Avnu's Use of 802.1 TSN Mechanisms for Industrial and Automotive Markets

IEEE 802.1 Plenary
July 2016

Avnu Industrial and Automotive Groups

RELIABLE SYNCHRONIZED NETWORKING

Background: The Role of Avnu

IEEE 802.1 and related standards provide AVB/TSN **mechanisms** to serve a diverse set of markets

- Pro A/V, Automotive, Industrial, Consumer, etc.

IEEE 802.1's mechanisms create a variety of **options** for using AVB/TSN to support diverse market requirements

- Multiple possible traffic shapers (CBS, TAS, etc.)
- Multiple options for time synchronization
- Multiple possible configuration mechanisms
- etc.

Background: The Role of Avnu

Options are necessary to serve diverse markets, but options create **challenges for interoperability**, both within and across markets

- 1588 profile proliferation, etc.

Avnu exists to enable **broad market adoption** of AVB/TSN mechanisms by:

- Selecting among the AVB/TSN options a given market should/shall use, enabling coordinated interoperability of equipment so that a variety of application protocols **coexist** on a shared AVB/TSN network
- Offering **certification** services for the AVB/TSN mechanisms comprising market-specific profiles, ensuring the implementation of those mechanisms is conformant to the relevant standards (based on 802.1 PICS)

Background: The Role of Avnu

Primary Mission: “The Avnu Alliance is a community creating an interoperable ecosystem servicing the precise timing and low latency requirements of diverse applications using open standards through certification.”

Foundational Technology: IEEE standards, IETF standards

- IEEE and IETF standards define deterministic networking capabilities (*mechanism*)
- Avnu defines how to apply deterministic networking capabilities to solve market-specific problems (*policy*)

Deliverables: Market-specific interoperability specifications (“profiles”), test plans, and certification program

- Avnu Alliance utilizes a third party, independent interoperability certification program to ensure products from different manufacturers just work.

Background: The Role of Avnu

Avnu is Community

Avnu is a legal entity providing a place for the TSN community to do its work

- Avnu consists of companies from different levels in the supply chain representing diverse markets and applications working together on TSN

Avnu offers:

- Community
- Educational Material
- Market Profiles and Requirements
- Liaisons with related organizations who use TSN
- Certification services
- Licensing of Test Plan IP

Background: The Role of Avnu

Avnu facilitates a common technical foundation across markets

Because there is one network:

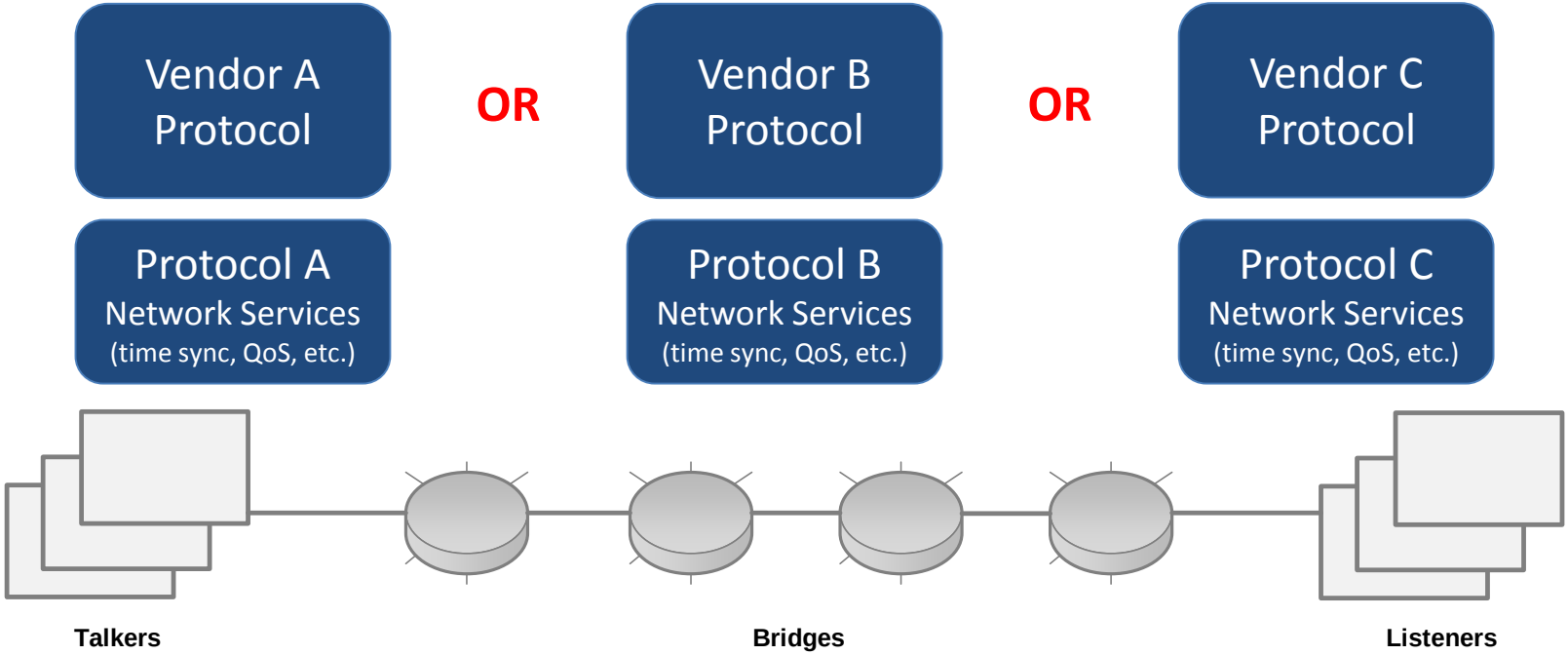
- There needs to be a common technology platform of network services for synchronous, deterministic networking on standard Ethernet

