# Repeaters in 802.3da

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3/31/2022

# Acknowledgements


- Thanks to several people for good and insightful conversations:
  - Geoff Thompson
  - Piergiorgio Beruto
  - (Dr.) Gergely Huszak
  - Chris Diminico
  - Michael Paul
  - Jason Potterf

# Overview

- Go-ahead question - PAR Scope – can we discuss/specify Repeaters in 802.3da?
- Why un-segmented multidrop is harder than it looks
- Segmenting the mixing segment

- What 802.3da needs to do

# Go-ahead question

- IEEE P802.3da PAR Scope –
  - “this project is called ‘10 Mb/s Single Pair Multidrop Segments Enhancement’ – isn’t a repeater a new device?
  - The PAR scope is: (emphasis added)
    - Specify additions and modifications <u>of the Physical Layer</u> (including reconciliation sublayers), management parameters, Ethernet support for time synchronization protocols, and optional power delivery supporting multiple powered devices on the 10 Mb/s mixing segment.
- So, the question comes down to, “Are repeater specifications ‘Physical Layer’?”

# Answer - YES

- See IEEE Std 802.3 Figure 27-1 (100BASE-T repeaters)
  - Repeater is PHYSICAL LAYER
- Repeater connects two segments just above the PCS layer – below the MAC
  - (and below the RS, which means PLCA may be above the repeater)
  - Also means you can use different PCS/PMA/PMD on the different segments
  - Fundamental purpose is to rebuild signals on the media, not to do MAC functions

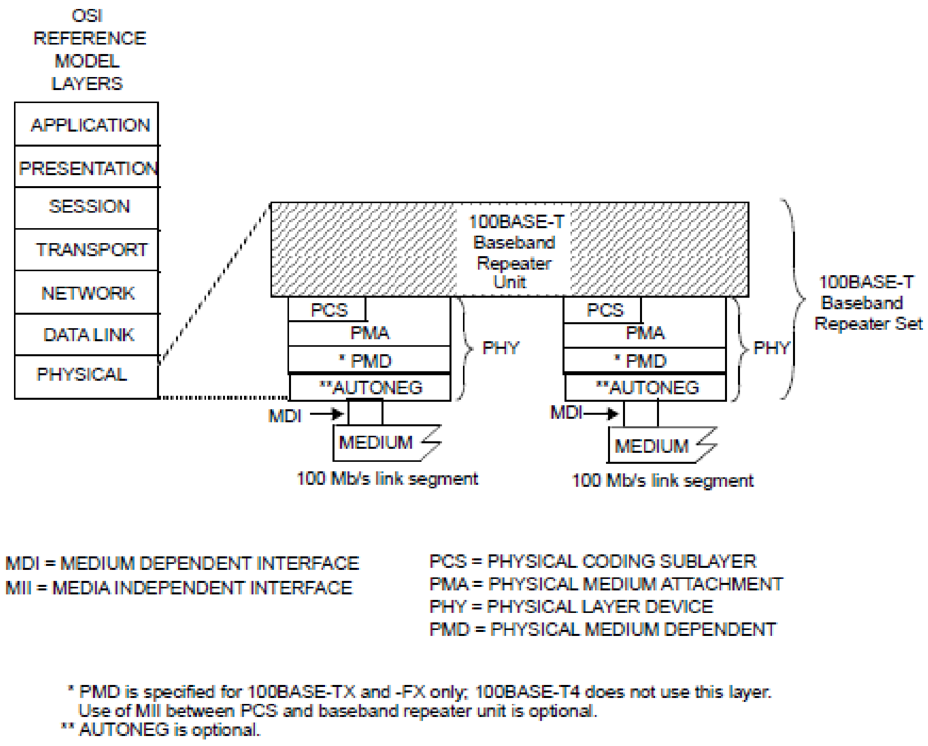



**Figure 27–1—100BASE-T repeater set relationship to the ISO/IEC OSI reference model**

Source: IEEE P802.3dc D.3.2, Figure 27-1

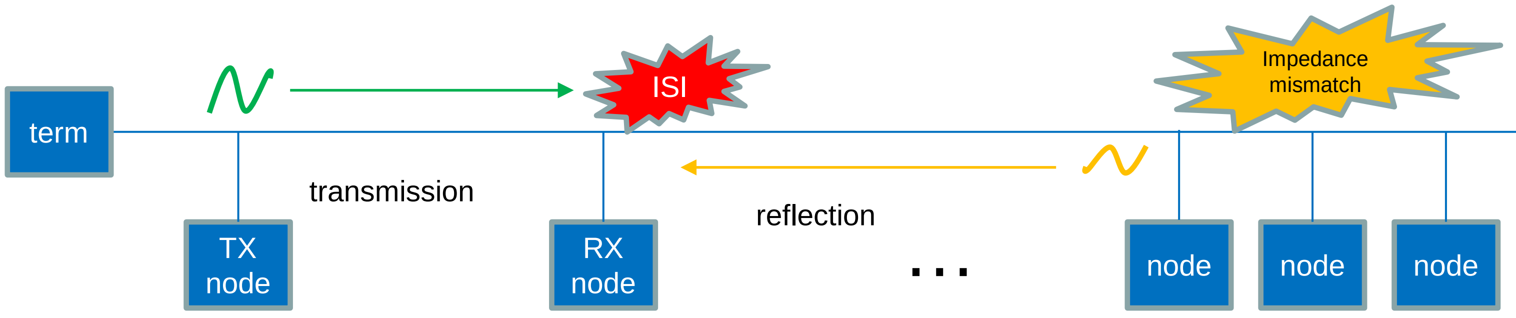
# WHY UN-SEGMENTED MULTIDROP IS HARDER THAN IT LOOKS

# Charming, but devilish in detail

- Un-segmented Multidrop is charming…
  - One phy per node
  - Just a power tap, no repeating
  - Each node is as simple as can be… (or is it?)
- Discussions in 802.3da have shown otherwise
  - Analog/lumped-circuit matching problems at nodes
  - Loading problems on distributed networks
  - Variations with installation and network configuration
- How do we know what is worst case over all variations?
  - Many dimensions - node spacing, loading, segment mismatch, stub length…

# Reflection Problem in Multidrop

- Simulating the electrical parameters of a topology to get an eye diagram is neither practical, nor does a clause 147 PHY have any requirement to operate under that condition
  - Hence, an “open eye” may make you feel good about operation, may be likely to work, but is neither NECESSARY nor SUFFICIENT for operation
- We need an ISI spec that the phy is required to operate over.
  - MDI return loss in multidrop is not explicitly specified in clause 147, but impedance is
- As a result, clause 147 mixing segments are engineered to minimize reflections
  - 802.3da has alleviated the issue of reflections off the MDI interface of the node

