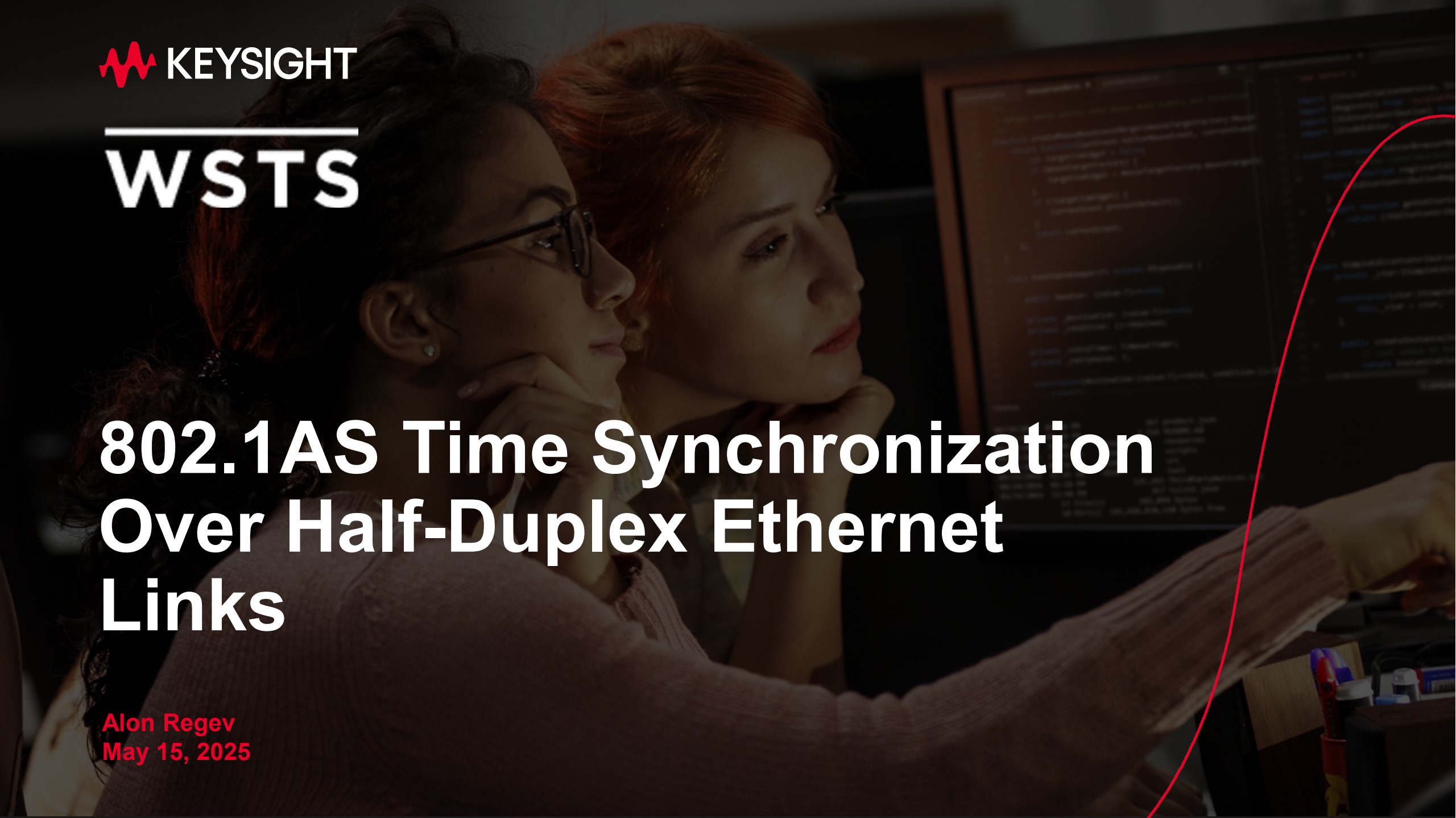


KEYSIGHT

WSTS

802.1AS Time Synchronization Over Half-Duplex Ethernet Links

Alon Regev

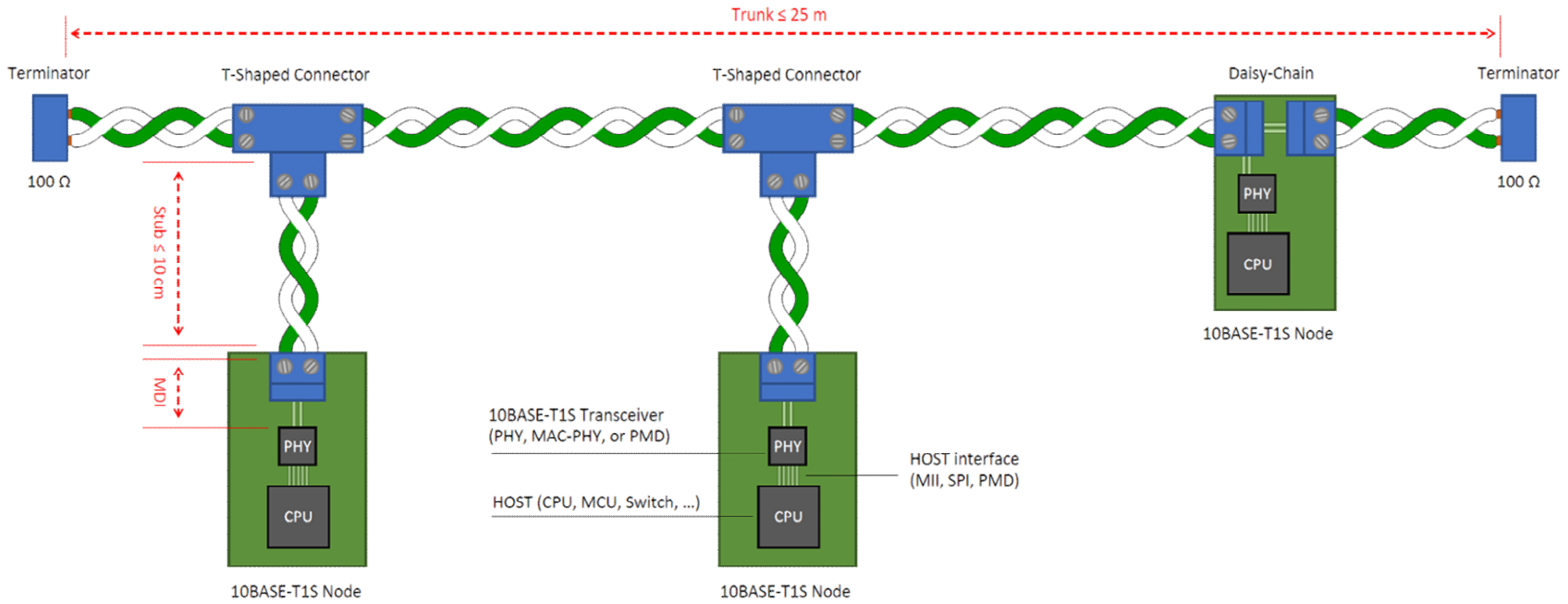
May 15, 2025

Agenda

- Why half-duplex? What is 10BASE-T1S?
- Time sync over half-duplex 10BASE-T1S and its issues
- 802.1ASds overview
- How to test time sync over half-duplex Ethernet
- Putting the test system together
- Issues encountered
- Test Results
- Open issues
- Next steps

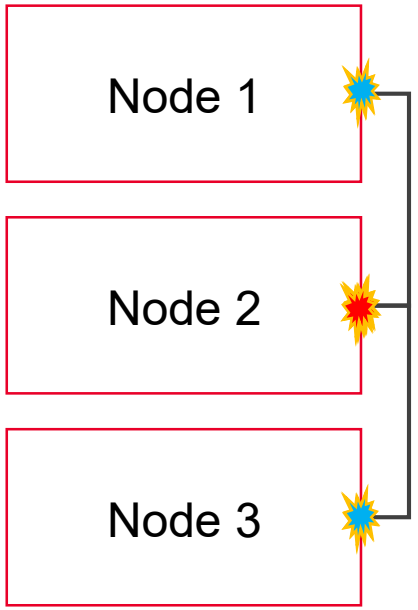
What is 10BASE-T1S (and 10BASE-T1M)

