What Is 10Base-T1S Automotive Ethernet?

TECHNICAL BRIEF

March 16, 2023

Summary

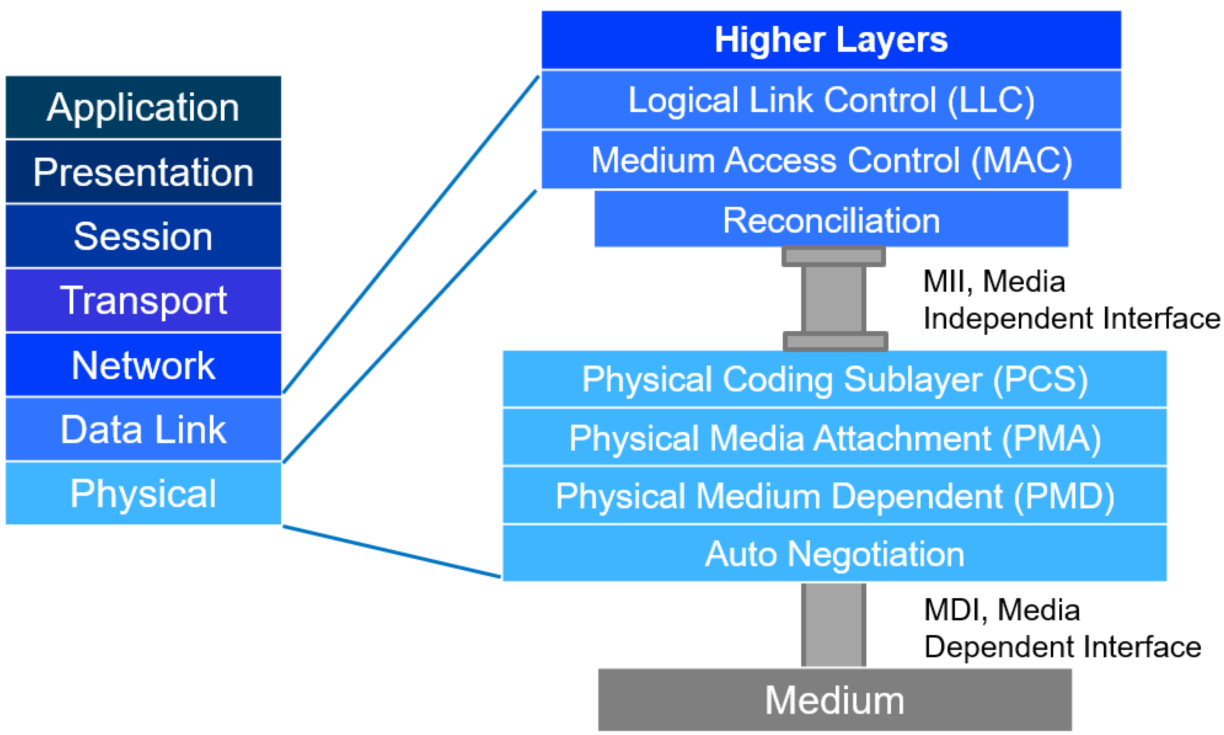
This technical brief describes the topology, signaling and PLCA operations related to the implementation of the 10Base-T1S Automotive Ethernet protocol.

Introduction

As in-vehicle electronics grow in volume and complexity–to support the goal for autonomous driving–we find 10Base-T1S Automotive Ethernet used to enhance In-Vehicle Network (IVN) architecture. With a short reach (up to 25 m), 10Base-T1S is applicable for connecting sensors, microphones and speakers to powertrain, car body and infotainment Engine Control Units (ECUs). This technical brief is intended to provide a glimpse into the operation of this Automotive Ethernet standard.

Benefits of 10Base-T1S

Single Pair Ethernet (SPE) protocols as described in IEEE 802.cg provide enhanced bandwidth, which can be utilized in pursuit of reduced latency communication on the bus line, allowing IVN applications to operate with higher quality data compared to legacy protocols such as MOST, CAN, LIN and FlexRay. The single twisted pair technology boasts lighter weight and lower costs, while meeting stringent automotive EMC requirements. A combination of 10Base-T1S and other Automotive Ethernet protocols allows a single software framework to be used throughout the vehicle from the lowest to highest speed ranges.



10Base-T1S physical layer operations focus on coordination and reconciliation from multiple mediums.