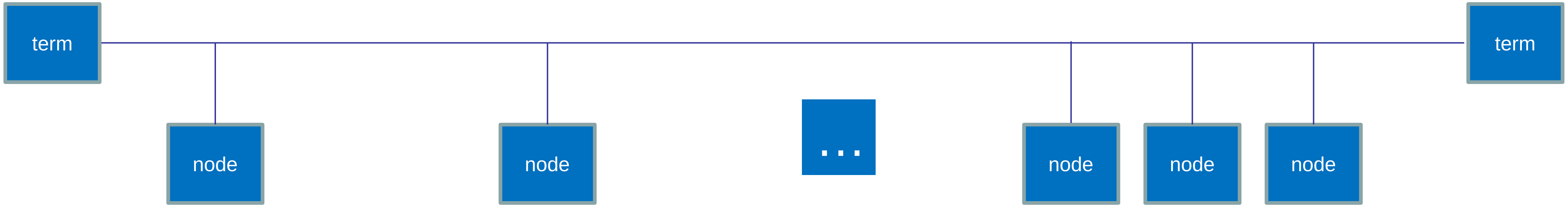


# Is there something more?

- Inductive compensation cleans up reflections off stub interfaces and removes one source of ISI
  - What is the next one?
- Reflections within the mixing segment backbone
  - Generally specified as the mixing segment return loss
- This gets into the structure of the mixing segment itself

# Two structures:
# Homogenous vs. Segmented mixing segments

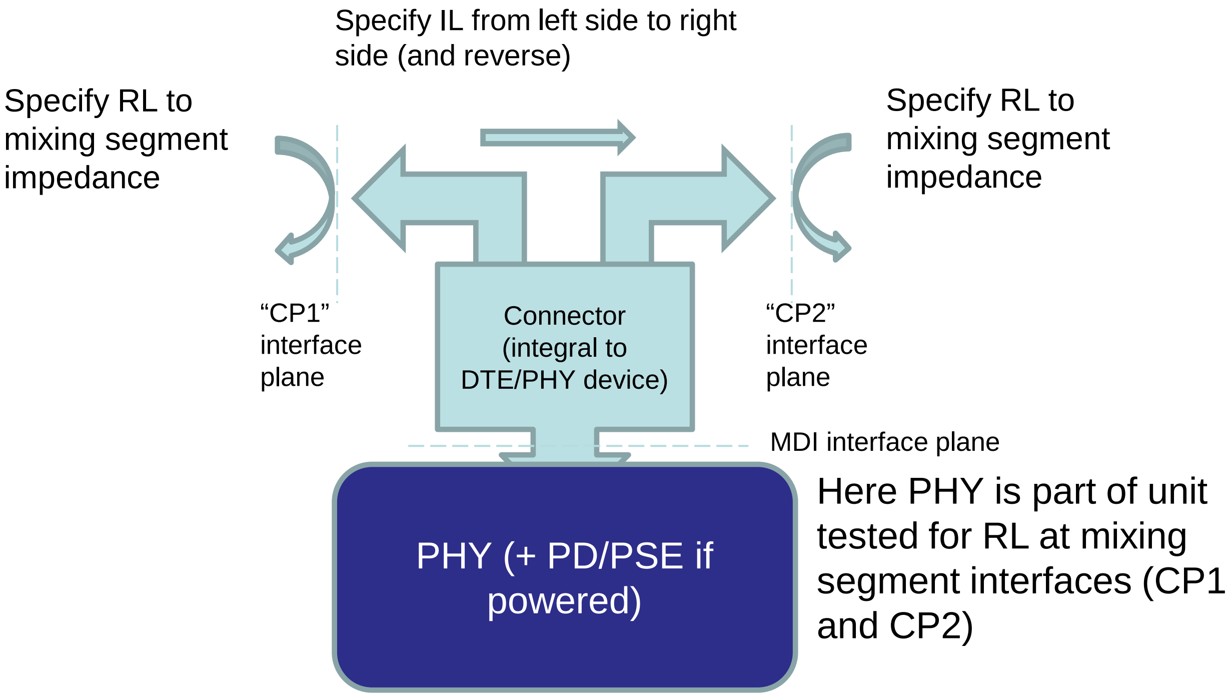
HOMOGENEOUS: One piece of cable – same batch, same characteristic impedance
- Note – implies taps, and, if not a contiguous cable, some careful matching

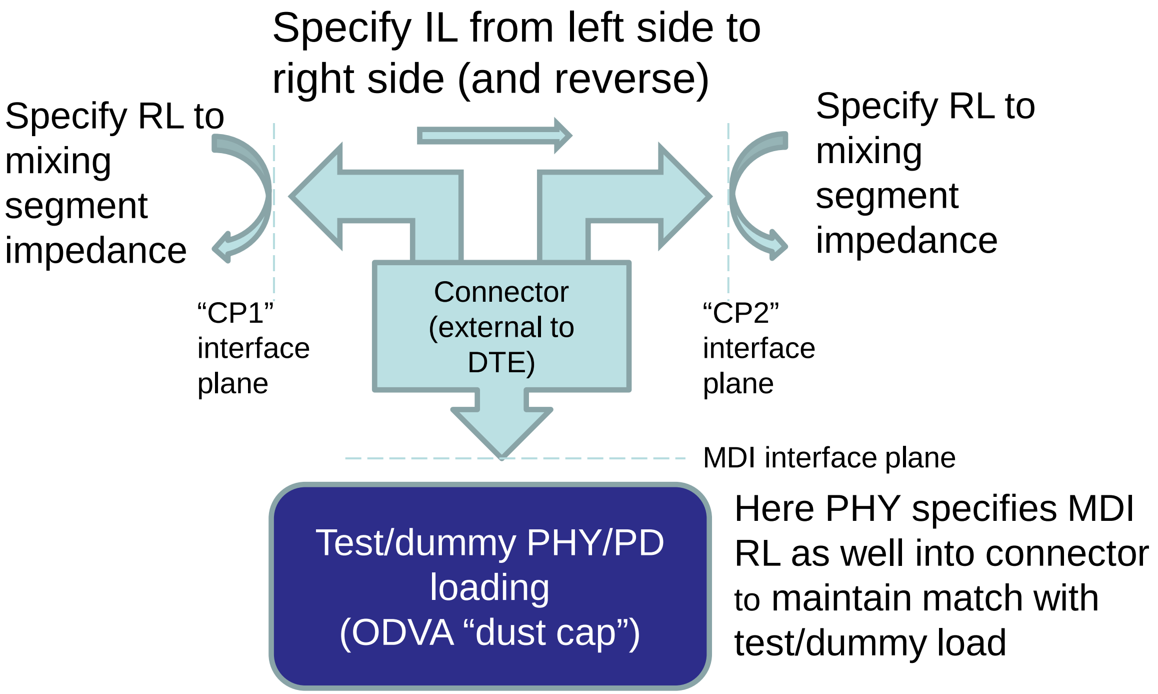



SEGMENTED: Separate pieces of cable between nodes – cable mismatch at each node

# Testing the segmented mixing segment

- Specify the MDI return loss for a connected PHY in ‘in and out’ mode
- Connection divides mixing segment into left & right
  - Two cases – connector integral to device, connector external to DTE



