802.3da: 10 Mb/s Multidrop Enhancements Overview

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NOVEMBER 2024

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Outline

Why should the non-SPE-oriented IEEE 802.3 WG member care?

What's in 802.3da – from 50,000 ft?

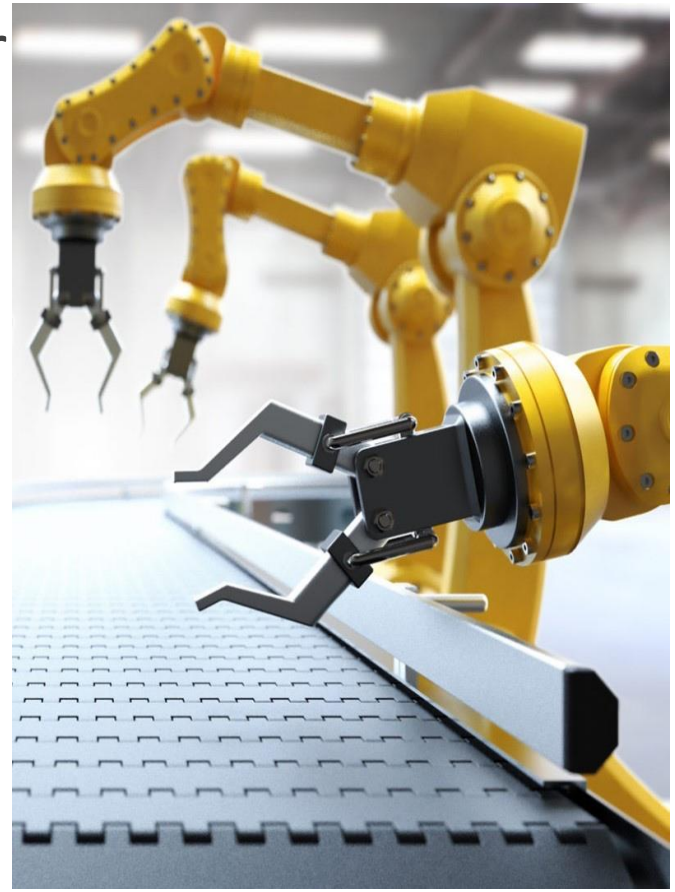
What is the PHY?

- Mixing Segment & Interface: Why was this so hard?

What is Dynamic-PHY Level Collision Avoidance (D-PLCA)?

What is this new powering scheme?

Summary



Why the non-SPE 802.3 members should pay attention to 802.3da

802.3 da may provide a control and power bus for unidirectional or asymmetric interfaces

- Simple, 10 Mbps Manchester-Encoded transceiver
- Can be daisy-chained to multiple devices

802.3da is not changing the Clause 147 (802.3cg) 10BASE-T1S PHY, but is making the mixing segment easier to engineer, adding power, and automatic setup for PLCA

Could be a good adjunct to optics or other high-speed one-way interfaces to imagers

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What's 802.3da all about?

802.3da STARTS with 10BASE-T1S (Cl. 147)

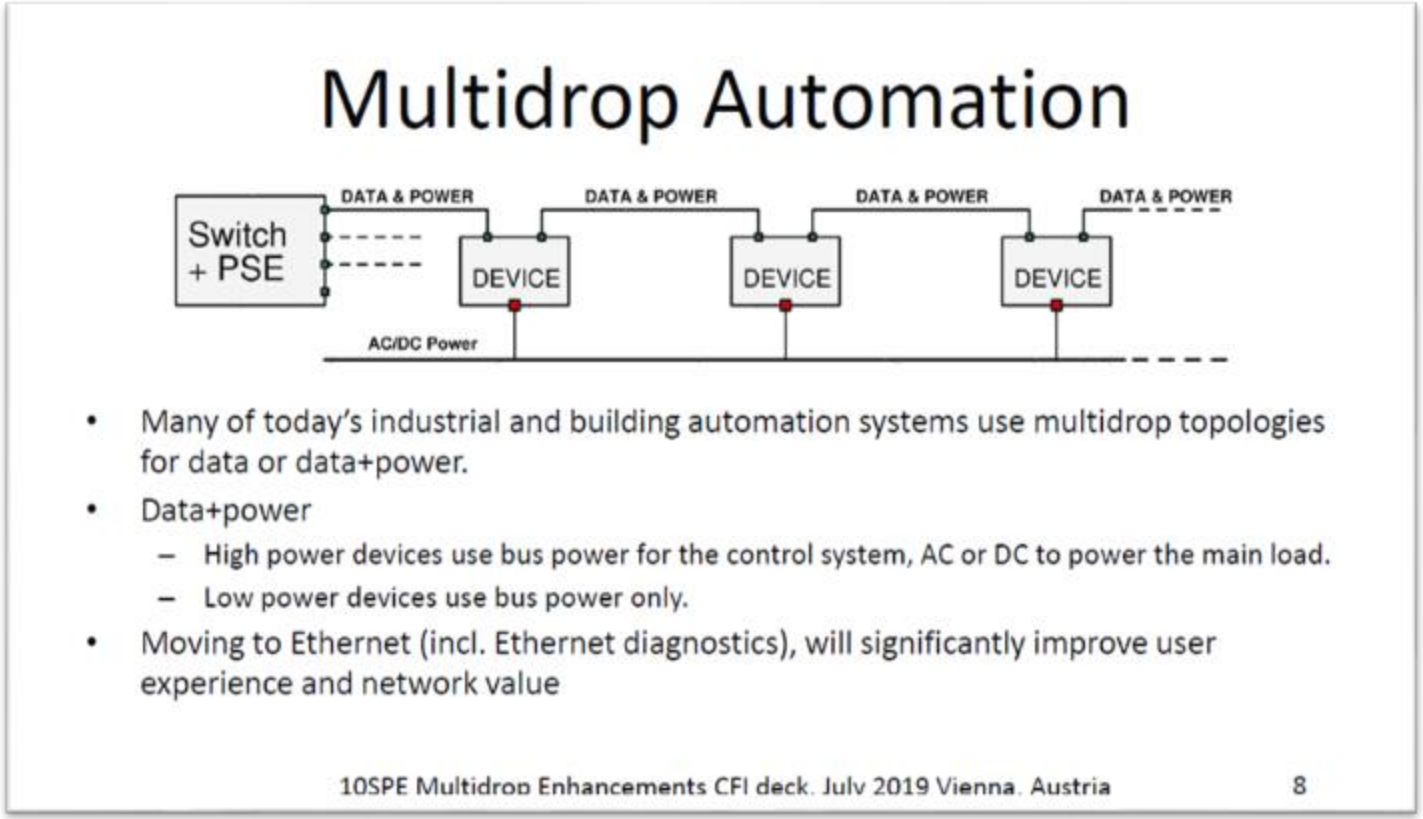
Multidrop (shared-media) half-duplex 10 Mb/s Ethernet introduced in 802.3cg

Designed for ‘engineered’ harnesses as the mixing segment

- Vehicles, backplanes, inside engineered equipment

802.3da develops enhancements to make it more ‘plug-and-play’

- Suitable for buildings and larger systems



10BASE-T1S Physical Layer has 3 parts

PHYs: 10BASE-T1S 10 Mb/s half-duplex PHY (Clause 147)

- Differential Manchester Encoded (DME), 4B5B encoded half-duplex Ethernet
- Does not specify power, but allows for it by specifying voltage tolerance of PHYs

