

Theory of Operations for TSN-Based Industrial Systems and Applications

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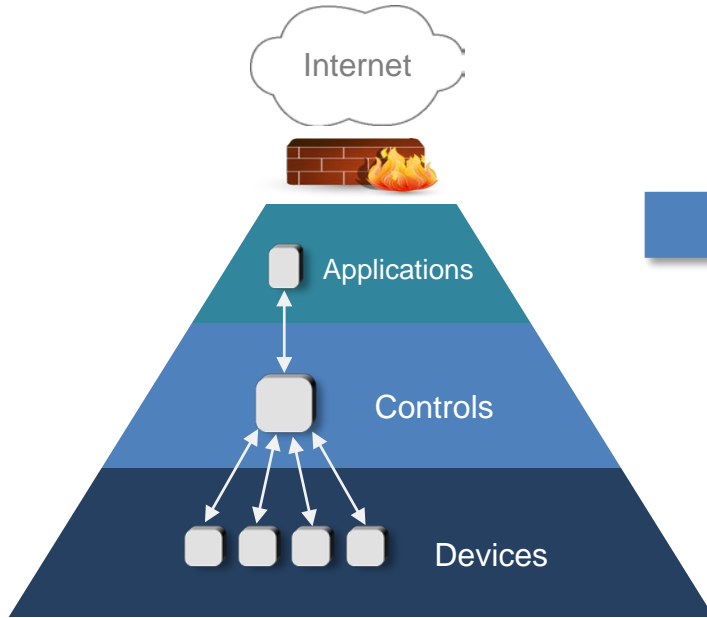


Agenda

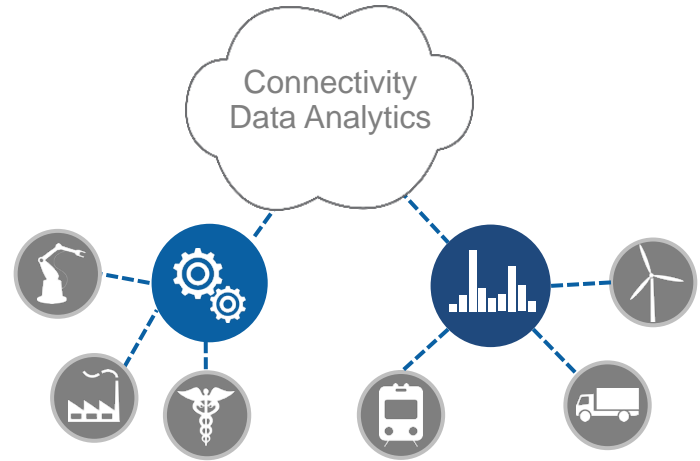
- **Why TSN? Value and Benefits**
- **TSN Standards – a brief Overview**
- **How TSN works – an Operational Model**
- **The Role of Avnu Alliance**

Industrie 4.0 Requires Flexible Data Access

TRADITIONAL Industrial System Design



Industrie 4.0 Converged IT and OT network with TSN



TSN for today's Industrie 4.0 network

A Standard for Deterministic Industrial Ethernet

Secure and protect critical traffic data performance and availability guarantees



Enables time-critical I4.0 applications on a scalable industrial Ethernet network



Operate a converged, IoT/I4.0 ready network that supports EtherNet/IP, OPC UA, etc.






Based on open standards (Deterministic Ethernet: IEEE 802.1, 802.3, IETF and AVNU)



