802.3da Power Decision Tree

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Outline

- Define Terminology
- Present Power Specification Decision Tree
- Propose Decision Tree Results

End Markets and How (and If) to Specify Them

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Room Segments

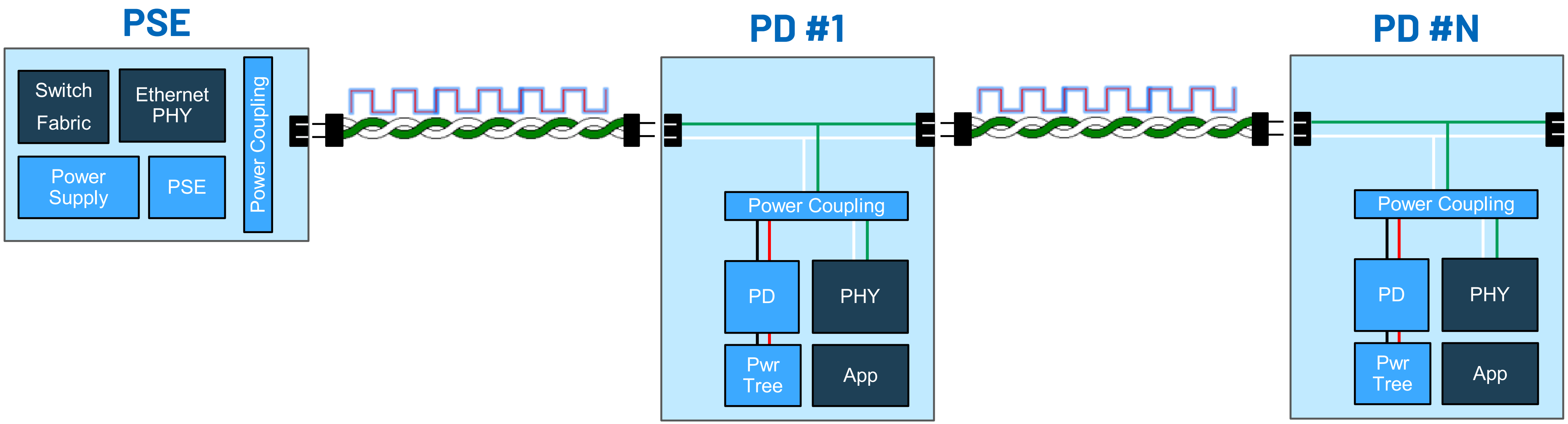
- Technician installed
- Strings (segments) of PDs spread out at moderate density
  - e.g. 10 PDs per $10m^2$
- Organic constitution and construction
- Strict cabling and topology rules
  - E.g. 100m total length
  - 18AWG cabling
  - Defined connector
  - Defined minimum PD-to-PD spacing

Chassis Segments

- Planned installations
- Strings of PDs spread out at high density
- Shorter total segment length, e.g. 10m
- Custom cabling, connectors
- Can use standard ICs

Question: Should chassis requirements effect all 802.3da requirements or a subset?

Basic Multi-drop Power/Data

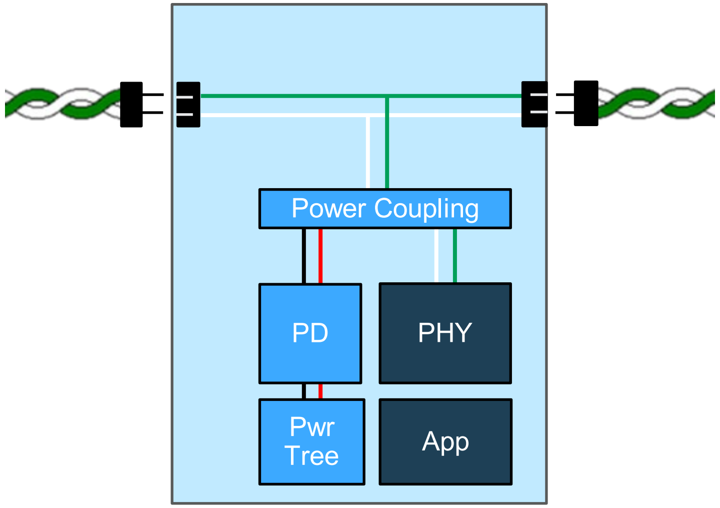


- In-Out Connection Shown
- T-connector can be envisioned
- Power and data flow through PD
- PSE Power Coupling Network (PCN) carries full current

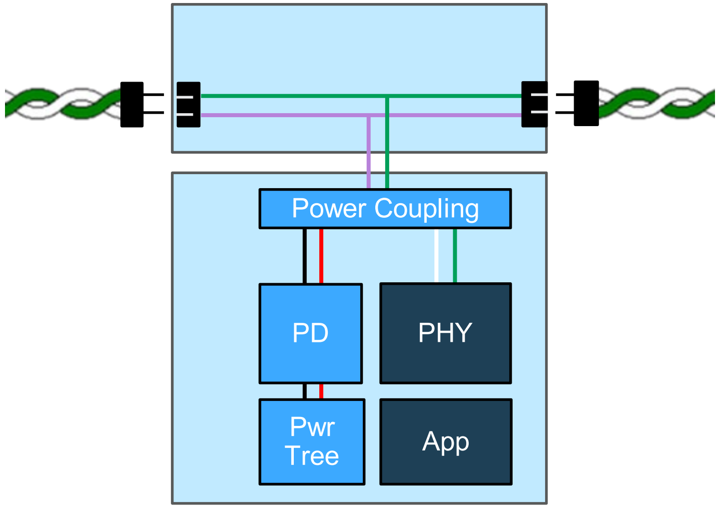
- Compensation network not shown (if needed)
- R-through-PD = $R_{Conn} * 2$
- No PCN inductor loss in through-path
- PD PCN Inductors sized to PD application