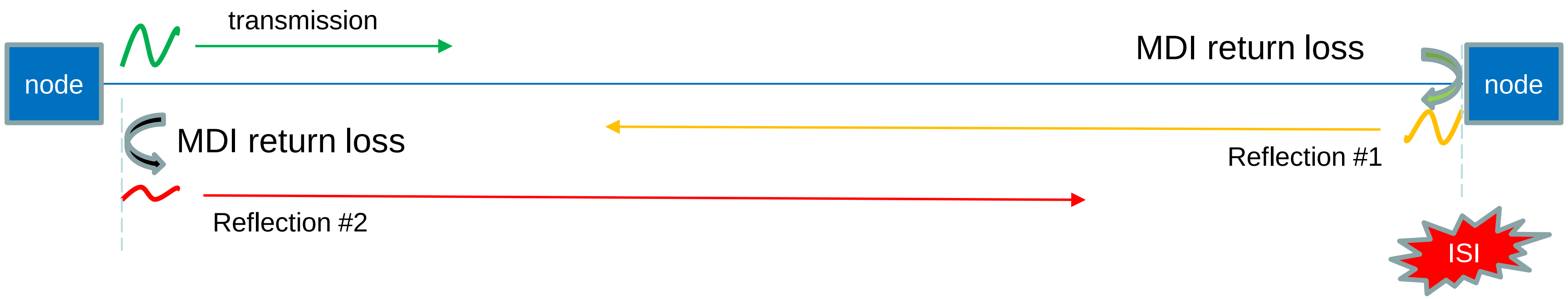



# Cable sample-to-sample matching and RL

- Controlled by the RL spec in TIA 568.5 and similar
  - But measured on a single sample – a channel made up of segments will have a different RL
  - May be able to qualify by RL on the assembled channel
  - 100m segment RL spec in 585.5 allows impedance to vary 92.7 to 105.7 ohms (6%)
- Discontinuities at cable segment junctions will be point reflections, attenuated by intervening spans from measurement or receiver location.
  - Measuring return loss at the end of the segment will attenuate reflections that might not be attenuated at the victim PHY
  - May need to compensate for cable IL

# How ISI is specified for clause 147 PHYs

- Multidrop mode in clause 147 is specified to work basically under the conditions of point-to-point half duplex
  - Point-to-Point half duplex is specified with a maximum link segment insertion loss, minimum link segment return loss, and minimum MDI return loss (Cl 96)
    - PHY must tolerate reflections attenuated by 2x MDI return loss + cable attenuation
    - What length of cable for delay?
      - Extreme limit: timing spec for DME (4ns clock transition to data transition window)
        - » ~ .84 m round trip, .4m cable – 2.8% of the IL spec = 0.07dB at 10 MHz)
      - Less extreme, realistic: one DME transition (one-half baud) interval (40nsec)
        - » ~ 8.4m round trip, 4m cable, 28% of IL spec = 0.7dB at 10 MHz
- Needs to tolerate noise in addition to ISI (134mVpp at BER spec)



# Deriving required return loss at CP1/CP2 from MDI RL only (near spacing)

- PHY to tolerate ISI 20.7 dB below signal (independent of other budgets)
- IF nodes reflect in phase (closer than 1/2 baud (4.2m) to each other)
  - Nominal reflection loss is CP_RL - $20*\log_{10}$(maxnodes -2) > 20.7 dB
    - 16 nodes gives 43.6 dB  (8 nodes gives 36.3 dB)
  - Attenuated by intervening connectors (*ILconn*) (currently not in spec)
  - Reflection level is actually : $CP_{RL} - 20\log_{10}\left(\sum_{k=1}^{maxnodes-2} 10^{-k\times 2\times ILconn/20}\right)$ dB
  - *ILconn* must be low to meet mixing segment IL at length (<0.5dB), but increasing *ILconn* helps connector RL requirement

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **ISI_limit** | **20.7** | | **maxnodes** | **16** | | | |
| **Ilconn (dB)** | **0.2** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** |
| **CP_RL (dB)** | **40.77** | **37.04** | **32.08** | **28.32** | **25.34** | **22.87** | **20.74** |

# Deriving required return loss at CP1/CP2 from MDI RL only (wide spacing)

- BUT, what if nodes reflect as power sum (further than 1/2 baud to each other, 4.2m)
  - To get 1e-10 BER, peaks are 6.3 times rms value (16 dB)
  - Nominal reflection loss is CP_RL - 10*$\log_{10}$(maxnodes -2) > 20.7+16.3 dB
    - 16 nodes gives 48.4 dB (59m cable) (8 nodes gives 45 dB (25m cable)
    - Attenuated by intervening connectors (*ILconn*) (currently not in spec)
  - Reflection level is actually : $CP_{RL}$ – 20$\log_{10}$ ( $\sum_{k=1}^{maxnodes-2} 10^{-k\times 2\times ILconn/20}$) dB
  - *ILconn* must be low to meet mixing segment IL at length (<0.5dB), but increasing *ILconn* helps connector RL requirement

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **ISI_limit** | **37** | | **maxnodes** | **16** | | | |
| **Ilconn (dB)** | **0.2** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** |
| **CP_RL (dB)** | **47.04** | **45.17** | **42.69** | **40.81** | **39.32** | **38.09** | **37.02** |

# Question – Can cable matching be good enough?

- If compensation is fixed, cable matching segment to connector needs to be at least CP1 RL (30-40 dB)
  - But, conventional (category cable) has 25 dB RL on the cable
  - This falls short of the required RL for the connecting segments
- Is actual cabling better than the 25 dB RL spec?
    - If so, we need a new specification that cabling will sign up to!
- Without a (substantially) improved cable matching specification, PHYs can see more ISI energy than they are specified to tolerate.
  - NOTE – this doesn't mean that PHYs built today don't tolerate it – it just means that the specification allows compliant PHYs that won't
  - Again… more specification work

