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Verification Challenges & Solutions of 10BaseT1s Automotive Ethernet PHY

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Agenda

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- Introduction to PLCA Multidrop
- Applications
- Need for Time Synchronization in Automotive Ethernet
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- Time Synchronization Challenges with Multidrop
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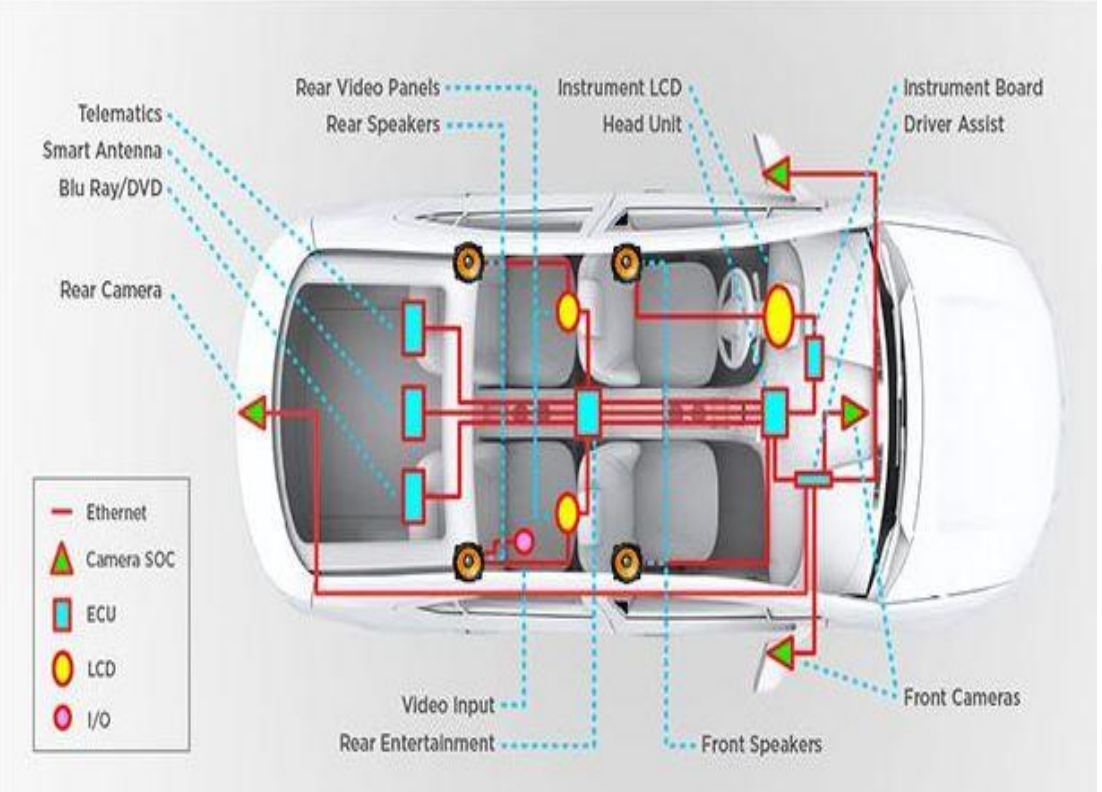
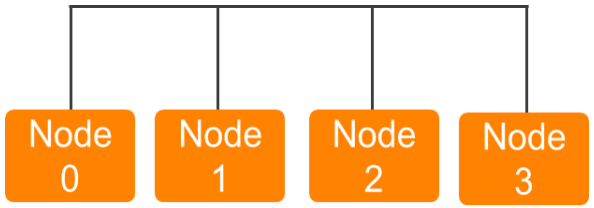
Motivation

- Currently automotive industry uses bunch of different networks in vehicles such as LIN, Flex-Ray, CAN-FD etc.
- 10BaseT1S can replace these legacy networks as it eliminates the need of gateways and cables used to bridge different network types.
- It is very cost effective and can be easily integrated into an existing ethernet architecture within vehicles.