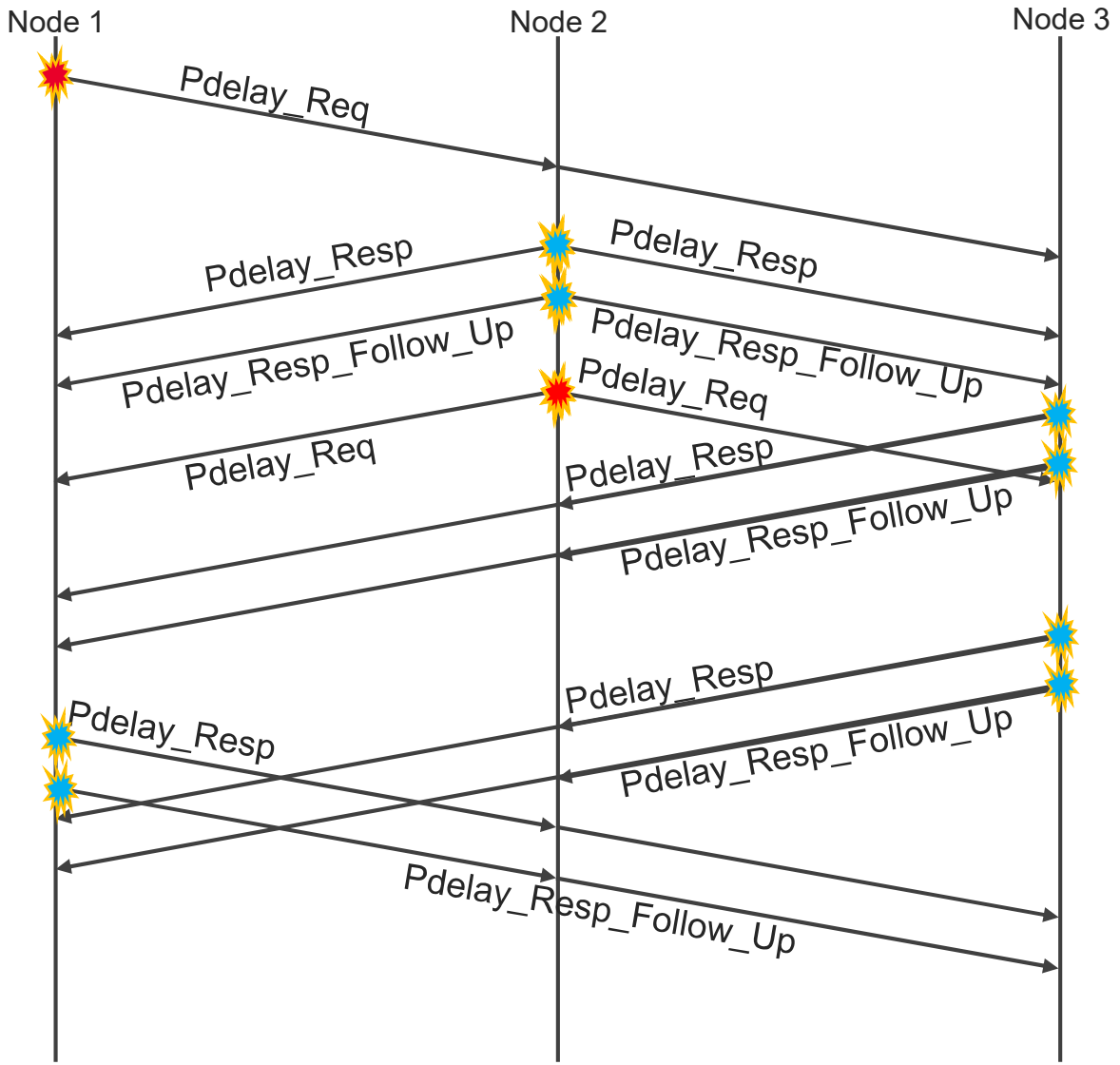
- 10BASE-T1S is a multi-drop 10 Mbps Ethernet standard
- Multiple nodes can connect to the same wires (no switch or hub is needed), reducing cost, latency, and complexity
- Designed to replace legacy multi-device busses such as CAN or FlexRay
- Mostly used in automotive, embedded, and industrial applications
- 10BASE-T1M is a draft Ethernet standard that extends 10BASE-T1S reach and node count and supports power over the data lines
- Time sync is required for many applications



Time Synchronization in 10BASE-T1S / half-duplex / PLCA – part 1

- 10BASE-T1S has a multidrop topology
  - The delays between different nodes on the multidrop segment are different
  - 802.1AS uses group addressing leading to confusion with pdelay_request / response
    - Which messages are destined for which node?

