IEEE 802.1 TSN – An Introduction

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Abstract

This presentation gives an introduction to IEEE 802.1 Time-Sensitive Networking (TSN) for the joint session of 802.11 TGbe and 802.1 TSN TG held at the IEEE 802 Plenary, July 2019.
Outline

- Deterministic service
- TSN standards and projects
- Basic concepts
- Example TSN tools
  - Scheduled Traffic (802.1Qbv)
  - Asynchronous Traffic Shaping (P802.1Qcr)
  - Frame Replication and Elimination for Reliability (802.1CB)
  - TSN Configuration (802.1Qcc)
- 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

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Loss probability

Buffers allocated

High Priority

Average

Application's requirement

Probability

End-to-end latency

Latency variation

Loss probability

Buffers allocated

Average

Application's requirement

Probability

End-to-end latency

Latency variation
TSN Profiles (Selection and use of TSN tools)

Audio Video Bridging (802.1BA)
Fronthaul (802.1CM)
Industrial Automation (IEC/IEEE P60802)
Automotive In-Vehicle (P802.1DG)
Service Provider (P802.1DF)

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)
Note: P upfront of an ID indicates ongoing Project

Latency

Synchronization

Reliability

Resource Mgmt

Zero congestion loss = Bounded latency

High Availability / Ultra 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)

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

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
    - P802.1DF TSN Profile for Service Provider Networks
    - P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications
Basic Components

- From IEEE 802.1 perspective, the world is divided into two types of devices: bridges and end stations
- Talker: The end station that is the source or producer of a stream
- Listener: The end station that is the destination, receiver, or consumer of a stream
- Stream: A unidirectional flow of data from a Talker to one or more Listeners
- Bridge: see next slides
Bridge Architecture

Control Plane Separated from Data Plane

- Control protocols are implemented as Higher Layer Entities
- External Agent (SDN Controller) may provide control instead of the distributed protocols
- The data plane is comprised of
  A MAC Relay and
  At least two ports

see Figure 8-2 – “VLAN-aware Bridge architecture” of 802.1Q for more details
Bridge Forwarding Process Functions

1. Reception Port State
   - Active topology enforcement (8.6.1)
   - Ingress filtering (8.6.2)
   - Frame filtering (8.6.3)
   - Egress filtering (8.6.4)
   - Flow metering (8.6.5)
   - Queuing frames (8.6.6)
   - Queue management (8.6.7)

2. Transmission Port State
   - Transmission selection (8.6.8)
   - Queue management (8.6.7)
Illustration of QoS Functions

- Filtering and Policing can be Per Stream, Per Class, etc.
- Shaping
- Queuing Per Class
- Transmission Selection

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
- Transmission 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
Per-Stream Filtering and Policing (PSFP) [802.1Qci]

- Protection against bandwidth violation, malfunctioning, attacks, etc.
- Decisions on per-stream, per-priority, etc.
- Filter
  - Filters, Counters
- Stream 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
Asynchronous Traffic Shaping (ATS) [P802.1Qcr]

- Zero congestion loss without time sync
  - Similar to per-flow IntServ shaping, except that:
    - All streams from one input port to the same output port share the same queue
- A shaper state machine for a set of streams, and the right shaper applied to the packet upfront of the queue
- Smoothen traffic patterns by re-shaping per hop
- Prioritize urgent traffic over relaxed traffic
ATS Components [P802.1Qcr]

- **Filter**
  - Selects treatment for frames of a stream, e.g., IPV, shaper

- **Internal Priority Value (IPV)**
  - Bridge internal traffic class of the frame
  - Used for ATS operations

- **ATS Shaper**
  - Applies a token bucket algorithm
  - Uses bridge local time variables
  - Pre-computes and assigns local eligibility times to frames
  - Eligibility time becomes effective in the queueing
  - Transmit frames that reached their Eligibility Time
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
TSN Configuration [802.1Qcc]

Fully distributed

Centralized network & distributed user

Fully centralized
Summary

• TSN provides deterministic service
• Multiple TSN tools provide bounded low latency
  • Time-based control of queueing provides deterministic behavior
    • Time synchronization is required
    • Asynchronous Traffic Shaping
• High availability / ultra reliability
• Configuration and resource reservation
Further Reading

http://www.ieee802.org/1/tns

TSN feature topic of the June 2018 Issue of IEEE Communications Standards Magazine
https://ieeexplore.ieee.org/document/8412457

Tutorial on TSN at IETF 99

Tutorial on IEEE 802 Ethernet Networks for Automotive

“A Time-Sensitive Networking Primer: Putting It All Together”
https://drive.google.com/file/d/0B6Xurc4m_PVsZ1lzWWoxS0pTNVE/view?usp=sharing

“Heterogeneous Networks for Audio and Video: Using IEEE 802.1 Audio Video Bridging”
http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6595589

Tutorial on IEEE 802.3br Interspersing Express Traffic (IET) and IEEE 802.1 Time-Sensitive Networking
http://www.ieee802.org/802_tutorials/2015-03/8023-IET-TF-1501-Winkel-Tutorial-20150115_r06.pptx

Tutorial on Deterministic Ethernet

Tutorial on IEEE 802.1Q at IETF 86

Paper on 802.1Q bridging