What is 10BaseT1S Automotive Ethernet

- 10BaseT1s is a 10Mbps short reach Ethernet PHY that uses single twisted pair cables for data transmission.
- It operates in full-duplex point-to-point mode and half-duplex multidrop mode.
- Multidrop mode is a bus topology in which at least 8 nodes can be connected on a bus segment.
- 10BaseT1s uses PLCA (Physical Layer Collision Avoidance) Reconciliation sub-layer to avoid collisions on the network.



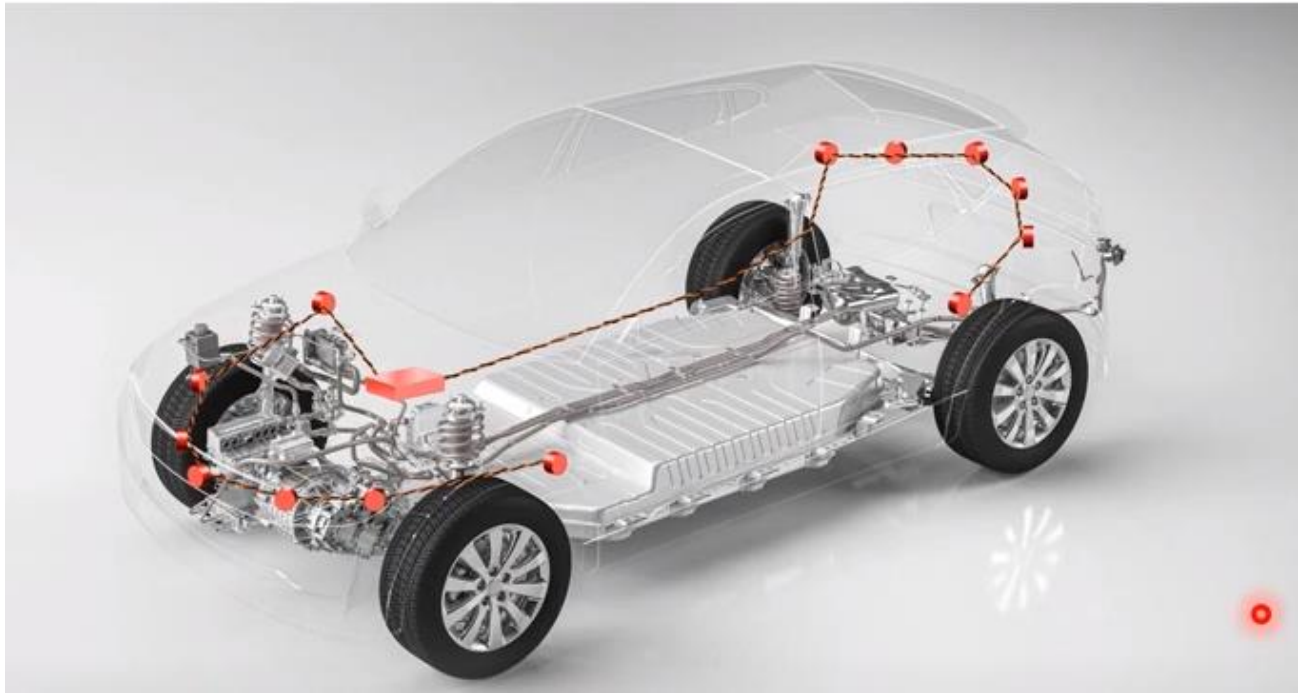
Multidrop Mode

Introduction to PLCA

- In PLCA, each node is assigned a unique node-Id.
- Node with ID=0 is the Master node.
- The arbitration process starts when Master node sends a special synchronization signal called BEACON.
- Each node is given a transmit opportunity in round-robin fashion.
- Only the node having transmit opportunity is allowed to send data.
- A node yields it transmit opportunity if it doesn't have packet to transmit.

10BaseT1S Applications

- In Car as Radar and Ultrasonic sensors.
- In Car door speakers.
- In front/back-light and indicators of Car.
- In elevators as sensor network.