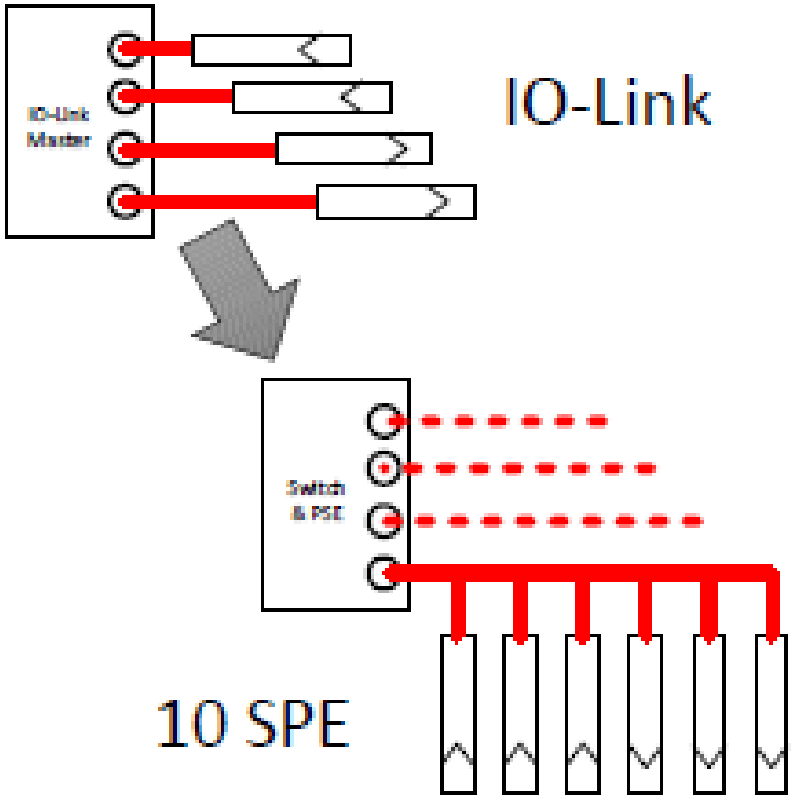
Mixing Segment Wiring (147.8):

- Specified for insertion loss and return loss *at each MDI attachment point*

Reconciliation Sublayer (Clause 148):

- Clause 148 PLCA “Physical Layer Collision Avoidance”
- Uses CSMA/CD MAC together with a management-assigned “Node ID” and a designated “coordinator” to avoid collisions by adhering to Transmit Opportunities

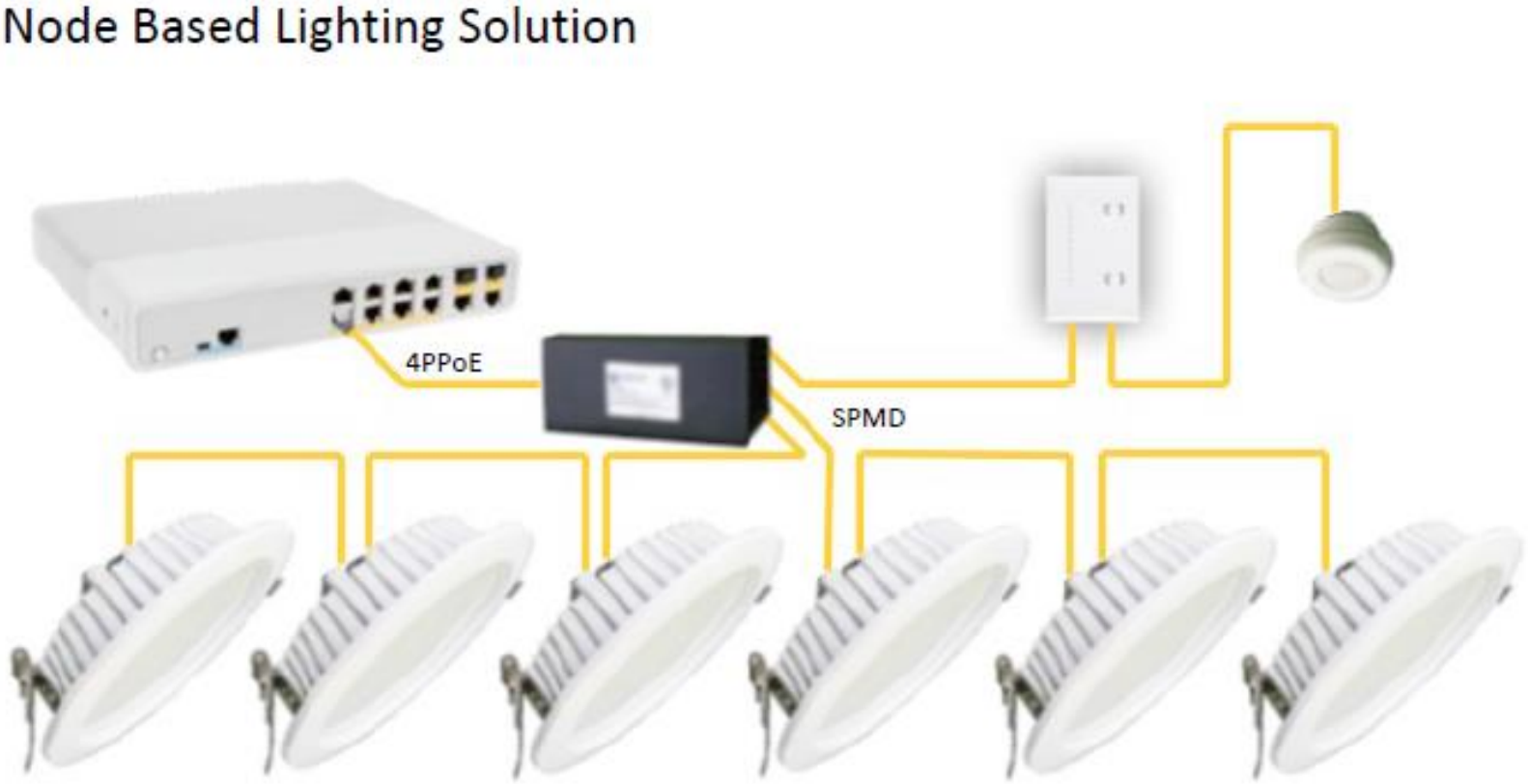
Plug-and-Play Multidrop: Enables Industrial Network Simplification



Simple sensors often come in M8/M12 housing (threaded rods with a longitudinal hole) with as little as 5mm in diameter on the inside

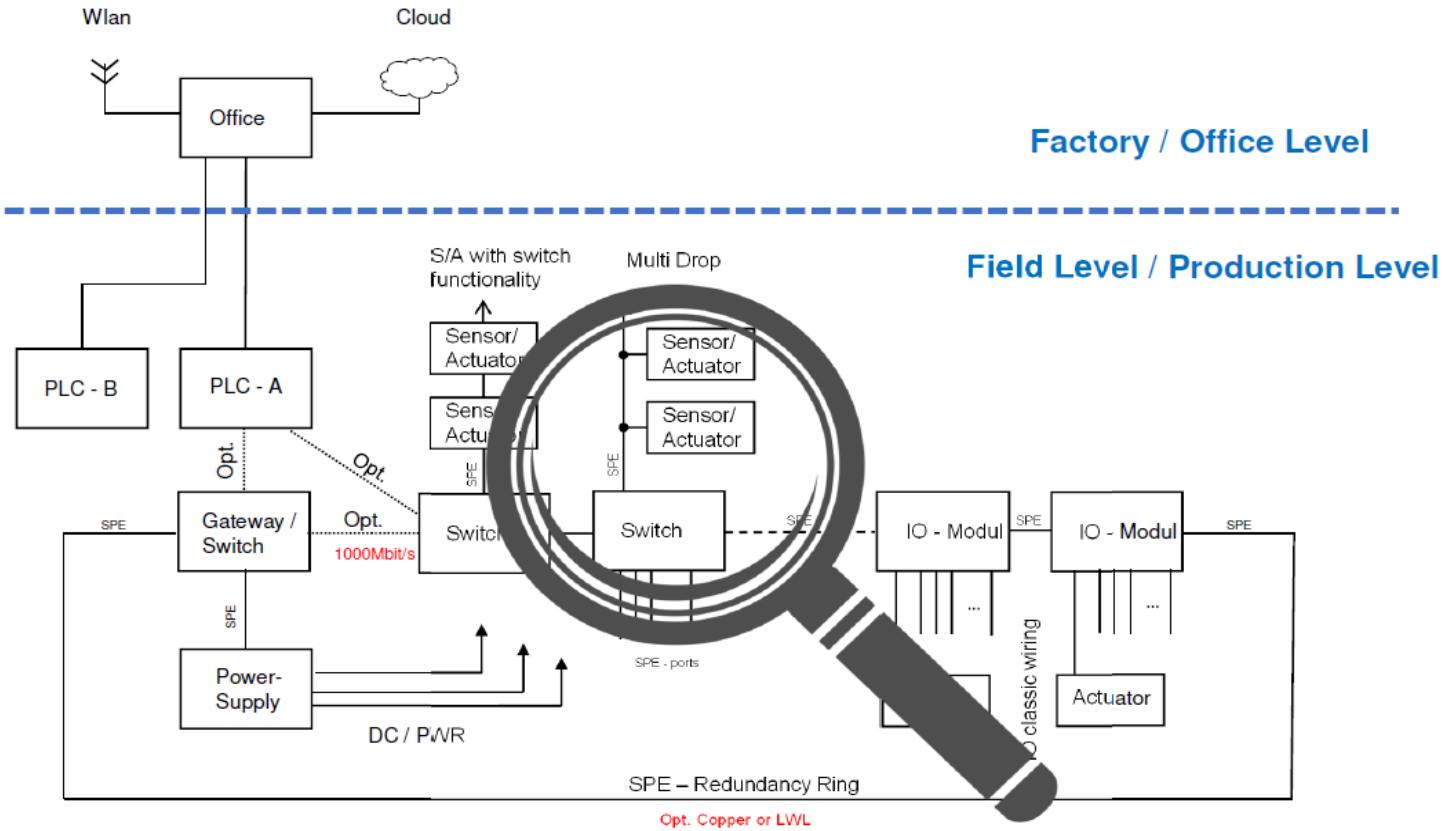
https://www.ieee802.org/3/SPMD/public/sep19/spmd_pohl_01_0919.pdf