This platform consists of:

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

Avnu Common Technical Foundation

Without Avnu, applications use AVB/TSN networks in a potentially incompatible manner and likely cannot coexist on a shared network



Avnu Common Technical Foundation

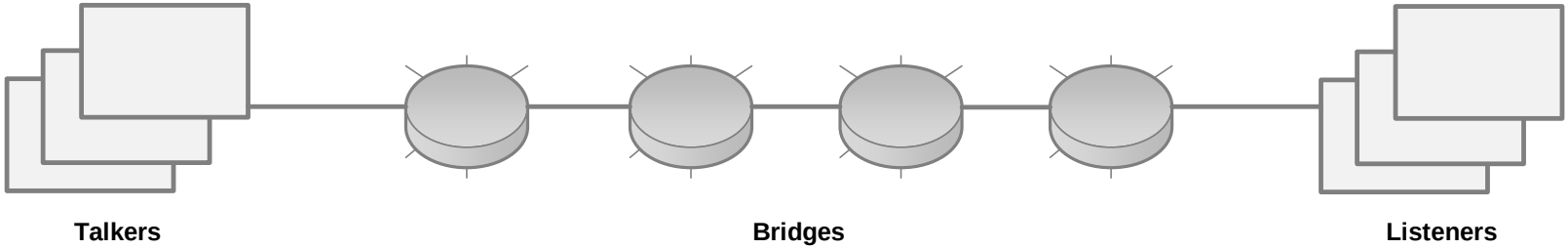
With Avnu, applications can coexist on a shared AVB/TSN network

Vendor A Protocol **AND** Vendor B Protocol **AND** Vendor C Protocol

IEEE/IETF Defined, Avnu Certified Common Network Services

Market-specific interoperability profiles for time sync, QoS, etc. and corresponding Test Plans

Certifiable open source software implementations with standardized APIs, HW reference designs, etc.



Avnu for Industrial: Use Cases

Initial use case focus:

- Machine control
- Power generation
- Power transmission and distribution
- Oil and gas
- Factory line integration

Avnu for Industrial: Requirements Summary

Requirement	Benefit
Time synchronization	Enables common clock for transmission scheduling, correlated I/O, etc.
High bandwidth, low/guaranteed latency	Enables fast control loops to support high bandwidth (Gb+) control systems
Reserved bandwidth	Enables applications to operate predictably in the presence of network congestion
Redundancy and policing	Enables fault tolerance due to component failures, misbehaving components, etc.
Converged network	Enables coexistence with best effort traffic and multiple industrial protocols
Topology flexibility	Enables common industrial network topologies including line, ring, tree
Scalability	Can grow from small systems to large systems (in both node and stream count)
Security	Examples: device authentication, stream encryption, network access, etc.

