



SPE and TSN Testing and Challenges

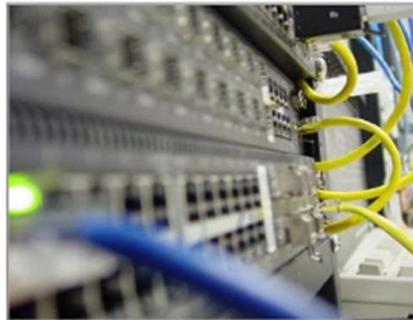
Bob Noseworthy, Principal Engineer

UNH-IOL: A Brief Overview

The University of New Hampshire's InterOperability Laboratory in a nutshell

UNH-IOL's Mission

To provide a neutral environment to foster interoperability, standards conformance, and development for the interconnected world, while attracting students to and preparing them for careers in cutting-edge technology.



Who We Are

- A neutral and independent lab that tests networking and data communications products for businesses across the globe.
- Started in 1988 on the University of New Hampshire Durham, NH campus.
- Non-profit organization and 100% funded by commercial industry with over 150+ member companies.
- State of the art facility with 28,000+ sq. ft. (1 hour outside Boston, USA).
- 4,200 sq. feet of pre-wired space dedicated to Plugfests.



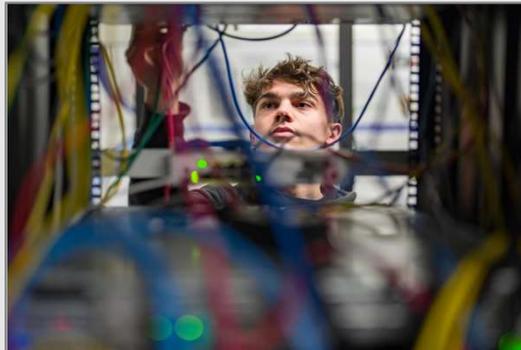
Training Future Engineers



120+ Graduate & undergrad student employees work with our staff, gaining hands-on experience with developing technologies and products.



99% job placement rate for our student employees, often before they graduate.



We provide career advancement opportunities including tech talks, training for common industry tools, networking events & an online resume binder.



Technology is What We Do

- Enable multi-vendor interoperability, conformance testing and develop custom testing solutions.
- Through industry involvement we can provide guidance and insight into new technology areas with testing needs and certification for testing programs.
- Promote early adoption through collaborative group testing (Plugfests).
- Offer members access to our world-class, multi-million dollar shared testbed which continues to grow.



Conformance & Interoperability

- Conformance test **predicts** future interoperability
- Interoperability test **proves** current interoperability

Both are essential.

Conformance testing is only as good as:

- The standard's coverage
- The test plan's coverage
- The test tools employed

Interoperability testing is only as good as the devices, topologies and traffic patterns scrutinized

Continuous Improvement Cycle

Standards:

- Eg: IEEE 802.3
 - Defines:
 - Interoperability requirements
 - Conformance requirements
 - Testability requirements

Testing:

- Test execution yields issues
- Issue resolution improves products, tools, test plans, and standards.

Test Plan:

- Details conformance & interoperability test procedures
 - Tool agnostic

Tools:

- Industry standard tools
- Automation Test Harnesses
 - Instantiate Test Plans
 - Multiple solutions
 - Enables 1st & 3rd party common test

Single Pair Ethernet (SPE) and Time Sensitive Networking (TSN) State of the Art

Literally Not Your Father's Oldsmobile

SPE State of the Art in one slide

- Spanning from 10Mbps to 10Gbps and soon 25Gbps
 - 2 10Mbps speeds:
 - 10BASE-T1S (15m reach Multidrop CAN/LIN gateway/replacement)
 - 10BASE-T1L (Industrial use-case, including Automotive Factory, 1km reach + SPOE)
 - 100BASE-T1 (Original “BroadR-Reach” to IEEE 802.3 standard, 15m reach)
 - 1000BASE-T1 (Type A: 15m reach, Type B: 40m reach)
 - MGBASE-T1 (2.5 / 5 / 10Gbps, 15m reach)
 - 25GBASE-T1 (11m reach)
- IEEE 802.3 Defines the SPE Standards, OPEN Alliance builds consensus for development of ISO Standards (eg: ISO 21111-6)