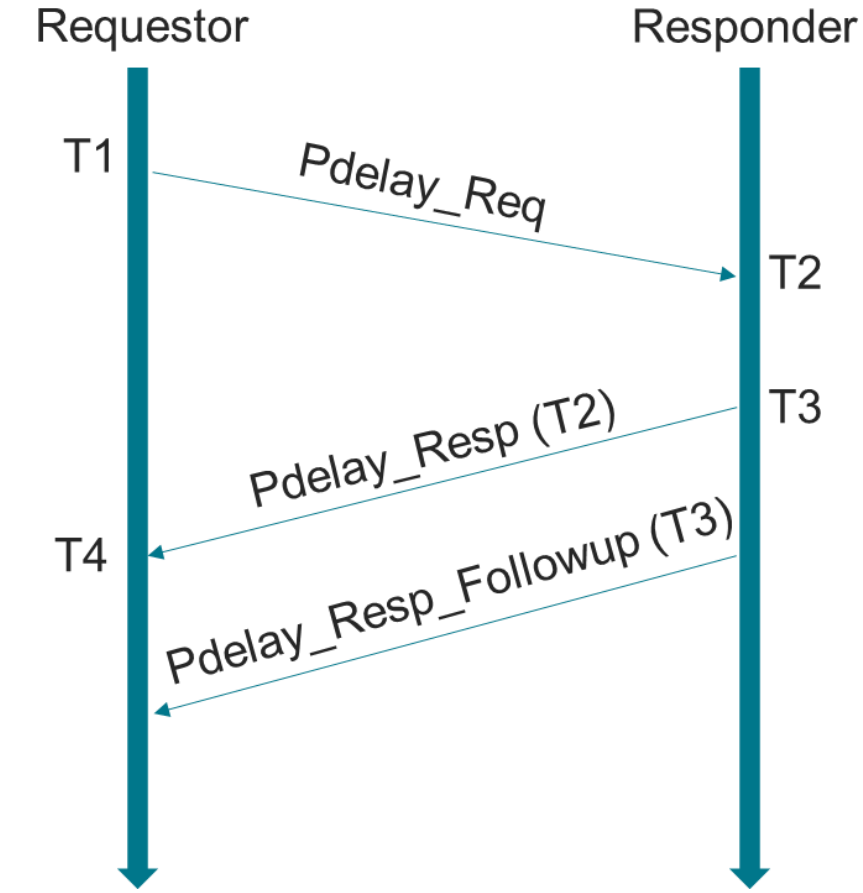


Need for Time Synchronization in Automotive Ethernet Network

- For real time data communication within vehicles.
- For minimal and deterministic latency of data packets for critical operations.
- For safety and reliability of automotive systems.
- For synchronized operation of ECUs and subsystems.

Time Synchronization using PTP

- PTP is used to synchronize clocks in a network with high accuracy.
- Works on Master-Slave hierarchy.
- Synchronization is achieved through exchange of messages having timestamp information.
- Sync/Follow-Up messages are used to synchronize nodes.
- Pdelay messages are used to calculate propagation delay between nodes.



Prop. Delay = (t4 - t1) – (t3 - t2) / 2

Running PTP on Multidrop

- Challenges of running PTP on multidrop mode ?
  - When Pdelay message is used in multidrop mode, each node will receive a PdelayReq message from the requestor node.
  - Moreover, the node that requested PdelayReq message will receive PdelayResp messages from each node.
  - The requesting node will be confused and will not be able to distinguish between the response from intended node and rest of the nodes.
  - A solution to this problem can be to use unicast Mac addressing instead of multicast addressing.

Running PTP on Multidrop Cont.

- PLCA algorithm introduces variable delay on the transmit path.
- Collision can cause unexpected delays.
- PTP operation is defined only for point-to-point links.
- 10BaseT1s is the first half duplex ethernet PHY.
- PTP standard should be enhanced to work with half-duplex ethernet networks.