# What does this mean for a way forward with simulations of mixing segments alone?

- In my opinion, we won't reach our objectives with the current clause 147 PHY or cabling segment specs
  - We might with more constraints and definition on PHY receiver ISI processing, or tighter cable matching
- What about the 'eyes'?
    - There are multiple ways to build a DME receiver, and each has its own 'worst case' features
    - Few behave strictly as an unfiltered eye diagram
    - Few behave with a single-frequency worst-case bound
- A consensus receiver model is needed, which probably means additional receiver specifications to constrain poorer performing designs

# Possible Cl 147/802.3da modifications

- Respecify Clause 147 to tolerate more ISI
  - Through link segment/mixing segment

    OR

  - Through a more relaxed MDI return loss specification
- Either way, we need a receiver model to figure what ISI a clause 147 PHY can actually tolerate, and we then need to specify it
- Additionally, we can segment the mixing segment to minimize the reflection interfaces that create ISI

# Where does this leave us?

- We likely need a parallel approach

- Work on refining the PHY ISI tolerance specifications
  - Including self-generated ISI (transmitter or receiver)
- AND – investigate changing the model for mixing segment enhancement
  - Enter the discussion of repeaters….

# SEGMENTING THE MIXING SEGMENT

# The beauty of (physical) point-to-point

**PROs**

- Reflections are terminated at the PMD
  - Relative cost of silicon is likely less than passive coupling network components
  - Avoid ohmic losses in coupling
- Segment-to-segment data isolation
  - Allows isolating a faulty segment
  - Fault tolerant, e.g., counterrotating rings
- Don’t have to tap off power AND pass data with minimal distortion
- Deterministic installation and configuration
  - Stubs are a non-problem

**CONs**

- 2 PMDs needed per PHY
  - And possibly 2 PMAs, 2 PCSs, 2 MACs
  - Extra PHY components consume power
  - Additional PHY electronics Not much of an issue if integrated
- Single-node failure can block downstream node access
- Conversion loss on power or need to bridge power but not data
- Configuration-dependent delay in transmission

# Repeaters and 802.3cg PHYs

- "IEEE Std 802.3cg decided not to use repeaters"
  - Well, *NOT EXACTLY*…
- IEEE Std 802.3cg decided that Clause 9 10 Mb/s repeaters do not apply to clause 146 and 147 PHYs
  - The only mention of repeaters in 802.3cg is in Clause 9:

**9.1 Overview**

Source: IEEE Std 802.3cg-2019

*Change the first paragraph of 9.1 as follows:*

This clause specifies a repeater for use with IEEE 802.3 10 Mb/s baseband networks, with the exceptions of 10BASE-T1L (Clause 146) and 10BASE-T1S (Clause 147). A repeater for any other IEEE 802.3 network type is beyond the scope of this clause.

Source: IEEE Std 802.3cg-2019, 9.1

***This leaves open a new clause to specify repeaters for these PHYs (may want a new objective though…)***

# Repeater basics (1)

- Repeaters restore signal waveform & timing
- Repeaters detect and forward collisions
- Repeater delays limit the size of the network

Repeater sets are used to extend the network length and topology beyond what could be achieved by a single mixing segment. Mixing segments may be connected directly by a repeater set (Figure 9–1) or by several repeater units that are, in turn, connected by link segments. Repeater sets are also used as the hub in a star topology network in which DTEs attach directly to link segments (e.g., 10BASE-T, Clause 14). Allowable topologies shall contain only one operative signal path between any two points on the network. The proper operation of a CSMA/CD network requires network size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of interpacket gap as it travels through the network. The method for validating networks with respect to these requirements is specified in Clause 13.

A repeater set can receive and decode data from any segment under worst-case noise, timing, and signal amplitude conditions. It retransmits the data to all other segments attached to it with timing and amplitude restored. The retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal.

Source: IEEE P802.3dc D.3.2, 9.1

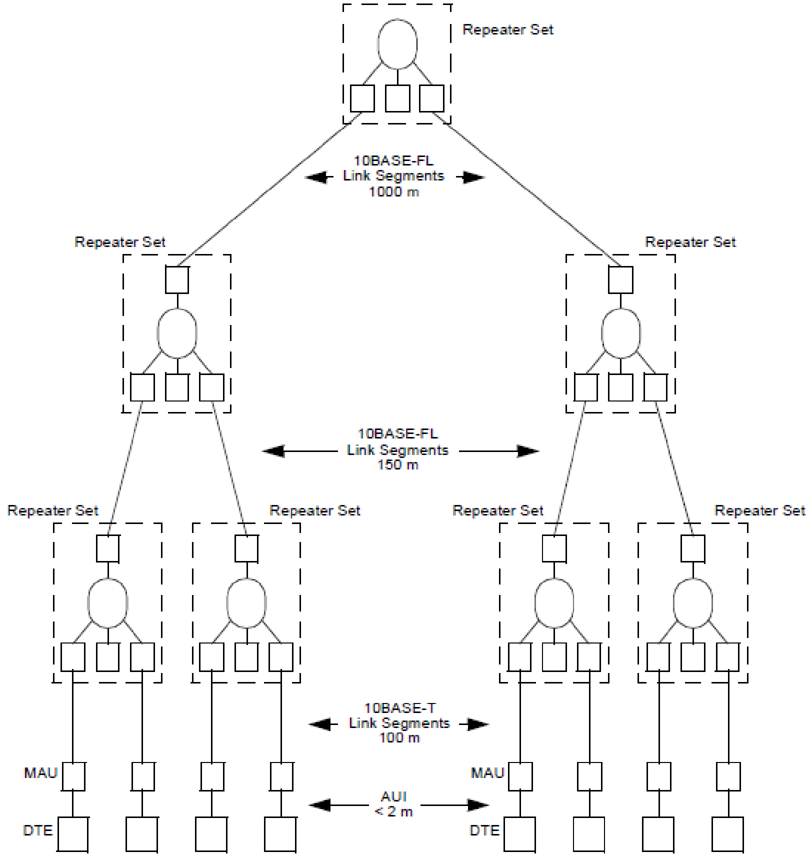



Figure 13–1—Example of maximum transmission path with five repeater sets enabled by Model 2 Transmission System validation

Source: IEEE P802.3dc D.3.2, Figure 13-1

# Repeater basics (2)

- Process and forward signaling between segments (repeater ports)
  - Preserve collision handling
    - Detect & generate Jam
    - Cl 9 & Cl 27 repeaters do this differently
  - Regenerate valid signals onto other segments
    - PLCA changes the definition of ‘valid’
- Connection to the media:
  TX, RX, Energy Detect/Signal Quality
  - Clause 9 uses a Clause 7 MAU, we could use a PMD, which is similar, except…
    - MAU has collision detect, jabber, and functions in PMA & PCS of 10BASE-T1S

