# IEEE 802.3 Single Pair Ethernet Enhancements
# Call for Interest Consensus Building Meeting

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Peter Jones / Cisco

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3/8/21

# Supporters & Contributors

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Piergiorgio Beruto - CanovaTech
David Brandt – Rockwell Automation
Theo Brillhart – Fluke
Steve Carlson – High Speed Design
Clark Carty – Cisco Systems
John D'Ambrosia - Futurewei
Chris DiMinico – MC Communications
Lars Ellegard – Microchip
Peter Fischer – BKS Kabel-Service AG
Matthias Fritsche – HARTING
Michael Hilgner - TE
Wayne Hopkinson – Commscope
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Jon Lewis – Dell EMC
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Mick McCarthy – ADI
Brett McClellan - Marvell
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Steve Zuponcic – Rockwell Automation

# Agenda

- What is Operational Technology and how does SPE fit into it?
- What Needs Enhancing?
- Near Term: Providing for TSN on SPE Trunks
- Long Term: The Next Step in long-reach pt-to-pt SPE
- Why now?
- Wrap-up and Q&A

# Why are we here?

- To:
  - Initiate discussion on the uses of Single Pair Ethernet in Operational Technology Networks
  - Enhance anything left out of point-to-point Single Pair Ethernet necessary for deployments in Operational Technology
  - Begin discussions on the next steps and future roadmap of point-to-point Single Pair Ethernet for Operational Technology

P. Jones

# WHAT IS OPERATIONAL TECHNOLOGY AND HOW DOES SPE FIT INTO IT?

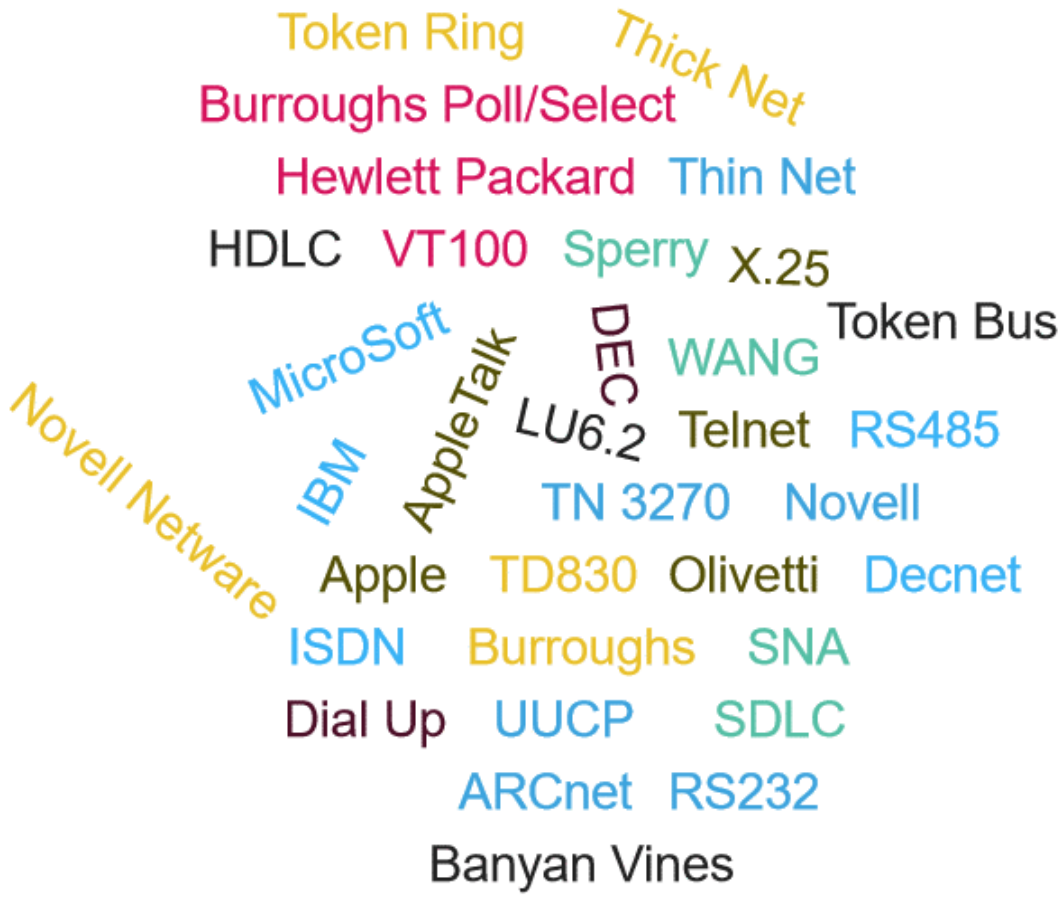
# What are OT Networks?