Deterministic Networks with TSN

IEEE 802.1 Key Advantages of TSN

	Secure
	Simple
	Intelligent

Guarantee
delivery and
bandwidth for
critical data flow



Guarantee
latency for
data delivery



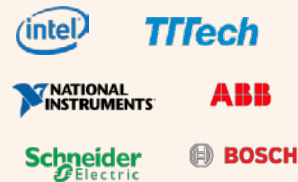
Converge
networks save
operating costs



Increase data
availability



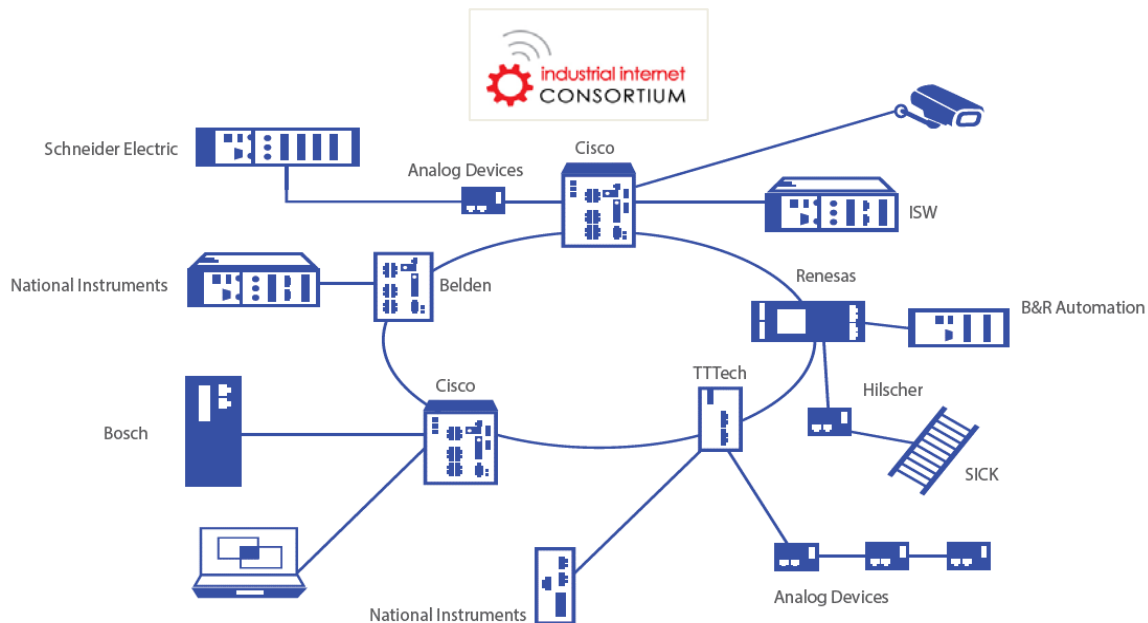
Leverage
Ecosystem
Expertise



Growing Ecosystem of TSN Vendors at IIC

Key Facts:

- **18 Vendors** participating today
- **6 Plugfests** conducted
- **2 Testbed facilities**
- **Demonstrations at 6 major shows**
- **Collaboration with multiple standards**



