TSN Components and Devices Testing

Dave Cavalcanti, Intel Corporation
Ganesh Venkatesan, Intel Corporation
Alon Regev, Keysight
Ionel Ghita, Keysight
Richie Pearn, NXP Semiconductor
Jeremy Rover, Intel Corporation
Mark Geisler, Analog Devices
Samantha Jaramillo, Analog Devices
Genio Kronauer, L-Acoustics
Henning Kaltheuner, d&b audiotechnik
Gavin Lai, MOXA
Pekka Varis, Texas Instruments
Abstract

This presentation provides an overview of the latest TSN components and device testing specifications, capabilities and certification programs in Avnu Alliance.
IEEE 802.1 TSN TG

Base standards for TSN
Profile standards: IEEE 802.1BA (AVB), IEEE/IEC 60802, ...

Test Specifications (for TSN/AVB features)
Wired (Ethernet) and Wireless (Wi-Fi and 5G)
Test Tools and Test Lab Partners
Certification Programs

Avnu Certified Interoperable TSN-capable components and network devices

ProAV
Auto
Industrial
Other
Avnu Alliance is enabling an ecosystem of interoperable networked devices using TSN technologies that guarantee real-time applications will just work.
Avnu Testing & Certification Programs

• Avnu (TSN Profile Agnostic) Component Certification (starting Q2 2024)
  – Ethernet TSN: Timing & Sync (.1AS), EST (802.1Qbv), IET/preemption (802.1Qbu), CBS (802.1Qav), ...

• Avnu Network Device Certification (new - Q2 2024)
  – Base TSN capability + TSN Profile specific requirements
  – AVB/TSN Bridge programs: updating to streamline testing and certification

• Other programs
  – Avnu Automotive Certification
    • 802.1DG
  – Milan Certification (ProAV specific)
    • Application layer network protocol for real-time media
  – TSN over Wireless (Wi-Fi and 5G): 802.1AS and 802.1Qbv (Rel. 1)

Focus of this presentation

EST: Enhancements for Scheduled Traffic
IET: Interspersed Express Traffic
CBS: Credit Based Shaper
Base TSN Test Plans

- TSN Profile Agnostic test plans
  - 802.1AS
  - 802.1Qbv
  - 802.1Qbu
  - 802.1Qav
  - …
802.1AS Testing

- Time synchronization test plan covers IEEE 802.1AS-2011 and 802.1AS-2020
  - Test cases for gPTP instances and gPTP instances with relay
  - Signaling message conformance
  - Conformance to 802.1AS state machines (BMCA, MDSyncSend, MDSyncReceive, MDPdelayReq)

Test Setup for end stations

Test Setup for bridges

DUT: Device Under Test
820.1AS Testing Example (1)

- Media independent test to validate Announce Message

<table>
<thead>
<tr>
<th>Pre-requisites</th>
<th>Applies to any gPTP device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test requirements</td>
<td>TS capable of acting as traffic generator and monitor</td>
</tr>
</tbody>
</table>
| Test procedure | • Start Pdelay emulation at TS 1  
| | • Capture all Announce messages received at TS 1 |
| Results | • PASS: Verify observed DA and EtherType are set as expected and reserved fields are set to zero (as specified in test procedure) |
820.1AS Testing Example (2)

- Media dependent test validate DUT’s Follow_Up messages on Ethernet full-duple point-to-point link

<table>
<thead>
<tr>
<th>Pre-requisites</th>
<th>Applies to any gPTP device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test requirements</td>
<td>TS capable of acting as traffic generator and monitor</td>
</tr>
<tr>
<td>Test procedure</td>
<td>• Start Pdelay emulation and collect/check Follow_Up messages from DUT</td>
</tr>
<tr>
<td>Results</td>
<td>• PASS: Each follow up has correct body fields (as specified in test procedure)</td>
</tr>
</tbody>
</table>
802.1Qbv Testing

- Test plan for 802.1Qbv covers
  - Transmission and Rejection of frames during queue gate operation
  - Queue cycle time conformance
  - Dynamic schedule changes
  - Bridges and Endpoints
  - Yang model validation
  - Test config over NETCONF
802.1Qbv Testing Example

- Transmission gate operation test to verify DUT maintains gate for each queue to allow/block traffic

<table>
<thead>
<tr>
<th>Pre-requisites</th>
<th>Applies to bridge or end station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test requirements</td>
<td>DUT passed 802.1AS validation</td>
</tr>
<tr>
<td></td>
<td>Traffic generators and monitors</td>
</tr>
<tr>
<td>Test procedure</td>
<td>• Test transmission gate for each queue one traffic class at a time and all at once</td>
</tr>
<tr>
<td>Results</td>
<td>• PASS: all frames are received within the expect timing requirements (as defined in test procedure)</td>
</tr>
</tbody>
</table>
802.1Qbu Testing

- Preemption (802.1Qbu) test plan covers point-to-point full duplex links
  - Capability exchange (preemption-capable) using LLDP TLV
  - Transmission of express and preemptable frames (Tx tests)
  - Reception of express and preemptable frames (Rx tests)

Bridge test set up
802.1Qbu Testing Example

- Validate ability of each DUT port to send and received LLDP messages indicating support for preemption and feature enabled