How 10Base-T1S Works

Signaling/Encoding Scheme

10Base-T1S employs the Differential Manchester Encoding (DME) method. DME is an example of a differential, bi-phase encoding technology specified in the IEEE 802.5 standard for Token Ring local area network (LAN) topology.

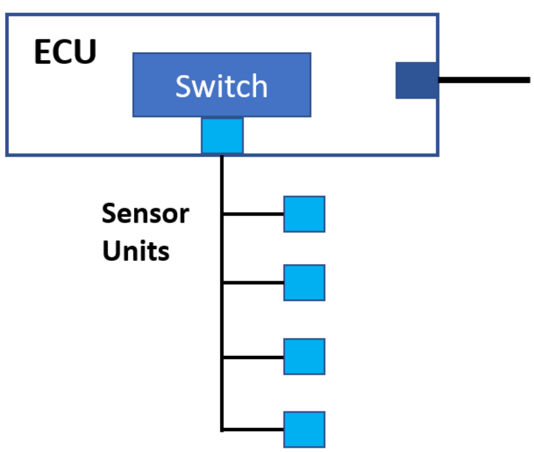
With DME, the clock is embedded and the data is sampled between the clocked edges. Because it lacks a DC component, this encoding scheme allows electrical connections easy galvanic isolation, ensuring the signal never remains at logic low or logic high for an extended period of time, allowing for versatility in a number of automotive applications.

In classic Manchester encoding, we see a digital modulation scheme where voltage *transitions* rather than voltage *levels* are used to represent 1's and 0's. In DME, only the *presence or absence* of a transition during the bit interval is important, not the polarity. The presence of a transition represents a logical 0, while the absence of a transition represents a logical 1. Whether the signal goes line-high or line-low depends simply on its state the previous bit interval, there is no need for reset transitions. This increases bit rate at lower bandwidths, because one bit is guaranteed to occur every interval. It also helps with data recovery in noisy environments, like automotive, because DME allows for a data stream to be inverted, yet still be properly decoded, unlike classic Manchester where the polarity is significant.

Physical Topology

10Base-T1S supports half-duplex and full-duplex communication, allowing either a point-to-point direct connection between two nodes, or use of a multidrop topology with up-to-eight nodes connected on a single 25 m bus segment.

Multidrop cabling of one bus line provides options to extend and scale with fewer physical wires and less weight than point-to-point topologies. With minimum connector space at the ECU, the bus line can be expanded simply by adding sensor units. A bus line with additional sensor units for ultrasonic and short-range radar is an example of how multidrop cabling can be scaled.



10Base-T1S multidrop topology requires less wire and fewer connectors than legacy topologies.

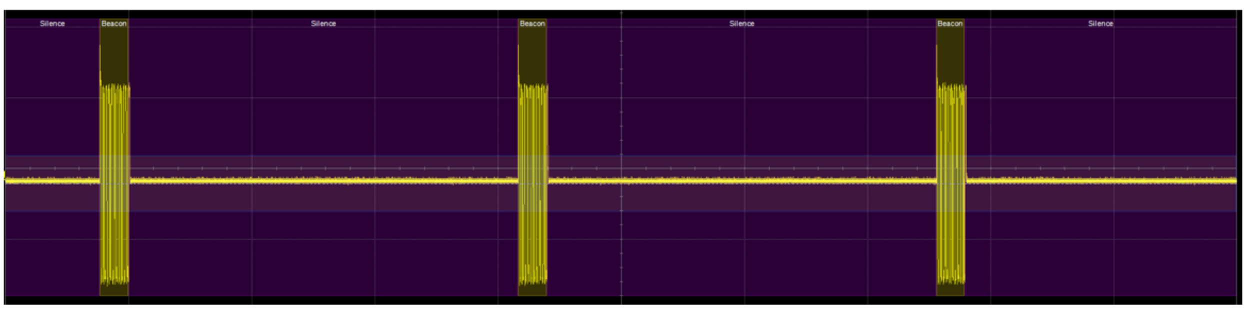
Use of PLCA within Multidrop Topology

Main objectives of the 10Base-T1S PHY layer are reconciliation of transmissions from a variety of mediums and ensuring cooperative behavior by the nodes on a multidrop bus. One way it does this is through the use of Physical-Layer Collision Avoidance (PLCA) technology to minimize dead time and avoid collisions.