AVS

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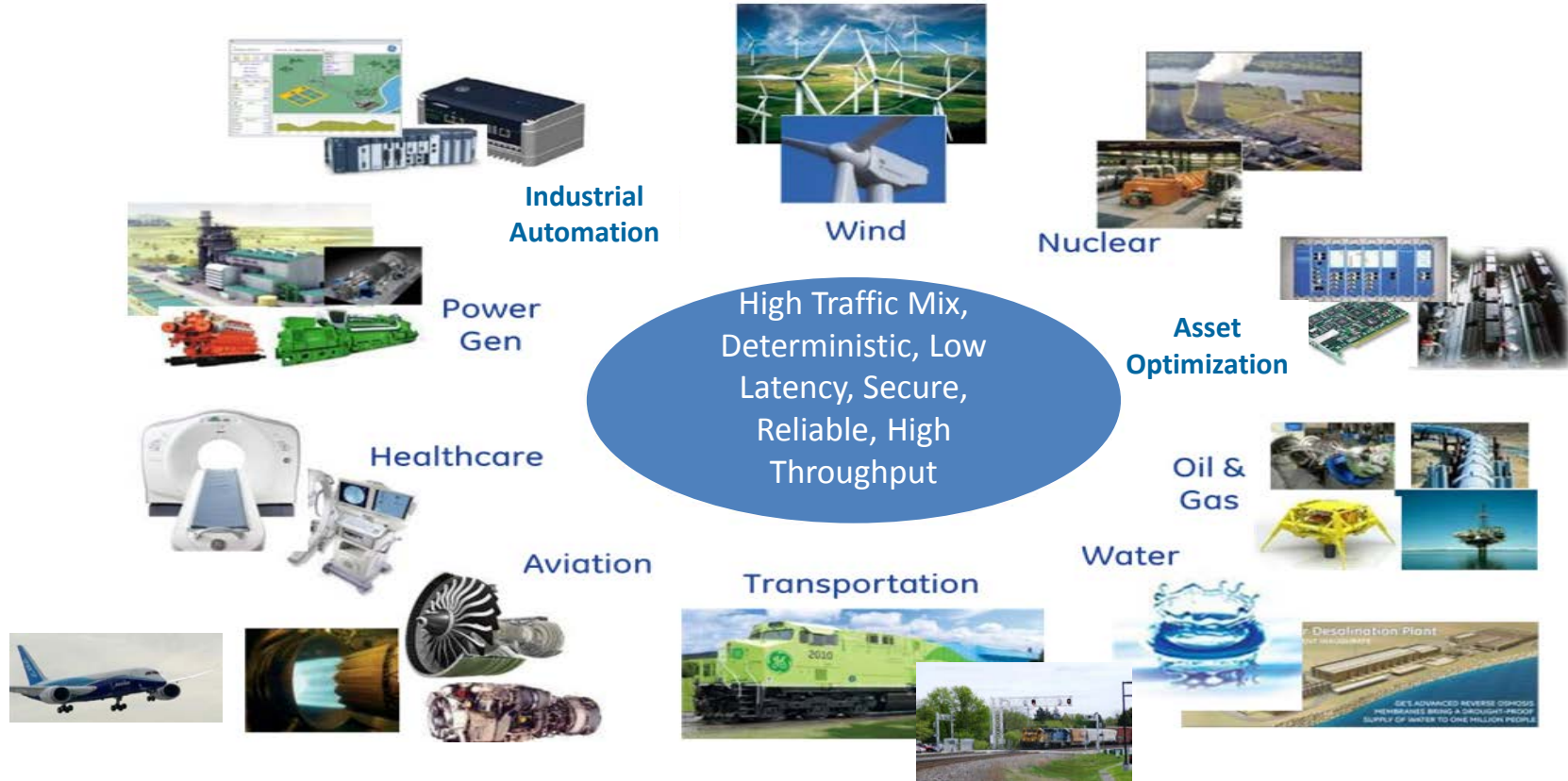
Calnex

KUKA

BOSCH

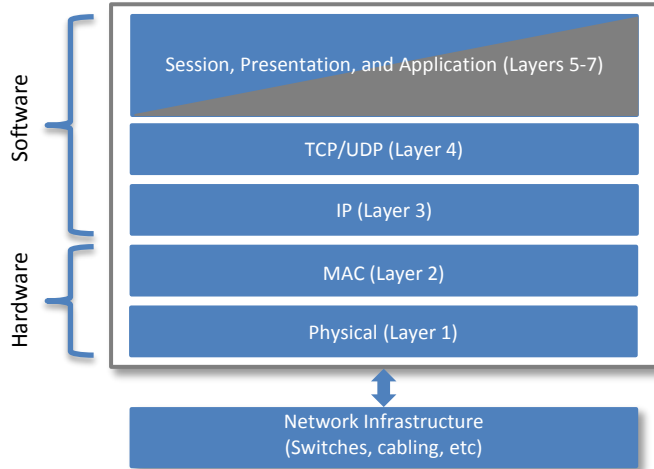
AVS

Industrial Implies a Diverse Set of Applications



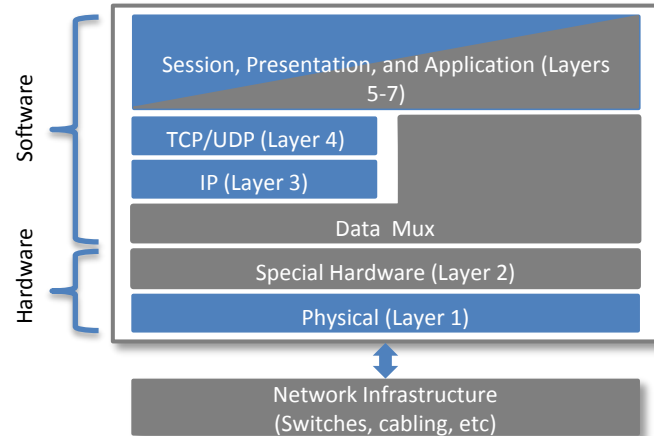
The Challenge

Custom
Standard



“Standard” Ethernet

- Best-in-class approach for openness and interoperability
- Cannot bound latency (needed for control applications)
- Cannot guarantee bandwidth (needed for reliability)