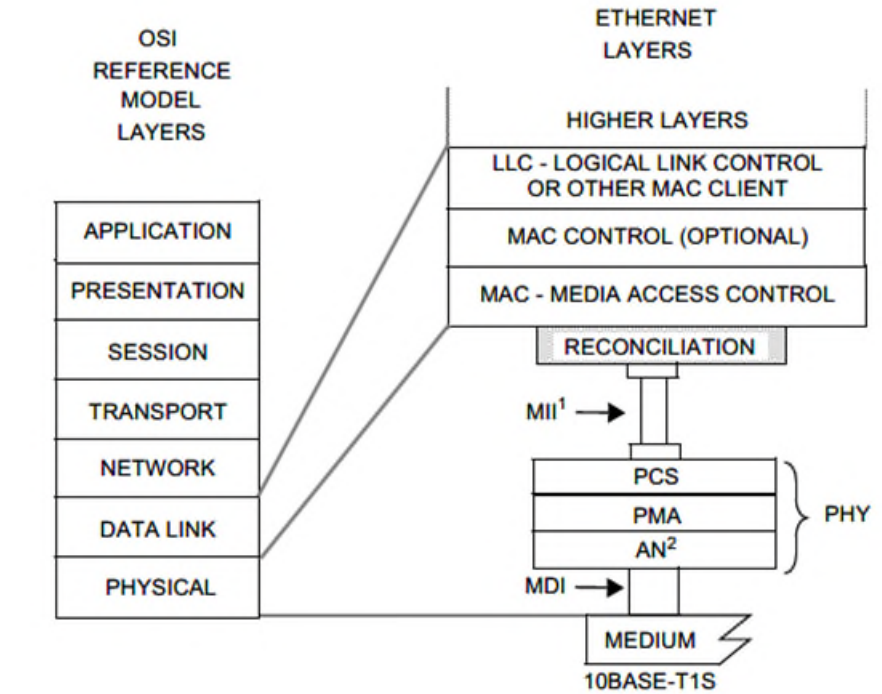




Time Synchronization in 10BASE-T1S / half-duplex / PLCA – part 2

- 10BASE-T1S can use a half-duplex MAC
  - Frames may be retransmitted
  - Need to timestamp the transmitted frame that doesn't collide (and ignore timestamps for collided frames)

- 10BASE-T1S can use PLCA
  - PLCA = PHY Level Collision Avoidance
    - Transmit opportunities are assigned to each node
    - During Tx Op, a node can transmit or not
    - Collisions are avoided
  - In PLCA mode, frame transmission is delayed in the PLCA Reconciliation Sublayer (typically implemented in the PHY silicon) until the node's transmission opportunity is reached
  - Timestamping needs to be done between below the PLCA RS to avoid the unknown buffering delays
  - 802.3 only defined timestamping for full-duplex mode of the MAC



MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE

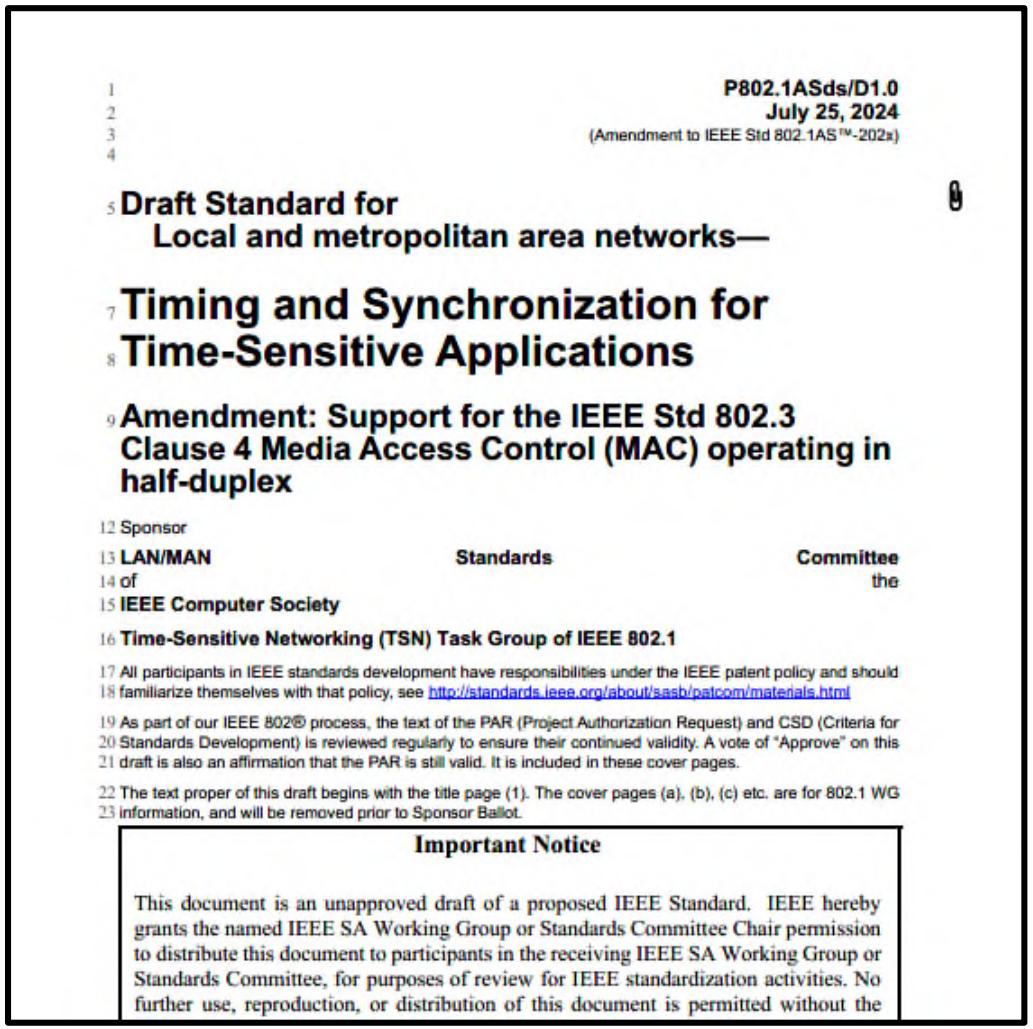
NOTE 1—MII is optional
NOTE 2—Auto-Negotiation is optional

PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
AN = AUTO-NEGOTIATION

Figure 148–1—Relationship of PLCA Reconciliation Sublayer to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

802.1ASds: 802.1AS support for half-duplex links

- New clause 19 defining operating in half-duplex
- CMLDS is not used
- Only TimeReceivers transmit Pdelay_Req messages
- Only TimeTransmitters respond to Pdelay_Req with Pdelay_Resp and Pdelay_Resp_Follow_Up
- TimeReceivers only process Pdelay_Resp and Pdelay_Resp_Follow_Up if clockIdentify field is equal to the clock identity of the originator of the Pdelay_Req
- Limitations of half-duplex operation
  - Only 2-step mode supported
  - External port configuration must be used
  - Hot Standby (802.1ASdm) is not supported
- Standardization status: D1.1 currently in 802.1 workgroup review



P802.1ASds/D1.0
July 25, 2024
(Amendment to IEEE Std 802.1AS™-202x)

Draft Standard for
Local and metropolitan area networks—

Timing and Synchronization for Time-Sensitive Applications

Amendment: Support for the IEEE Std 802.3 Clause 4 Media Access Control (MAC) operating in half-duplex

Sponsor

LAN/MAN Standards Committee
of the
IEEE Computer Society

Time-Sensitive Networking (TSN) Task Group of IEEE 802.1

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As part of our IEEE 802® process, the text of the PAR (Project Authorization Request) and CSD (Criteria for Standards Development) is reviewed regularly to ensure their continued validity. A vote of "Approve" on this draft is also an affirmation that the PAR is still valid. It is included in these cover pages.

The text proper of this draft begins with the title page (1). The cover pages (a), (b), (c) etc. are for 802.1 WG information, and will be removed prior to Sponsor Ballot.

