INTRODUCTION TO IEEE 802.1

Focus on the Time-Sensitive Networking Task Group

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WELCOME!
Before we start – decorum

› Press (i.e., anyone reporting publicly on this meeting) are to announce their presence (SASB Ops Manual 5.3.3.5)

› Photography or recording by permission only (SASB Ops Manual 5.3.3.4)

› Cell phone ringers off please
B E F O R E  W E  S T A R T –  
S E C U R I T Y  I S S U E S

› Please wear your badge when in the meeting areas of the hotel

› This will help the hotel security staff to improve the general security of the meeting rooms

› PCs HAVE BEEN STOLEN at previous meetings – DO NOT assume that meeting areas are secure
BEFORE WE START – PATENT SLIDES

› http://standards.ieee.org/about/sasb/patcom/materials.html
BEFORE WE START

- This presentation should be considered as the personal views of the presenter not as a formal position, explanation, or interpretation of IEEE 802.1.
AGENDA

› IEEE 802.1 Overview

› IEEE 802.1 Time-Sensitive Networking (TSN)
  – Audio Video Bridging (AVB) and TSN
  – AVB standards
  – TSN standards
  – TSN projects

› Background
  – Bridge architecture
IEEE 802.1 OVERVIEW
IEEE 802 LAN/MAN STANDARDS COMMITTEE (AKA IEEE 802 OR LMSC)

- Develop LAN and MAN standards
- Mainly for link and physical layers of the network stack
- In operation since March 1980
IEEE 802 is here: a standards committee formed by the Computer Society
SOME TERMS

› PAR – Project Authorization Request – the document that authorizes work on a project.
› CSD – Criteria for Standards Development – the basis for determining whether to forward a PAR.
› WG – Working Group – responsible for developing standards in an area
› TAG – Technical Advisory Group – experts on a topic area that crosses working groups – may develop a recommended practice.
› Task Group (TG) or task force – a part of a Working Group which focuses on a particular project.
ALL THOSE DOTS ....

- 802.1 Bridging and Architecture
  - generally the top of the link layer
- 802.3 Ethernet
- 802.11 Wireless LAN (WLAN)
- 802.15 Wireless Personal Area Network (WPAN)
- 802.16 Broadband Wireless Access (BWA)
- 802.18 Radio Regulatory TAG
- 802.19 Coexistence TAG
- 802.21 Media Independent Handover
- 802.22 Wireless Regional Area Networks (WRAN)
- 802.24 Smart Grid TAG
PRINCIPLES OF THE IEEE STANDARDS PROCESS

› **Due process** – procedures are publicly available and followed consistently

› **Consensus** – requiring agreement of a majority or supermajority – for technical decisions here ≥75%

› **Openness** – ensuring materially interested and affected parties can participate

› **Balance** – representation from all interested parties without overwhelming influence from any one party

› **Right of appeal** – process to ensure due process
IEEE 802.1 WORKING GROUP

› Chair: Glenn Parsons
› Vice-chair: John Messenger
› Data Center Bridging (DCB) and Addressing TG
  – Chair: Patricia Thaler
› Maintenance TG
  – Chair: John Messenger
› OmniRAN TG
  – Chair: Maximilian Rigel
› Security TG
  – Chair: Michael Seaman
› Time-Sensitive Networking (TSN) TG
  – Chair: János Farkas
IEEE 802.1 STANDARDS

- The ones with capital letters, e.g. 802.1Q or 802.1AX are independent standards
- Amendments to these standards are identified by lower case letters e.g. 802.1ah, 802.1Qbg or 802.1AEbn
- Periodically the amendments get merged into a revision of the main standard, e.g. 802.1ah and 802.1Qay are part of 802.1Q-2014
- 802.1Q can be considered as many individual standards integrated into a single document
  - Clauses 6 through 9 give a general overview of the 802.1Q bridge architecture
  - To get oriented on an additional area, it’s best to read the Clause titled the “Principles of <area>”
  - Once oriented, references in the subclause of Clause 5 Conformance for the relevant device can be helpful
STANDARD DEVELOPMENT PROCESS (HIGH LEVEL)