TSN State of the Art in one slide

- 3 orig. “AVB” Standards: Credit based shaper (CBS), gPTP, MSRP; + 1 Profile:.1BA
- Leads to >45 IEEE Standards (+ IETF DetNet work) - All form a “**TSN Toolbox**”
 - Bounded Latency: CBS(.1Qav) Preempt(.1Qbu) Sched(.1Qbv) Cyclic(.1Qch) Async(.1Qcr) QoS (.1DC)
 - Reservation protocols: MSRP(.1Qat) SRPv2(.1Qcc) PCR(.1Qca) LRP(.1CS) RAP(.1Qdd)
 - Redundancy solutions: FRER (.1CB), PCR (.1Qca), LinkAg (.1AX), Hot Standby (.1ASdm)
 - Timing solutions: 802.1AS-2011 (gPTP) superseded by 802.1AS-2020
 - Management: Config. Enhancements for TSN (.1Qdj), numerous YANG definition standards.
- Several profiles in development now:
 - 802.1DG – TSN Profile for Automotive In-Vehicle Ethernet Communications
 - IEC/IEEE 60802 – TSN Profile for Industrial Automation
 - 802.1DF – TSN Profile for Service Provider Networks
 - 802.1DP – TSN Profile for Aerospace Onboard Ethernet communications

Supporting Organizations

- UNH-IOL: Third party test plan development, tool developer and supplier, test facility for Avnu and OPEN Alliance, plugfest host, etc
- IEEE: Principal Standard Defining Organization (SDO)
- Avnu Alliance:
 - Promoting AVB / Pro Audio Certification; and
 - Avnu Automotive Profile and Certification (offered by UNH-IOL)
- OPEN Alliance:
 - PHY Testing; Wake-Up and Sleep specification (“TC10”), Switch Requirements (TC11), and ECU Requirements (TC8)
- Agricultural Industry Electronics Foundation (AEF) – 1000BASE-T1 Type B

A Tale of Two Automotive Profiles

IEEE 802.1DG (Automotive TSN Profile)

- D1.4 (since Dec 2021) – A new draft is progressing, but this work is not done
- Routine Calls and meetings held
 - Next Concall is Oct 3 9am EDT (Currently held every two weeks)
 - <https://1.ieee802.org/tsn/calendar/>
 - One (of many) areas of active discussion, to require strict compliance to IEEE 802.1AS-2020 (which requires Announce messages), or not, driven by AUTOSAR feedback in March Plenary

Avnu Automotive Profile (D1.4 – D1.6)

- Older profile (5+ years old) pre-dating IEEE 802.1AS-2020 (oft referred to as “.1AS-Rev” at the time)
- Did not require BMCA (hence no Announce), statically set port role pre-AS definition

UNH-IOL Services Snapshot

A Brief Summary of SPE and TSN Related Services and Tools

UNH-IOL Current SPE Services: 100 Mbps to 1Gbps+

- 100BASE-T1 Testing Service:
 - OPEN TC1 Defined PMA, PCS, PHY Control and TC10 Wake/Sleep Test Service.
 - TC9 – 100BASE-T1 Cable testing
 - Contact us about In-house test capability (BitPhyer and QualiPhyer)
- 1000BASE-T1 Testing Service:
 - OPEN TC12 Defined PMA, PCS, PHY Control
 - TC9 – 1000BASE-T1 Cable testing (including Type B)
- MGBASE-T1 Pay-per-test Service:
 - OPEN TC15 Defined PMA

UNH-IOL Current SPE Services (10 Mbps)

- 10BASE-T1S
 - OPEN TC14 Defined PMA
 - UNH-IOL Defined PCS, PLCA and Half-Duplex MAC Conformance Testing
- 10BASE-T1L / APL
 - Advanced Physical Layer (APL) uses 10BASE-T1L with APL Group defined Power delivery over the SPE
 - Developed APL Group Certification Test Plans, Tools, Software and Service, Supported by APL Group (PNO, ODVA, Fieldcomm Group, and OPC Foundation)
 - UNH-IOL Semiconductor conformance validation for 10BASE-T1L: PCS, Phy Control, Auto-Negotiation in our 10BASE-T1L Service Group

UNH-IOL Current SPE Solutions

- BitPhyer® Tool enables 100BASE-T1 PCS/Phy Control/TC10
 - Specialized tool for IEEE compliance
 - <https://www.iol.unh.edu/solutions/test-tools/ethernet/bitphyer>
- APL Violet® enables 10BASE-T1L In-house testing for APL
 - <https://www.iol.unh.edu/solutions/test-tools/apl/software>
 - Companion Test Fixtures available at <https://www.iol.unh.edu/solutions/test-tools/apl>
- In development: QualiPhyer® for SPE
 - To enable in-house testing utilizing UNH-IOL methodologies
 - <https://www.iol.unh.edu/solutions/test-tools/ethernet/qualiphyer>
- All IOL Products at: <https://license.unh.edu/products/iol>