Multidrop simplifies node-based Ethernet lighting



https://www.ieee802.org/3/SPMD/public/dec1819/SPMD_Usecase_node_based_lighting.pdf

Multi-drop fits sensor networks



https://www.ieee802.org/3/SPMD/public/dec1819/SPMD_Usecase_Train_industrial_Sensor_CE.pdf

IEEE 802.3da Multidrop Enhancements: High Level Overview

Enhancements related to 10 Mb/s Multidrop SPE introduced as 10BASE-T1S in IEEE P802.3cg, in 5 easy pieces:

- ***No New Device:*** Half duplex operation, 10 Mb/s, shared media PHYs, backward compatible with Clause 147 10BASE-T1S – SAME PHY as Multidrop mode
- ***More Plug-and-Play Wiring:*** Improved specifications for the mixing segment and interface from the device to the wiring
- ***Mixing Segments for buildings:*** 50m reach more nodes
- ***Self-configuring PLCA:*** D-PLCA removes the need for management to configure node IDs on the mixing segment
- ***Powering for multidrop:*** Detect/classify, provide power only when needed

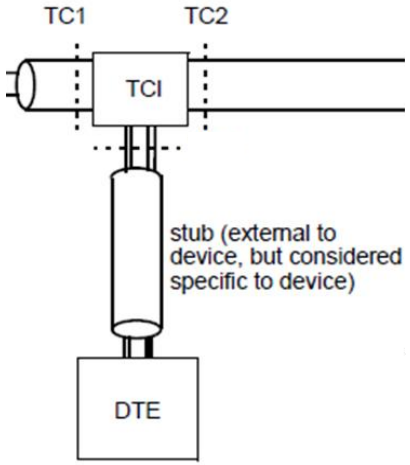
The Trunk Connection Interface (TCI):

An MDI with 2 connections to a non-branching mixing segment, or “Trunk”.

Specification points are called “Trunk Connection” 1 and 2 (TC1 and TC2)

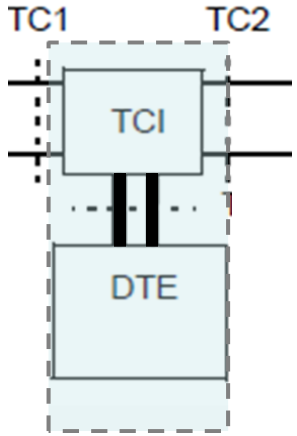
Supports 2 connection models:

T-bridges with DETACHABLE CONNECTION (e.g., stubs) to Nodes



Couples mixing segment, DTE impedances, and stub

IN-AND-OUT Connections to PMA (e.g., mixing segment runs through the node)



Mixing segment cannot be complete without DTE attached

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What's in the PHY?

Issues in IEEE 802.3da

PHY / Mixing Segment Specification:

- Need to specify TCI reflections & loss
  - RL at left, right, & PMA connections
  - IL through and between trunk and PMA
- Need to specify mixing segment losses
  - IL, RL from edge terminations along trunk
  - Needs to include TCIs and loading

Length and number of nodes

- 50m/16 nodes is a minimum
- People want more…

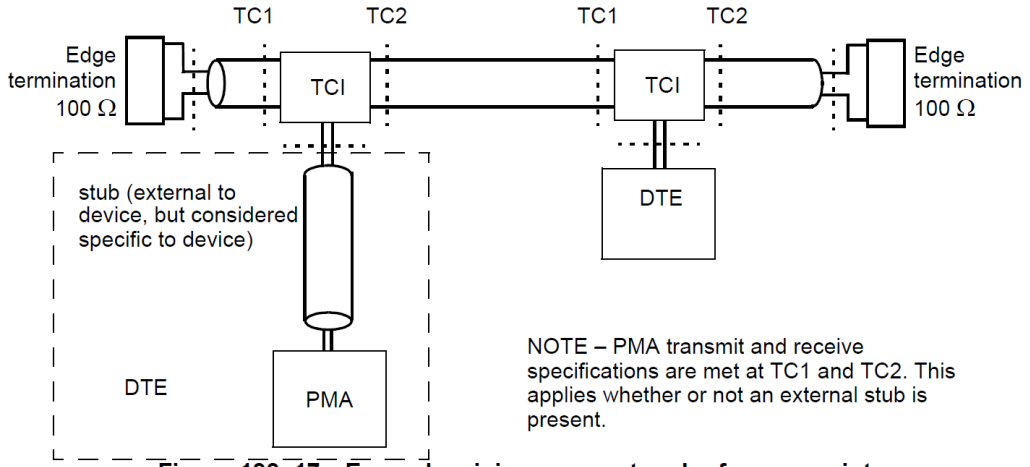
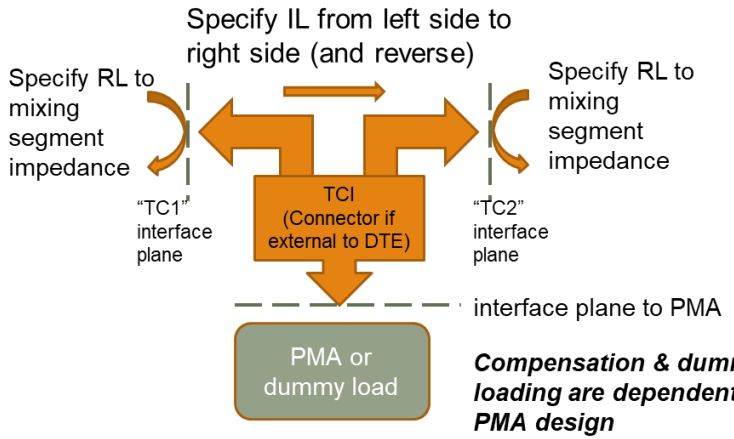


Figure 188–17—Example mixing segment and reference points



Compensation & dummy loading are dependent on PMA design

10BASE-T1M: 10BASE-T1S (Cl 147) but ONLY Multidrop

Half-Duplex Multidrop with support for collision avoidance (PLCA from 802.3cg)

Same 4B/5B PCS as Clause 147

- No point-to-point only functions, like heartbeat or Link Monitor

Same DME Encoding and timing

Same PMA with some refinements:

- Refinement of Test Fixtures to work at new “TCI” line interface
- Tightening of lower transmit PSD mask to improve interoperability

Expectation is 10BASE-T1S multidrop PHY Silicon (PCS/PMA) will meet 10BASE-T1M requirements

New MDI specifications “Trunk Connection Interface” are outside the PHY chip

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Mixing Segment and Interface:

WHY PLUG-AND-PLAY MULTIDROP IS HARDER THAN IT LOOKS

Charming, but devilish in detail

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- Multidrop is charming…
  - One phy per node
  - Just a tap, no repeating PHY
  - No switch, or even a two-port MAC relay