“Hard Real-Time” Ethernet

- Best-in-class approach for latency and control
- Cannot “share the wire” (no third party devices)
- Cannot scale with Ethernet (e.g. limited to 100 Mb/s)
- Proprietary HW/SW increases costs

- Standards effort through IEEE 802 to improve latency and performance while maintaining interoperability and openness
- Time Sensitive Networking (TSN) will provide:
 - Time synchronization
 - Bandwidth reservation and path redundancy for reliability
 - Guaranteed bounded latency
 - Low latency (cut-through and preemption)
 - Bandwidth (Gb+)
 - Routable to support complex networks and wireless

IEEE Time Sensitive Networks Overview

Standard	Area	Title
IEEE 802.1ASrev, IEEE 1588	Timing & Synchronization	Enhancements and Performance Improvements
IEEE 802.1Qbu & IEEE 802.3br	Forwarding and Queuing	Frame Preemption
IEEE 802.1Qbv	Forwarding and Queuing	Enhancements for Scheduled Traffic
IEEE 802.1Qca	Path Control and Reservation	Path Control and Reservation
IEEE 802.1Qcc	System Configuration	Enhancements and Performance Improvements
IEEE 802.1Qci	Time Based Ingress Policing	Per-Stream Filtering and Policing
IEEE 802.1CB	Seamless Redundancy	Frame Replication & Elimination for Reliability
...	Additional Projects	Continual Evolution of the Standard

Time Sensitive Networking: Key Elements

Time Synchronization



Traffic Scheduling



System Configuration



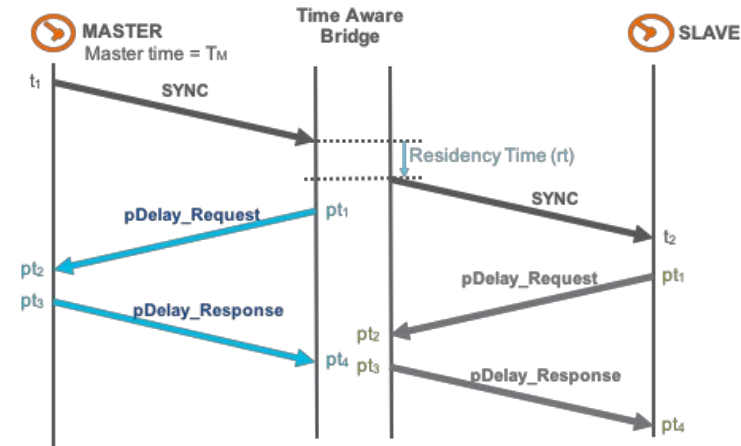
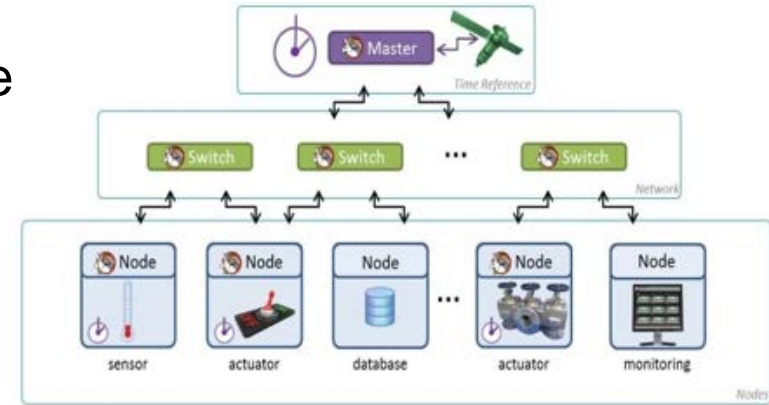
Time Synchronization

IEEE 802.1AS a Precision Time Protocol profile

Well designed for high-speed, precise industrial applications:

- Highly precise, 2-way, peer-to-peer time transfer protocol
- Scalable design with Boundary clock-like support
- Resiliency enhancements for low-impact of failures and improving with .1AS-Rev
- Ability to determine roles (e.g. Grand-Master)
- Full support from chip-vendors and other technology suppliers (HW and SW based)

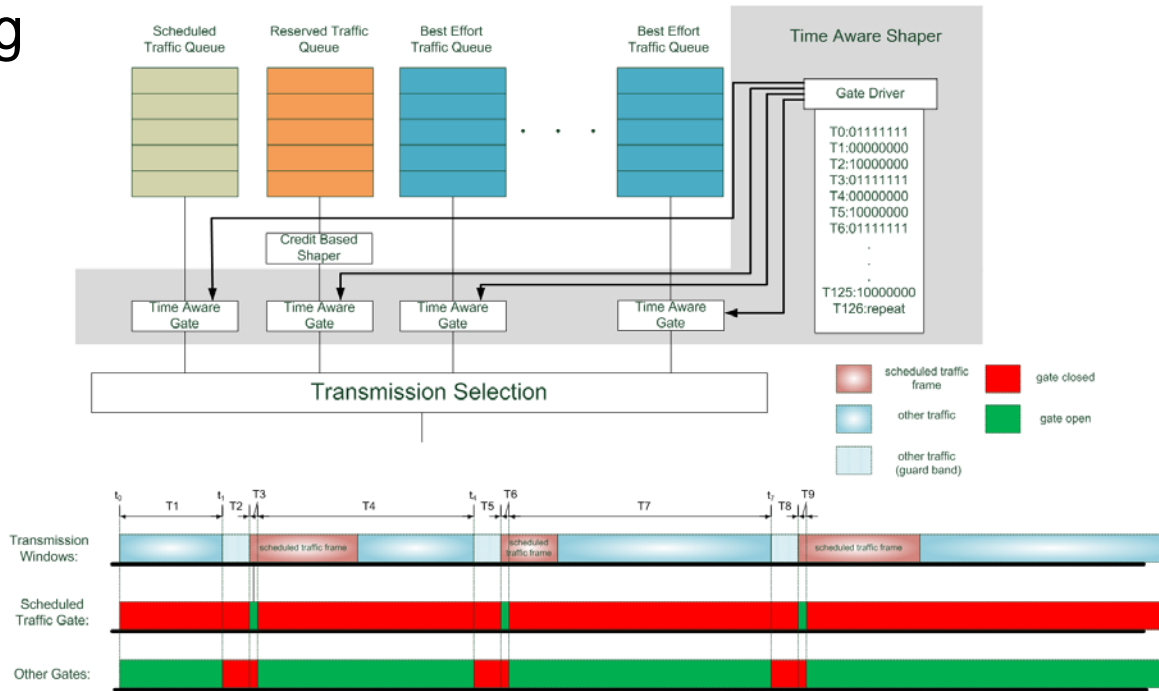
Other profiles exist for power industry and telecommunications.