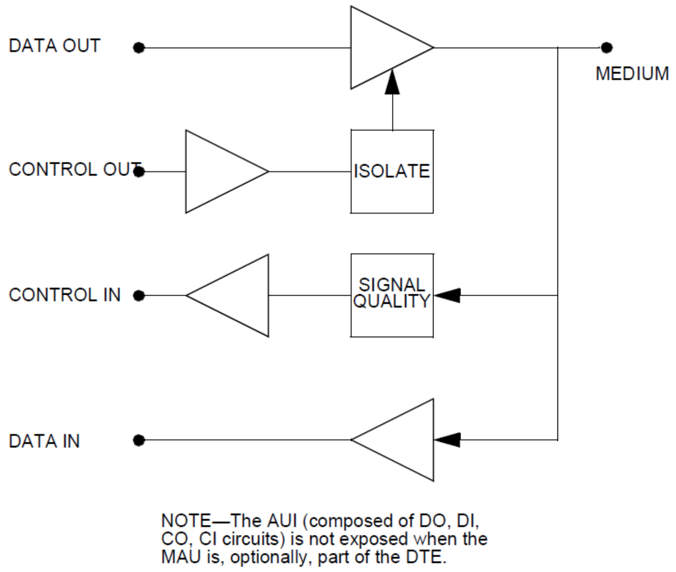



**Figure 7–2—Generalized MAU model**

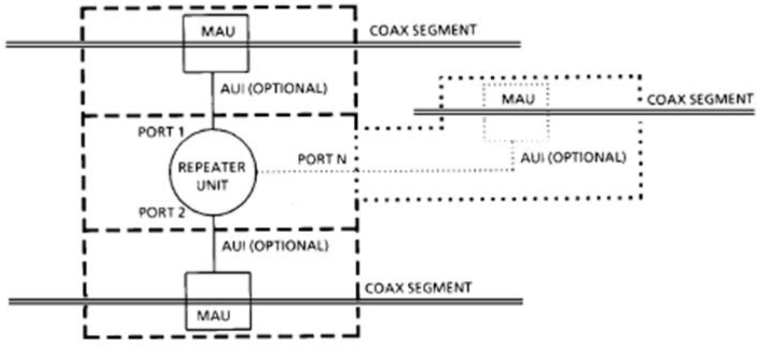
Source: IEEE P802.3dc D.3.2, Figure 7-2

NOTE – this figure is in the early part of IEEE Std 802.3, and the MAU only attaches to mixing segments. If attached to a link segment, the signal quality indicator, in particular, is likely to be derived including other (e.g., digital logic of data out & data in) signals.

# Basic Repeater Architectures

## Clause 9: Old 10 M architecture

- Repeater connects at AUI
  - Similar to PMD concept
  - Low latency/Complexity
- Supports mixing segment 'strings'
  - .3cg-like small mixing segment definition



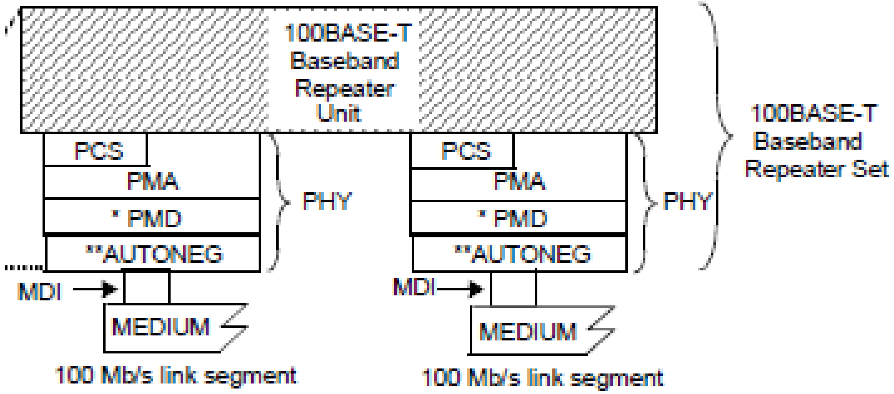

NOTE: The AUI is not necessarily exposed when the MAU is, optionally, part of the physical repeater.

**Figure 9–1—Repeater set, coax-to-coax configuration**

Source: IEEE P802.3dc D.3.2, Figure 9-1

## Clause 27: 100 M architecture

- Repeater connects at PMA/PCS
  - Full PHY stack
  - Higher latency/Complexity
- Designed around point-to-point connections
  - Easier for media definition




Source: IEEE P802.3dc D.3.2, Figure 27-1

# What to segment?

- Several models
  - Clause 9 – MAU – AUI – Repeater – AUI – MAU
    - Interfaces at AUI
      - Issue – we don’t have a MAU or AUI…. Would require substantial redefinition of the PHY (this was one main reason 802.3cg avoided the model)
  - Clause 27 – PMD/PMA/PCS – Repeater – PCS/PMA/PMD
    - Interfaces at PMA and PCS
      - Issue – not a well-defined electrical interface – defined as primitives
      - Issue – doesn’t just isolate the signal, also expands collisions, jams, etc.
  - General – regenerative repeater
    - Would interface at a PMA or at a PMD

# Repeater Interface Point Choices - delay

- Interface at the PCS or PMA (similar to Cl 27)
  - PMA processes as 5B code groups, PCS decodes 5B codes
  - At least 5B (4BT) delay in repeater reception stack processing
    - About equal to 50m round-trip delay, multiple repeaters would likely impact PLCA timing, require segmentation of PLCA operation
    - Practically, the delay is greater due to clock recovery, etc.
- Interface at PMD (similar to MAU and Cl 9)
  - Regenerative buffering of transmission
  - Ability detect and passon collisions
  - Minimal latency – repeat on a bit-by-bit basis…
    - (some detect and retiming delay)

# Did he say PMD? I thought we had a PMA in Clause 147 – what is the difference?

- IEEE Std 802.3 defines a PMD and PMA overlapping, and some PHYs use both, some only one:
  - PMD: “portion of the Physical Layer responsible for interfacing to the medium”
  - PMA: “contains the functions for transmission, reception, and (depending on the PHY) collision detection, clock recovery and skew alignment.”
- 10BASE-T1S subsumes PMD in the PMA, but others (e.g. OPEN) are defining the line interface as a separate part
  - Would need to liaise to determine usability