In-Out vs T Connector

PD with In-Out



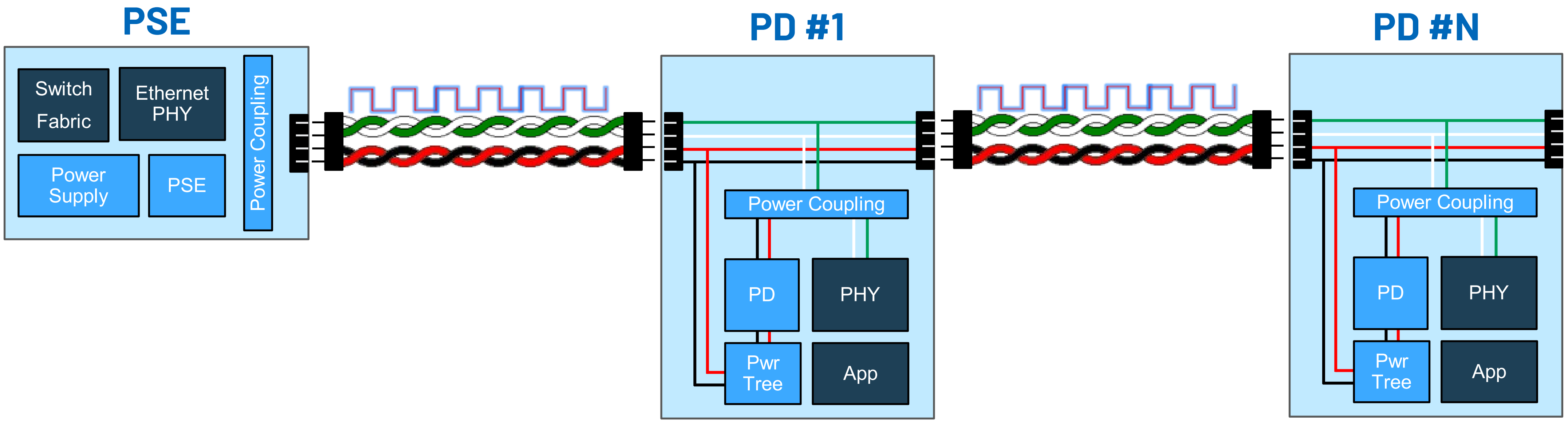
Tee and PD



- In-Out Connection
  - Ensures drop length is controlled
  - Adding a PD to the end of the segment is a seamless hot-add
  - Adding a PD to the middle of the segment will bring down all downstream PDs for the duration of the reconfiguration event
  - Only two interfaces require specification
    - PD-In, PD-Out

- Tee Connection
  - Drop length is non-deterministic
  - Hot-adds can be accomplished at any pre-installed T
  - Addition of a new T brings down the network, just like In-Out
  - Four interfaces require specification
    - T-In, T-Out, T-Node, PD-Node

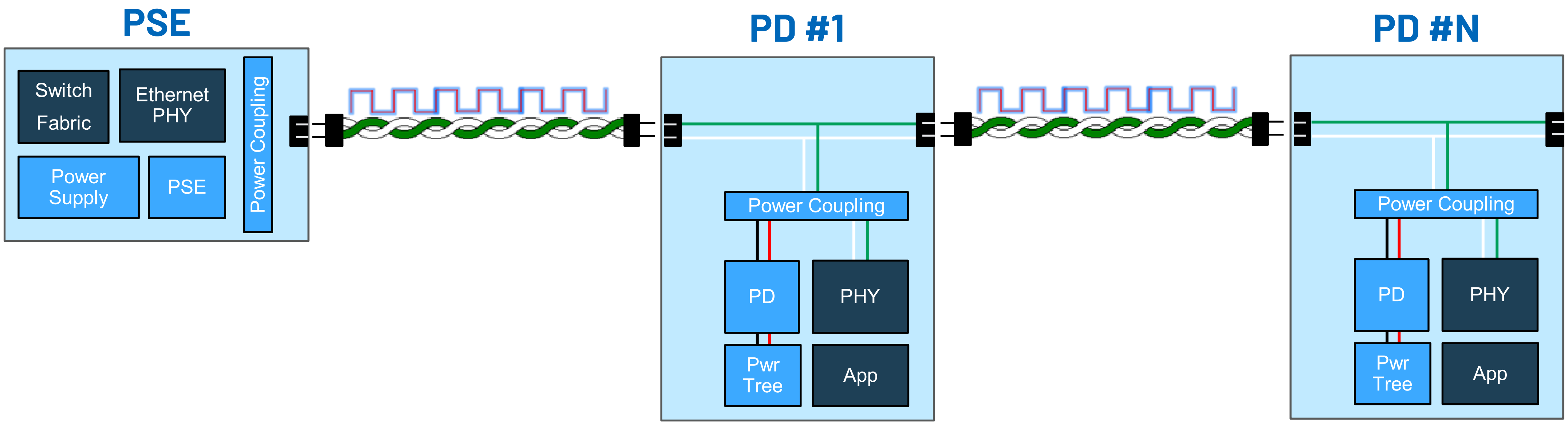
Primary Multi-drop Power/Data
Secondary Multi-drop Power