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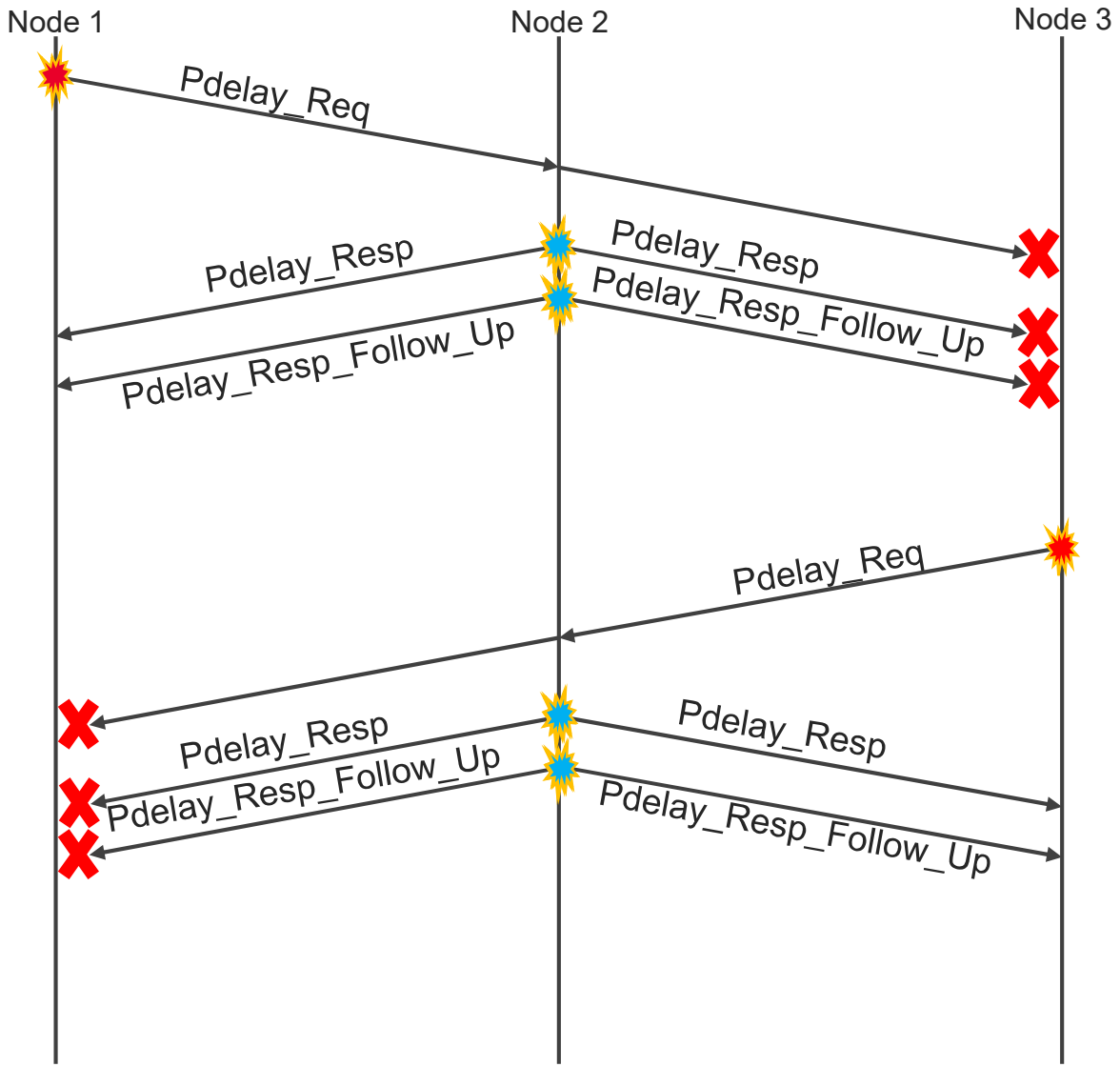
Example

- Nodes 1 and 3 are TimeReceivers
- Node 2 is a TimeTransmitter
- Node 2 (TT) never sends Pdelay_Req
- Nodes 1 and 3 ignore received Pdelay_Req
- Node 1 ignores responses to requests from Node 3
- Node 3 ignores responses to requests from Node 1



gPTP testing approaches

- Conformance testing validates that implementation meets Standards requirements
  - Example: does TimeTransmitter send Pdelay_req
  - Example: are timestamps correct for gPTP packets retransmitted due to a collision
- Testing performance of the time synchronization
  - Example: measure the time error between TimeTransmitter and TimeReceiver

Tested for this presentation

  - Example: measure the accuracy of the neighborRateRatio
- Interoperability testing between different PHYs and different stacks
- Increase node count and domain count to test scalability