- With only one PHY, each node is as simple as can be… (or is it?)…

Charming, but devilish in detail

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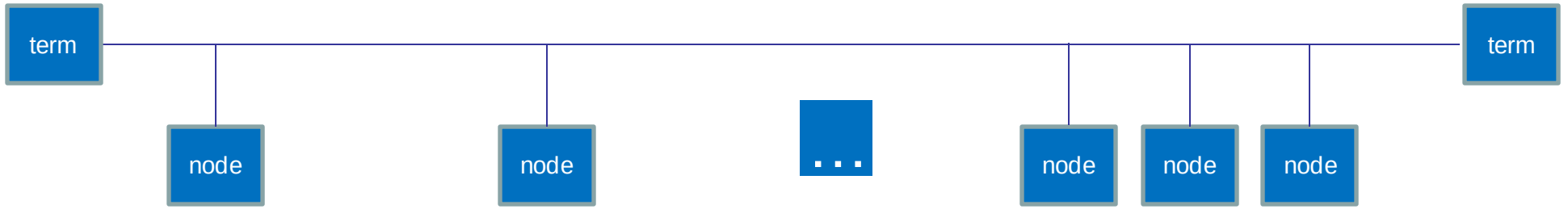
- Discussions in 802.3da have shown otherwise
  - Variations with installation and network configuration
  - Analog/lumped-circuit matching problems at nodes
  - Management of multiple powered nodes
  - Management of node IDs for PLCA
- Hard to cover reasonable worst-case due to many dimensions
  - Node spacing, segment loading, segment mismatch, stub length, power consumption, activity timing…

Two structures: Homogenous vs. Segmented mixing segments

HOMOGENEOUS: One piece of cable – same batch, same characteristic impedance
Implies taps – are those taps part of the original mixing segment, part of the DTE, or their own component?



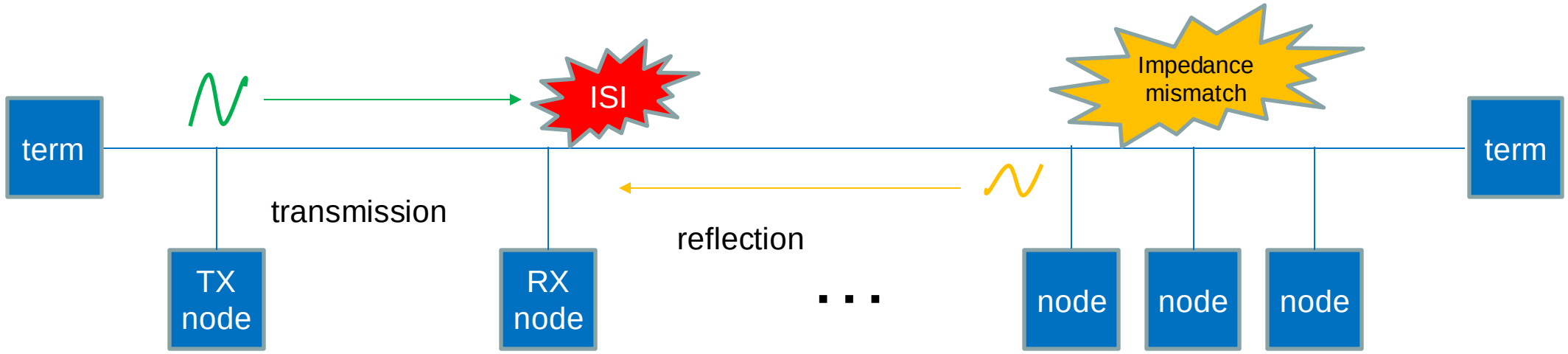
SEGMENTED: Separate pieces of cable between nodes – cable mismatch at each node
e.g., pre-terminated segment pieces and T connectors or 2 connectors/DTE.

Reflection Problem in Multidrop

Simulating some particular network may give you insight, but specs are needed…

- A simulated “open eye” may make you feel good about operation, may be likely to work, but is neither NECESSARY nor SUFFICIENT for operation

The PHY designer needs to know how much intersymbol interference (ISI) there is…



Reflection Problem in Multidrop

As a result, clause 147 mixing segments are engineered to minimize reflections

- Lumped impedance specified at
- OK for mass-produced harnesses, problematic for plug-and-play

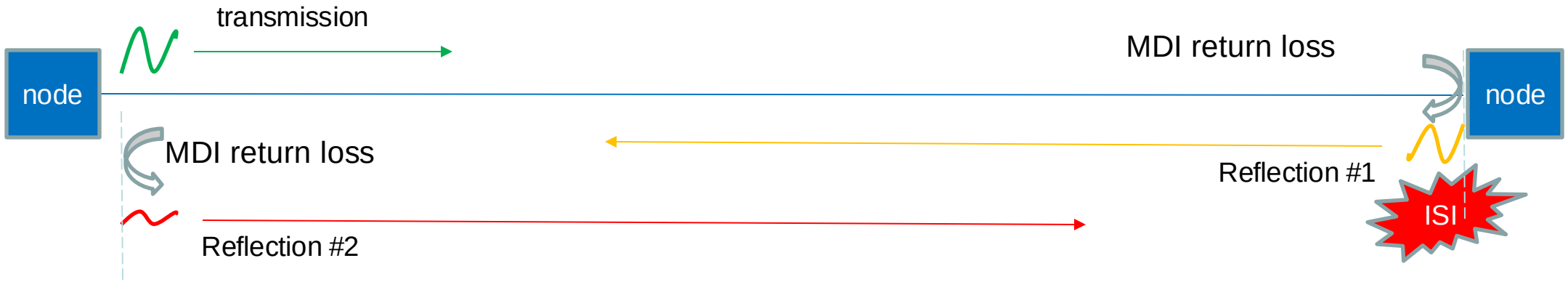
147.8.2 Return loss

The mixing segment shall meet the return loss characteristics specified for link segments in 147.7.2 at any MDI attachment point. The reference impedance for the return loss specification is 50 Ω.

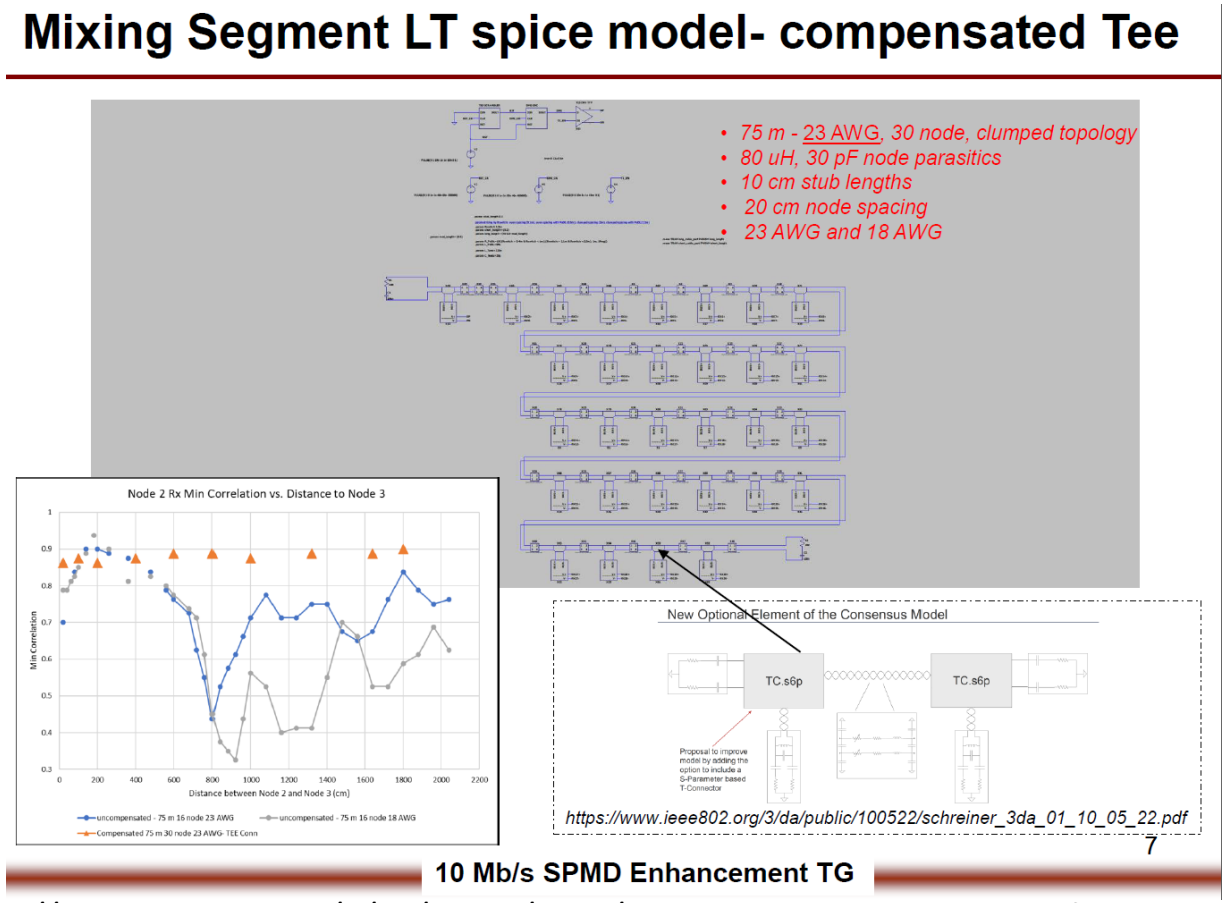
How we managed reflection ISI other PHYs