Note: The above list is not exhaustive

Avnu for Industrial: Alignment to the Core Vision

Status Quo: Industrial protocols use networks in manners that do not coexist well
Vision: Industrial protocols take advantage of ubiquitous, common network services, enabling coexistence on a shared TSN network

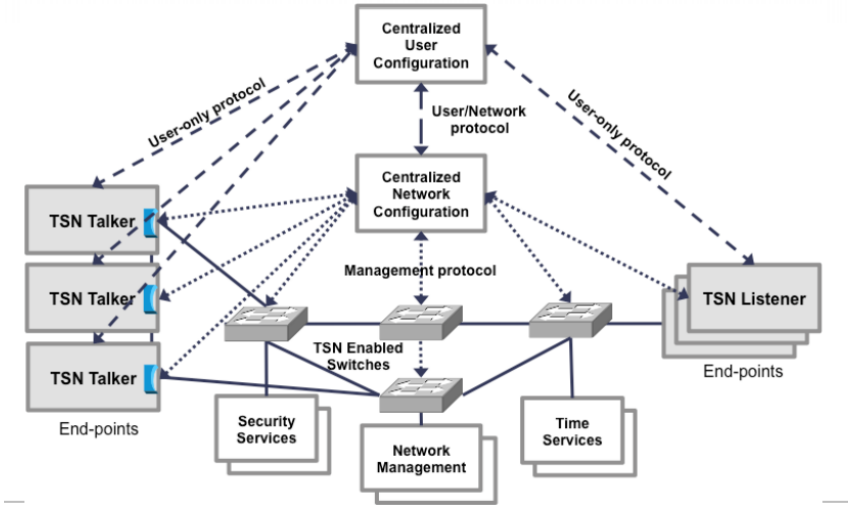
Common TSN Network Services for Industrial

In-work

- SDN-inspired network configuration
- Synchronized time
- Bandwidth and latency guarantees via time-aware traffic scheduling

Future

- Redundancy for data and time synchronization
- Bandwidth and latency guarantees via additional traffic shapers, preemption, etc.
- Security
- …

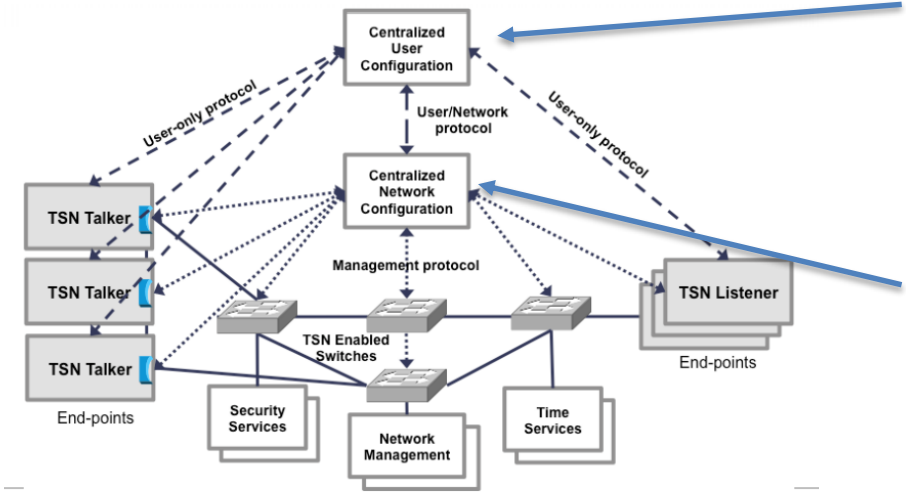


SDN-inspired Network Configuration

Core TSN Network Services

To manage traffic schedules and paths (including redundant paths) for data and time-sync, a **centralized configuration** approach is beneficial

- Can be supported with existing protocol standards, can lower costs for end nodes and bridges, can scale to support future network capabilities (new shapers, etc.)



