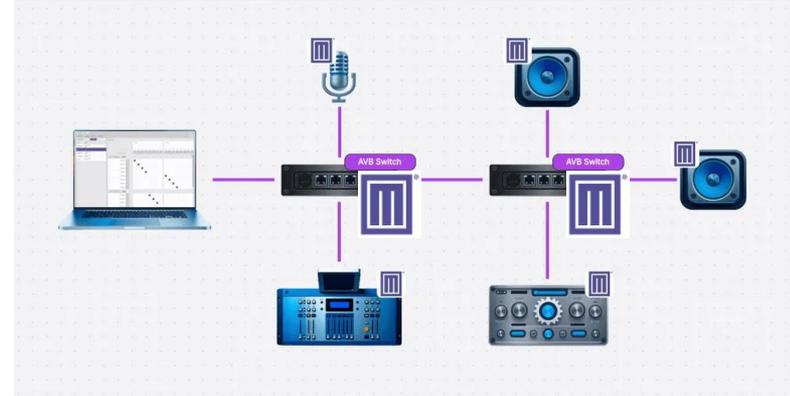
ProAV Specific Testing

Additional testing based on the 802.1BA AVB profile

On track to be released Q2 2026

→ Similar programs are planned for other verticals (Industrial/60802, Aerospace/802.1DP)

The missing piece for a fully certified Milan Network

MILAN Deployment Example: Super Bowl Halftime Show

MILAN Deployment Scale
The Super Bowl halftime show deployment exemplifies MILAN's capability in large-scale, complex live audio environments.

Network Redundancy and Reliability
The system used MILAN with tertiary AES redundancy ensuring zero tolerance for audible failure during the event.

Mission-Critical Performance
MILAN's profile-constrained IEEE 802.1 TSN system meets strict timing and mission-critical requirements in extreme conditions.

Industry Significance
Deterministic system behavior in time-critical/ failure-intolerant environments.

AVB/TSN Live!
Enabled by Avnu
Certified Milan
Devices

Lessons for other TSN Profiles & Verticals
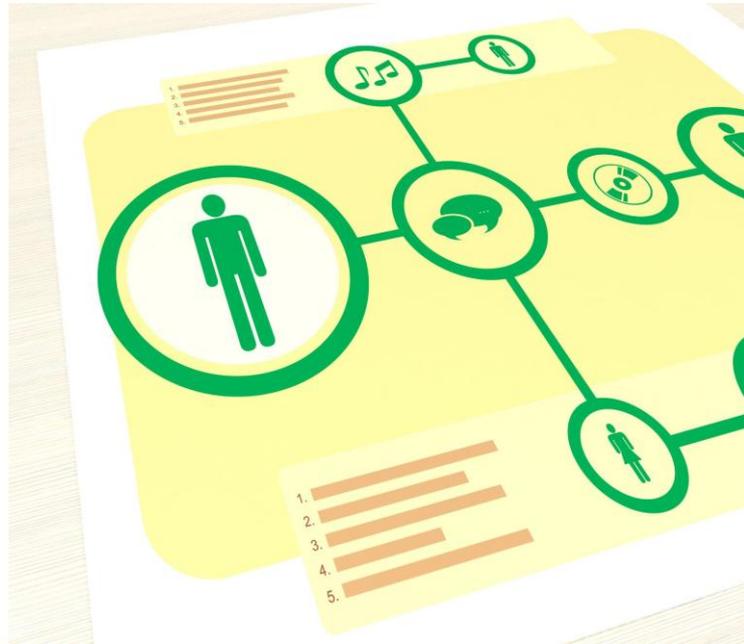
Application-Driven Profiles

Profiles must be explicit and application-focused, defining mandatory features for clear interoperability.

Risks of Excessive Optionality

Too many optional features reduce interoperability and increase deployment risks.

Testability and Certification Design

Profiles should be designed for testability, but test specifications and certification efforts are critical to enable verified compliance.

Ongoing Profile Refinement

Feedback from deployment should drive continuous refinement of profiles and capabilities for scalability and robustness.

Avnu testing and certification framework

Market/segment needs, use cases, requirements

Avnu-certified devices/components

Industry Standards & Profiles

IEEE
IEC
WiFi ALLIANCE
3GPP A GLOBAL INITIATIVE

Test Plan Dev.