- Same Power/Data topology on Primary pair
  - Top pair, Green-White
- Additional power bus on Secondary pair
  - Bottom pair, Red-Black

- Secondary power attributes are out of scope for 802.3da
- We can **and should** consider adding LLDP telemetry, control, and power management to the Secondary power bus

Basic Multi-drop Power/Data



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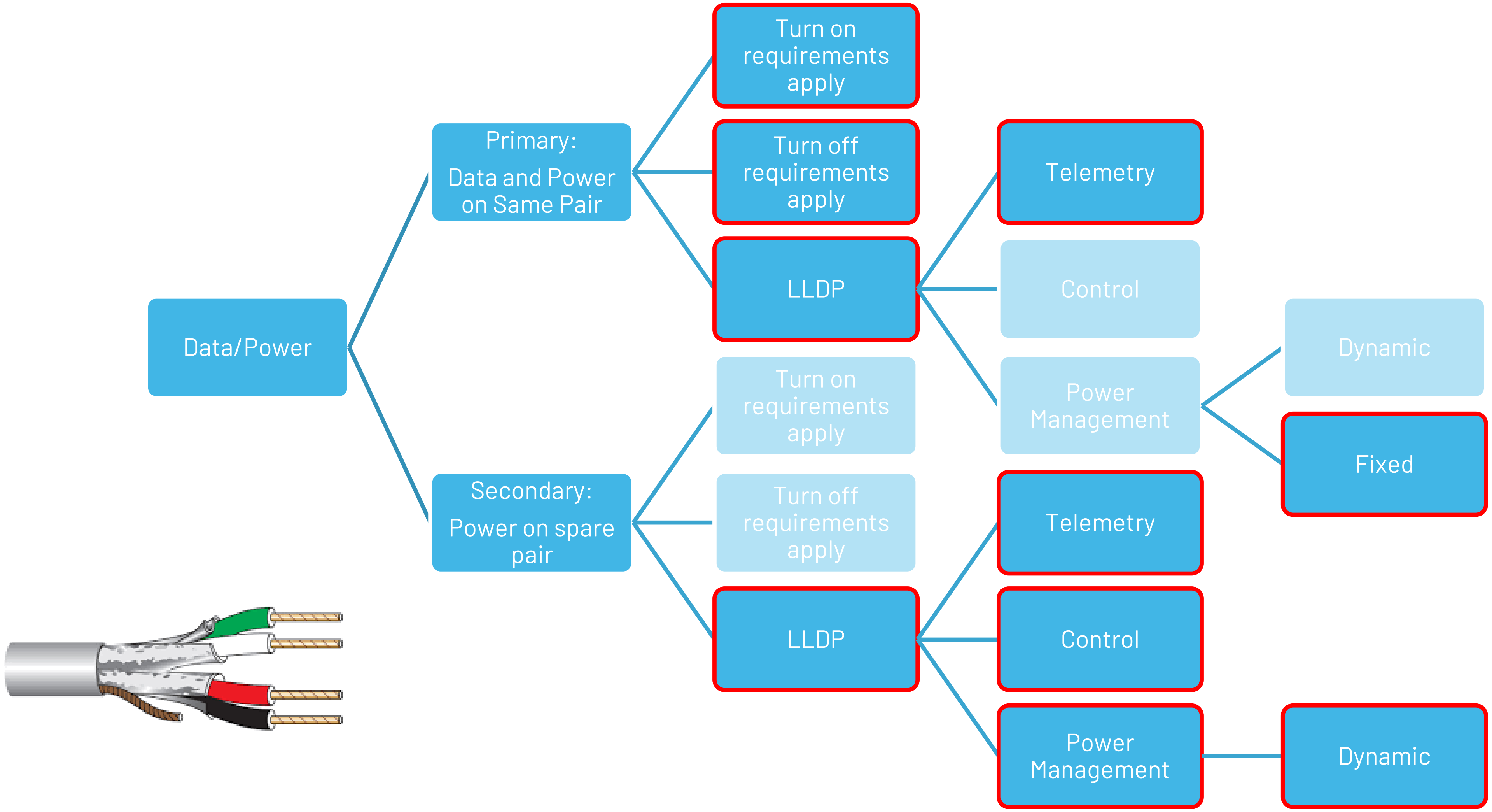
Data&Power vs Power-Only Requirements Map



PD Power Allocation

- Modern PoE switches typically have power managed allocations
  - Meaning a 48 port 802.3at 30W switch does not have a 48 * 30 = 1.44kW supply
  - Rather ports are powered until power budget is exhausted
  - Once exhausted ports will no longer be powered
  - Typically a visually indication is provided
  - In addition a network management plane will allow inspection of port power allocations