OT networks are control networks

They monitor and control the profit-making assets of a business (e.g. factories, buildings)

SPE targets edge applications in OT networks

# IT Transition circa 1990





# OT Modernization Challenge

EtherNet/IP
Foundation FieldBus
Mitsubishi Electric
RS232 Yokogawa DALI
Modbus Signify CAN
Schneider Electric
ABB
Kone VAN
MOST
Emerson Byteflight
EtherCAT IEBUS D2B Omron SCADA
FlexRay Endress Hauser
Rockwell Automation
ProfiBus 4-10mA
PROFINET
Two Wire
FieldComm
HART
RS485
JCI
FDI
Siemens
CIP
Honeywell
Pepperl Fuchs
ODVA
DeviceNet
ControlNet
CompoNet

Physical Conditions, Cabling Structures, etc

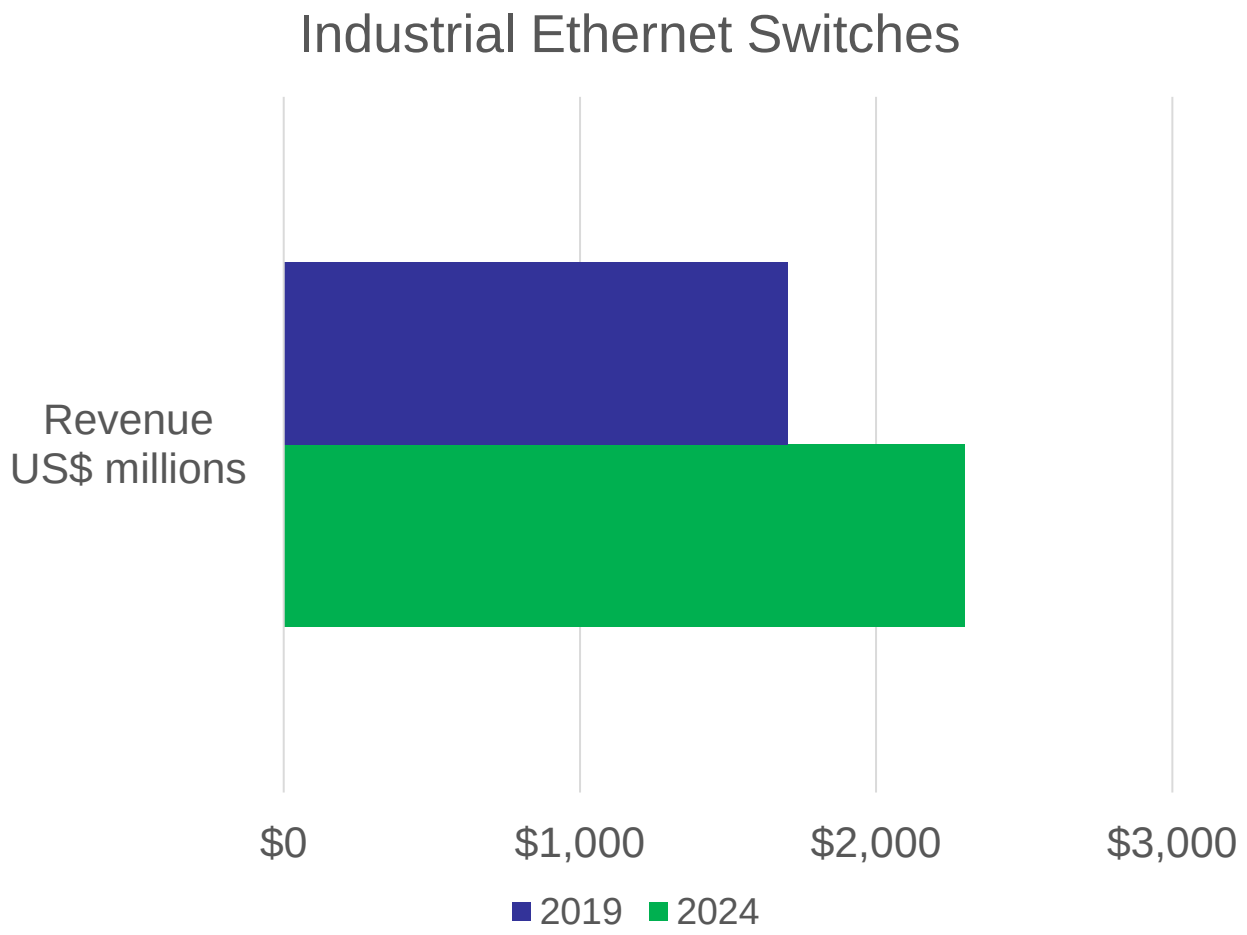

# Promise of Ethernet for OT Network

| | |
|---|---|
| Improved Cybersecurity | • Improved cybersecurity via Ethernet adoption |
| Flatter Networks | • Reduce or eliminate protocol translation gateways |
| Single Connection | • Power and data delivered with one connection |
| Plug and Play | • Simpler and easier to deploy |
| SPE Advantage | • Suited for the target environments and topologies.<br>• “Right Sized” for the sensor market |

# Industrial Ethernet Market Size

Industrial edge networking components (includes switches, routers, access points, gateways, connectors).

- The world market for in 2019 is estimated to have been $2.86 billion
- Switches are the bulk of the revenue.
- In 2020, revenues are forecast to decline by 3.4%; overall, from 2019 to 2024, revenues are forecast to grow at a 7.1% compound annual growth rate (CAGR). The decline in 2020 is the result of the economic meltdown due to COVID-19.
- Unit shipments are forecast to grow at a 6.7 % CAGR from 2019 to 2024, while the ASP is forecast to increase at a 0.4% CAGR.




Data: Omdia - https://www.cisco.com/c/dam/en/us/solutions/collateral/internet-of-things/omdia-industrial-edge.pdf