Point-to-Point performance is specified with a maximum link segment insertion loss, minimum link segment return loss, and minimum MDI return loss

- Half-duplex doesn't need to consider direct echo paths, but reflections still matter…
- Internal reflections on cabling connectors are within the link segment return loss
- Cabling standards handle the assembly of multiple pieces of cabling into a channel/link segment



802.3da did Extensive Modeling Work



https://www.ieee802.org/3/da/public/0324/diminico_3da_01_031224.pdf

Consensus model of mixing segment and nodes using LT-Spice

- Simulates variation of node placement and loading of node connections

Validated to lab measurements by multiple participants

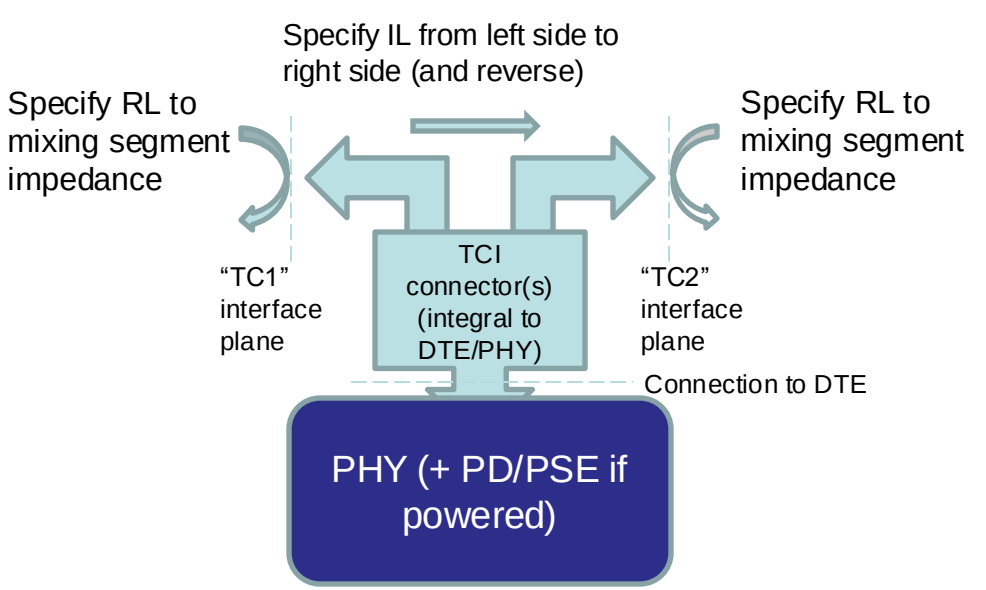
Enables specification of key parameters

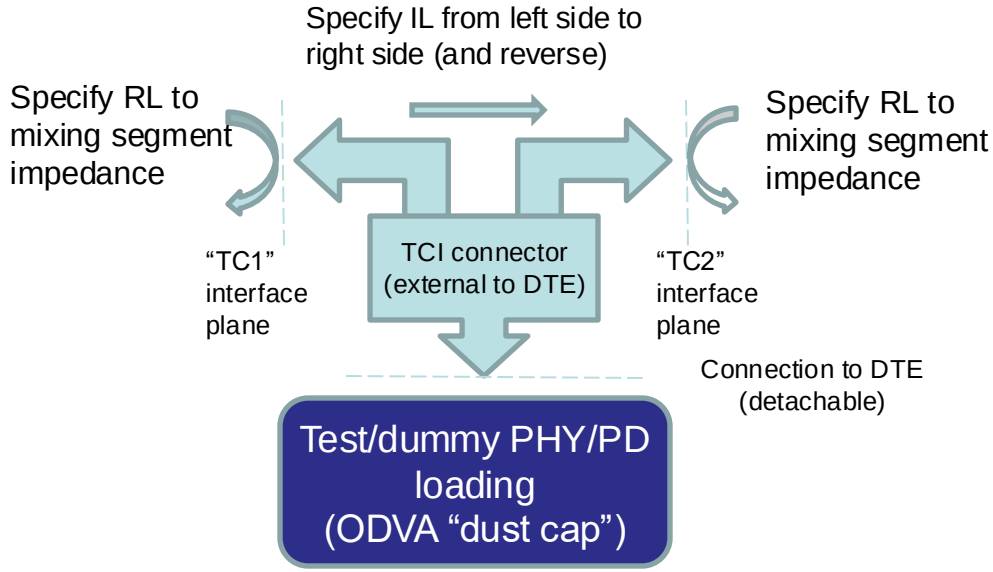
Key PHY Clause Enhancement: Specifying reflections and the TCI