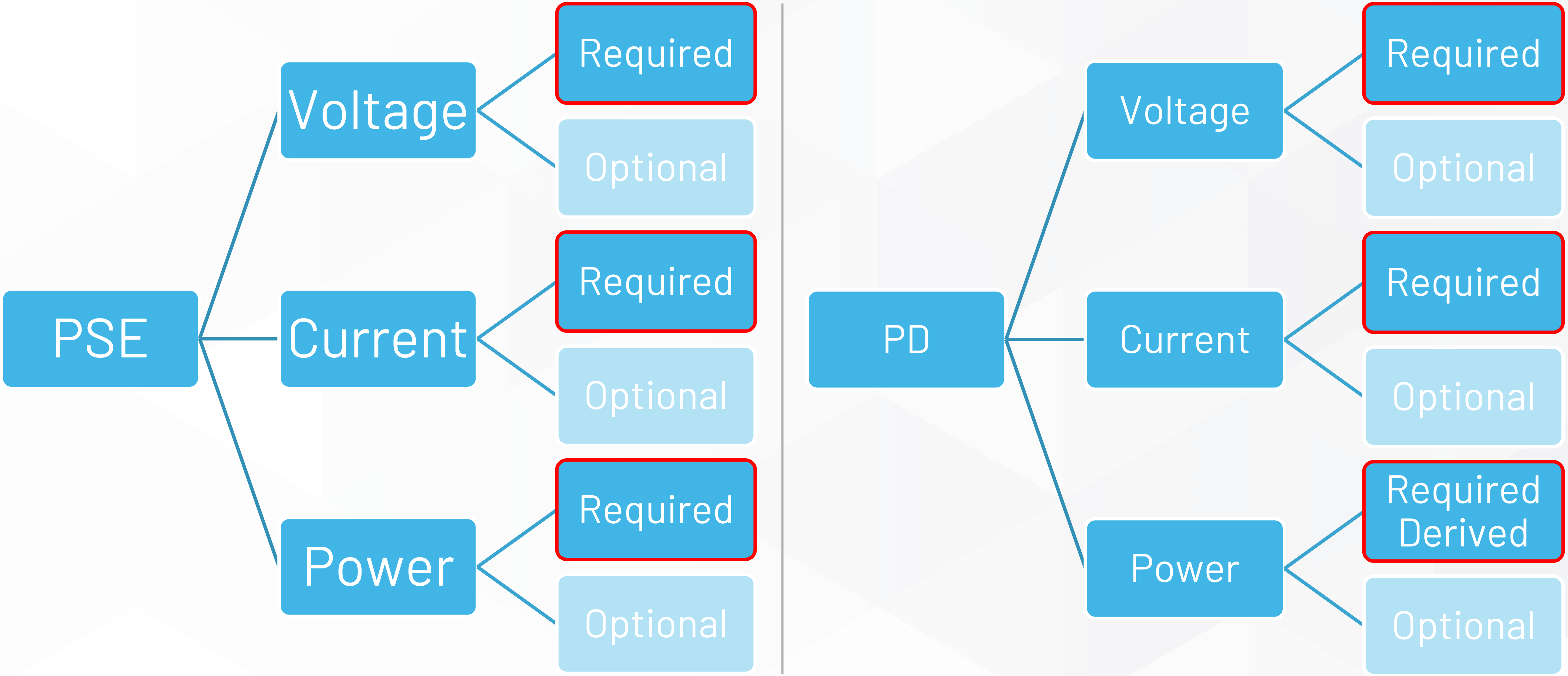
- A multi-drop PoE segment can have up to 31 PDs
- Example 1
  - PD #1 is granted the entire PSE power allocation
  - Any future hot add will bring down the link
- Example 2
  - PD #1 is granted *almost* the entire PSE power budget
  - PSE reserves
    - num_unpowered_pds * min_pd_allocation
  - Outcome is that PDs requiring more than min_pd_allocation will not be able to perform their function

Fixed PD Power Allocation

- In a fixed PD power allocation scheme each PD will be granted equal and invariant power allocation
  - $fixed\_pd\_allocation = \frac{(pse\_power - cable\_loss)}{max\_num\_pds}$

- Each PD is granted enough power for
  - PHY
  - MAC
  - Microprocessor
  - Simple IoT functions
  - e.g. 0.5W
- At 54V fixed power grant can be higher e.g. 2W
- Higher power requirements are incompatible with a high node count power sharing paradigm
- PDs requiring significant power (>2W) can utilize local mains or the secondary power bus

Telemetry


PSE
Voltage
Required
Optional
Current
Required
Optional
Power
Required
Optional
PD
Voltage
Required
Optional
Current
Required
Optional
Power
Required Derived
Optional

Symmetric PSE/PD Telemetry Requirements

- Multi-drop systems rely on collaboration and compliance
- $I_{PSE} = SUM(I_{PD[0..n]})$
- Security via telemetry
  - Operational states can be spoofed
  - Power states cannot be easily spoofed
- *Note:* PSE and PD current measurement accuracy limit utility