Forwarding and Queuing: 802.1Qbv

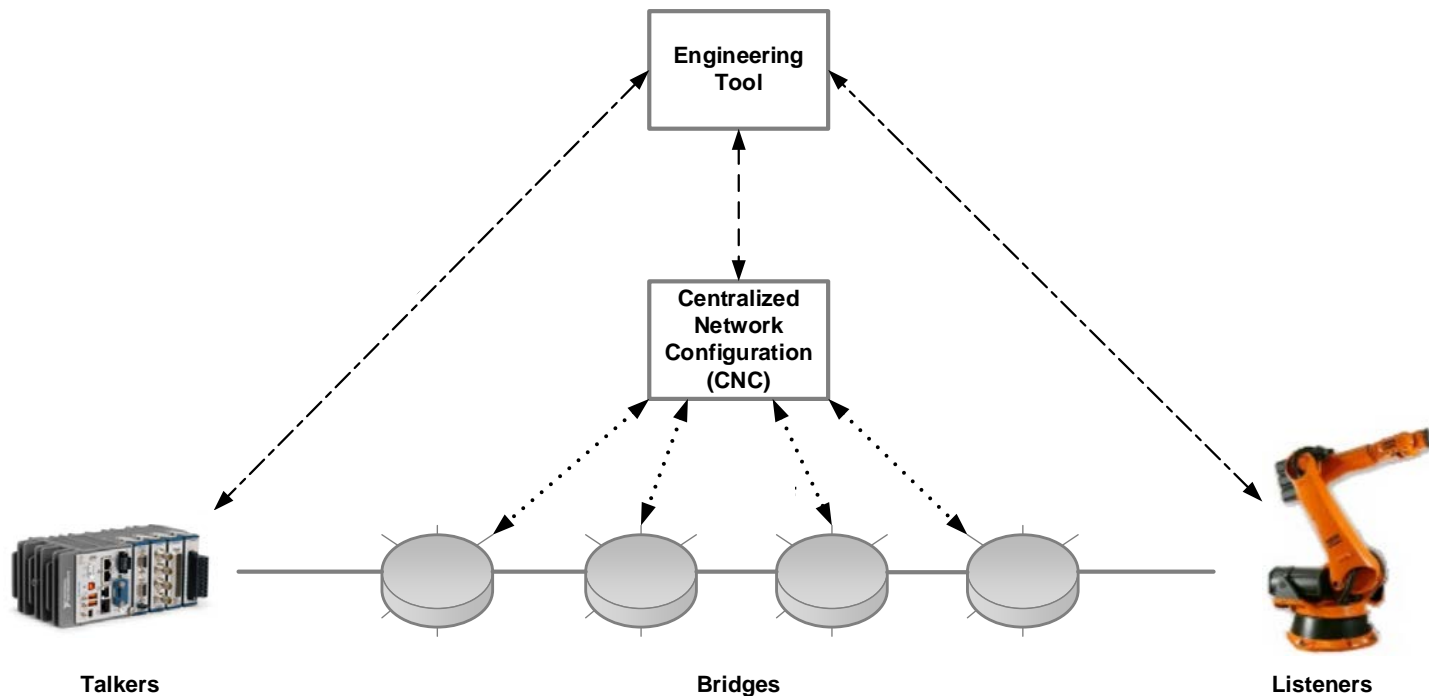
Time-Aware Traffic Shaping

- **Summary:** Enables the scheduled transmission of frames between network elements based on time synchronization
 - Schedule to be read / written in switches is in a standard format (see 802.1Qcc)
 - State machines for schedule configuration and execution defined
 - Ports have a Time Aware shaper
 - Prevents un-scheduled traffic from interfering with scheduled traffic, yet leaves bandwidth available if unused
- **Relevance:** Enables very consistent delivery of Control traffic within a single, converged, standard network infrastructure



System Configuration

AVNU's TSN Theory of Operations



Key Concept: Fully Centralized Configuration

Note: CUC, CNC, Talkers / Listeners and Bridges are *logical roles* in the Fully Centralized Architecture

- Not intended to imply discrete products
- Can be realized in variety of product embodiments