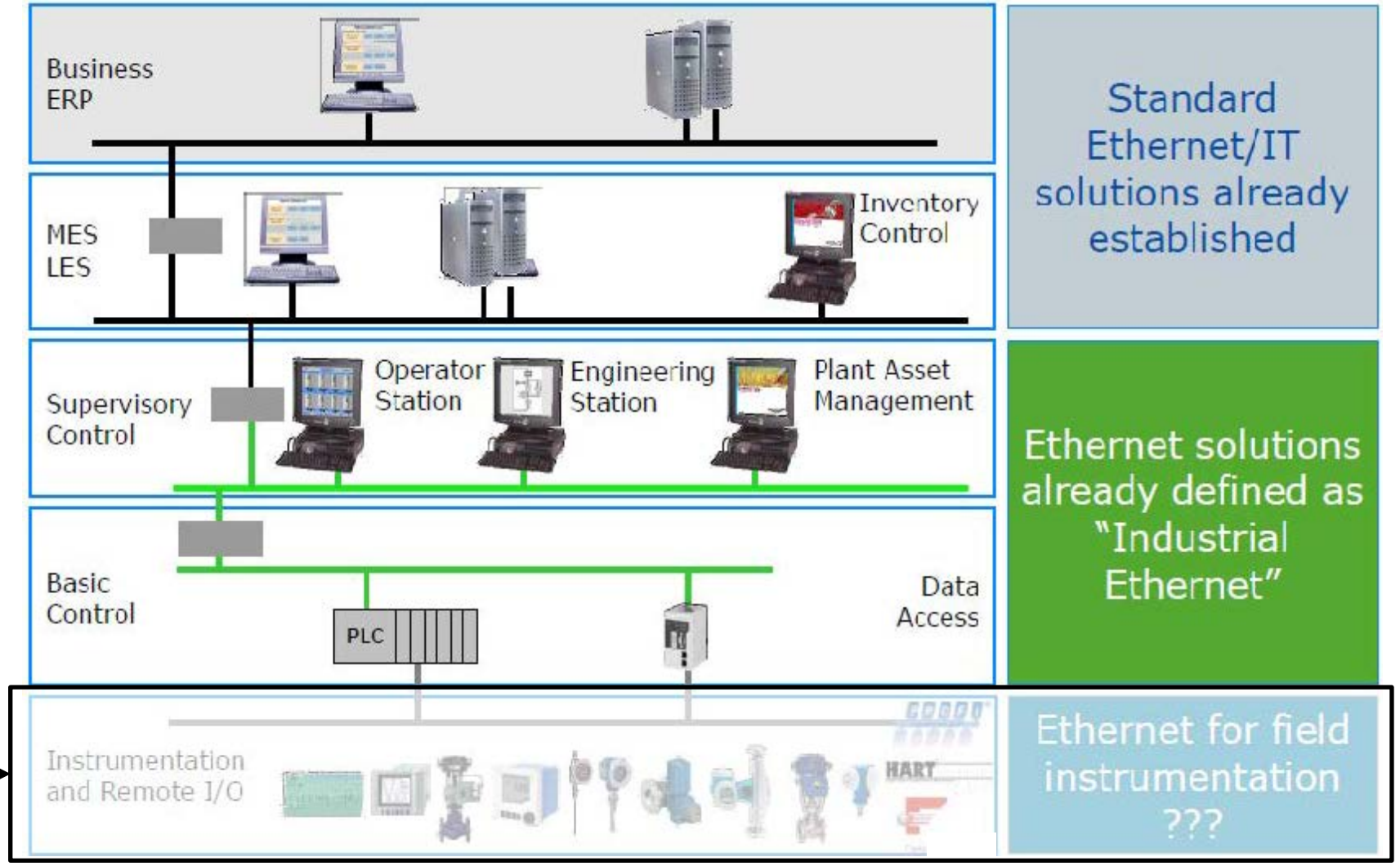
# Ethernet in OT Edge

Non-Ethernet fieldbuses still required to complete communications to the edge

- Cable lengths > 1km
- 1200 baud to hundreds of kb/sec
- Challenges: Combined reach & rate, special environments, cost of operation

Ethernet Gap at the 'Edge' →

*Credit: Dr.Raimund Sommer, Endress+ Hauser, ODVA Industry Conference, Oct. 2014.*