# PMD Basics

- Inputs:
  - Transmit data bit (clockless)
  - Transmit control (isolate or TX)
- Outputs:
  - Rx data bit (clockless)
  - 'Energy detect' outside of expected values
    - Greater than TX waveform
    - Greater than noise threshold
- Minimal state diagrams, instead controlled by PMA
  - Additional functions (sleep, fault diagnosis, ordering, loopback) possible but these are the basics

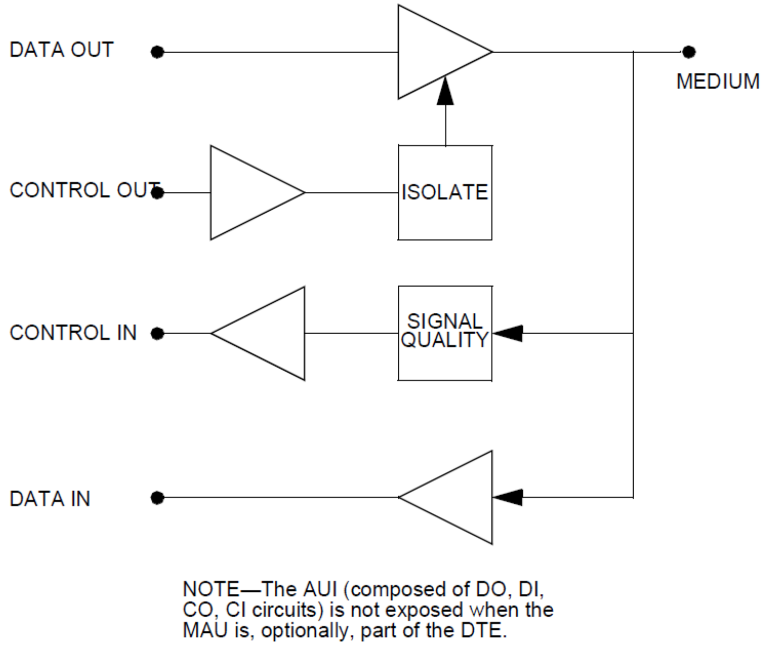


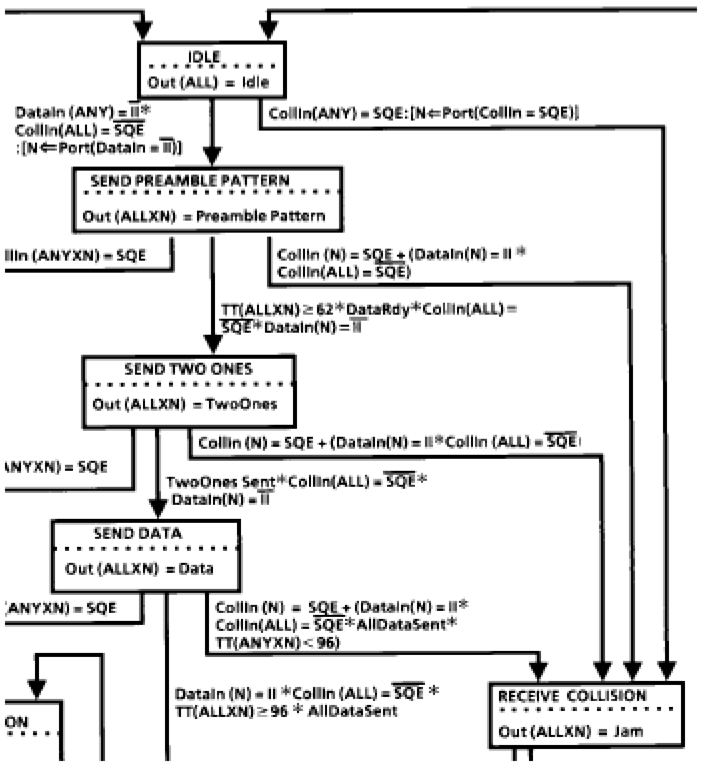

**Figure 7–2—Generalized MAU model**

Generalized MAU from early in 802.3 applies to half-duplex media (e.g., mixing segments)
Similar to PMD at an interface level

***Need to define & standardize control, required functions, and interface***

# Cl 9 AUI Interface: Collision Processing

- Repeater begins forwarded transmission on energy detect
  - Preamble or Jam based on collision (SQE) from MAU
    - Preamble & Jam first 62 bits are identical
    - Fragments are extended to 96 bits
- This would block forwarding of PLCA signals
  - BEACON & COMMIT replaced by preamble
- Would require modifications:
  - Collisions would need to be detected fully within PMD or else added to repeater functionality
  - Either repeater state diagram or PLCA need modification to be compatible
  - Note – prop delay, energy on segment and data are different in Clause 9 than Clause 147




Source: IEEE P802.3dc D.3.2, Figure 9-2

# Cl 27 PMA/PCS Interface: Collision Processing

- Repeater begins forwarded transmission on energy detect on any segment
  - Preamble or Jam based on whether more than one segment is active
    - Detected at the repeater
- Repeater can pass on PLCA signals
  - BEACON & COMMIT could be retransmitted, with realignment of ‘activity’ variable
- Introduces additional delay due to required PCS processing
  - This makes each node a repeater or end station on string

