Overview of IEEE 802.1 TSN and IETF DetNet

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Authors:

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliations</th>
<th>Address</th>
<th>Phone</th>
<th>email</th>
</tr>
</thead>
<tbody>
<tr>
<td>János Farkas</td>
<td>Ericsson</td>
<td></td>
<td>+3614377100</td>
<td><a href="mailto:janos.fakas@ericsson.com">janos.fakas@ericsson.com</a></td>
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Outline

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  DetNet scope
  DetNet deliverables
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Summary
We Are Interested in Deterministic Service

Traditional Service
Curves have long tail
Average latency is good
Lowering the latency means losing packets (or overprovisioning)

Deterministic Service
Packet loss is at most due to equipment failure (zero congestion loss)
Bounded latency, no tails
The right packet at the right time
Potential Markets (not comprehensive)

Industrial Automation

Wind

Nuclear

5G

Power Gen

Healthcare

Aviation

Transportation

Oil & Gas

Water

High Traffic Mix, Deterministic, Low Latency, Secure, Reliable, High Throughput
TIME-SENSITIVE NETWORKING (TSN)
IEEE 802.1 Time-Sensitive Networking (TSN) Task Group

The TSN TG specifies the tools of the TSN toolbox, as well as the use of the tools for a particular purpose.

TSN TG is chartered to provide deterministic services through IEEE 802 networks:
- Guaranteed packet transport
- Low packet loss
- Bounded low latency
- Low packet delay variation

The TSN TG has been evolved from the Audio Video Bridging (AVB) TG.

The TSN TG includes the former Interworking TG.
Grouping of TSN Standards & Projects

Profiles:
- 802.1BA: Audio Video Bridging
- 802.1CM: Fronthaul (for cellular)
- IEC/IEEE 60802: Industrial Automation

Configuration:
- 802.1Qcp: YANG Data Model
- 802.1Qcc: TSN Configuration
- P802.1ABcu: YANG for LLDP
- P802.1Qcw: YANG for Qbv, Qbu, & Qci
- P802.1CBcv: YANG & MIB for 802.1CB

Base technology:
- 802.1AS: Timing & Synch
- 802.1Qat: Stream Rsv. Prot.
- 802.1Qau: Credit Based Shaper
- 802.1Qbu: Frame Preemption
- 802.1Qbv: Scheduled Traffic
- 802.1Qci: Per-Stream Filtering
- 802.1CB: Frame Repl. & Elim.
- P802.1Qcr: Async. Traffic Shaping
- P802.1CS: Link-local Rsv. Prot.

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IEEE 802.1 TSN Tools and Configuration

**TSN Components**

**Common Standards**

- **Synchronization**
  - Timing and Synchronization (802.1AS)
  - includes a profile of IEEE 1588 (revision ongoing: P802.1AS-Rev)

- **Reliability**
  - Frame Replication and Elimination (802.1CB)
  - Path Control and Reservation (802.1Qca)
  - Per-Stream Filtering and Policing (802.1Qci)
  - Reliability for time sync (P802.1AS-Rev)

- **Latency**
  - Credit Based Shaper (802.1Qav)
  - Frame preemption (802.3br & 802.1Qbu)
  - Scheduled Traffic (802.1Qbv)
  - Cyclic Queuing and Forwarding (802.1Qch)
  - Asynchronous Traffic Shaping (P802.1Qcr)
  - QoS Provisions (P802.1DC)

- **Resource Mgmt**
  - Stream Reservation Protocol (802.1Qat)
  - TSN configuration (802.1Qcc)
  - Basic YANG (802.1Qcp)
  - Link-local Registration Protocol (P802.1CS)
  - Resource Allocation Protocol (P802.1Qdd)
  - YANG for CFM (P802.1Qcx)
  - YANG for LLDP (P802.1ABcu)
  - YANG for Qbv, Qbu, and Qci (P802.1Qcw)
  - YANG & MIB for FRER (P802.1CBcv)
  - Extended Stream Identification (P802.1CBdb)

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**Time synchronization:**

- Timing and Synchronization (802.1AS)
- includes a profile of IEEE 1588 (revision ongoing: P802.1AS-Rev)

**Bounded low latency:**

- Credit Based Shaper (802.1Qav)
- Frame preemption (802.3br & 802.1Qbu)
- Scheduled Traffic (802.1Qbv)
- Cyclic Queuing and Forwarding (802.1Qch)
- Asynchronous Traffic Shaping (P802.1Qcr)
- QoS Provisions (P802.1DC)

**Zero congestion loss**

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Note: P upfront of an ID indicates ongoing Project
TSN Profiles