Need to specify the reflections from each device back out to the others

- In addition to loss through the connection to devices down the link

Aligned specifications with measurements from devices





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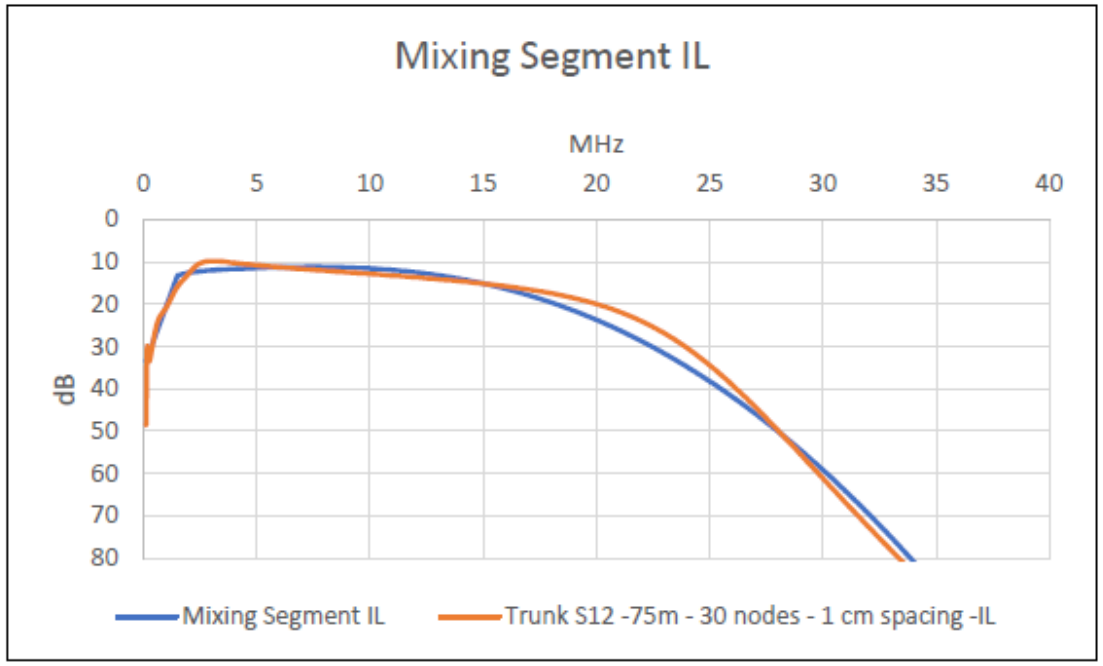
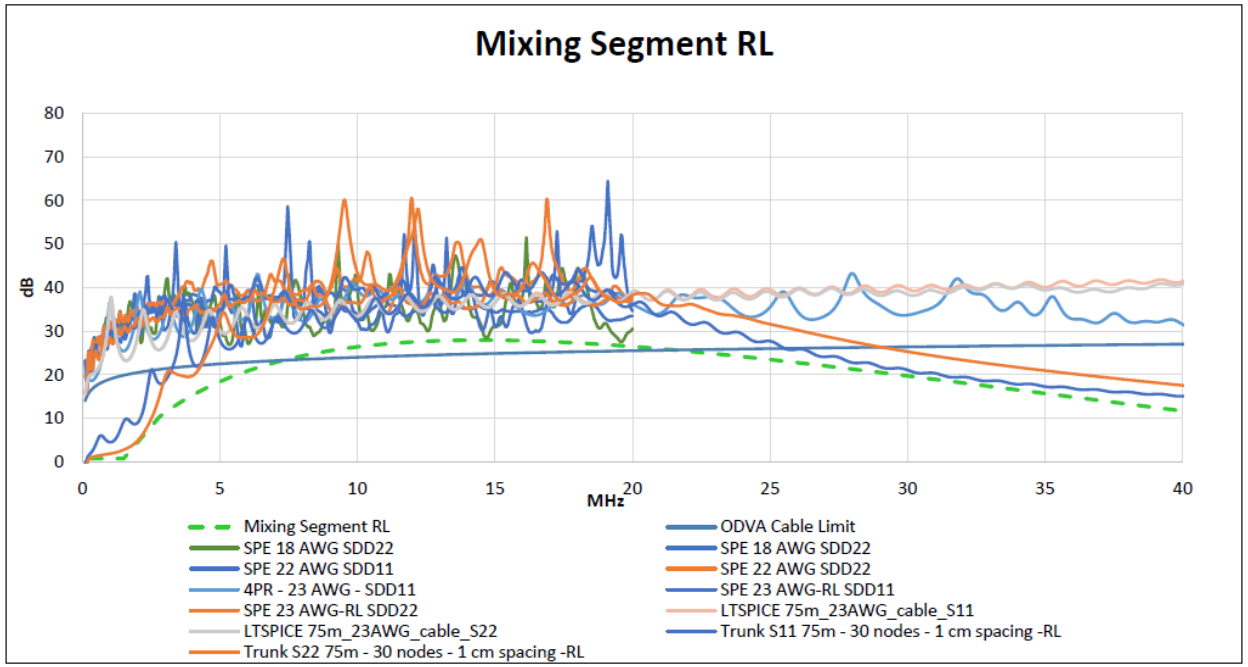
Enhancements to the Mixing Segment

Re-specified Mixing Segment Specifications to Support 75m/30nodes:

- Based on: PHY simulations and experience, and TCI specifications





https://www.ieee802.org/3/da/public/0524/diminico_SPMD_01_0524.pdf

https://www.ieee802.org/3/da/public/0724/diminico_SPMD_01a_0724.pdf

Minor Enhancements: Tightening the Transmitter PSD

There is a significant difference between results obtained in devices with a “typical PSD” transmitter model and the “Minimum compliant PSD” in clause 147.

- 802.3da tightens up the lower PSD mask for transmitters
- Existing PHYs are expected to be compliant – may desire this for clause 147 maintenance

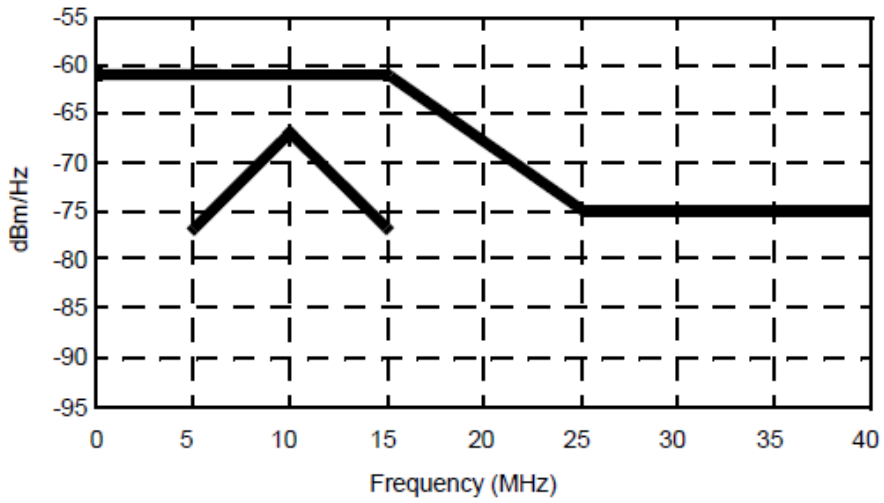


Figure 147–18—PSD upper and lower limits

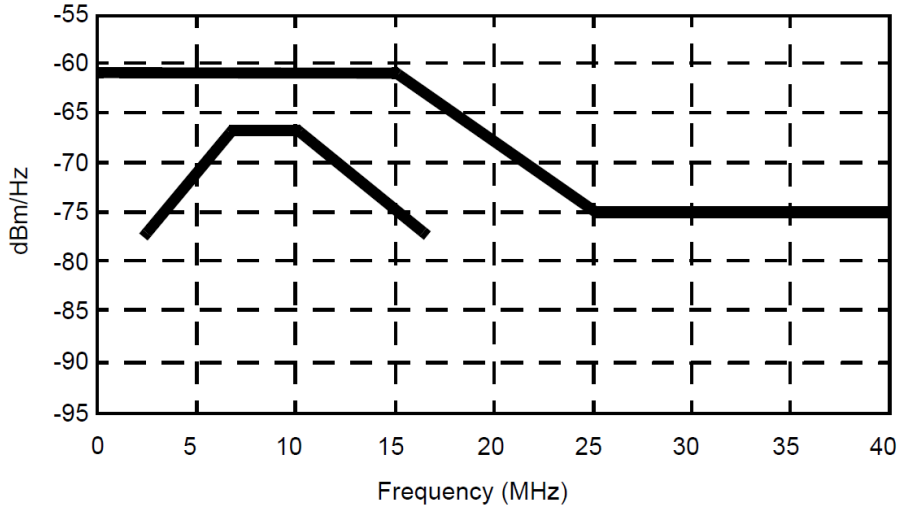


Figure 188–15—PSD upper and lower limits

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What is D-PLCA?

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D-PLCA Allocates PLCA node IDs

PLCA works by assigning “transmit opportunities” to nodes based on a node ID (local to the mixing segment)

- PLCA is interoperable with CSMA/CD nodes

PLCA node IDs are assigned by the management entity – outside the scope of clause 148

- Plug-and-play networks would like these IDs assigned automatically.
- Also would like “coordinator” assigned automatically

802.3da adds an optional functionality to Clause 148, D-PLCA, to “Specify an optional PLCA node ID allocation method” (Objective 3)

How D-PLCA works

Look for “stolen” Transmit Opportunities (TOs)

- Detecting that a node is transmitting during another’s TO
  - Accomplished by detecting carrier or commit

Each node keeps a list of used TOs, and frees them up with an aging criterion

- 2 kinds of node ID claims – HARD (with a COMMIT) or SOFT (without)

Each node grabs a transmit ID after listening to build a table based on what is used