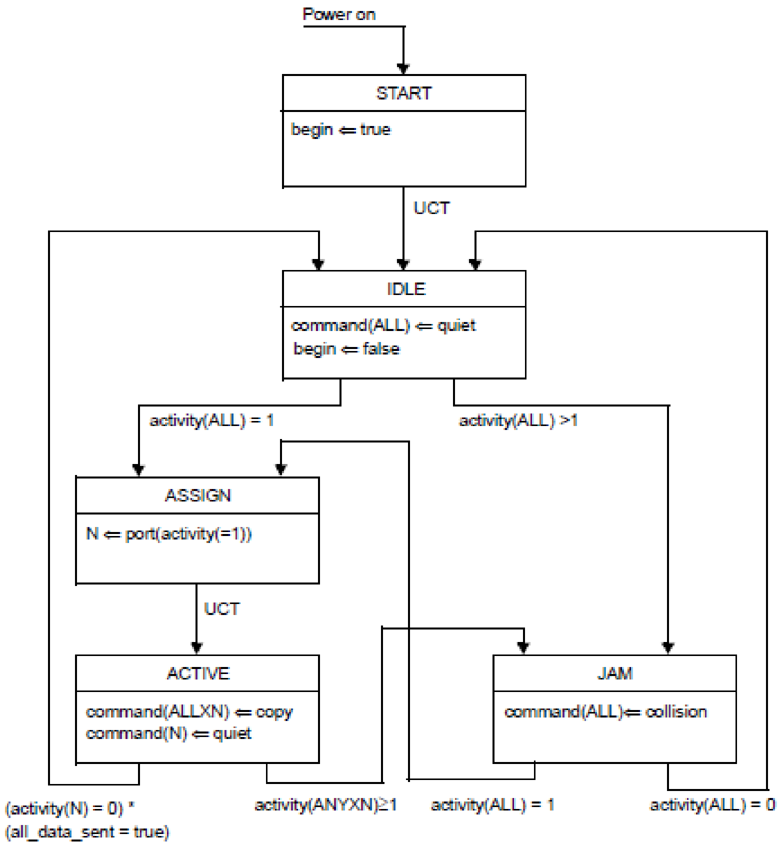



**Figure 27–2—Repeater Core state diagram**

Source: IEEE P802.3dc D.3.2, Figure 27-2

# PMD-level Interface repeater

ALTERNATIVE: Clause 27 model - PCS/PMA

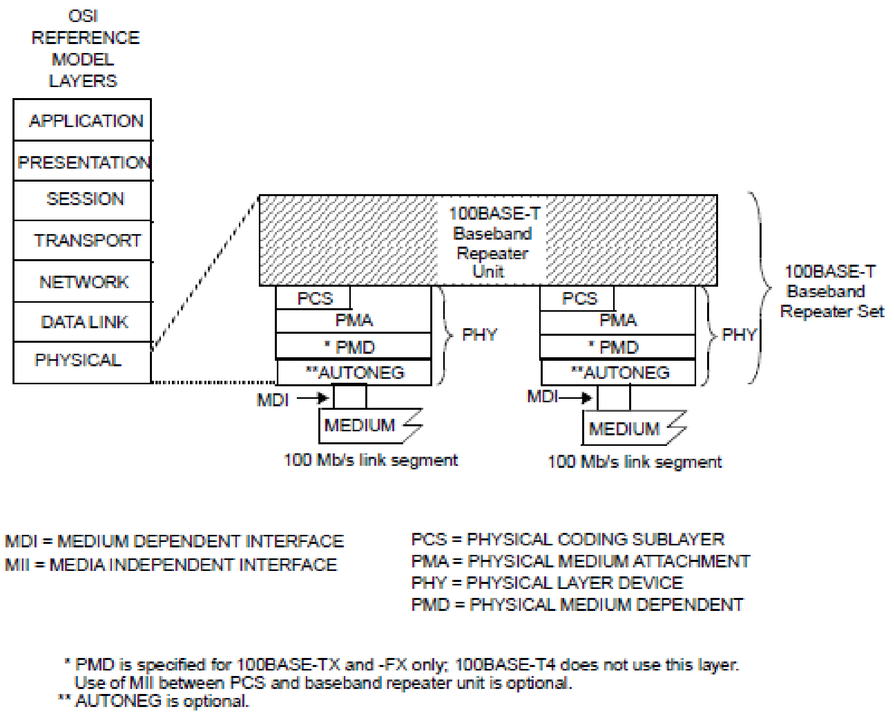
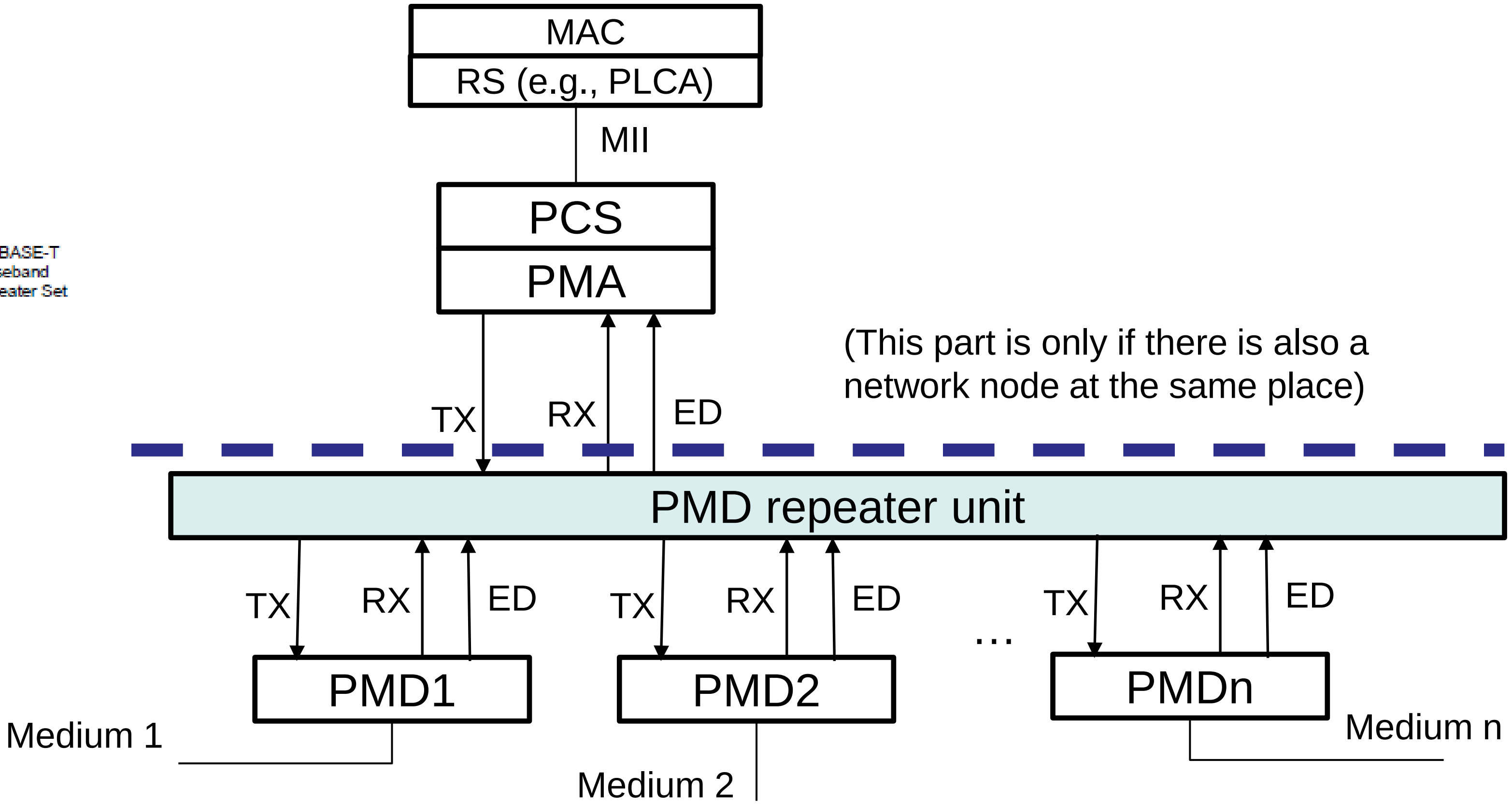