UNH-IOL Current TSN Services

- Automotive Networking Test Service:
 - Avnu Automotive Certification
 - Avnu AVB Bridge Certification
 - OPEN Alliance TC8 / TC11 Testing
 - Exploring OPEN Alliance TC17 (MACsec) leveraging earlier UNH-IOL MACsec Compliance testing
- IEEE 1588 / PTP Test Service:
 - gPTP Conformance Testing
 - Upcoming IEEE-SA Certification for Power Profile (IEC 61850-9-3, IEEE C37.238)
 - Other IEEE 1588 Profiles (Default, etc) and capabilities (One-Step TC Semiconductor Verification)
- In-house test software available Avnu Violet[®] and PTP Violet[®]
 - <https://www.iol.unh.edu/solutions/test-tools/avnu>
 - <https://www.iol.unh.edu/solutions/test-tools/ptp>

MGBase-T1 Testing Challenges

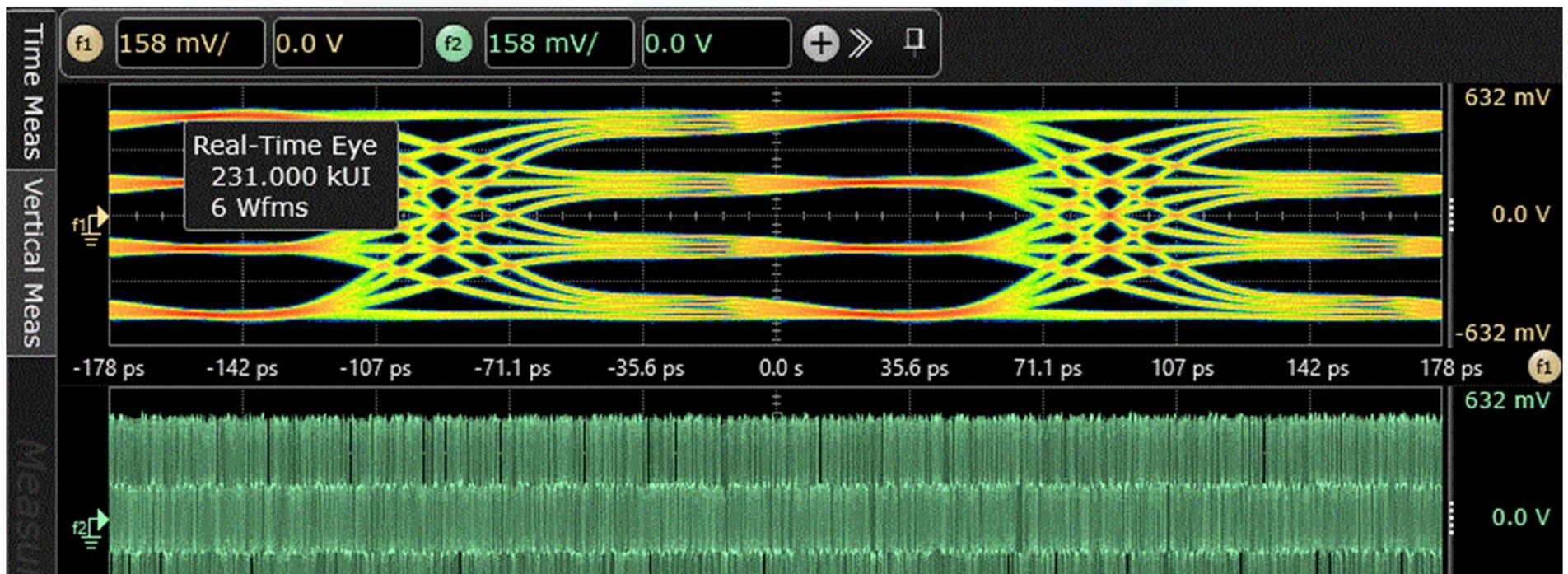
A quick overview – Contribution from UNH-IOL's Jason Sisk

MGBASE-T1 Testing Overview from UNH-IOL

- **Physical layer testing challenges grow in difficulty as the automotive network continues to increase in data rates in order to support high density communication within a vehicle network.** The newest group to complete their standard is 2.5G/5G/10GBase-T1 in 2020 although the 25GBase-T1 group is now completed as of the middle of calendar year 2023 ([background info for why 10G+](#)).
- 2.5G/5G/10GBase-T1 are PAM4 Full Duplex Technologies paving the way for high speed in vehicle networks in which the future 25GBase-T1 hopes to expand upon as the backbone for new topologies.
- UNH-IOL is developing PMA Compliance Test Software, and pursuing tooling for PCS/PHYC
 - Options exist for early PCS and PHYC testing
 - Solutions could exist for PCS and PHYC before years-end offering partial coverage of requirements (estimated to be 40-60% of requirements).