Example

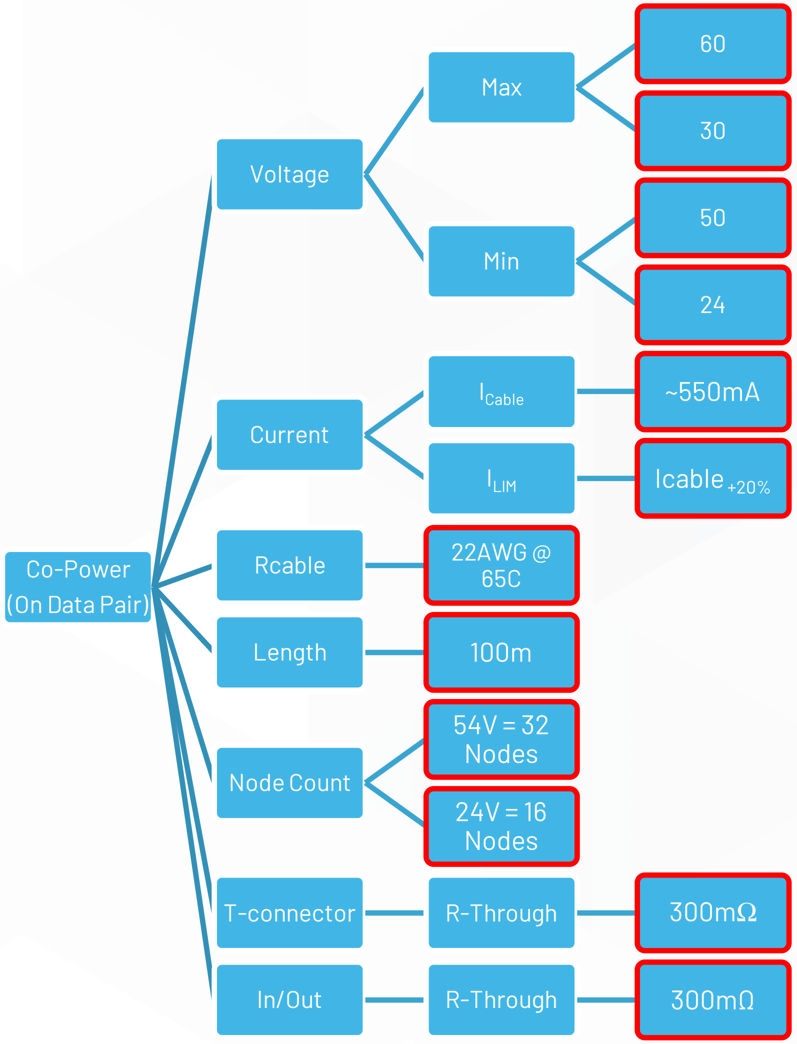
- 54V System
- 10 PDs connected and powered
  - All report $I_{PD[0..n]} = 30mA \pm 5\%$ (each)
  - $SUM(I_{PD[0..n]}) = 300mA$
  - 1 malicious PD is actually drawing 80mA
- Are all PDs in their reported power states?
- PSE reports $I_{PSE} = 350mA \pm 3\%$
- $I_{PSE} \mathrel{!=} SUM(I_{PD[0..n]})$
- Conclusion
  - **One or more PDs is in an illegal state**

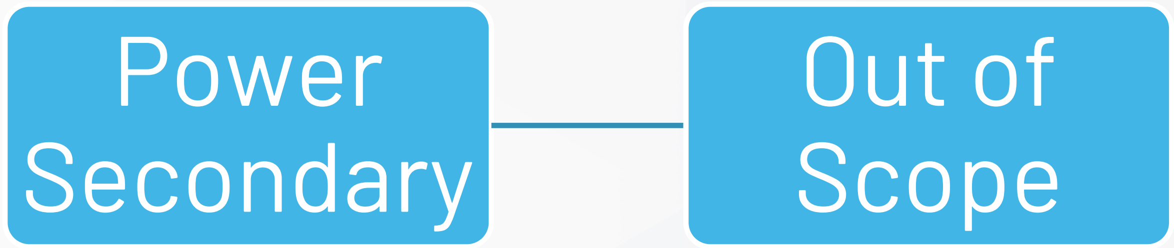
Midspans

- Midspans allow power to be added to a network retroactively
- Midspans do not have data access
- Power debug of a Midspan-based segment is not possible
- Midspans will have non-deterministic effects on signal integrity
  - Power coupling network is not co-located with PHY