Centralized User Configuration (CUC)

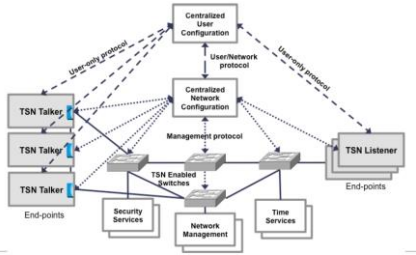
- Receives requirements from users of TSN network services (Talkers/Listeners)
- Sends requirements to manager of TSN network services (CNC)

Centralized Network Configuration (CNC)

- Receives *consolidated* requirements from users of TSN network services (CUC)
- Sends requirements to enablers of TSN network services (TSN-enabled switches)

SDN-inspired Network Configuration

Core TSN Network Services



To minimize the work required to adopt TSN, especially for existing industrial protocols, enabling a **separation of concerns** with respect to network configuration is beneficial

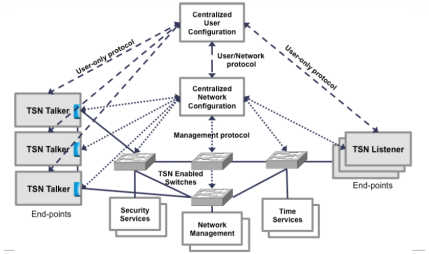
- Talkers/Listeners don’t need to know how to directly configure TSN network services in switches; they continue to exchange requirements via their CUCs

The **802.1Qcc “Fully Centralized” configuration model** offers the centralized management and separation of concerns benefits by applying concepts from Software Defined Networking (SDN)

- Uses whole-network knowledge to manage transmission schedule, paths, etc.
- Abstracts network service details (QoS mechanisms, etc.) from users of TSN network

SDN-inspired Network Configuration

Core TSN Network Services



Avnu Industrial's assumptions about applying Qcc:

Configuration Data Information Model

- 802.1Qcc will specify the information (data) exchanged between the CUC and CNC
- All network configuration data (bridge managed objects, etc.) will be described using YANG modules
- Industrial application protocols can use their existing configuration data models for User←→CUC configuration data exchange

Configuration Protocols

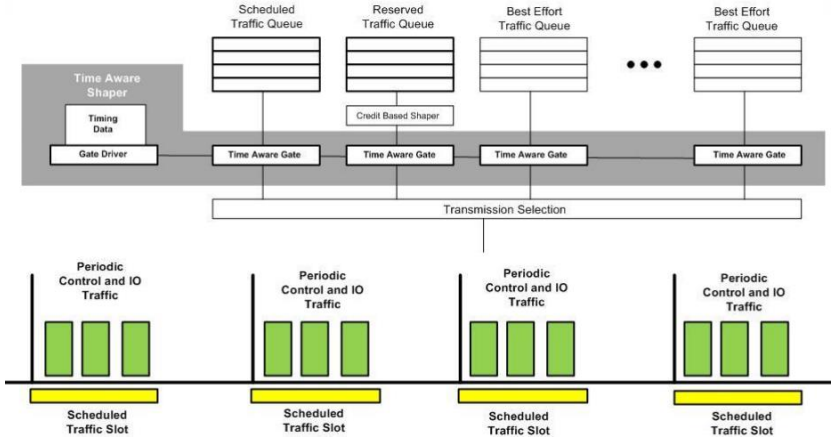
- Avnu will select suitable existing management protocols (e.g. NETCONF, RESTCONF, etc.) for CNC→Bridge configuration
  - Must enable options for constrained and non-constrained environments
- Avnu will select suitable protocol and/or API for CUC←→CNC communication (for UNI data)
- Industrial application protocols can use their existing User←→CUC protocols for Talkers/Listeners to request network services

Time-aware Traffic Scheduling

Core TSN Network Services

To meet performance requirements for some industrial applications, time-aware **traffic scheduling**, specified in 802.1Qbv, is beneficial

- Assuming a properly-configured network, all traffic types (including best effort and non-periodic) can use scheduling
- Note: Traffic scheduling is *one way* to achieve the QoS guarantees needed for industrial applications; Avnu does not intend to preclude additional QoS mechanisms (other shapers, etc.)