<table>
<thead>
<tr>
<th>Pre-requisites</th>
<th>Applies to any device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test requirements</td>
<td>Traffic generators and monitors</td>
</tr>
<tr>
<td>Test procedure</td>
<td>• Test exchange of additional Ethernet Capability TLV message using LLDP message</td>
</tr>
<tr>
<td>Results</td>
<td>• PASS: received LLDPU message contains expected TLV with preemption capability status set to 1.</td>
</tr>
</tbody>
</table>
802.1Qbu Testing Example

- Transmission of preemptable traffic, preempted by express traffic

<table>
<thead>
<tr>
<th>Pre-requisites</th>
<th>Applies to any device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test requirements</td>
<td>DUT capable of generating test traffic and Test Station as traffic monitor</td>
</tr>
<tr>
<td>Test procedure</td>
<td>• Start preemptable traffic, load eMAC service interface while pMAC is transmitting</td>
</tr>
<tr>
<td>Results</td>
<td>• PASS: correctly receive preemptable and express frames</td>
</tr>
</tbody>
</table>
Avnu Network Device Testing and Certification

• Base TSN features (Component Test Plans)
  – e.g. FQTSS/Qav, gPTP tests

• Plus profile-specific tests
  – e.g. 802.1BA Bridge MVRP tests
  – e.g. IEEE/IEC 60802 Bridge CC-A/B supports ‘x’ Class Queues

Launching updated Bridge program in Q2 2024
Plugfests: Helping members develop, test and certify TSN-based interoperable devices

Plugfests running since 2019

Last Plugfest (Oct’23, Stuttgart)
- ~21 Member Companies
- ~36 Devices tested
- Features covered: 802.1AS, 802.1Qbv, 802.1Qbu, 802.1Qav, Wireless TSN (5G and Wi-Fi), MILAN and Switches

Next Plugfest events:
- April 1-5, Malaga, Spain (5G only)
- April’24, Krakow, Poland (Ethernet and Wi-Fi)
### Available Test tools

<table>
<thead>
<tr>
<th>Available Test tools</th>
<th>Avnu TSN Test Capabilities</th>
</tr>
</thead>
</table>
| Avnu Express Test Suite (AETS) | • Time Synchronization (802.1AS-2011 and 802.1AS-2020)  
• Milan Certification (802.1BA-2011, 802.1AS-2011, 1722.1, 802.1Q-2014, etc.)  
• Avnu .1BA Switch |
| Keysight Test tools for (Ethernet, Wi-Fi and 5G) | • Time Synchronization (802.1AS-2011 and 802.1AS-2020)  
• Enhancements for Scheduled Traffic (802.1Qbv)  
• Interspersed Express Traffic (.1Qbu/.3br)  
• Credit-based Traffic Shaping (.1Qav)  
• Wireless TSN (Wi-Fi and 5G): 802.1AS-2020 and 802.1Qbv  
• Avnu .1BA Bridge |

### Other vendors developing test tools: Spirent

- Avnu-approved test tools are used in the certification programs to verify conformance with TSN standards
- Avnu members can use the tools to support their in-house development and during Plugfests.
- Avnu’s Certification Policy defines and executes a rigorous test tool V&V process

Product testing performed by Avnu Registered Test labs:
- Allion Labs
- Granite River Labs
- Excelfore
- IOL
Testing TSN for Industrial Automation

- TIACC is not a new org
  - Multi-org collaboration
- Goal is to work together on how to test and enable the TSN ecosystem for industrial automation
- Primary deliverable is a shared test plan for 60802

<table>
<thead>
<tr>
<th>TSN feature/Test Plan</th>
<th>Status (Q1 2024)</th>
<th>Is feature a 60802 Requirement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.1AS</td>
<td>802.1AS-2011 &amp; 2020 Test plan (Rev. 1.0) completed</td>
<td>Yes</td>
</tr>
<tr>
<td>802.1Qbv</td>
<td>802.1Qbv Test Plan (Rev.1.0) completed</td>
<td>Yes</td>
</tr>
<tr>
<td>802.1Qbu</td>
<td>802.1Qbu and .3br Test plan Rev. 1.01 completed</td>
<td>Yes</td>
</tr>
<tr>
<td>802.1Qav</td>
<td>802.1Qav Test Plan (Rev.1.0.1 completed)</td>
<td>Optional</td>
</tr>
</tbody>
</table>

www.tiacc.net/
Wireless (Wi-Fi and 5G) TSN Testing

- Test plans (Rel.1) covering 802.1AS and 802.1Qbv over 802.11/Wi-Fi and 5G
- Rel.2 tests under development: mobility/roaming, configuration and redundancy
Conclusions

- Avnu testing and certification programs are covering TSN components and network devices
  - 802.1AS, 802.1Qbv, 802.1Qav, 802.1Qbu, …
  - Testing coverage includes core requirements of the TSN Industrial profile (60802)
  - Testing framework and process including multiple test tools validation
  - Multiple devices/vendors contributing to testing through plugfest/interop events

- Avnu is addressing fundamental TSN capabilities for multiple markets (Industrial, Automotive, ProAV, …)
  - Closely following the IEEE 802.1 TG progress and new capabilities
  - Avnu members plan to continue reaching out to 802.1 to provide feedback and ask for clarification as testing progresses
Thank you!
Applications (mixed criticality) coexisting
One TSN for wired and wireless networks serving multiple Markets

![Diagram showing TSN protocols and ecosystems]