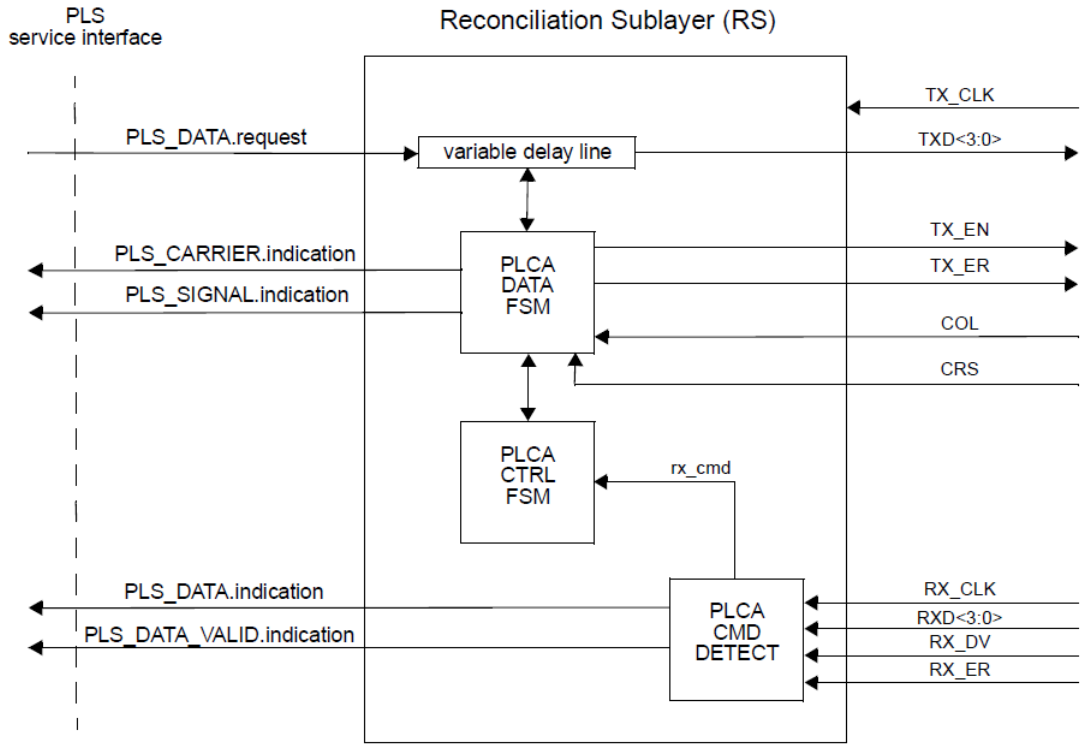


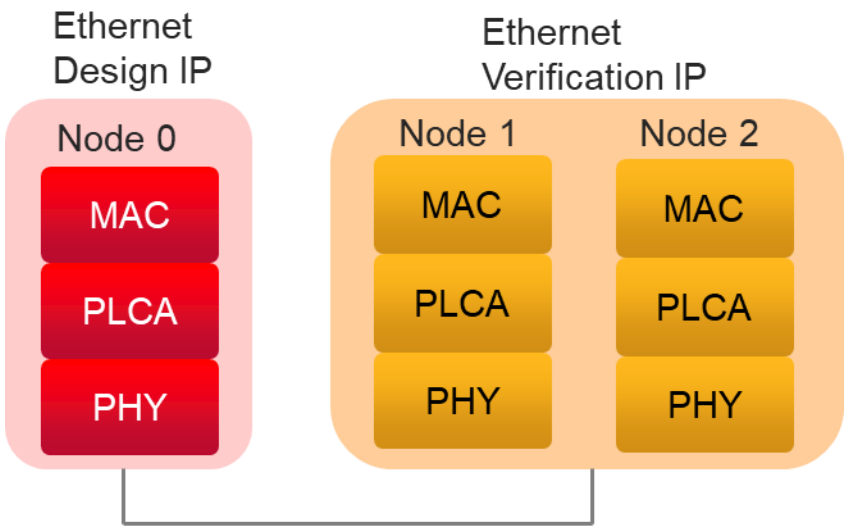
Figure 148–2—PLCA functions within the Reconciliation Sublayer (RS)