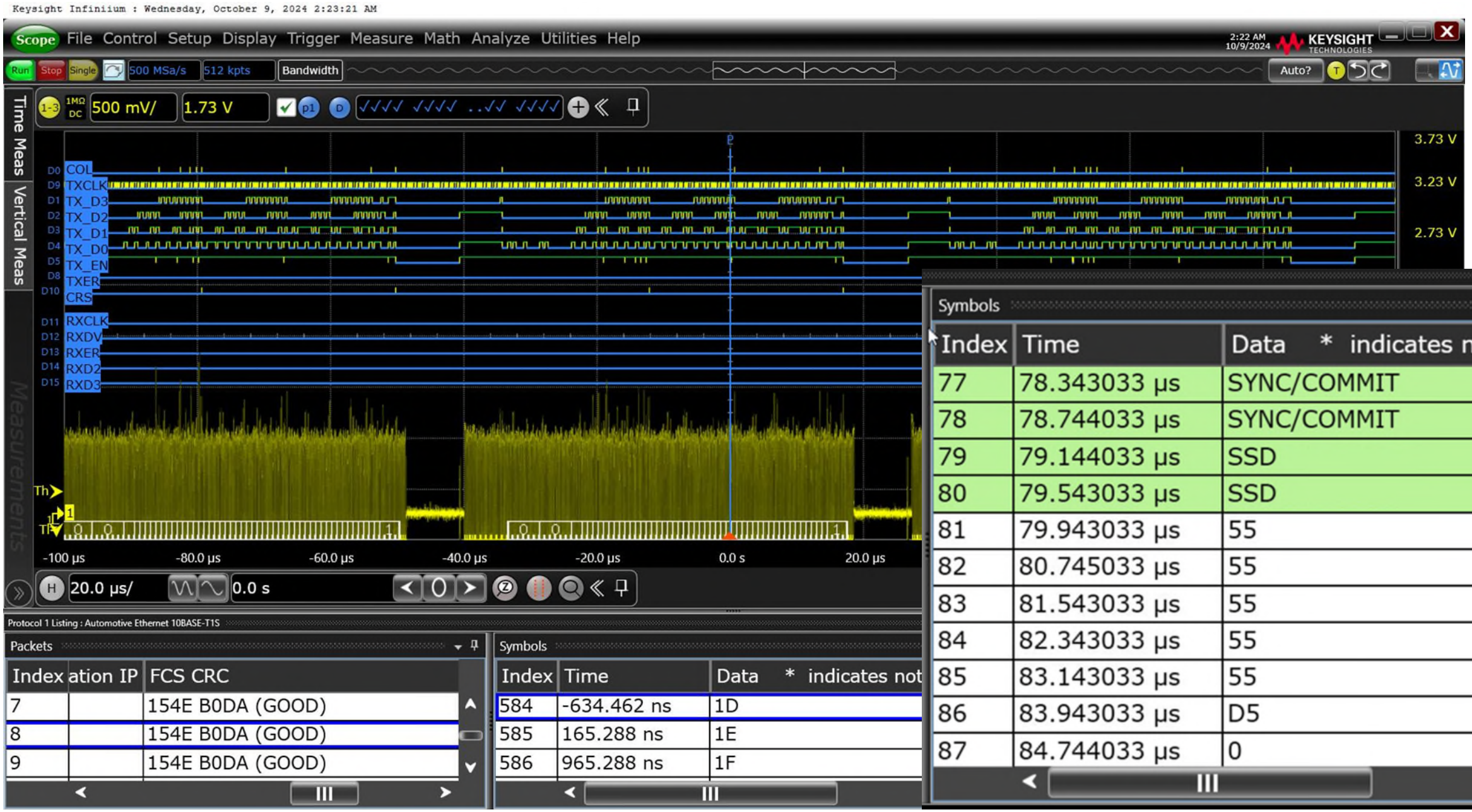
Future Work

Putting the test system together

- Modify 802.1AS protocol implementation to support 802.1ASds
  - TimeTransmitter will not send any peer delay request message and TimeReciever will not respond to any peer delay request message.
  - Disable the use of CMLDS, even if multiple domains are used
  - Force Two-Step mode
  - Disable signaling messages
- Use existing 10BASE-T1S PHYs (which provide a method to get Tx and Rx timestamps)
  - We experimented with different PHYs and different methods to get timestamps.
- Use an oscilloscope to
  - determine compensation for Tx/Rx intrinsic delays in the PHY
  - Validate timestamp time accuracy (time packet was transmitted vs. timestamp inside the packet captured on the scope)