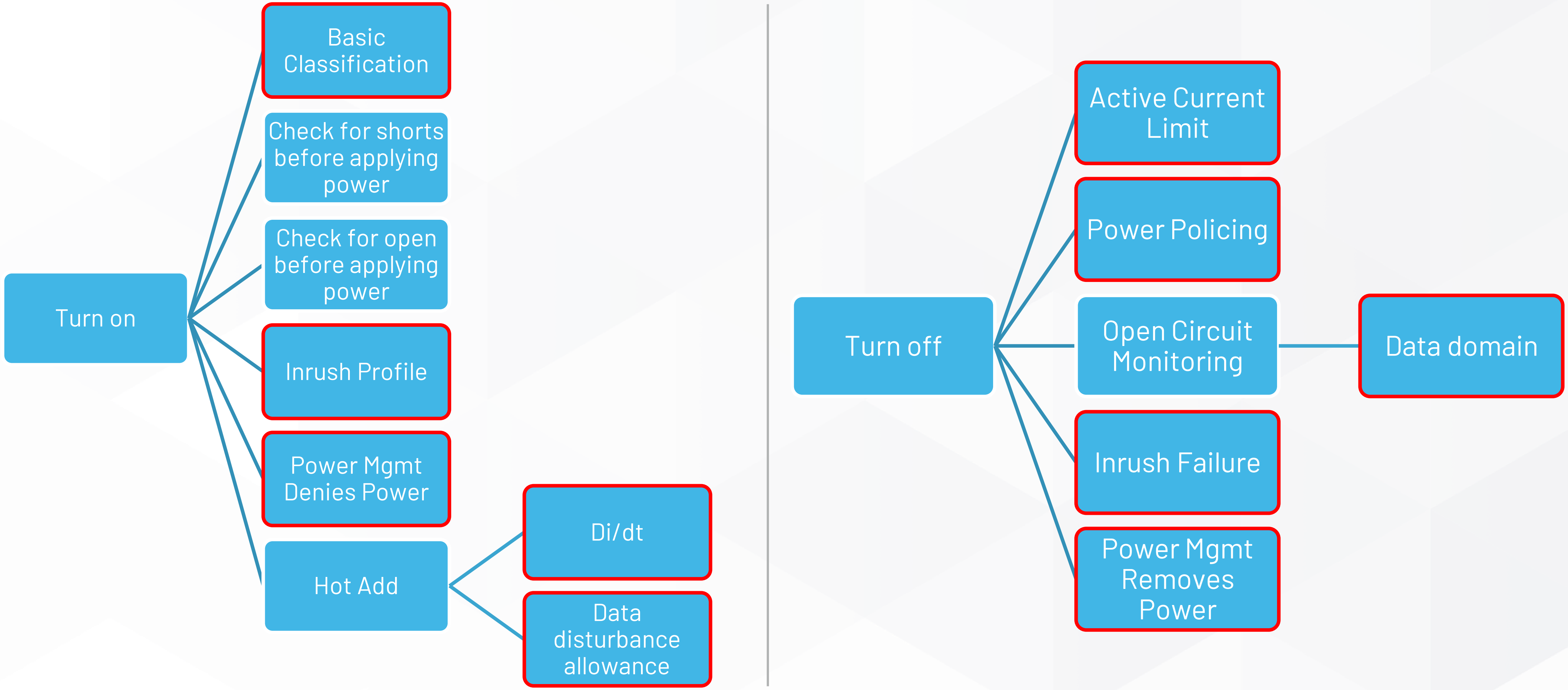
- **Propose:** Midspans are left out of scope
- **Propose:** PSE are required to provide Voltage, Current and Power telemetry
- **Propose:** PDs are required to provide Voltage, Current and Power telemetry

Power Attributes





Power Control



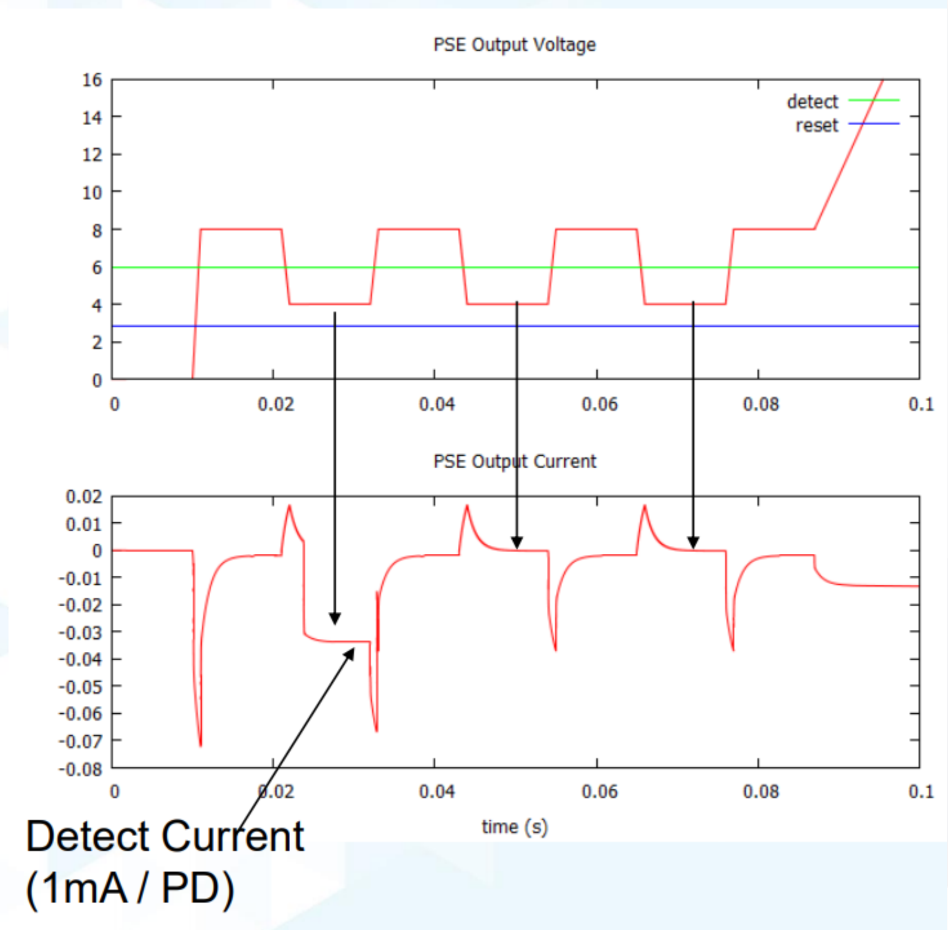
Basic Classification

- Axioms
  - Multi-drop links are communities
  - Members must behave
  - Identifying and eliminating bad actors culminates in working networks
- **Option 1:** Always hot with limited current/voltage
  - No segment debug assistance
  - Not best-effort nor state-of-the-art
- **Option 2:** Basic detection
  - Is at least one valid 802.3da PD present?
  - Allows power to be applied only when a valid PD is present
    - Not short
    - Not completely open
    - Difficult to support deterministically with parallel PDs
- **Option 3:** Perform classification
  - Simple "vote"
    - 802.3da 24V PD(s) present?
    - 802.3da 54V PD(s) present?
    - 802.3da Hybrid 24V/54V PD(s) present?
  - Creation of multiple voltage classes pragmatically mandates classification discovery
- Consider
  - Segment populated with
    - (30) 54V PDs, (1) 24V PD
  - PSE preforms classification
  - PSE reports "Illegal device mix"
  - IT department opens ticket