1. Project Authorization Request (PAR)
   - NesCom approval

2. Task Group ballot
   - Scope: the whole document
   - i

3. Working Group ballot
   - Scope: the whole document
   - j

4. Working Group recirculation ballot
   - Scope: only the changes
   - k

5. Sponsor ballot
   - Scope: the whole document
   - l

6. Sponsor recirculation ballot
   - Scope: only the changes
   - m

7. RevCom approval

8. Publication
Please follow the instructions provided in the ballot invitation
- Goal of the ballot
- Ballot email body and subject (e.g., “Comments (with abstain)” from non-voting contributor)
- xls for ballot comments: http://www.ieee802.org/1/files/private/commenting-tool/MyBallot-tools

In the xls
- Please fill in “First name”, “Surname”, and “Affiliation”
- Please fill in each column including “Must Be Satisfied”
- Please leave each cell empty in rows without comment
- Please do not use anything else than the binary choices for “Category” and “Must Be Satisfied” (e.g., a dot at the end screws it)
- Please do not go fancy with the line number, the Editor will figure it out
  - Single number is enough
  - Although, entries with two numbers seem to be OK, e.g., “19-25”, “19-25”, or “19, 25”
  - Entries with more than two numbers screw it, e.g., “17-22, 29-42”
  - The tool does not accept Figure number either in the Line or Sub-clause filed

Thank you!
MEETINGS

› Face-to-face
   – 802.1 f2f meetings: http://www.ieee802.org/1/meetings
   – 802 agenda (meeting rooms): http://802world.org/attendee
   – attendance: https://imat.ieee.org
   – TSN agenda: http://www.802tsn.org/agenda
     › agenda request: http://www.802tsn.org/agenda-for-next-meeting

› Virtual
     (https://join.me/ieee802.1)
     › Mondays: 8am PT: Generic TSN – 9am PT: Synchronization
       › agenda request by Thursday: http://www.802tsn.org/weekly-call-call-agenda-requests
   – Virtual meetings of each Task Group are announced on the 802.1 email list
     › TSN agenda items or cancellation on Friday
FURTHER NAVIGATION

› http://www.ieee802.org/1 (projects, drafts, everything)
  – TSN: http://www.ieee802.org/1/pages/tsn.html (conference calls, etc.)
› public folder: http://www.ieee802.org/1/files/public
› file upload – at the bottom of http://www.ieee802.org/1/filenaming.html
  – Follow the file naming conventions please
› email list: http://www.ieee802.org/1/email-pages
› ongoing ballots: http://www.ieee802.org/1/email-pages/ballots.html
› minutes & opening/closing plenary slides: http://www.ieee802.org/1/pages/minutes.html
› get program: https://standards.ieee.org/about/get/802/802.1.html
IEEE 802.1 TIME-SENSITIVE NETWORKING (TSN)
FROM AVB TO TSN

IEEE 802.1 Audio Video Bridging (AVB) Task Group (TG)
- Started in 2005
- Address professional audio, video market
- Consumer electronics
- Automotive infotainment
- AVnu Alliance: associated group for compliance and marketing

IEEE 802.1 Time-Sensitive Networking (TSN) TG
- AVB features become interesting for other use cases, e.g.
  - Industrial
  - Automotive
- AVB was not an appropriate name to cover all use cases
- AVB TG was renamed to TSN TG in 2012
- Interworking TG and TSN TG were merged in 2015
AVB STANDARDS

- IEEE Std. 802.1AS-2011 – generalized Precision Time Protocol (gPTP)
  - A Layer 2 profile of the IEEE 1588 Precision Time Protocol (PTP)
- IEEE Std. 802.1Qav – Forwarding and Queuing of Time-Sensitive Streams (FQTSS):
  - Specifies Credit-Based Shaper (CBS)
- IEEE Std. 802.1Qat – Stream Reservation Protocol (SRP)
  - Registration and reservation of time-sensitive streams
- IEEE Std. 802.1BA – AVB Systems
  - Provides an overall AVB architecture and AVB profiles
- CBS + SRP to provide delays under 250 μs per bridge
TSN STANDARDS AND PROJECTS

› P802.1AS-Rev – Timing and Synchronization - Revision
› 802.1Qbu – Frame Preemption – published
› 802.1Qbv – Enhancements for Scheduled Traffic – published
› 802.1Qca – IS-IS Path Control and Reservation (PCR) – published
› P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
› P802.1Qch – Cyclic Queuing and Forwarding – based on Qci
› P802.1Qci – Per-Stream Filtering and Policing
› P802.1Qcj – Auto-attach to PBB services
› P802.1Qcp – YANG Data Model
› P802.1Qcr – Asynchronous Traffic Shaping (ATS)
› P802.1CB – Frame Replication and Elimination for Reliability
› P802.1CM – Time-Sensitive Networking for Fronthaul
› P802.1CS – Link-local Registration Protocol (LRP) – PAR development
## Status & Industry Interest