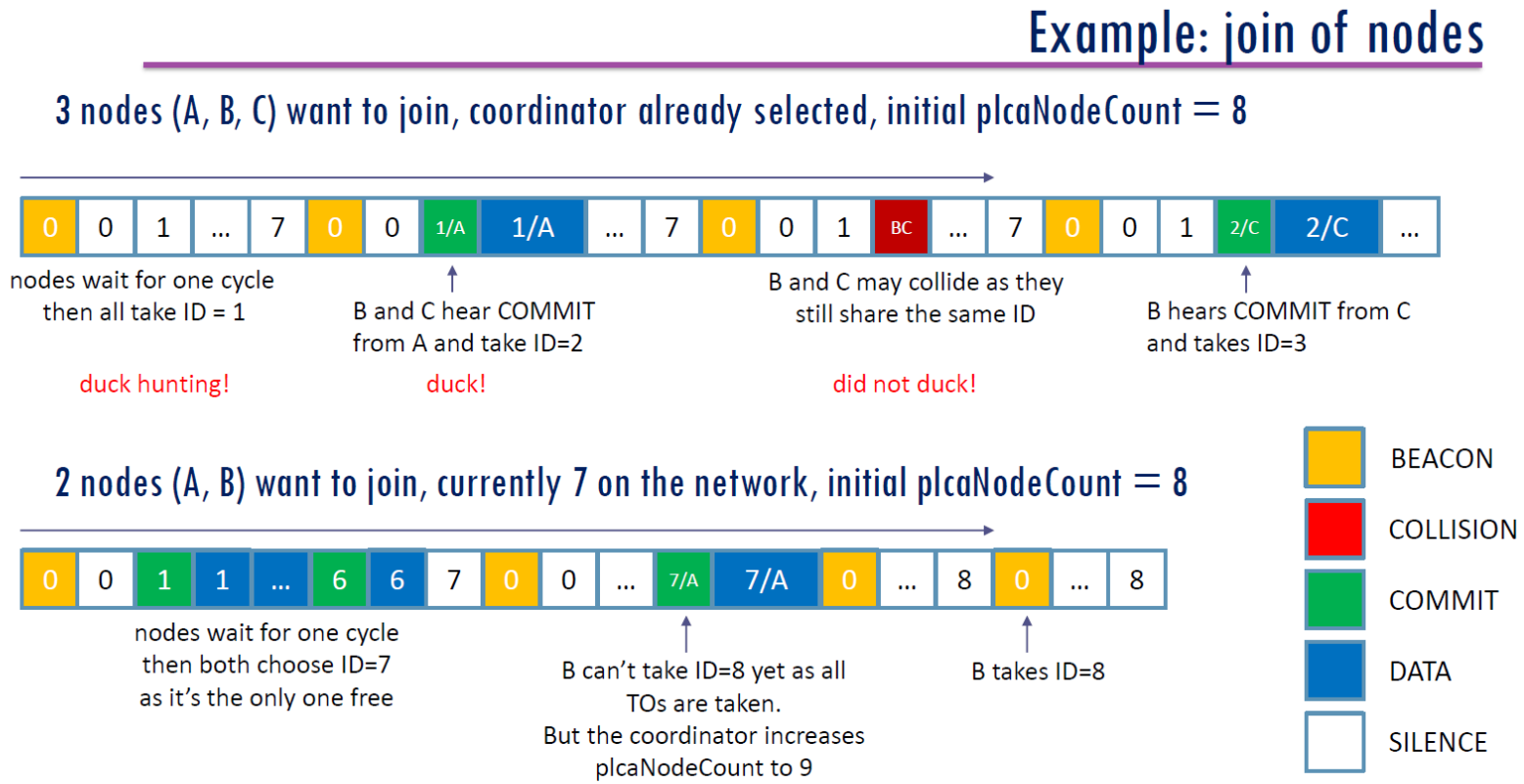
- Grabs another if that one wasn’t actually free

Nodes that want “coordinator” role similarly monitor beacons

See: https://www.ieee802.org/3/da/public/0321/beruto_3da_01_031021.pdf

Example of nodes finding an ID

See: From: beruto_3da_01_031021.pdf

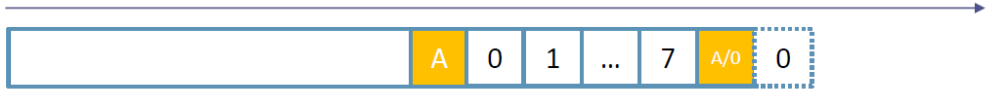


Example of election of coordinator

See: From: beruto_3da_01_031021.pdf

Example: election of coordinator (localNodeID = 0)

3 nodes (A, B, C) eligible to take the coordinator role, plcaNodeCount = 8 (default)



Ex 1: simple case, node A sends the BEACON first, nodes B and C "hear" it and renounce

Ex 2: BEACONs from A and B collide, then A and B hear the BEACON from C and both renounce.

Ex. 3: worst case, BEACONs from A, B, C collide repeatedly then nodes B and C detect the COMMIT from A and renounce.
If the packet from A collided, then **the MAC** would re-transmit after the usual random back-off

NOTE that during this time nodes can still send/receive data in plain CSMA/CD mode

New State diagrams in Clause 148

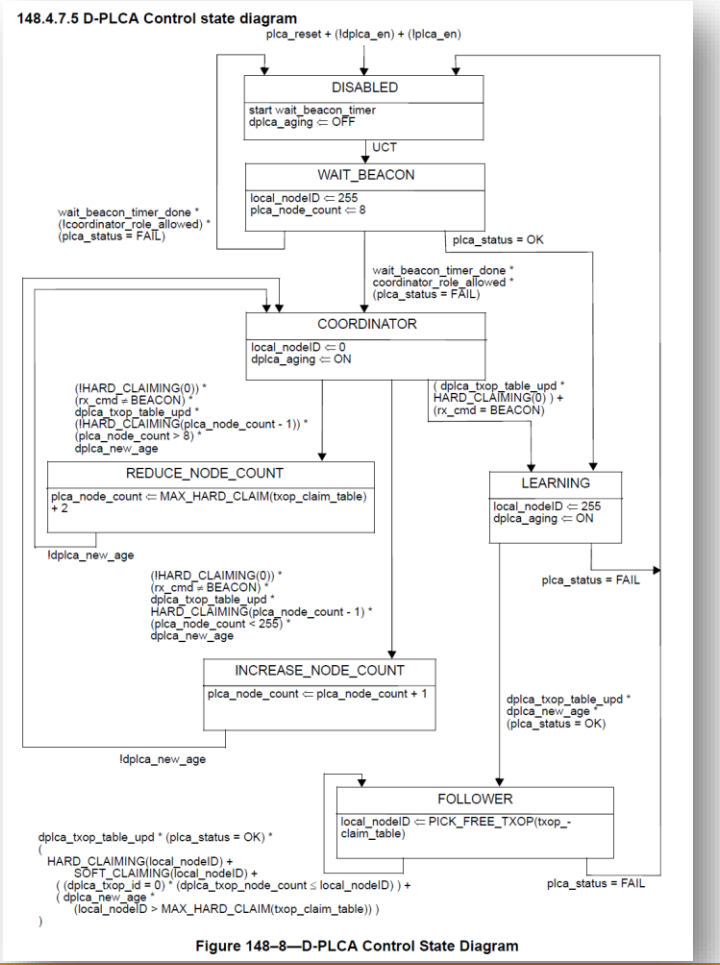


Figure 148–8—D-PLCA Control State Diagram

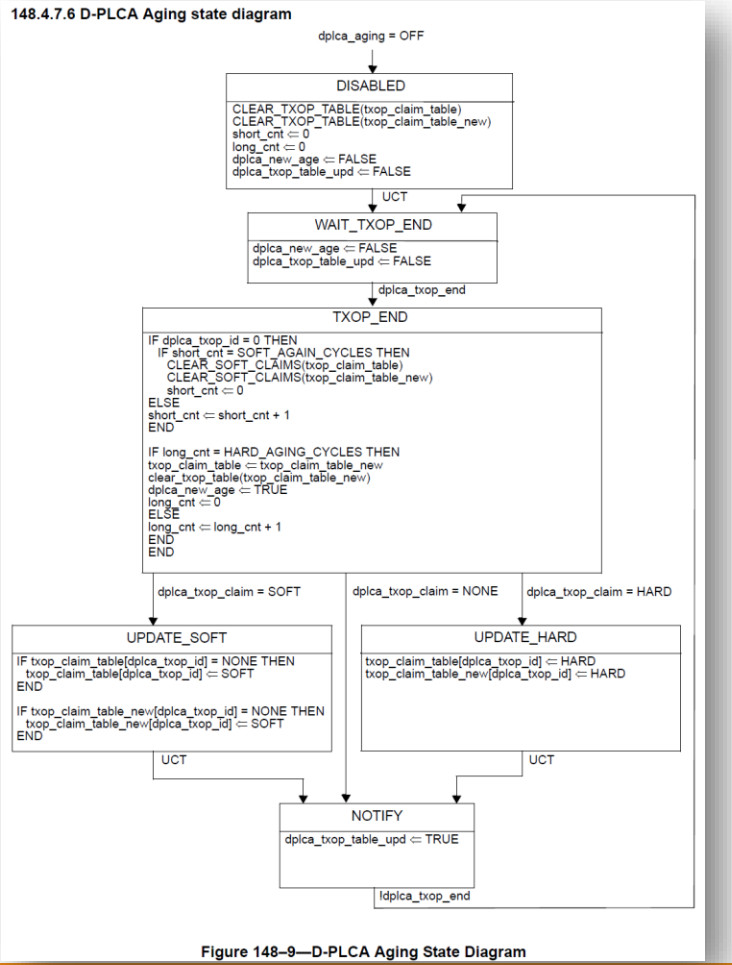


Figure 148–9—D-PLCA Aging State Diagram

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What is this new powering scheme?