From https://www.ieee802.org/3/cfi/0716_1/CFI_01_0716.pdf

# Expanding Ethernet in OT

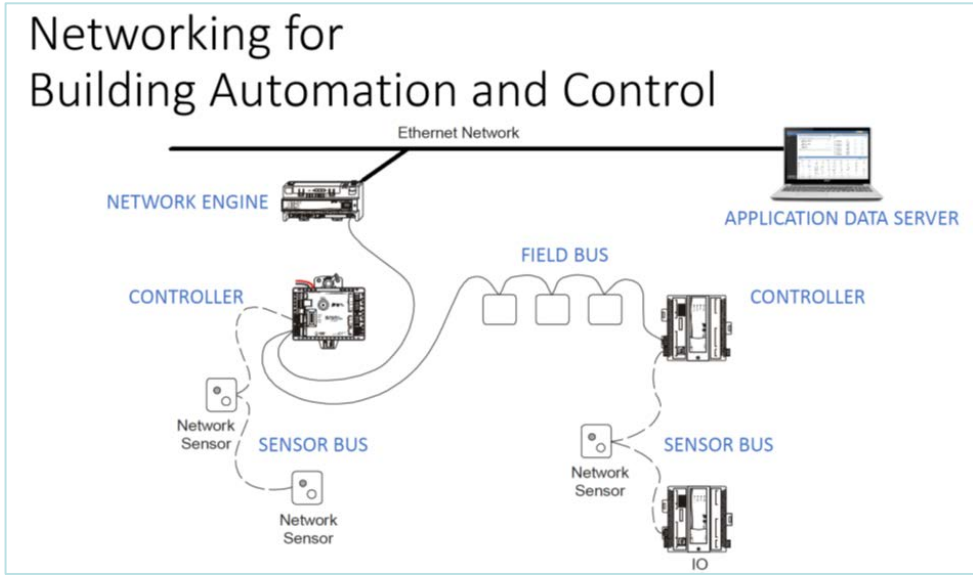
| | |
|---|---|
| Familiar Topologies | • ***Network topology driven by use case***<br>• ***Point to point, multidrop, trunk & spur***<br>• ***Reach, cable type*** |
| Power Delivery | • ***Power small device (e.g., sensor, field switch)***<br>• ***Power control system for larger device (e.g., HVAC air handling unit)*** |
| TSN - synchronization | • ***Precision Time Protocol (e.g., IEEE 1588 default, 802.1AS, IEC 62439-3, SMPTE 2059)***<br>• Tracking events<br>• Coordinating actions |
| TSN – Latency | • ***Frame Preemption (IET)***<br>• Credit Based Shaper<br>• ***Scheduled Traffic*** |
| TSN – Reliability | • Frame Replication and Elimination<br>• Path Control and Reservation<br>• Per-Stream Filtering and Policing |
| TSN - Resource Management | • Stream Reservation Protocol<br>• Link-local Registration Protocol<br>• LLDPv2 for MultiframeData Units<br>• Multicast and Local Address Assignment |