Latency Variation in Multidrop Mode

- Challenges of variable latency in multidrop mode ?
  - Multidrop mode can introduce variable latency which can impact time synchronization.
  - Min latency per node = 32 bit-times (TO timer) ~ 3.2us
  - Max latency per node = node transmitting a 1524-byte packet = 1.2176ms ~ 1ms.
  - Latency variation for 8 node network
    - Min Latency assuming 1 node transmitting 1524 bytes and 7 nodes idle = (1*1ms) + (7*3.2us) ~ 1ms
    - Max Latency assuming 8 nodes transmitting 1524-bytes packet = 8*1ms ~ 8ms
  - Latency can be reduced by limiting the packet size.

Verification Topology for Multidrop Mode

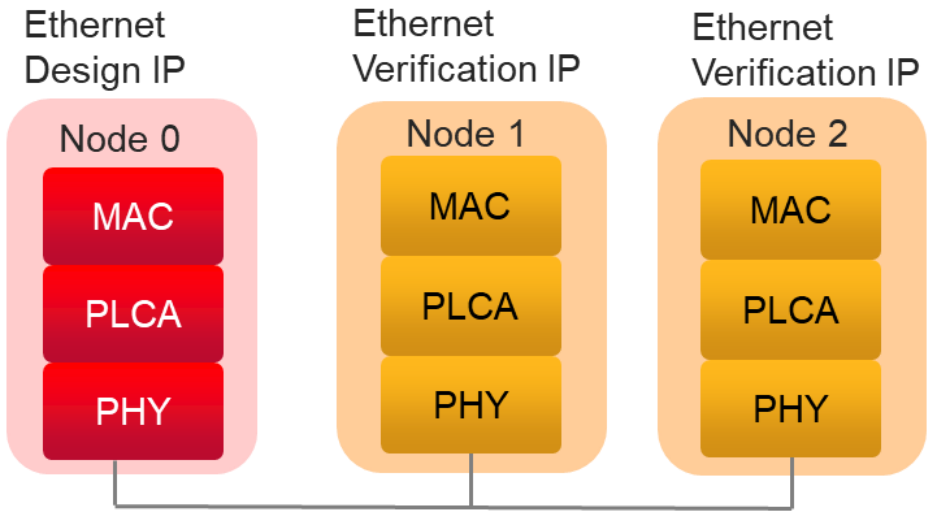
- Challenges in determining verification topology for multidrop mode ?
- Two topologies can be possible while verifying multi-node PHYs:
- Using a single Instance incorporating multiple nodes.
  - Reduces the pin connections of multiple nodes in testbench.
  - Highly scalable as the number of nodes can be increased/decreased using some configuration.
  - Makes verification environment simple and easy to use.



Single Agent Topology

Verification Topology for Multidrop Cont.

- Using multiple instances where each instance represents a single node.
  - Overhead of pin connection of multiple nodes in testbench.
  - Not very scalable topology.
  - Makes verification environment complex as number of nodes increases.



