INTRODUCTION TO IEEE 802.1 AND P802.1CM TIME-SENSITIVE NETWORKING FOR FRONTHAUL

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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
BEFORE WE START – SECURITY ISSUES

› **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
  – Ongoing TSN projects
  – Some TSN tools

› P802.1CM TSN for Fronthaul
  – Status update
  – Draft 0.2 insight
    http://www.ieee802.org/1/files/private/cm-drafts/d0/802-1CM-d0-2.pdf

› 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
› 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
› Time-Sensitive Networking (TSN) TG
  – Chair: Michael David Johas Teener
  – Vice-chair: János Farkas
› Security TG
  – Chair: Michael Seaman
› Data Center Bridging (DCB) TG
  – Chair: Patricia Thaler
› OmniRAN TG
  – Chair: Maximilian Rigel
› Maintenance TG
  – Chair: John Messenger
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
NAVIGATION

› [http://www.ieee802.org/1](http://www.ieee802.org/1) (projects, drafts, everything)
› [http://www.ieee802.org/1/pages/tsn.html](http://www.ieee802.org/1/pages/tsn.html) (conference calls, etc.)
› file upload: at the bottom of [http://www.ieee802.org/1/filenaming.html](http://www.ieee802.org/1/filenaming.html)
  – Follow the file naming conventions please
› TSN agenda: [http://www.802tsn.org/agenda](http://www.802tsn.org/agenda)
  – agenda request: [http://www.802tsn.org/agenda-for-next-meeting](http://www.802tsn.org/agenda-for-next-meeting)
  – agenda request on a virtual meeting: [http://www.802tsn.org/weekly-call-agenda-requests](http://www.802tsn.org/weekly-call-agenda-requests)
› 802 agenda (meeting rooms): [http://802world.org/attendee](http://802world.org/attendee)
› email list: [http://www.ieee802.org/1/email-pages](http://www.ieee802.org/1/email-pages)
› f2f meetings: [http://www.ieee802.org/1/meetings](http://www.ieee802.org/1/meetings)
› attendance: [https://imat.ieee.org](https://imat.ieee.org)
› get program: [https://standards.ieee.org/about/get/802/802.1.html](https://standards.ieee.org/about/get/802/802.1.html)
› patent slides: [http://standards.ieee.org/about/sasb/patcom/materials.html](http://standards.ieee.org/about/sasb/patcom/materials.html)
VIRTUAL MEETINGS

› TSN general: Wednesdays at 9AM US-Pacific (6PM CET)
  - WebEx 927 424 544
    https://broadcom.webex.com/broadcom/j.php?ED=195636462&UID=492401017&RT=MiM0

› AS-Revision: Mondays at 9AM US-Pacific (6PM CET)
  - WebEx 922 420 917
    https://broadcom.webex.com/broadcom/j.php?MTID=md9f73d1a389ac05a7fa1c3f73d3a2948

› P802.1CM TSN for Fronthaul
  - https://join.me/ieee802.1
    › https://join.me/intphone/684645640/0
  - February 2 at 7AM PT, 4PM CET
    › https://join.me/timezone/1454425200000/1454428800000
  - March 1 at 7AM PT, 4PM CET
    › https://join.me/timezone/1456844400000/1456848000000
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
IEEE 802.1 TSN PROJECTS

› P802.1Qbu – Frame Preemption – ready
› P802.1Qbv – Enhancements for Scheduled Traffic – ready
› P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
› P802.1Qci – Per-Stream Filtering and Policing
› P802.1Qch – Cyclic Queuing and Forwarding
› 802.1Qcj – Auto-attach to PBB services
› P802.1AS-Rev – Timing and Synchronization – Revision
› P802.1CB – Frame Replication and Elimination for Reliability
› P802.1CM – Time-Sensitive Networking for Fronthaul

related
related
to each
other
Express frames can suspend the transmission of preemptable frames

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.

### New Part

**Gate control list**

<table>
<thead>
<tr>
<th>Traffic Class</th>
<th>Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>oooooooo</td>
</tr>
<tr>
<td>01</td>
<td>oooooooo</td>
</tr>
<tr>
<td>02</td>
<td>ooooooo</td>
</tr>
<tr>
<td>03</td>
<td>oooooooo</td>
</tr>
<tr>
<td>04</td>
<td>oooooooo</td>
</tr>
<tr>
<td>05</td>
<td>cccccccc</td>
</tr>
<tr>
<td>06</td>
<td>oooooooo</td>
</tr>
<tr>
<td>07</td>
<td>cccccccc</td>
</tr>
<tr>
<td>08</td>
<td>oooooooo</td>
</tr>
<tr>
<td>09</td>
<td>cccccccc</td>
</tr>
<tr>
<td>T78</td>
<td>oooooooo</td>
</tr>
<tr>
<td>T79</td>
<td>REPEAT</td>
</tr>
</tbody>
</table>