Basic Classification, Continued

- Possible **Basic Classification** status result codes
  - (not exclusive) At least one 24V PD present
  - (not exclusive) At least one 54V PD present
  - (not exclusive) At least one 24/54V PD present
  - (exclusive) Open
  - (exclusive) Short
  - (exclusive) Classification error

- See paul_01_da_051921

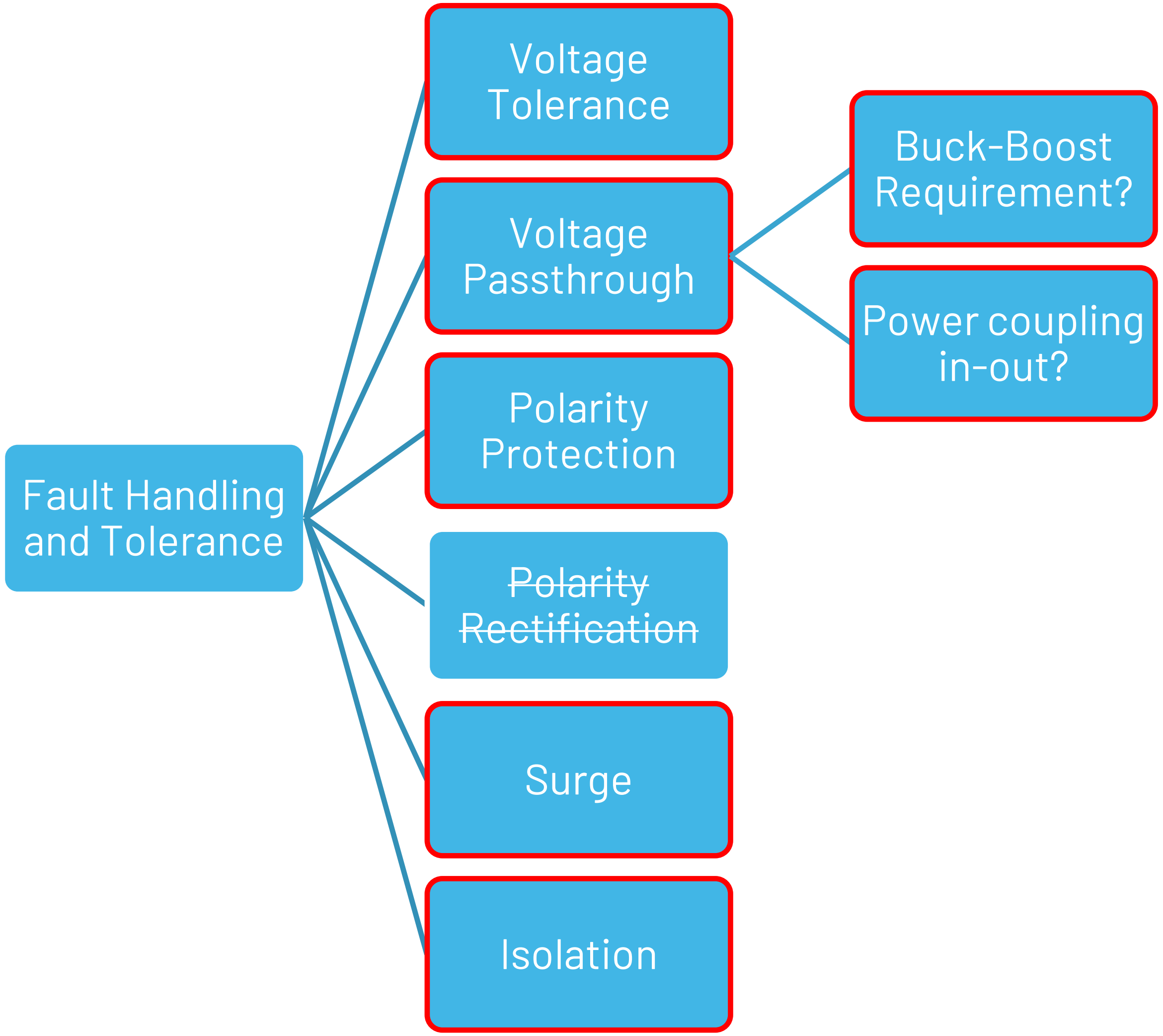


Open Circuit*

- Proposed minimum PD power allocations have been as low as 0.5W
- At 54V, 0.5W, PD Current is 9.25mA
- If a single PD is populated it is very difficult to differentiate a single PD in standby mode from an open circuit
- Example: If all PDs must draw 5mA, 31 PDs would consume
  - 31 * 5mA * 54V = 8.4W

- Propose
  - PDs can draw 0 mA sleep current
  - Data link queries PD presence periodically
  - Packet or LOS signaling
  - If zero PDs respond in “query” interval
    - Remove power
- Discussion
  - Does 802.3da support PHY-based open-circuit detection?