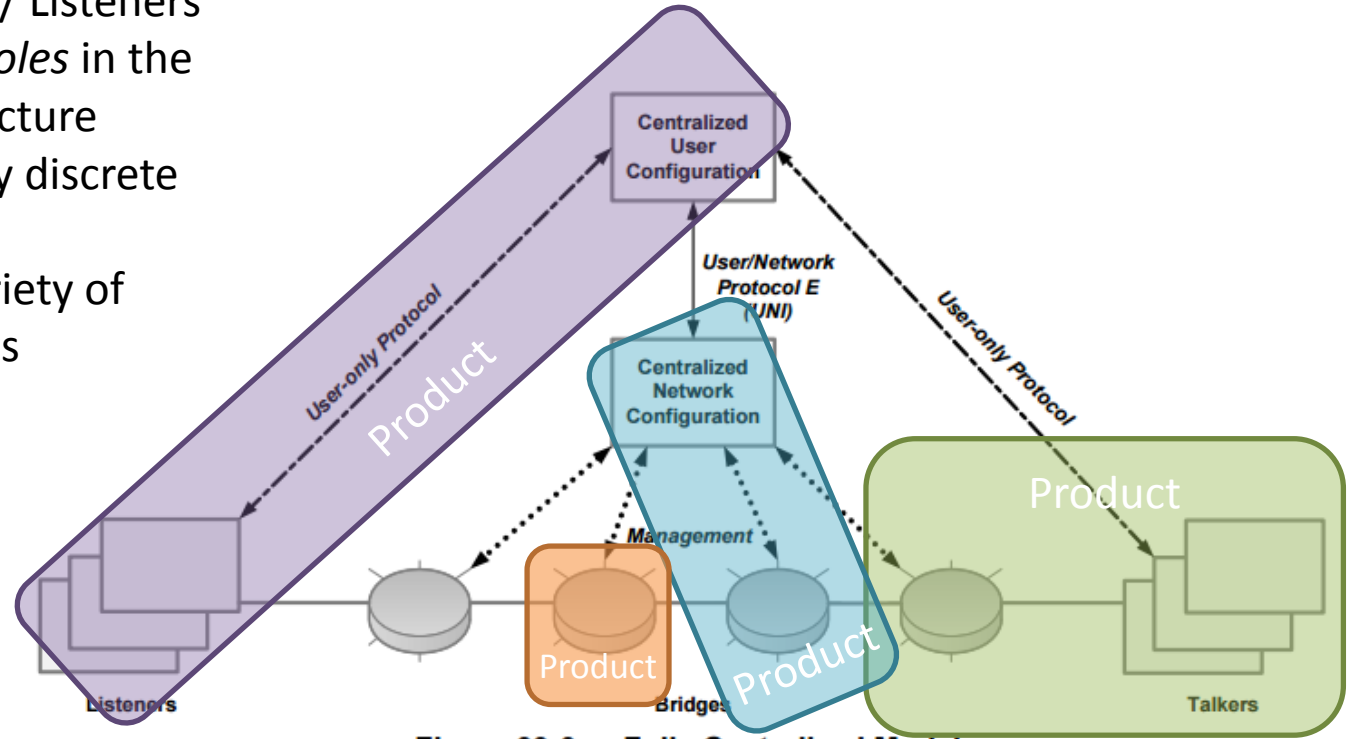


Figure 99-3 — Fully Centralized Model

Roles of the Standard Organizations

Testbed and Reference Architectures

- Testbeds to evaluate “full stack” and provide feedback to members and liaison organizations
- Application specific architectures to aid in market adoption
- Outbound marketing to create awareness



Application Layers

- Define data models for end-device communication
- Integration of TSN communications and configuration models into application tools
- Application flow for end-node configuration
- Conformance for data models and end node configuration



TSN Transport Interoperability and Conformance

- Define network services needed by market
- Fill gaps in standards to provide interoperable network configuration services
- Conformance of transport and network services
- Establish certification services