Wide breadth of choices in IEEE 802 standards

A TSN Profile

Narrows the focus ➔ ease interoperability and deployment
Selects features, options, defaults, protocols, and procedures
Describes how to build a network for a particular use
Provides configuration guideline if needed

TSN Profiles so far

Published TSN Profiles:
IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks
IEEE Std 802.1CM TSN for Fronthaul (for cellular networks)

Ongoing: IEC/IEEE 60802 TSN Profile for Industrial Automation

On the horizon:
P802.1DF TSN Profile for Service Provider Networks
P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications
Illustration of QoS Functions

frame reception

Filtering and Policing

Shaping

Queuing

frame transmission

Transmission Selection

Per Class

note: other functions are not shown in this figure, e.g., relay, reliability
Scheduled Traffic (802.1Qbv)

Reduces latency variation for frames with known timing
Time-based control and programming of the bridge queues
Time-Gated queues
Gate (G): Open or Closed
Periodically repeated
time schedule
Time synchronization is needed

Note: gate of non-critical data can be closed in advance to protect critical data
Frame Preemption (802.3br and 802.1Qbu)

**Express** frames suspend the transmission of **preemptable** frames
- Decrease delay variation for **express**, increase bandwidth for **preemptable**
- It is link local per hop, i.e., it is not IP fragmentation

**Scheduled rocks of critical packets in each cycle:**

Conflict excessively with **non-guaranteed packet rocks:**

Problem solved by **preemptable sand** between the **rocks:**
Per-Stream Filtering and Policing (802.1Qci)

Protection against bandwidth violation, malfunctioning, attacks, etc.
Decisions on per-stream, per-priority, etc.

Filter
  Filters, Counters

Time-gate
  Time scheduled gate
  Open or Closed

Internal Priority Value (IPV)
  Bridge internal traffic class of the frame

Meter
  Bandwidth Profile of MEF 10.3
  Red/Yellow/Green Marking
Frame Replication and Elimination for Reliability (FRER) (802.1CB)

Avoid frame loss due to equipment failure

It is a per-frame 1+1 (or 1+n) redundancy
   NO failure detection / switchover

Send frames on 2 (or more) maximally disjoint paths, then combine and delete extras
DETERMINISTIC NETWORKING (DETNET)

based on
DetNet WG Scope

The Deterministic Networking (DetNet) Working Group focuses on deterministic data paths that operate over Layer 2 bridged and Layer 3 routed segments, where such paths can provide bounds on latency, loss, and packet delay variation (jitter), and high reliability.

DetNet addresses Layer 3 aspects in support of applications requiring deterministic networking.

DetNet focuses on solutions for networks that are under a single administrative control or within a closed group of administrative control.

DetNet is NOT for large groups of domains such as the Internet.

Note: DetNet leverages existing techniques as much as possible instead of inventing new ones.
DetNet Deliverables

Based on WG Charter

https://datatracker.ietf.org/wg/detnet/about

**Overall architecture:**

- encompasses the data plane, OAM, time synchronization, management, control, and security aspects.

**Data plane specification:**

- document how to use IP and/or MPLS to support a data plane of flow identification and packet forwarding over Layer 3.

**Data flow information model:**

- identify the information needed for flow establishment and control and be used by reservation protocols and YANG data models.
- The work will be independent from the protocol(s) used to control the flows (e.g. YANG+NETCONF/RESTCONF, PCEP or GMPLS).

**YANG models:**

- This work will document device and link capabilities (feature support) and resources (e.g. buffers, bandwidth) for use in device configuration and status reporting.

**Problem statement (as needed):**

- This effort will establish the deployment environment and deterministic network requirements.

**Vertical requirements (as needed):**

- This effort will detail the requirements for deterministic networks in various industries, for example, professional audio, electrical utilities, building automation systems, wireless for industrial applications.
DetNet Building Blocks

**Congestion protection**
Addresses latency and packet loss due to congestion. Provides bounded end-to-end latency and packet delay variation.
Focused on service parameters; not on queuing mechanism, which may be subnetwork specific.

**Service Protection**
Addresses random media errors and equipment failures. Packet replication, ordering, and elimination functions (PREOF) on disjoint paths.

**Explicit routes**
Addresses impact of the convergence of routing protocols (i.e., temporary interruptions).
DetNet uses already defined explicit routing techniques, does not define new one.
Summary

TSN and DetNet provide guaranteed delivery with bounded low latency, low delay variation, and extremely low loss.

Extreme values (µsec, lossless, …) often appear; the main target is guaranteed upper bound.