Test setups

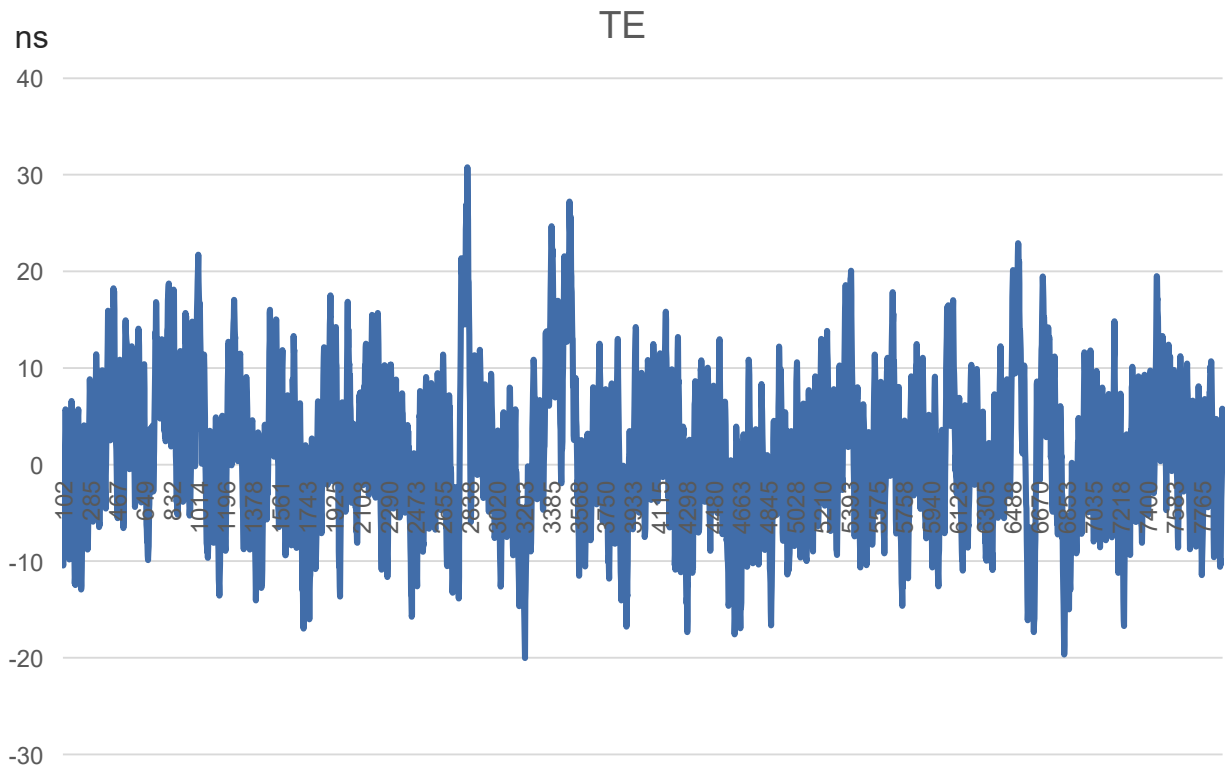
Scope capture and decode at MDI & MII to validate timing



Sample test results

- constant Time Error (cTE*) ~ 6ns (fixed offset)
- dynamic Time Error (dTE*) ~ 25ns (variable offset)

- Caveats:
  - Measurement starts after time sync stabilizes
  - Only 3 devices on the 10BASE-T1S bus
    - 1 TT and 2 TRs
  - Somewhat ideal channel with PLCA and no retransmits
  - Temperature and other environmental conditions are at relatively steady-state



* For definition of cTE and dTE see ITU-T Std. G.8260

Next Steps

- Additional tests to run
  - More devices on channel
  - Multiple gPTP domains
  - Different message rates
  - Different implementations
- Develop standardized conformance and performance tests for 802.1ASds
  - Leveraging existing 802.1AS test suites
  - Remove / modify tests using features not used (i.e. CMLDS or announce messages)
  - Validate TT does not send any peer delay request message
  - Validate TR does not respond to any peer delay request message.
  - If multiple domains are used, validate that each domain has independent controls

KEYSIGHT

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Thank you

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