High-level description of MPoE

Defines an MPSE and an MPD (similar to a PSE and a PD in PoE)

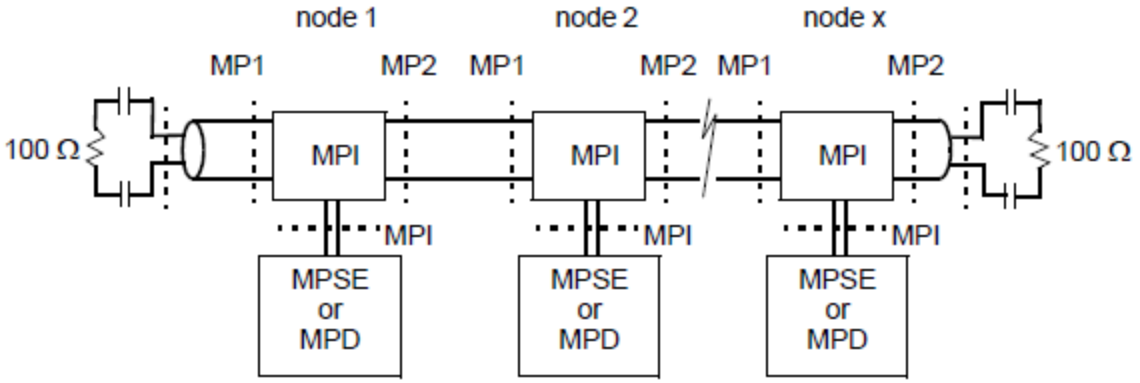
Generally only one MPSE per mixing segment
- More than one MPSE isn't disallowed, but is out of scope

Can have one or more MPDs on the wiring
- PSE provides no power until at least one MPD is detected

Devices on the mixing segment may or may not take power (supports non-MPDs)

Defines the MPI (Multidrop power interface) which can be the TCI (data interface)

Defines unit loading for MPD power consumption



NOTE – The MPI may not be exposed. If it is not exposed, specified values are calculated from values observed at MP1 and MP2.

Figure 189–1—Mixing segment and reference points for power

Multidrop Power over Ethernet (MPoE)

Specifies:

- The characteristics of an MPSE to add power to the cabling system.
- The characteristics of an MPD's load on the power source and the cabling.
- A method for determining the presence of one or more MPDs prior to applying power.
- A method for applying and removing power from the mixing segment in a controlled manner.
- A method for scaling supplied power back to the idle level when power is no longer requested or required.
- A method for MPDs and MPSEs to negotiate and allocate power.
- Power fault sensing and recovery.
- Requirements for adding an MPD to an already powered mixing segment.

System Types, Unit Loads, and "Cold Power"

Two System Types (30V and 50V)
- MPSEs and MPDs may be 30V, 50V, or "Mixed" (capable of either)

Each mixing segment supports at least 16 "unit loads"
- A PD has a positive integer number of unit loads
- MPSEs provide at least 1W current when powering
- The unit load for a 30V system is 1W, and for a 50V system is 2W

MPSEs provide "Cold Power" – no powering voltage unless PDs are present and identified
- MPDs provide a "Transmit Power Signature"(TPS) similar to PoE's "Maintain Power Signature" (MPS)
- MPSEs remove power in the absence of any MPD TPS

MPSEs (also) remove power for faults (overload or short), or on command

Discovery

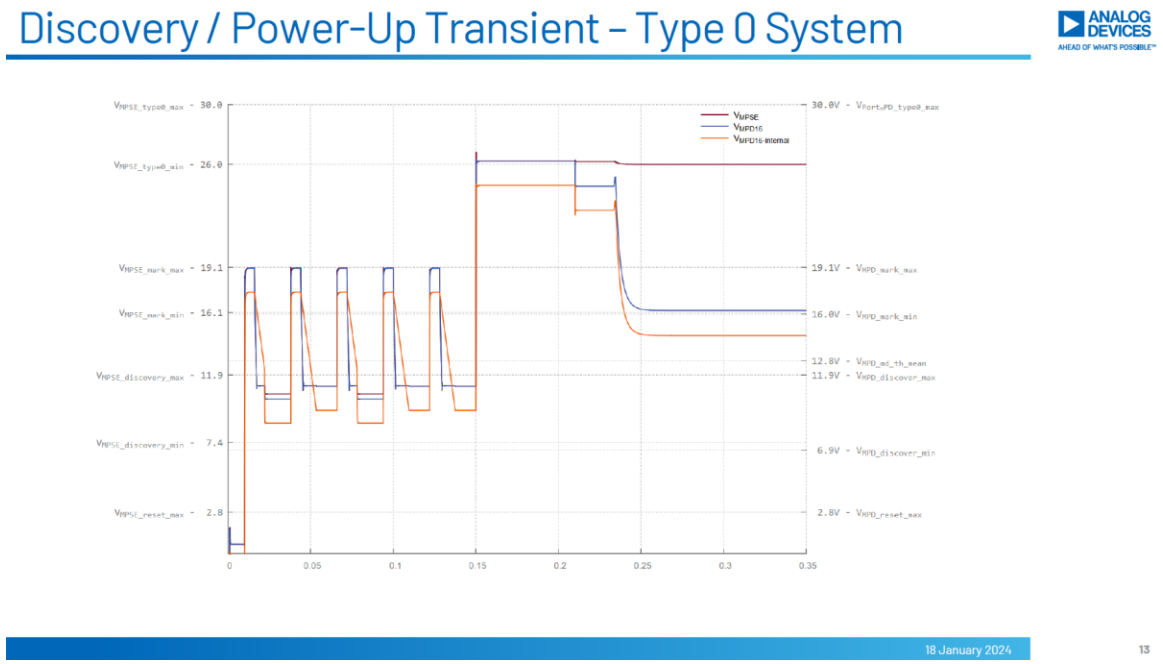
An MPSE discovers and classifies types of MPDs present through a sequence of high & low states

- Presenting a High “Mark” voltage low current, followed by
- Measuring current draw at a Lower voltage with a higher current limit

MPDs respond with:

- Minimal current at the Mark states
- Current draw at the low state depending on the state number and the MPD type

All MPDs are measured at once



https://www.ieee802.org/3/da/public/0124/Paul_da_01_20240124.pdf

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Summary

IEEE 802.3da Multidrop Enhancements: Review

Enhancements support plug-and-play multidrop with 10BASE-T1S

- Half duplex operation, 10 Mb/s, shared media PHYs, backward compatible with Clause 147 10BASE-T1S
- ***SAME PCS & PMA, SAME Registers, SAME PHY as 10BASE-T1S…., but only multidrop mode***

Refined specifications on *PHY electricals, Mixing Segment & Interface* to improve multidrop plug & play experience

- Improving specifications of the mixing segment and interface (TCI) to better support plug-and-play operation, longer reach, and more nodes

Adds dynamic assignment of PLCA Node IDs and coordinator (D-PLCA)

Adds a “Cold Power” powering protocol for multidrop busses

IEEE 802.3da: Moving to WG ballot…

Draft moves to a “technically complete” state and starts initial Working Group ballot out of November plenary

Need for review and initial WG ballot comments focusing on:

- Validating changes to transmitter specifications in clause 147
  - Lower bound on transmit PSD mask and consideration of the droop specification
- Cleaning up the isolation text
- Validating the powering state diagrams and specifications

Validation of ease of building plug and play TCIs/mixing segments per the specification


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Thank You!