Avnu Alliance® Test Plan
802.1AS Time Synchronization

Avnu Alliance® Test Plan
802.1Qbv Traffic Scheduling and Shaping

Avnu Alliance Profile Agnostic Conformance Test Plan for
Interspersed Express Traffic (IET)
IEEE802.1Qbu/.3br
Revision: 1.01
Aug 2022
Authors

- Base TSN test plans
- Profile-specific plans

Member dev. & testing capabilities V&V

Member devices & components development

Plugfests

Test Tools V&V

- Conformance & Interop tests between vendors and tools

Certification Program

Testing scope

Approved Tools

Approved Test Facilities

- Component, network device, segment-specific programs

AVNU

TIACC Testing strategy for IEC/IEEE 60802

Vendor-tested (attestation):
- Low level clock requirements (Table 9)
- Clock control system reqs. (Table 11)
- Base PHY/MAC specifications

PASS 802.1AS 802.1Qbv 802.1Qbu ...

TSN Component (bridges & end stations) Testing

PASS IA-Station Performance Man/Configuration

PASS Certified

Device meets IEC/IEEE 60802 Requirements
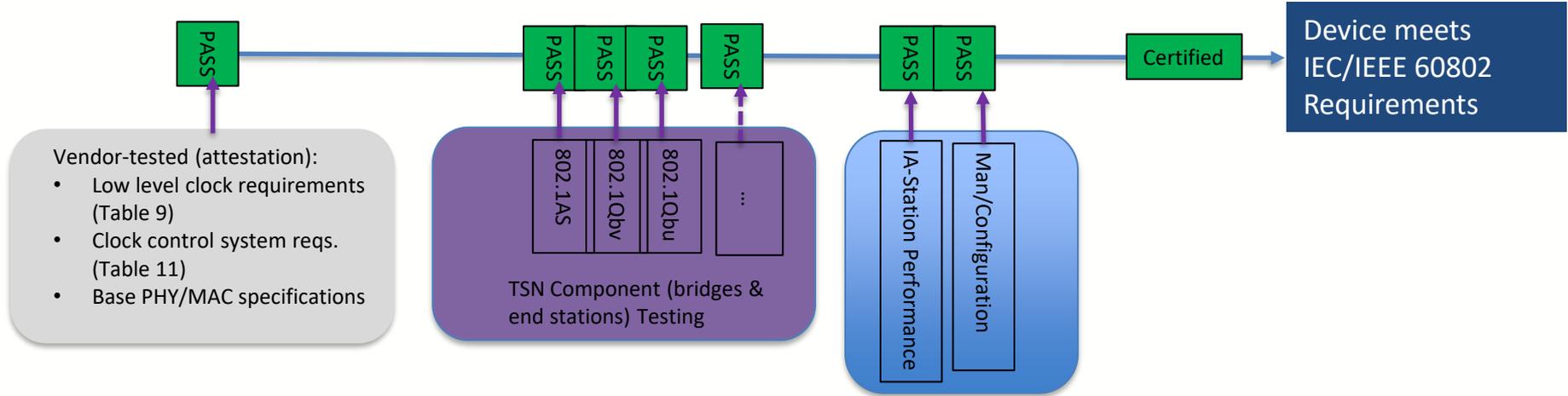
Examples:
- Profile specific configuration (802.1AS Protocol settings - Table 10)
- System and time sync performance (Table 12, 13, 14)

TIACC Common Test Specification 1.0 on track for July 2026!