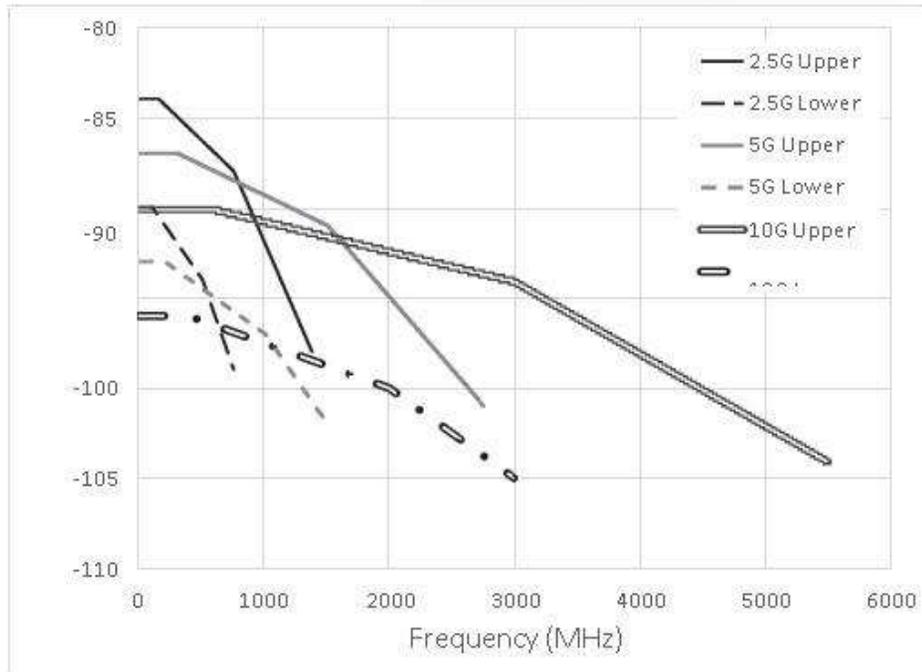
MGBASE-T1 Challenges: Linearity

- PAM4 signaling is new for the SPE technology. Understanding TX signal levels vs Noise (SNDR) is crucial.

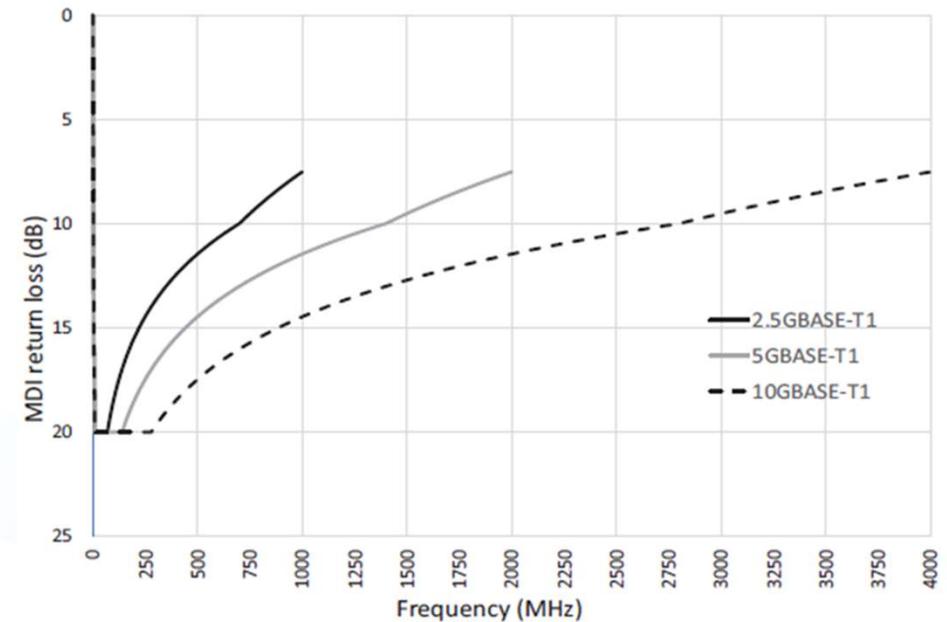


MGBASE-T1 Challenges: Test and Data Bandwidth

Power Spectral Density Mask (to 5.5GHz)