<table>
<thead>
<tr>
<th>Standard / Project</th>
<th>Subject</th>
<th>Status</th>
<th>D #</th>
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<tr>
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<td>Time synchronization</td>
<td>TG</td>
<td>4.2</td>
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<tr>
<td>802.1Qbu</td>
<td>Frame Preemption</td>
<td>Published</td>
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<td>SRP Enhancements</td>
<td>WG</td>
<td>1.1</td>
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<td>TG</td>
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<tr>
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<td>LRP (Registration)</td>
<td>PAR</td>
<td></td>
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</table>

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[http://www.802tsn.org/home/project-list](http://www.802tsn.org/home/project-list)
A profile of 1588 for Layer 2 Ethernet

The Revision includes:

- Common peer delay service for all domains, for measuring link delay and neighborRateRatio
- Support of Fine Timing Measurement (FTM) for IEEE 802.11 transport
- Support for Link Aggregation (802.1AX)
- Improved scalability
- One step processing
- Improved support for long chains, rings
- More responsive
- Faster Grand Master change over
- Reduce BMCA convergence time
- Multiple domains with synchronization information
- Redundancy: configure redundant paths and redundant GMs (further redundancy may be defined by a new project)
We will refer to it very soon
Express frames can suspend the transmission of preemptable frames

**802.3br**

**INTERSPERSING EXPRESS TRAFFIC (FRAME PREEMPTION) – ILLUSTRATION**

- **Preemption request**
- **FCS**
- **pre**
- **MCRC**
- **IFG**
- **header**
- **pre**
- **original preemptable frame**
- **remaining fragment**
- **min 64 Bytes**
- **min 60 Bytes**

Pre includes Preamble and Start mPacket delimiter (SMD)
Time-critical frames can suspend the transmission of non-time-critical frames while one or more time-critical frames are transmitted.

Specified by:
1. 802.3br – Interspersing Express Traffic (IET)
2. 802.1Qbu – Frame Preemption

802.1Qbu makes the adjustments needed in 802.1Q in order to support 802.3br, e.g.
- each traffic class queue supported by the Port is assigned a value of frame preemption status
- the possible values of frame preemption status are *express* or *preemptable*

Minimum fragment size is 64 bytes including CRC
Transmission from each queue to be scheduled relative to a known timescale

A transmission gate is associated with each queue
- the state of the gate determines whether or not queued frames can be selected for transmission
- Open: queued frames are selected for transmission, (according to the transmission selection algorithm associated with the queue)
- Closed: queued frames are not selected for transmission
Preemption and Enhanced Scheduling – Overview

802.1Qbv – Enhanced Scheduling
Gate control list

T00: C00C0000
T01: C00C00CC
T02: C00C0000
T03: C00C00CC
T04: C00C0000
T05: C00C00CC
T06: C00C0000
T07: C00C00CC
T08: C00C0000
T09: C00C00CC
.............

C = closed, o = open

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Guard band can protect the express traffic completely from interference from preemptable traffic.
P802.1Qci – PER STREAM FILTERING AND POLICING

› Per-Stream Filtering and Policing (PSFP) allows filtering and policing decisions to be made on a per-stream basis

› Stream filter
  - Stream ID
  - Priority
  - Filters
  - Meter ID
  - Counters

› Stream gate
  - open (o)
  - Closed (C)

› Flow meter
  - Parameters as specified in Bandwidth Profile Parameters and Algorithm in MEF 10.3, plus some additional parameters
Synchronized cyclic enqueuing and queue draining achieve zero congestion loss and deterministic latency

Two buffers served alternated, e.g., that of S1 and S2

To be combined with frame preemption, see next slide
Each frame of a Stream stays one cycle at each hop
Provide IS-IS control beyond Shortest Path Trees (SPTs)
- Augmenting IS-IS with non-shortest path capabilities

No protocol changes, only a couple of new sub-TLVs and reuse of existing ones as much as possible

A hybrid Software Defined Networking (SDN) approach
- IS-IS provides basic functions, e.g., topology discovery, default paths
- One or more controllers control Explicit Trees