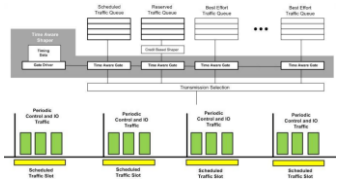


How Avnu Industrial will use Qbv traffic scheduling:

- Industrial control traffic guaranteed bandwidth by allocating sufficient gates to scheduled traffic queue
- Best effort traffic queue can be allocated remaining gates
- Assumption: Clock source for gates will not jump in time

Time-aware Traffic Scheduling

Core TSN Network Services



To enable a reliable and predictable schedule,

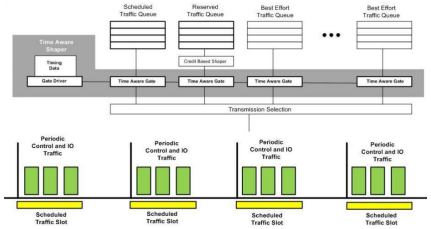
the traffic scheduling clock source, referred to as the **working clock timescale**, must:

- Be monotonically increasing
- Avoid significant snaps/skips/jumps (i.e., perform to a minimum level)

If required for a given industrial application, a second time source can provide globally-traceable time, referred to as the **universal clock timescale**

Time-aware Traffic Scheduling

Core TSN Network Services



Avnu Industrial's assumptions for applying Qbv:

Traffic Schedule Configuration

- One CNC per scheduled TSN network
  - Exploring need for multi-CNC; broader problem than just scheduling
- Multiple CUCs possible, operating on behalf of multiple industrial application protocols
- CNC manages bridge Qbv gate configuration using Avnu-selected management protocol(s)

Traffic Schedule Working Clock

- The clock source for the Qbv gate schedule must be monotonically increasing and be performant to a specified minimum (avoiding snaps/skips/jumps)
- 802.1AS is the bridged network's working clock source
  - Exploring use of gateways to bridge between other 1588 profiles (on end stations) and .1AS (in network)
- 802.1AS, and 802.1Q generally, will not specify the working clock requirements
  - Avnu, to fill this interoperability gap, will specify the working clock requirement
- CNC manages working clock domain configuration using selected management protocol(s)
  - No BMCA

Avnu Industrial Requirements

What we want from 802.1 today

802.1Qbv

- Done (thank you!)

802.1Qcc

- UNI information model (CUC ←→CNC)

802.1AS-rev

- External port configuration (i.e., sync path configuration without BMCA)
- Ability to support multiple timescales (e.g. working clock + universal clock)
- 1-step is not an requirement at this time

802.1Qcp

- YANG for “baseline” 802.1Q
- Also need: YANG for .1AS-rev, Qbv, Qcc
- **Avnu would like 802.1 to create projects for adding YANG modules for .1AS-rev, Qbv, and Qcc**
  - Future: YANG for Qci, CB, etc.

Goal: First bridge certifications in mid-2017

Avnu Industrial Requirements

What we plan to use from 802.1 in the future

802.1CB and 802.1AS-Rev

- Seamless redundancy for data and time-sync

802.1Qbu

- Frame preemption

802.1Qci

- Ingress policing

802.1AS-Rev

- Future enhancements for testability of time synchronization

- … and more as market requirements justify

Avnu Industrial Requirements

Historical Perspective

New work being discussed | No work underway | Work in progress | Standard complete

Complete, revision in progress

Standards situation

Activity	Standard L2 Hardware	Standard L3 Hardware	Standard L2 Software	Standard L3 Software
Time Synch	1588		802.1AS-REV	1588
AVB Streams	AVB		AVB 802.1Qcc	DetNet
Scheduling	802.1Qbv		802.1Qcc	DetNet
0 Congestion Loss TSN	802.1Qch Cyclic Queuing and Forwarding		802.1Qcc	DetNet
Preemption	802.1Qbu, 802.3br		802.1Qbu	N/A
Multipath	HSR PRP 802.1Q	MPLS, SPUD	HSR PRP 802.1Qca	DetNet
Seamless Redundancy	HSR PRP 802.1CB	DetNet	HSR PRP 802.1CB	DetNet
Robustness	802.1Qci	DetNet	802.1Qcc	DetNet

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AVnu Industrial Minimum Viable Feature Timeline and Priority