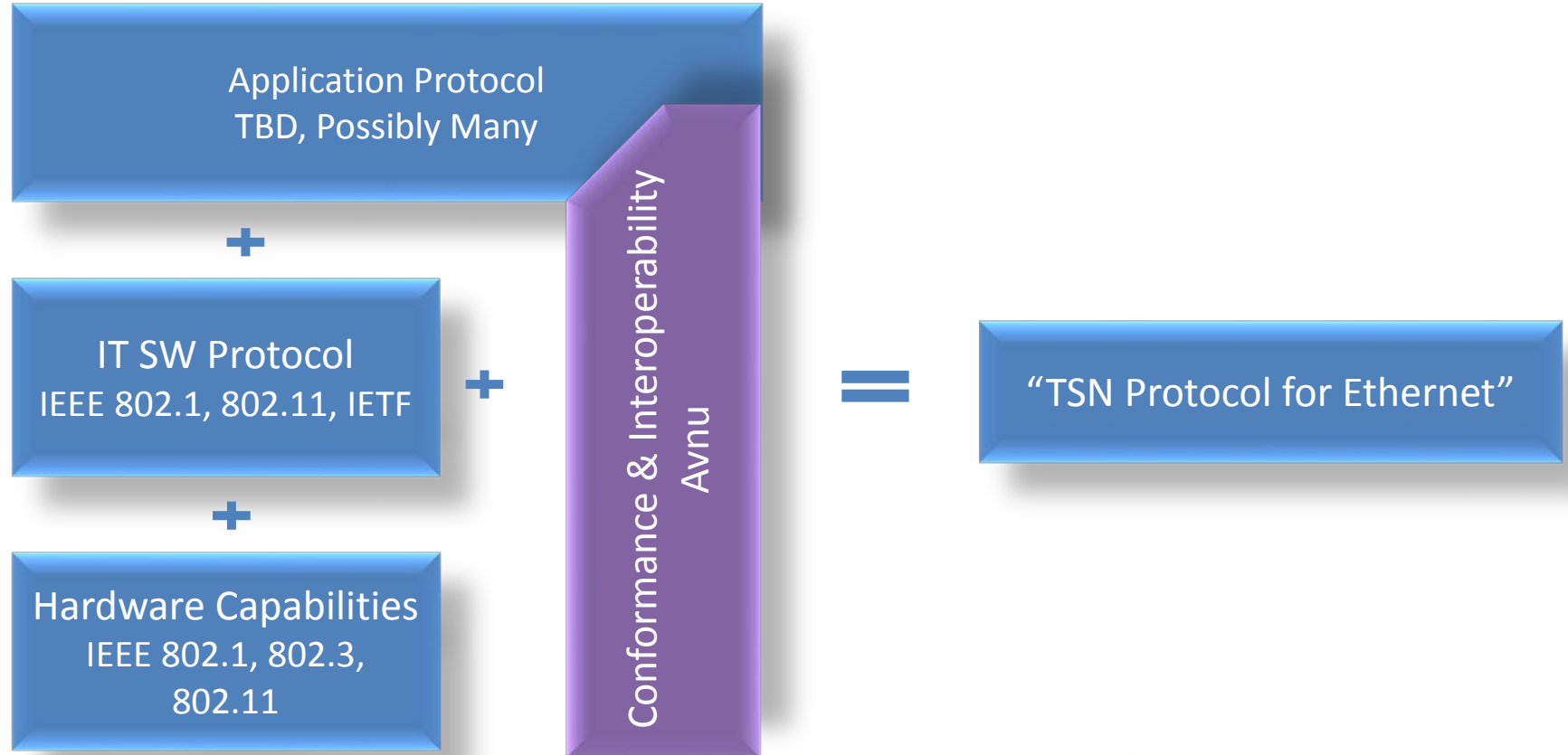


Network standards

- Define standard features to provide Time Sensitive Networking “deterministic communication” capabilities including updates to OSI Layers 1-4
- Assure proper operations and backwards compatibility with IT and OT



What Standards Specify TSN Protocol for Ethernet?



What is Avnu Alliance?



Creating a certified ecosystem to bring **precise timing, reliability** and **compatibility** to networks

- Team of 70+ companies promoting open standards for deterministic networking, such as AVB/TSN
- Spans many industries: pro A/V, consumer A/V, automotive, energy, manufacturing, and more
- Certifies products to ensure interoperability and compatibility among models and brands



Background: The Role of Avnu

Avnu facilitates a common technical foundation across markets

Because there is one network:

- There needs to be a common technology platform of network services for synchronous, deterministic networking on standard Ethernet

This platform consists of:

- Open Source Software
- Standardized APIs
- HW Reference Designs
- Test Plans

Avnu - Theory of Operations



- 71 Pages
- Provides an overview of how to use TSN features of Ethernet
 - Use Cases and Requirements
 - States the problem
 - Introduction to TSN Foundational Mechanisms
 - Describes tools used to solve the problem
 - System Architecture
 - Shows how to use tools to solve the problem
 - Examples
 - Shows how tools solve specific problems relevant to industrial use cases

Join the Effort

- Avnu Alliance has created an **Industrial Advisory Council** for manufacturers and end users to learn more about the Alliance and the standards and to get involved with shaping the future of industrial networking.
 - Be informed of the evolutions happening in standard Ethernet to support converged time-synchronized networking.
 - Provide input and feedback to influence the on-going activities for conformance and certification of products coming to market.
 - Network with other thought leaders in the areas of converged, time-synchronized communications.
 - Gain visibility into suppliers and consultants when looking to build a conformant system
 - Learn tips and best practices on building and maintaining converged time-synchronized systems.
- If you or someone you know is interested in joining (no fee) or finding out more, please contact administration@avnu.org.