Return Loss Limits (to 4GHz)

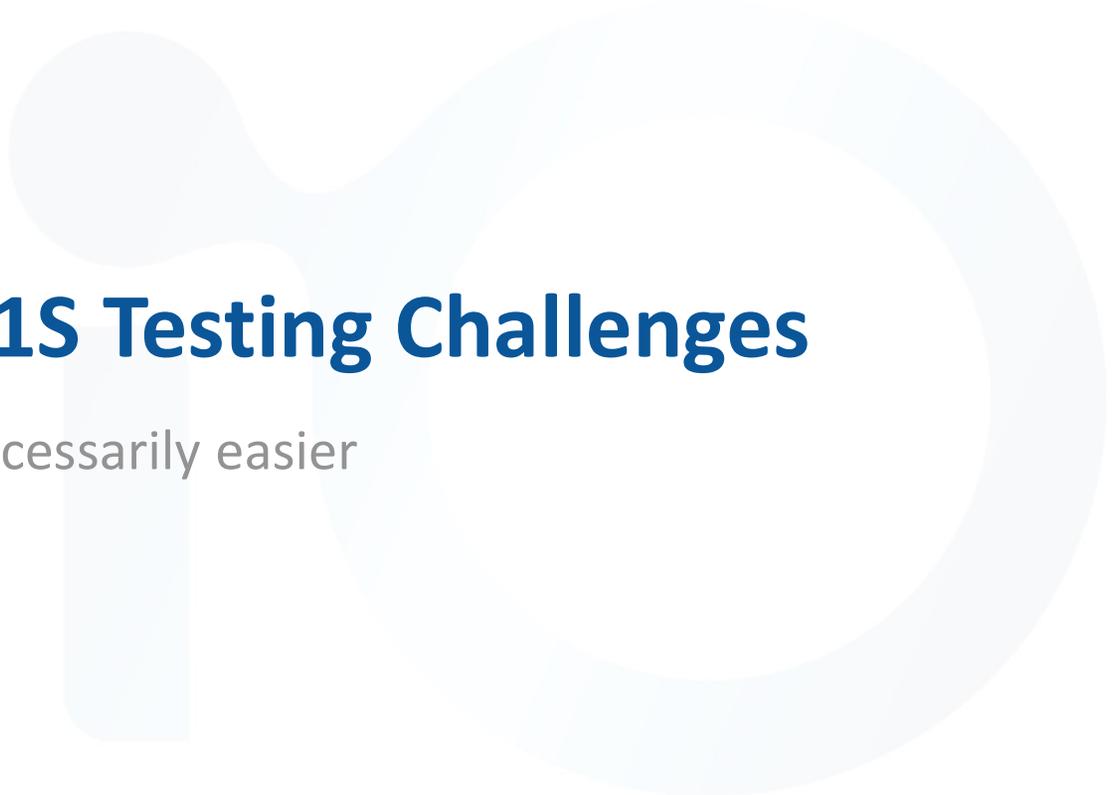


MGBASE-T1 Challenges and Solutions:

- As in-vehicle network continue to evolve with higher data rates the testing challenges associated with the technology also evolve.
- Keeping in mind the appropriate testing methodologies allows one to quantify the communication systems TX and RX are meeting the desired expectations for not only compliance but for future interoperability.
- UNH-IOL is developing a white paper in partnership with Keysight to explore these challenges in detail compared to previous flavors of the SPE technology.
 - Keysight has generously provided long-term access to a UXR0334A for these purposes
 - Discussions with other T&M vendors are ongoing and welcome, to enable a rich validation ecosystem!