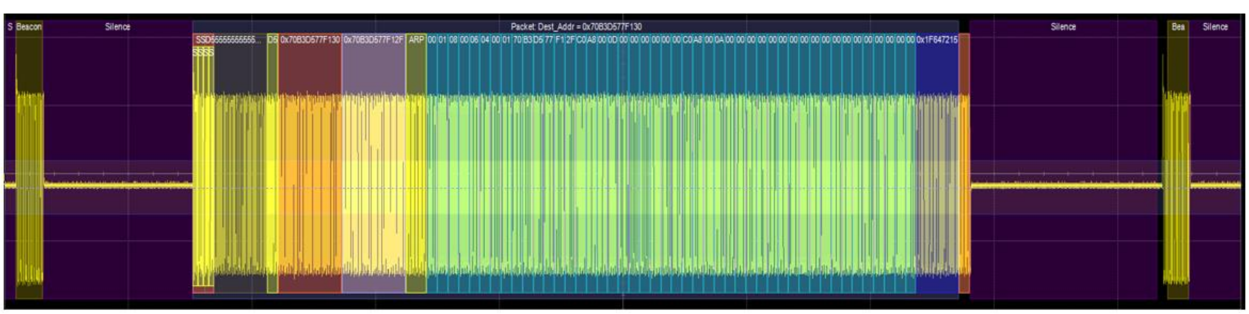
Essentially, PLCA establishes a transmission cycle used to choreograph Transmit Opportunities (TOs) on the bus. As with a group of individuals participating in a team-building exercise, if all nodes were chaotically speaking their minds at once, nothing would be heard properly and nothing would get accomplished in the time allotted. A PLCA transmit cycle establishes the opportunities to speak and the order in which nodes can be heard, while leaving enough flexibility that time is not wasted waiting for those who have nothing to say.

In PLCA, each node (aka PHY) is assigned with a unique PHY ID, and only the PHY device that owns the transmit opportunity is allowed to send data. The transmit opportunities are allocated in a round-robin algorithm starting from PHY ID = 0, which is allocated to the Master. Nodes can initiate a transmission only during the transmit opportunity that matches their own node ID. A new cycle is started when the Master node sends a synchronization pattern called the BEACON to signal the start of the PLCA cycle.

The PLCA cycle itself consists of the BEACON followed by N+1 time slots, allowing N+1 variable size DATA packets to be sent. During their transmit opportunity, a PHY may immediately transmit a packet or must transmit a COMMIT pattern of SYNC symbols to compensate for any MAC latency and to buy additional time before transmitting a packet. Nodes can enlarge the time slot to accommodate larger transmissions and can burst high priority messages. The other nodes will wait for a node to complete transmission before the cycle moves to the node with the next transmit opportunity. A new time slot starts if nothing is transmitted within a defined time (TO_TIMER) or at the end of any packet transmission.



If there is no data traffic, only BEACONs are seen on the bus.

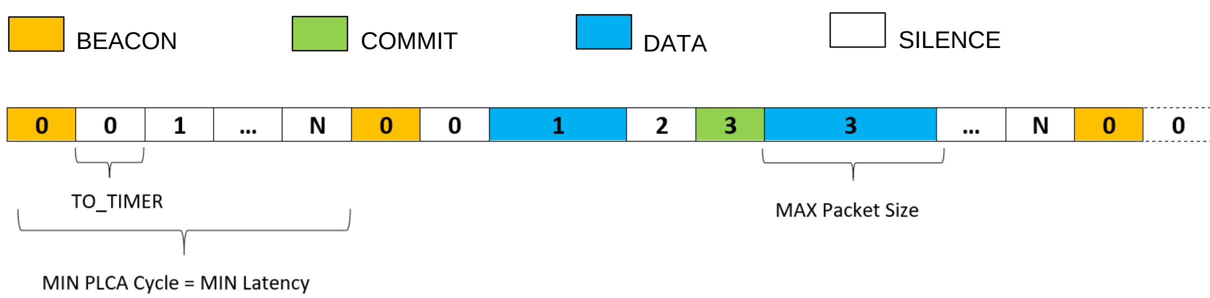


Data from a node will expand the time between two BEACONs.