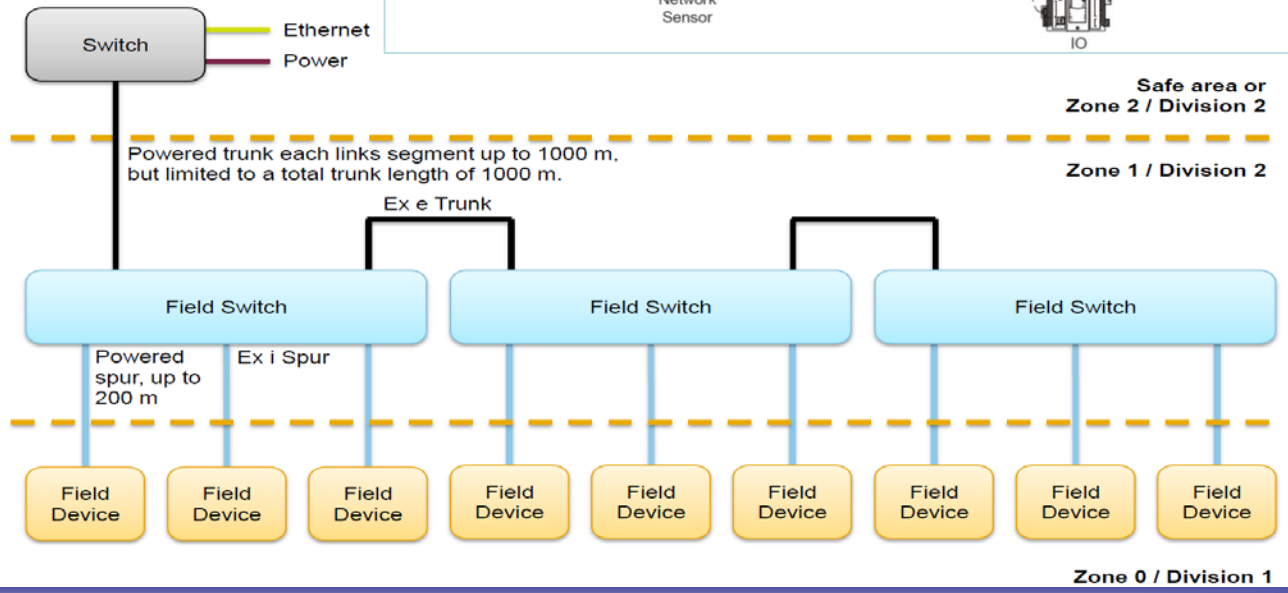
G. Zimmerman

# WHAT NEEDS ENHANCING?

# Example SPE Cases

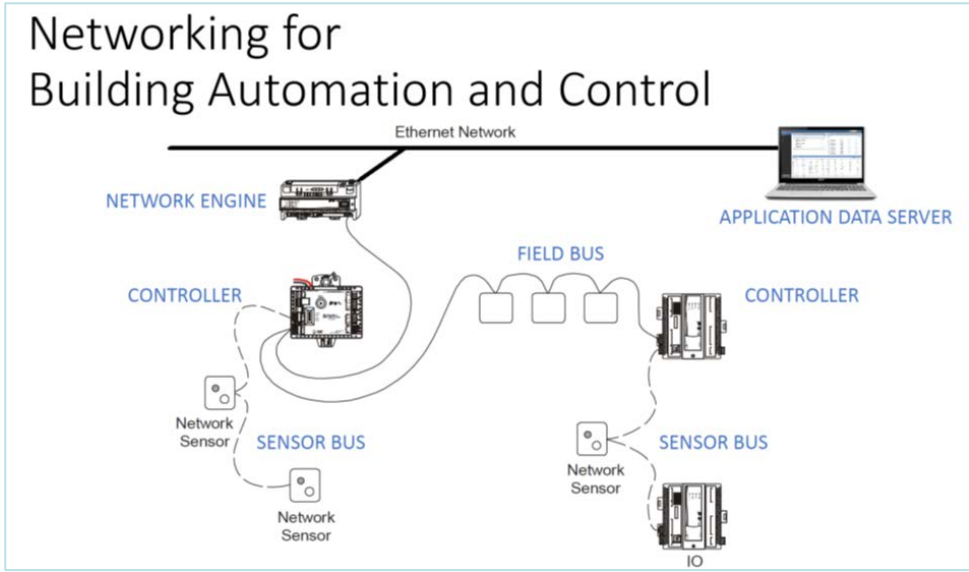
- Short:
  - In-cabinet, chassis
  - Vehicles
  - Multipoint topologies
- Medium:
  - Industrial pods (5-40m)
  - Building control networks (50-100m)
  - Process control “spurs” (200m)
- Long:
  - Process control trunks (1km)
  - Building automation trunks (500m)
- Application drives cabling (e.g., wire gauge)