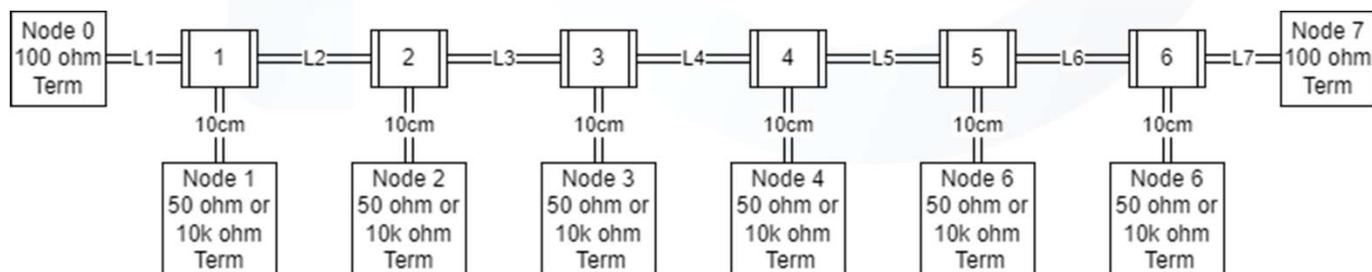
10BASE-T1S Testing Challenges

Slower is not necessarily easier



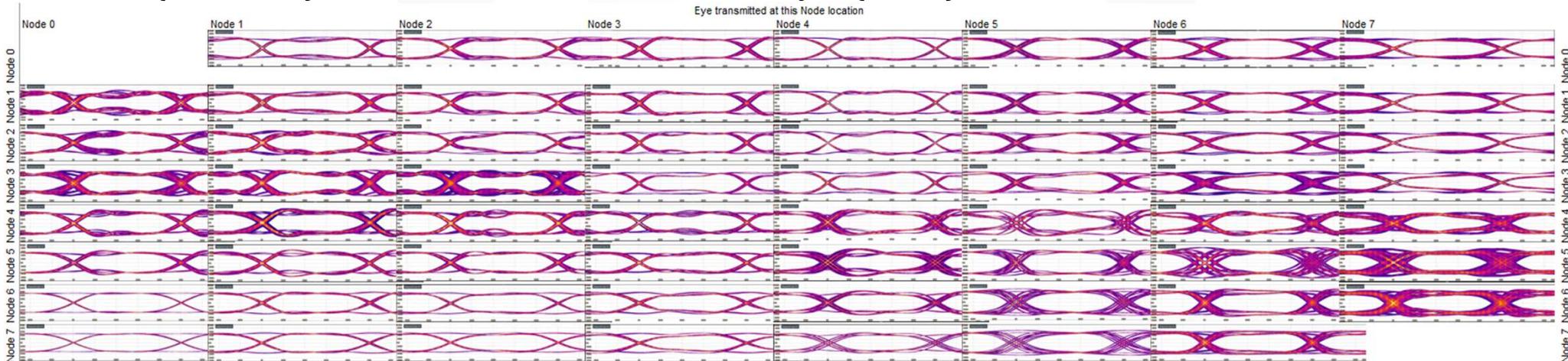
10BASE-T1S Testing Overview from UNH-IOL

- **10BASE-T1S is a shared medium technology to provide a low-cost path traditionally supported by CAN/LIN technologies.**
- “Shared medium” does mean “half-duplex”, but this is not purely CSMA/CD of old.
 - PLCA (Physical-Layer Collision Avoidance) allows for maximized fair use of the 10Mbps BW with minimal impact on overhead.
 - Validation must span from Channel, to PMA, PCS, PLCA, MAC and (optionally) SPI to/from MAC
- The “Multi-drop” channel presents some challenges for validation and test.



10BASE-T1S Challenges: Multi-Drop Channel

- Channel is principally limited by capacitive loading. 8 Nodes should be possible, 16 may be with care. Each node may see different eyes as a function of topology and node transmit source.
- Shown below, Transmitted Eye, when transmitting from Node <x> {Column} vs that received at Node <y> {Row}