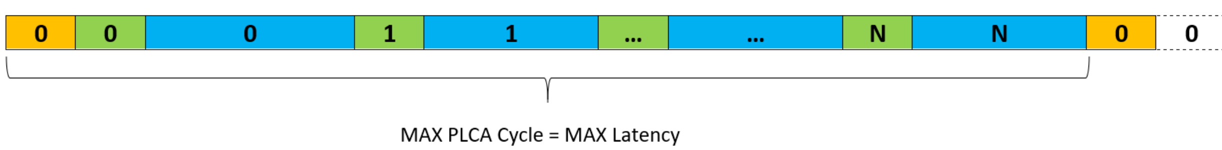
In attempting to understand the PLCA cycle, it may help to visualize the use of a variable delay line to relate transmit opportunities to each node on the bus. The driving scheme of PLCA is to sync TO_TIMERs so that the max latency consistently remains less than one PLCA cycle. TO_TIMER is very short (typically 20 bits), so there is a negligible loss of throughput when waiting for PHYs that have nothing to transmit.

At the beginning of each transmission cycle, Node 1 on the bus is first assigned the transmit opportunity. If there is no DATA for this node to transmit and it cannot COMMIT, it cedes its transmit opportunity to the next node on the bus.

The benefit of this system is that the individual nodes track TO_TIMER independently following the BEACON. Because nodes with no data to transmit will yield their transmit opportunity, the short window afforded by the TO_TIMER ensures a minimal loss of throughput or increase of latency. This variable delay is similar to TDMA, but PLCA is not a fixed or absolute reference for timed packets; instead, it adjusts according to the transmit needs of each node on the bus.



Minimum latency PLCA cycles. No one has anything to transmit in cycle 1, so total latency is equal only to the number of nodes times the TO_TIMER. Only Nodes 1 and 3 have transmissions in cycle 2, so all the other nodes cede their transmit opportunity. Node 1 immediately transmits DATA; Node 3 sends a COMMIT followed by DATA.



Maximum latency PLCA cycle. Every node has the maximum size packet and sends a COMMIT while waiting for the MAC.

Glossary

The table below defines some acronymns relevant to 10Base-T1S used throughout this technical brief.

	TERM	DEFINITION
CSMA/ CD	Carrier Sense Multiple Access/ Collision Detection	A media access control method used in early Ethernet technology for local area networking. It uses carrier-sensing to defer transmissions until no other stations are transmitting.
DME	Differential Manchester Encoding	A line code in digital frequency modulation in which data and clock signals are combined to form a single, two-level self-synchronizing data stream.
ECU/ ECM	Electronic Control Unit/ Electric Control Module	An embedded system in automotive electronics that controls one or more electrical systems or subsystems in a vehicle
gRS	generic Reconciliation Sublayer	Any IEEE 802.3 Reconciliation sublayer (RS) used to interface a MAC with any PHY through the MII.
IVN	In Vehicle Network	Generic term for an automotive data communication system that is used to connect electronic control units in today's vehicles.
MAC	Media Access Controller	Sublayer that controls the hardware responsible for interaction with the wired, optical or wireless transmission medium.
MDI	Media Dependent Interface	Physical and electrical/optical interface from a physical layer implementation (PHY) to the physical medium used to carry the transmission.
MII	Media Independent Interface	A standard interface used to connect a MAC block to a PHY chip.
PCS	Physical Coding Sublayer	Interface between the PMA sublayer and the MII responsible for data encoding/decoding, scrambling/descrambling, alignment marker insertion/removal, block/symbol redistribution, and lane block synchronization and deskew
PLCA	Physical Layer Collision Avoidance	An optional gRS defined in IEEE 802.3cg clause 148 used for collision avoidance in multidrop topologies.
PMA	Physical Medium Attachment	Sublayer that defines the details of transmission and reception of individual bits on a physical medium.
RR	Round Robin	Algorithm used by process and network schedulers in computing to avoid collision. In RR schemes, time slices of equal portions are assigned to each process in circular order without priority.
SPE	Single Pair Ethernet	Ethernet implementations that use a PHY layer transceiver over a single pair of wires, instead of the four pairs used in legacy Ethernet.
TDMA	Time Division Multiple Access	A channel access method for shared-medium networks.
TO	Transmit Opportunity	The time duration for which a node can send packets after it has gained contention for the transmission medium.

Additional Resources

Test Happens Blog:

10Base-T1S Automotive Ethernet vs. 10Base-T1L Industrial Ethernet

Automotive Ethernet in the Vehicle