Power Handling and Tolerance



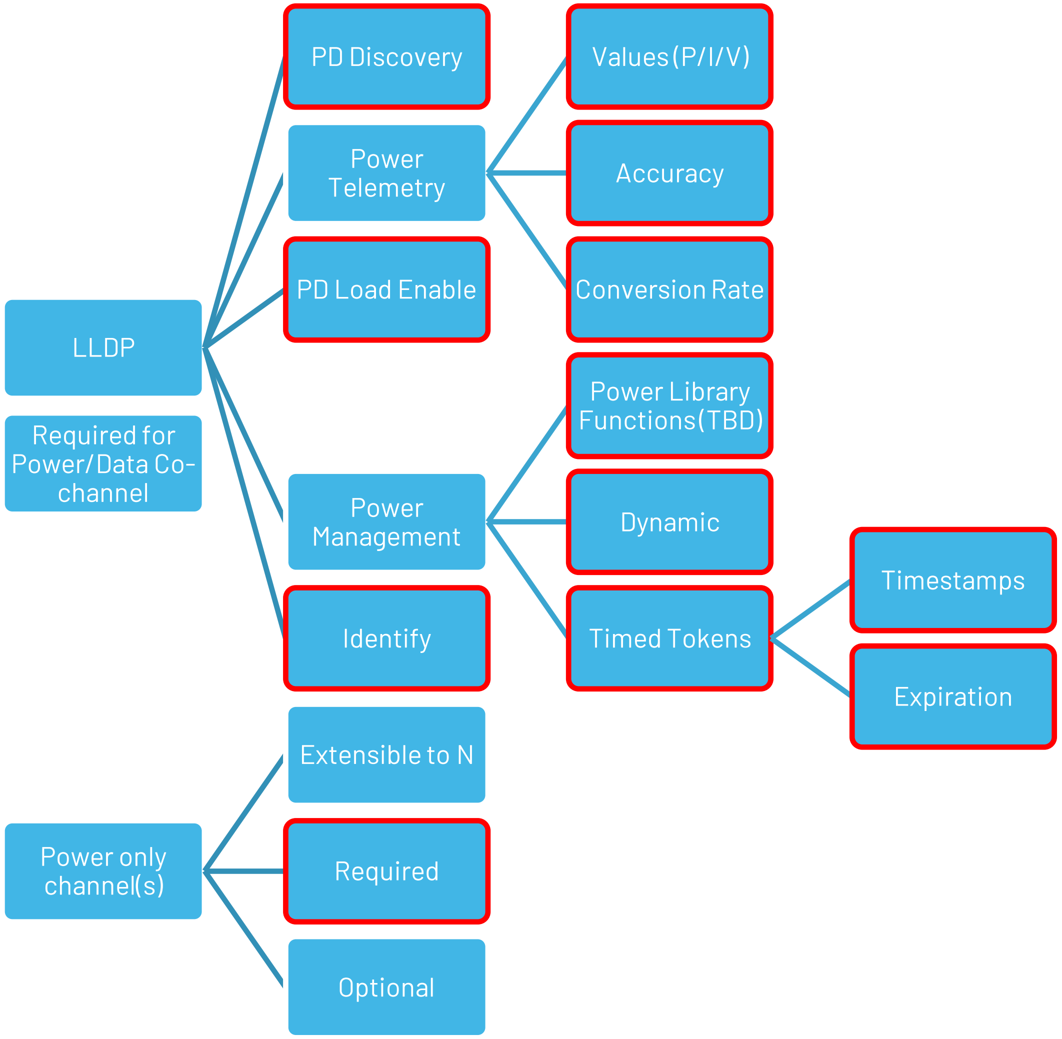
Power Handling and Tolerance

Topic	Sub-topic	
Voltage Tolerance		Given the multi-drop, hot add paradigm: **Propose** all PDs must tolerate 60V and I_{PSE} indefinitely
Voltage Passthrough	Direct Connect In-Out & T	(Avoiding compensation circuit discussion as orthogonal to power discussion) **Propose** Direct Connect is lowest relative power loss and lowest relative cost
	Buck-Boost Requirement	Buck-boost stage invokes ~10% power loss **Propose** avoid requirements leading to node buck-boost
	Power Coupling In-out	Power coupling in-out invokes 100s of mOhm of IR drop and significant relative cost disadvantage **Propose** no power coupling in through-path

Power Handling and Tolerance, Continued

Topic	Sub-topic	
Polarity Protection		Mis-wiring can occur. A simple polarity swap should not damage equipment. **Propose** PDs are non-functional but tolerant-to polarity swap
Polarity Rectification		Relative cost of polarity rectification is high. This feature offers limited real-world benefit (see "Polarity Rectification"). **Propose** No polarity rectification requirement.
Surge		**Propose** Mimic Clause 145
Isolation		**Propose** Mimic Clause 145

LLDP Features – Hide for now



Assumptions

- Data related discussions describe the number of nodes as N
- For power related discussions power network performance is a function of the number of PD nodes
  - Data nodes = N
  - PSE node = 1
  - PD nodes = N-1