Steps towards 60802 device interoperability: Testing & Certification

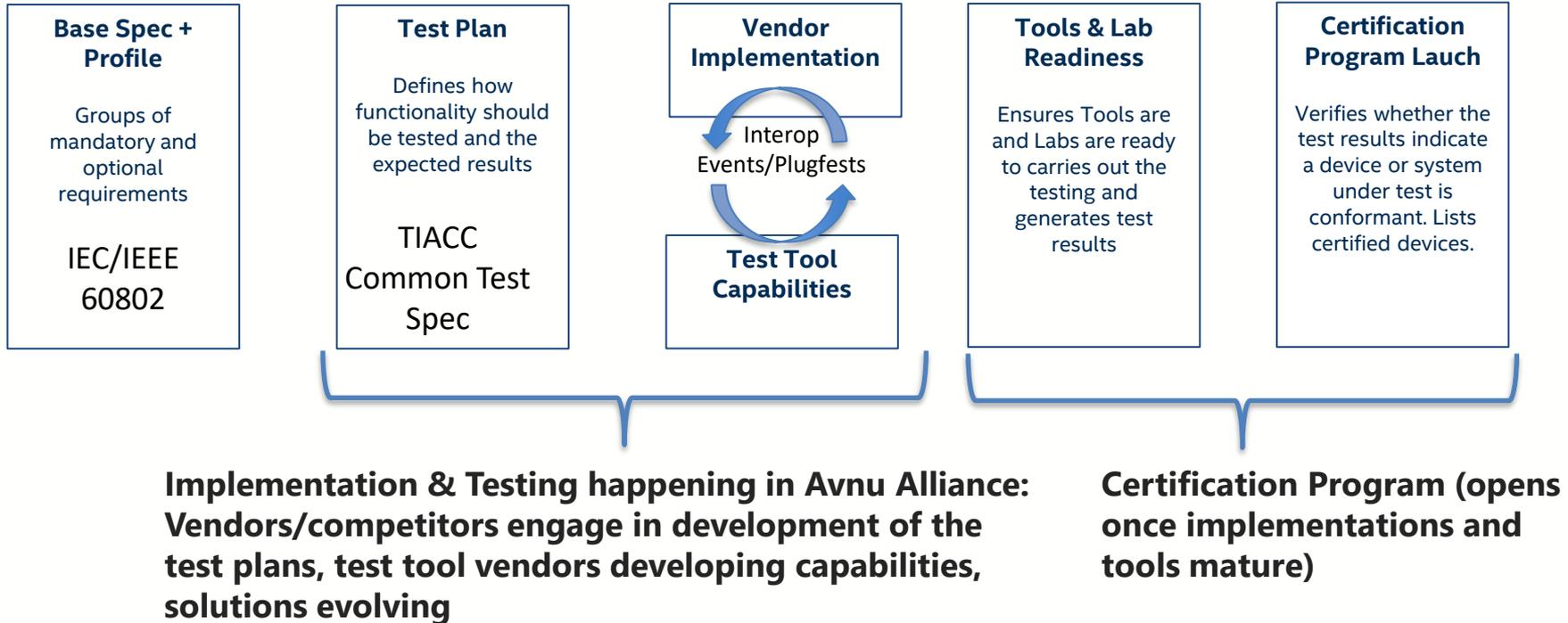| Base Spec + Profile	Test Plan	Vendor Implementation	Tools & Lab Readiness	Certification Program Lauch
Groups of mandatory and optional requirements

IEC/IEEE 60802 | Defines how functionality should be tested and the expected results

TIACC Common Test Spec | Interop Events/Plugfests

Test Tool Capabilities | Ensures Tools are and Labs are ready to carries out the testing and generates test results | Verifies whether the test results indicate a device or system under test is conformant. Lists certified devices. |

Implementation & Testing happening in Avnu Alliance: Vendors/competitors engage in development of the test plans, test tool vendors developing capabilities, solutions evolving

Certification Program (opens once implementations and tools mature)

802.1DP TSN Profile for Aerospace
The new opportunity

Required TSN Capabilities

1.Time Synchronization: based on IEEE 802.1AS enables devices to operate on a unified time reference.

2.Traffic Shaping: specifies the use of the credit-based shaper algorithm and enhancements for scheduled traffic.

3.Redundancy and Failover: Frame Replication and Elimination (FRER) provides continuous backup mechanisms to avoid packet loss in the event of network failures.

4.Stream Isolation: requires strict separation between streams to prevent faults in one device from impacting others, which is essential for handling mixed-criticality.

Avnu Alliance Certification Programs

Industry-specific Certification

Industry-specific Certifications by other organizations

Network Device Certification (Profile-based)

Pro AV — **IEEE 802.1BA Milan-AVB Switches**

Industrial — **60802-ready IA-Stations***

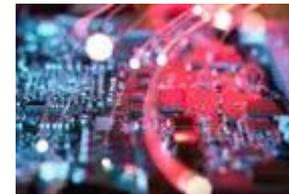Automotive — **IEEE 802.1DG Automotive**

Aerospace — **802.1DP-ready Devices***

TSN Component Certification (Profile-agnostic)

IEEE 802.1AS
IEEE 802.1Qbv

IEEE 802.1Qav
IEEE 802.1Qbu …

* Programs under development

Conclusions

- Milan shows that TSN works at scale when profiles are strict and application-driven

- Testing and Certification enable interoperable multi-vendor systems.

- The Milan approach provides a proven blueprint for scaling TSN across other verticals.

- Avnu Alliance members are applying this approach to Industrial and Aerospace verticals in collaboration with the broader industry ecosystem.