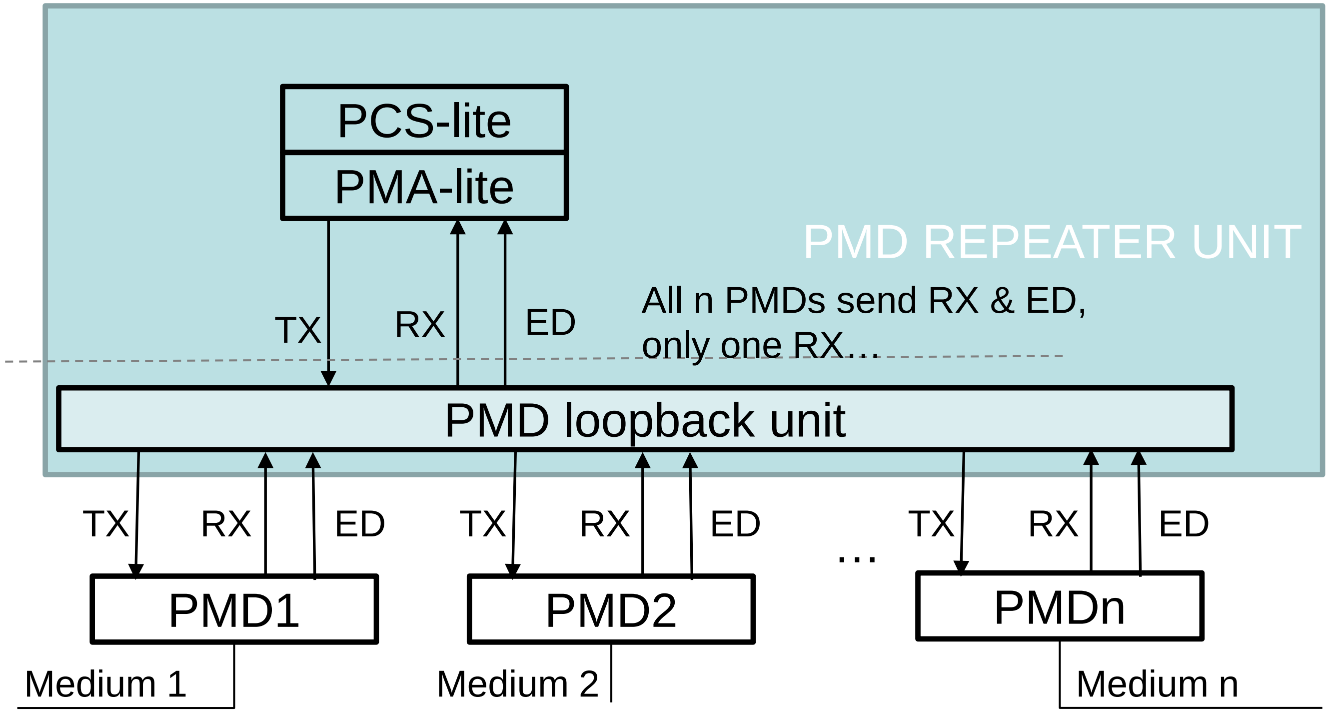

**Figure 27–1—100BASE-T repeater set relationship to the ISO/IEC OSI reference model**




Source: IEEE P802.3dc D.3.2, Figure 27-1

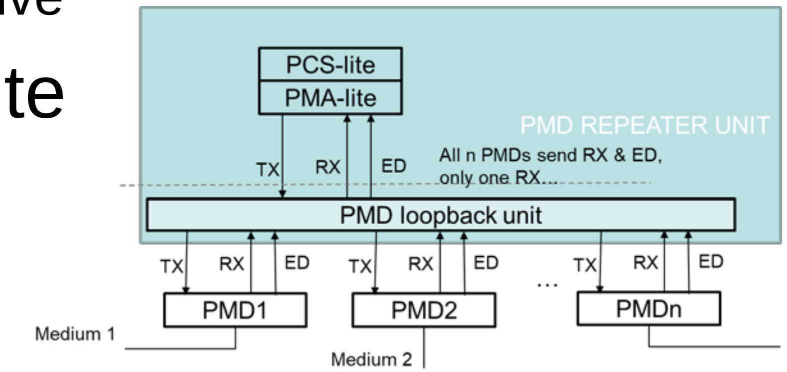
# Collision handling – “PLCA-aware” repeater with parallel codegroup validation

- Partial PCS/PMA in the repeater
- PMA-lite performs
  - Clock recovery
  - Second-stage signal quality (SQ)
- PCS-lite
  - Third-stage SQ with codegroups including PLCA signals
  - Collision detection in parallel
    - Can interrupt PMD output after the first bits are transmitted
- Minimizes delay



# Potential New Repeater State Diagram Basics

- Signal comes in on PMDn
  - Generate EDn and RXn
    - Forward to PMA-lite/PCS-lite for optional further validation
    - Further processing can distinguish noise from actual collisions
- Inter-port collision - How many EDn active?
  - If multiple EDn active, declare a collision
  - If only one EDn active, loop RXn to other ports
    - Do not propagate jam to ports that already have EDn active
- After process delay (~20 BT), PMA-lite/PCS-lite either indicates collision or gives all clear



# Big questions still to solve

- Can we / do we want to specify repeatable, plug-and-play short multidrop strings between repeaters
  - OR, do we require all nodes to be either repeaters or end-of-the-line?
- What are the delay constraints of PLCA & how much repeater delay can we tolerate?
  - PLCA Transmit Opportunity and Beacon/Commit timing are dependent on short propagation time (repeaters may limit)
- What are the implications for powering?
  - Can we bridge power across the repeater
- Do we want to include fault tolerance features

# Recommendations for 802.3da:

- Actionable: define a PMD interface for clause 147/802.3da PHYs
  - Suggest 802.3 liaise with OPEN requesting information to consider leveraging work
- Additional/need work:
  - Refinement of PHY specifications (impact mixing segments by themselves)
  - Consider collision detect & delay issues on PLCA
    - (see, e.g., TO opportunity size and performance, BEACON validation timer, etc.)
  - Determine the maximum delay that can be tolerated in a PLCA domain
  - Consider topology, i.e., do: Repeaters only connect to a single port (end node or repeater), or can they connect to mixing segments with multiple nodes attached
    - If they connect to link segments is every .3da PHY a repeater?
    - If mixing segments, could connect to Cl 147 as end stations in between repeaters

  - And the big one - how to bridge power…