Priority	Requirement	Project(s)	2015	2016	2017
1	Network time synch with static config	ASrev	Y	Y	Y
1	Scheduling	Qbv	Y	Y	Y
1	Centralized config	Qcc, Restconf/Netconf 1722?	Y	Y	Y
2	Seamless redundancy including time synch	CB, ASrev	N	Y	Y
2	Ingress policing including BE limiting	Qci	Y/N	Y	Y
2	Frame preemption	Qbu	N	N	Y
2	L3 support		N	N	Y
3	Cyclic schedule	Qch	N	N	TBD
3	Credit based shaper	Qav	N	N	TBD
3	Stream management (SRP)	Qat	N	N	TBD
-	ISIS	Qca	N	N	TBD

source: http://www.ieee802.org/1/files/public/docs2015/tsn-sexton-feature-priority-request.pdf

Timelines have shifted, but priorities and planned use of 802.1 features unchanged

What Avnu is Doing in Pursuit of the Vision

- Framing the problem
- Describing a vision for solving the problem
- Defining and describing a reference architecture, consistent with the vision, for solving the problem
  - Describing a system architecture
  - Describing an endpoint reference architecture
  - Selecting data models and protocols for network configuration
  - Describing solutions to coexistence challenges (working clock synchronization, etc.)
- Collaborating with other standards groups on requirements and solutions for common network services foundation
  - OPC-UA, ODVA, IEC 61850, IETF DetNet, etc.

What Avnu is Doing in Pursuit of the Vision

Theory of Operations

Informative “Best Practices” white paper

Goal: Late 2016

Industrial Interoperability Specification

Normative requirements for switches and endpoints

Goal: 1.0 (switch requirements only) in early 2017

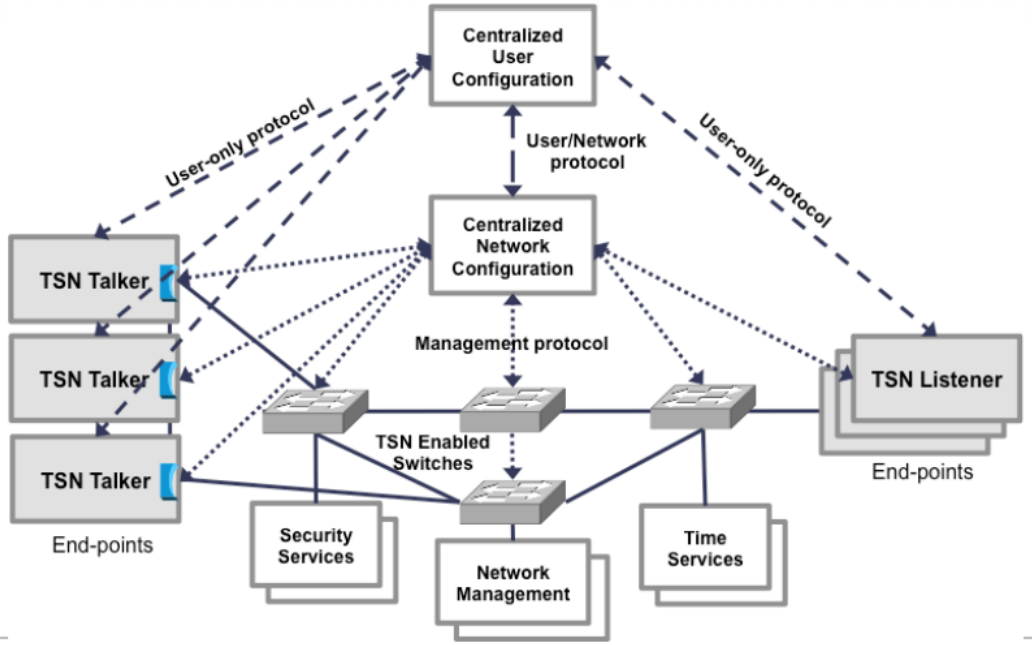
Formal and informal engagement with outside standards orgs

Liaisons, etc.

Future Liaison Activities

- Request for response back from IEEE on Avnu specification needs and timelines
- Future Avnu update on Automotive activities

Thank you!


Centralized User Configuration
User/Network protocol
User-only protocol
User-only protocol
Centralized Network Configuration
Management protocol
TSN Talker
TSN Talker
TSN Talker
End-points
TSN Enabled Switches
TSN Listener
End-points
Security Services
Network Management
Time Services