C = closed, o = open
PREEMPTION AND ENHANCED SCHEDULING – OVERVIEW

802.1Qbv – Enhanced Scheduling

Gate control list:
- T00: oooooooo
- T01: oCcCcCcCc
- T02: oCccCccCc
- T03: oCcCccCcc
- T04: oooooooo
- T05: oCcCcCcCc
- T06: oCccCccCc
- T07: oCcCccCcc
- T08: oooooooo
- T09: oCcCcCcCc
- ..........  
- T78: oooooooo
- T79: REPEAT

C = closed, o = open

**Transmission Selection**

**MAC Control**

**eMAC**

**pMAC**

**MAC Merge Sublayer**

**PHY** (unaware of preemption)

**Transmission Selection**

**Queue for traffic class #7**

**Queue for traffic class #6**

**Queue for traffic class #5**

**Queue for traffic class #4**

**Queue for traffic class #0**

**Transmission Selection Algorithm (Table 8-5)**

**Transmission Gate = C**

**Transmission Gate = o**

**Transmission Gate = C**

**Transmission Gate = C**

**Transmission Gate = C**

**Express**

**802.3br**

Interspersing Express Traffic (IET)
Guard band can protect the express traffic completely from interference from preemptable traffic.
Perform frame counting, filtering, policing, and service class selection for a frame based on the particular data stream to which the frame belongs.

A Stream Filter
- Contains a Stream ID and Priority
- Selects Stream Gate and Meter for a particular stream

A Stream Gate is either Open or Closed

Note – 802.1Qci is in an early stage: [http://www.ieee802.org/1/pages/802.1ci.html](http://www.ieee802.org/1/pages/802.1ci.html)
802.1Qch – CYCLIC QUEUEING AND FORWARDING (CQF)

› 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

Example bridge with two delay classes, S1 and S2

Note – 802.1Qch is in an early stage: http://www.ieee802.org/1/pages/802.1ch.html

IEEE Std. 802.1BA specifies AVB profiles

An AVB 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 AVB functionality for a specific class of user applications.

One of the objectives of an AVB profile is to allow the construction of AVB networks that meet a common performance metric in terms of the worst-case end-to-end latency that a stream will experience in transmission between a Talker and a Listener.

A profile identifies functionality defined in other standards

TSN profile for fronthaul in the forthcoming slides
A profile of 1588 for Layer 2 Ethernet
The Revision includes:
- 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
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://en.wikipedia.org/wiki/Audio_Video_Bridging
P802.1CM
TSN FOR FRONTHAUL

http://www.ieee802.org/1/pages/802.1cm.html
GOALS

› Develop standard TSN profiles for Fronthaul in order to enable the transport of Fronthaul streams in a bridged network

› The 802.1CM specification
  – collect 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 CPRI
    › describing how the selected TSN features and components can be combined, configured and used in order to meet Fronthaul requirements

› The P802.1CM project may identify additional TSN functions that would be useful
ROUGH TIMELINE

› What happened so far
  - Project Authorization Request (PAR) approved by IEEE 802 (July 17, 2015)
  - PAR approved by IEEE SA NesCom (New Standards Committee) (September 3, 2015)
  - P802.1CM project started: D0.0 (September 8, 2015)
  - f2f and virtual meetings

› Ongoing
  - Gathering requirements, use cases
  - f2f and virtual meetings
  - D0.2 (March 13, 2016) http://www.ieee802.org/1/files/private/cm-drafts/d0/802-1CM-d0-2.pdf

› Future steps
  - Task Group Ballots
  - Initial Working Group Ballot
  - Working Group Recirculation Ballot(s)
  - Initial Sponsor Ballot (latest by PAR: July 2018)
  - Sponsor Recirculation Ballot(s)
  - Submission for IEEE SA RevCom (Review Committee) approval (May 2019)
BRIDGE
ARCHITECTURE
Control Plane Separated from Data Plane

- 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

Simplified “baggy pants” model

External Agent

MAC Bridge

Higher Layer Entities

Relay

Port

Port

LAN

LAN

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

(Frame in) Ingress Port (Action Set1)
(Frame out) Relay (Action Set2)
(Frame in) Egress Port (Action Set3)

(mac bridge)

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., and SDN controller for TE paths
- External control can be a non-802.1 protocol: PCE, GMPLS

Summary of control options
- Management controls (enable/disable port)
- SPB, PCR, MSTP, RSTP
- SPB, PCR, MMRP, SRP
- 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
NOTATIONS

Legend:
- Bridge ID
- Port ID
- Bridge
- end station
- LAN

Bridged network

RE₁
11
1
2
3

RE₂
12
1
2
3

RE₃
13
1
2
3

RE₁
11
1
2
3

RE₃
55
1
2
3

RE₂
21
1
2
3

RE₃
22
1
2
3

Legend:
- Bridge ID
- Port ID
- Bridge
- end station
- LAN
SEE YOU!