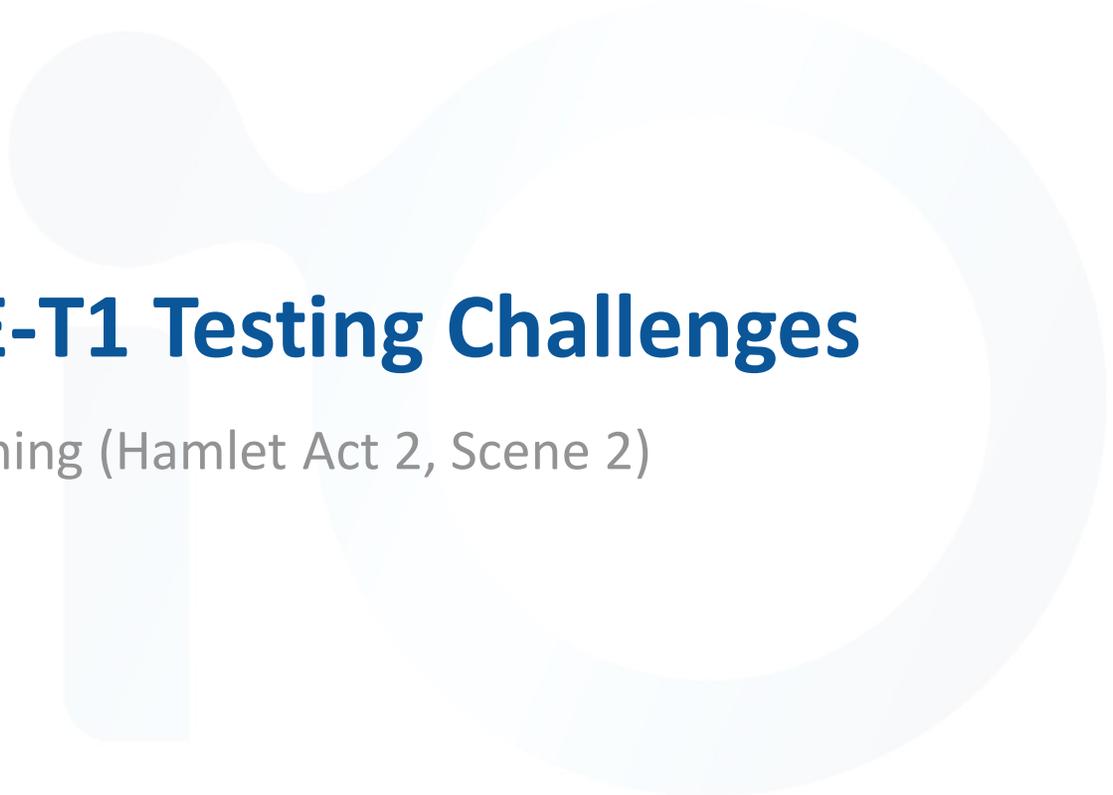


10BASE-T1S Challenges and Solutions:

- For repeatable interoperability and compliance testing, representative ‘worst-case’ channels are necessary. OPEN Alliance TC9 and TC14 groups working to address this.
 - Efforts in IEEE P802.3da to define Multidrop Segments Enhancement improve the channel definition but do so for “10BASE-T1M” (objective: 16 nodes, 50m, interoperable with 10BASE-T1S.)
- PLCA is introduced with 10BASE-T1S, hence all tooling in new.
- UNH-IOL Currently offers services for 10BASE-T1S:
 - PMA
 - Half-Duplex MAC Conformance Validation
 - Draft/early PCS and PLCA testing.
 - Hosting **Second 10BASE-T1S Plugfest June 26-30** at UNH-IOL in Durham NH.
 - Exploring additional Interoperability services (eg: cable fault testing, etc)

1000BASE-T1 Testing Challenges

The play's the thing (Hamlet Act 2, Scene 2)



- 1000BASE-T1 Type B

1000BASE-T1 Testing Overview from UNH-IOL

- **Having a Test Plan; and, Having a Test Tool, are two different things.**
 - While a Test Plan for PCS and PHY Control (PHYC) have existed in the OPEN ALLIANCE TC12 group for several years, only recently announced tooling enables all test cases defined therein.
- The Challenge: Enabling a tool that can generate 1000BASE-T1 valid signaling while “breaking the rules” when needed to validate compliance with a ‘negative’ test case.
 - 1000BASE-T1 PCS & PHYC Coverage now fully online as announced on Business Wire in Jan’23