Example
- Exception traffic steering
- SPT of Edge Bridge (EB) 1 is via Core Bridge (CB) 1
- Explicit Tree (ET) of EB 1 is via CB 2
P802.1Qcc – STREAM RESERVATION PROTOCOL (SRP) ENHANCEMENTS

› SRP enhancements
  – New version: MSRPv1, which translates to MSRPv0
  – New AttributeTypes that provide enhanced capabilities

› TSN configuration
  – Fully Distributed Model
  – Fully Centralized Model
  – Centralized Network / Distributed User Model
P802.1Qcp – YANG DATA MODEL

› Scope: subset of 802.1Q features
› Model representation via UML
› YANG structure and relationships

P802.1Qcj – AUTO-ATTACH TO PBB SERVICES

Auto Attach Model
- Auto Attach Clients (AAC): non-Provider Backbone Bridging (PBB) device
- Auto-Attach Server (AAS): PBB device, e.g., Backbone Edge Bridge (BEB)
Asynchronous: no time synchronization needed

Basic idea

1. Smoothen traffic patterns by re-shaping per hop
2. Prioritize urgent traffic over relaxed traffic

Example

* formerly referred to as Urgency Based Scheduler (UBS)
P802.1CB – FRAME REPLICATION AND ELIMINATION FOR RELIABILITY (FRER)

› It is a per-packet 1+n redundancy
› Serialize packets, send on 2 (or more) maximally disjoint paths, then combine and delete extras

Key:
a: Add sequence numbers to Stream 31.
b: Split Stream 31 into Streams 26 and 31.
c: Merge Streams 26 and 31 into Stream 31.
d: Eliminate duplicates on Stream 31.
e: Merge Streams 26 and 31 into Stream 26.
Each system’s output ports marked with Streams transmitted and functions performed.
Develop standard TSN Profiles for Fronthaul in order to enable the transport of Fronthaul streams in a bridged network.

Current focus: Profile(s) for current (CPRI 7.0) Radio Base Station (RBS) split such that the different Fronthaul flows (IQ, C&M, and Sync) are supported separate from each other.

Further profiles may be specified, e.g., for future RBS split.
A Profile is a set of feature and option selections that specifies aspects of bridge and end station operation, and states the conformance requirements for support of a specific class of user applications.

The 802.1CM specification

- collects requirements for Fronthaul networks
- provide guidance for meeting Fronthaul requirements, which includes
  - selecting 802.1 TSN features in order to build networks capable of transmitting Fronthaul streams like Decomposed CPRI
  - describing how the selected TSN features and components can be combined, configured and used in order to meet Fronthaul requirements
FURTHER READING

› http://www.ieee802.org/1
› http://www.802tsn.org
› “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
› SDN by 802.1Q: https://arxiv.org/abs/1405.6953
› https://en.wikipedia.org/wiki/Audio_Video_Bridging
BRIDGE
ARCHITECTURE
CONTROL PLANE SEPARATED FROM DATA PLANE
(BASIC SDN CHARACTERISTICS)

› Control protocols are implemented as Higher Layer Entities
› External Agent 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
Data Plane Actions
(IEEE 802.1Q-2014)

- Ingress Port (Action Set1)
  - Filtering (drop), (un)tagging, VID translation, de/en-capsulation
- Relay (Action Set2)
  - Forwarding, filtering
- Egress Port (Action Set3)
  - Filtering, (un)tagging, VID translation, de/en-capsulation, metering, queuing, transmission selection

Data Plane

(redrawn)

(“baggy pants” is simple)
A VLAN is assigned to a control mode
- Multiple control modes may co-exist in the same network
- Hybrid control by distributed protocols and an External Agent, e.g., an SDN controller
- External control can be a non-802.1 protocol: PCE, GMPLS

Summary of control options
- Station Location (MAC address topology)
- VLAN Topology
- Active Topology (shortest path, spanning tree, TE path)
- Physical Network Topology

VLAN space:
- spanning tree VLANs
- shortest path VLANs
- software defined VLANs

Control:
- Multiple Spanning Tree Protocol
- IS-IS
- External Agent

MAC Bridge
Higher Layer Entities
Control Plane
External Agent
Ingress Port
Relay
Egress Port
Data Plane
Frame in
Frame out

Introduction to IEEE 802.1 (focus on TSN TG)
SEE YOU!