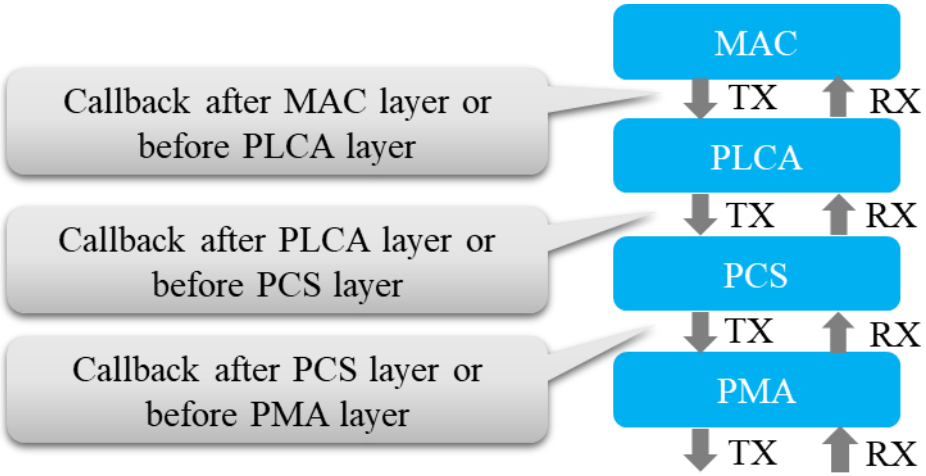
Multiple Agent Topology

Collisions in PLCA Multidrop

- Challenges associated with collision in PLCA ?
- Logical Collision
  - Occurs when two or more nodes try to transmit data simultaneously, but the arbitration mechanism forces the MAC to hold a frame while waiting for a transmit opportunity.
  - Does not cause data corruption.
  - Can be tested by scheduling packets from multiple nodes at the same time.
- Physical Collision
  - Occurs when two or more nodes transmit data at the same time, resulting in collision at the physical lines.
  - Causes data corruption.
  - PLCA is designed to avoid physical collision.

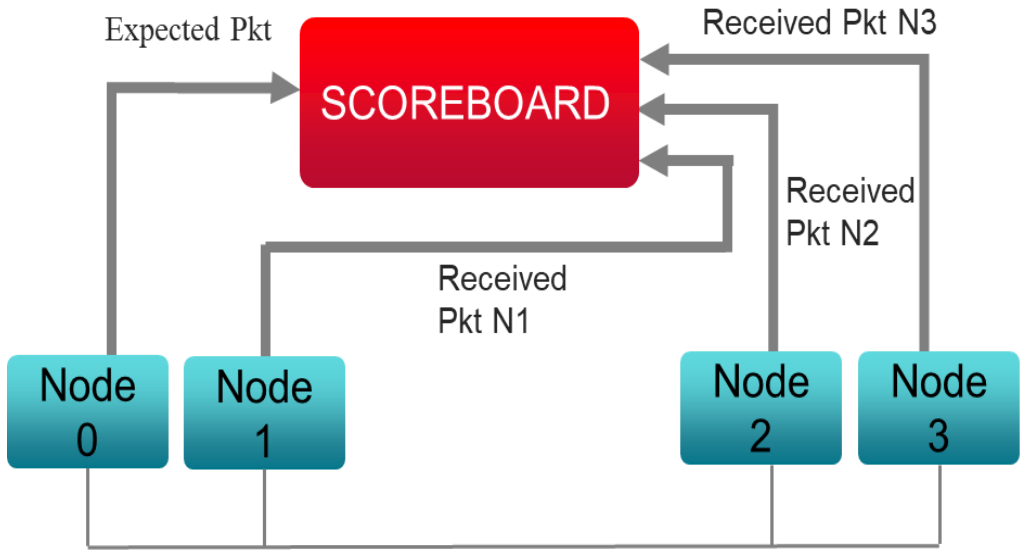
Negative Testing of PLCA Multidrop

- Challenges associated with negative testing of PLCA ?
  - Numerous negative scenarios are possible in PLCA.
  - Negative testing is necessary to ensure complete verification.
  - Negative testing can be done by error injection on callbacks.
  - Callback at different layers of Ethernet PHY stack provides flexibility to modify data at each layer and create various error injection scenarios.



Score-boarding Packets in Multidrop Mode

- How to scoreboard packets in multi-node environment ?
  - In PLCA, packet transmitted by a node is received by all other nodes.
  - Thus, score-boarding becomes different in this case.
  - The transmitted packet becomes the expected packet for scoreboard.
  - When this packet is received by all other nodes, it is sent to the scoreboard for comparison.
  - The Scoreboard compares the expected packet with received packet from each node to ensure all nodes have received the packet correctly.



Conclusion

- 10BaseT1S is the future of Automotive, hence, its verification becomes crucial.
- Positive as well as negative scenarios need to be tested to ensure complete verification.
- In Multidrop, complexity increases as the number of nodes increases.
- Debugging such environments may be extremely challenging and time consuming.
- IEEE is coming-up with 802.3dg standard to overcome various challenges related to time synchronization in multidrop mode.

Questions