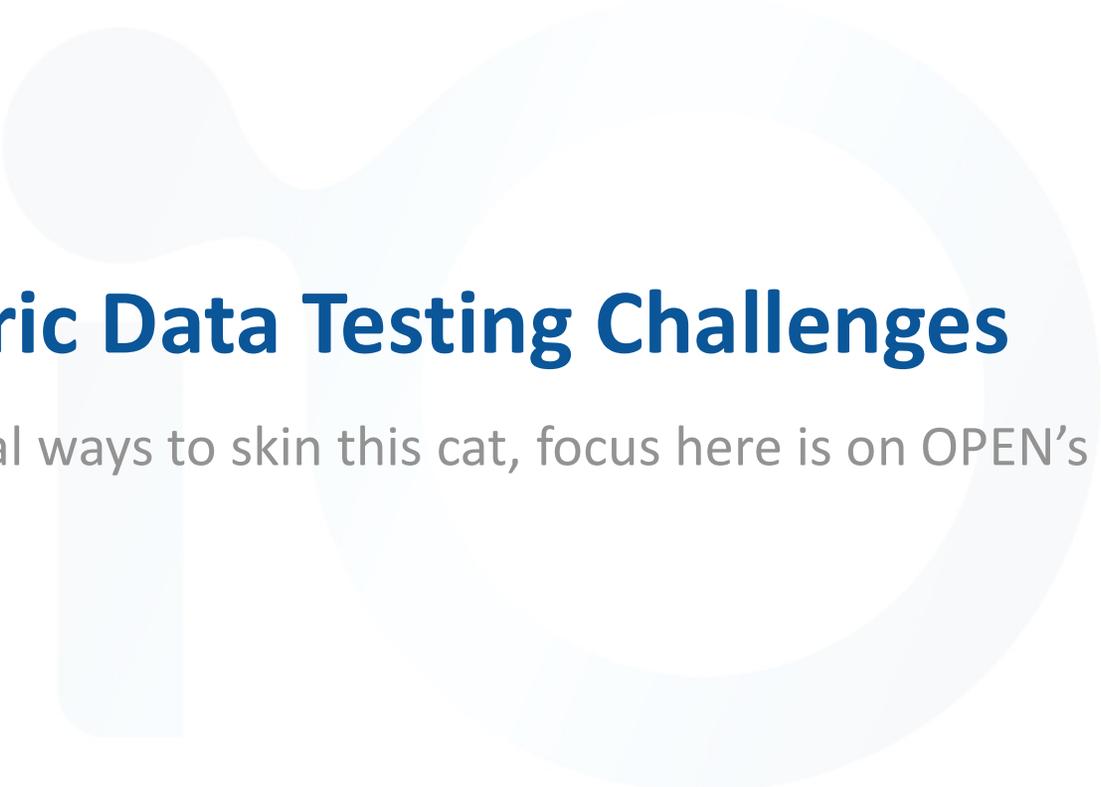
UNH InterOperability Lab and Microchip Technology Partner to Expand 1000BASE-T1 PCS and PHY-C Automotive Compliance Testing

January 24, 2023 10:00 AM Eastern Standard Time

DURHAM, N.H.--(BUSINESS WIRE)--The [University of New Hampshire InterOperability Laboratory](#) (UNH-IOL), an independent provider of broad-based testing and standards conformance services for the networking industry, today announced they have expanded testing for the 1000BASE-T1 PCS and PHY Control market to help further compliance for the automotive industry. By partnering with Microchip Technology, who created a development test platform that is compatible with OPEN Alliance Test Plans for 1000BASE-T1 conformance testing, the automotive industry is even closer to having a complete compliance for chip manufacturers. The enhancements of the testing will allow manufacturers the ability to go to market with greater confidence in their products.

1000BASE-T1 Remaining Challenges:

- **TC10**
 - Test Specification for Sleep/Wake for 1000BASE-T1 still in process
- **Type B**
 - Coordinating with the Agricultural Industry Electronics Foundation (AEF) and OPEN to develop 1000BASE-T1 Type B (40m) PMA Test Plans for emerging silicon, in addition to on-going OPEN TC9 Cable testing for Type B channels.
- **1000BASE-T1 PMA receiver testing**
 - UNH-IOL is currently updating automotive test channels with cabling provided by Leoni
- **Non-test-mode testing.**
 - Supporting the exploration of testing IEEE requirements (typically requiring a Test Mode to be enabled) with non-test mode signaling - as a device that knows it is being tested may differ from its real-world behavior.



Asymmetric Data Testing Challenges

There are several ways to skin this cat, focus here is on OPEN's TC16

Energy Efficient Ethernet (EEE) Testing Challenges:

- While defined for 100BASE-T1 and 1000BASE-T1, principal expected use-case is in MGBASE-T1 speeds (2.5/5/10Gbps) to support camera flows and similar.
 - Supporting OPEN ALLIANCE TC16 efforts for Test Plan and Plugfest planning
- UNH-IOL Currently offers EEE testing for several “BASE-T” speeds
 - Leveraging this knowledge combined with 1000BASE-T1 and MGBASE-T1 Testing know-how to accelerate MGBASE-T1 Validation
- Challenge: Asymmetric Data flow results in the SPE line always having energy in one direction, hence selectively monitoring the EEE “low power idle” (LPI) is a challenge that UNH-IOL can help solve.
 - Complete PCS Validation requires negative test case and hence stimulation.
 - Overall power savings is a system-level consideration
 - Not typically an IEEE nor OPEN specification, but an informative measure UNH-IOL can measure given sufficient definition of test environment

Questions?

Technical Contacts:

- Bob Noseworthy ren@iol.unh.edu
- Jason Sisk jsisk@iol.unh.edu

Operations and Sales:

- Michelle Whisnant mwhisnant@iol.unh.edu
- Mike Goding mgoding@iol.unh.edu



Thank You!