# Enhancements: 802.3da

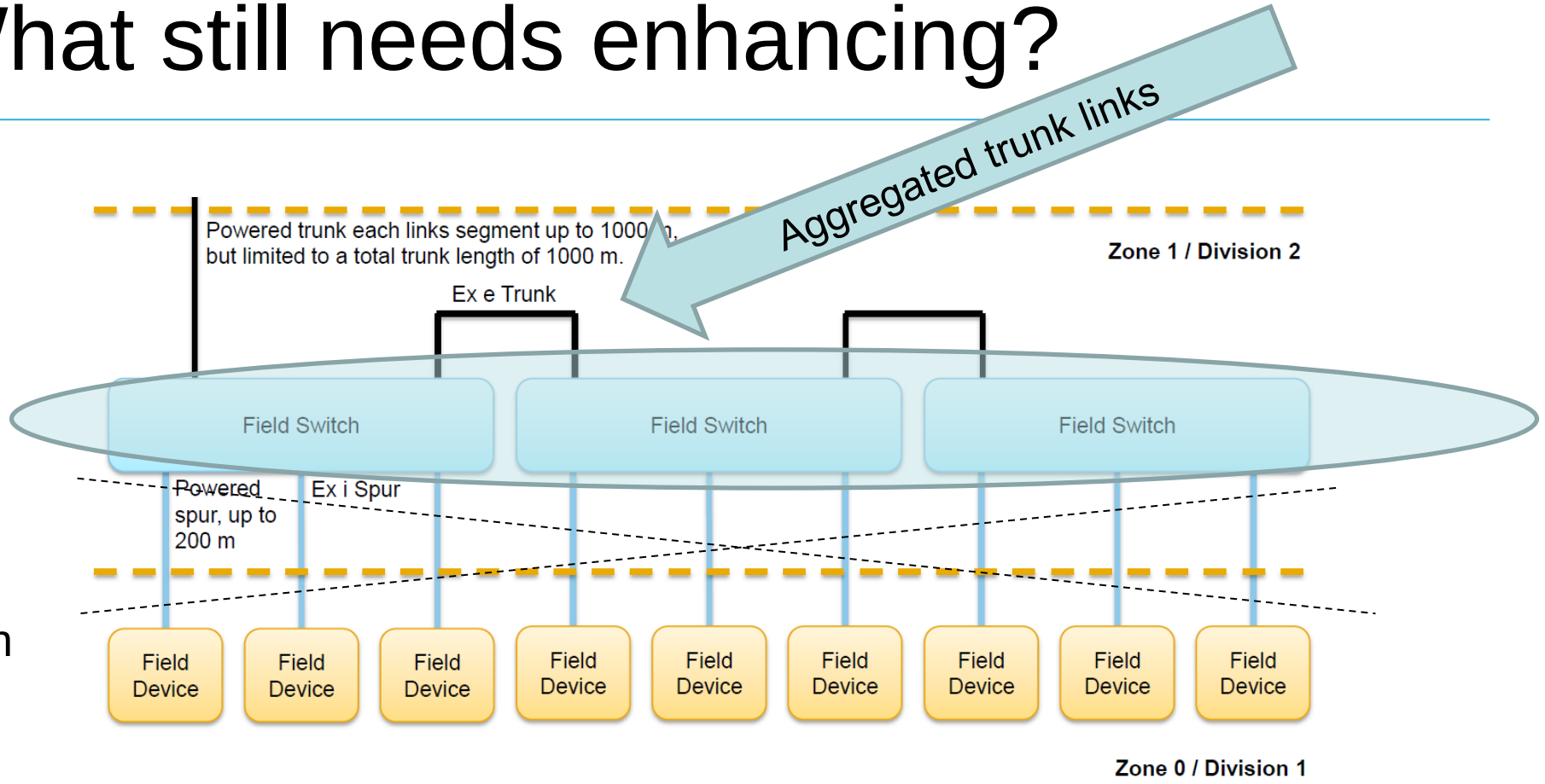
- Short:
  - In-cabinet, chassis
  - Vehicles
  - Multipoint topologies
- Medium:
  - Industrial pods (5-40m)
  - Building control networks (50-100m)




802.3da **multidrop** **(NOT THIS CFI)**

# What still needs enhancing?

- Long:
  - Process control trunks (1km)
  - Building automation trunks (500m)
- Medium
  - Higher bandwidth devices (spurs, 200m) will follow trunks

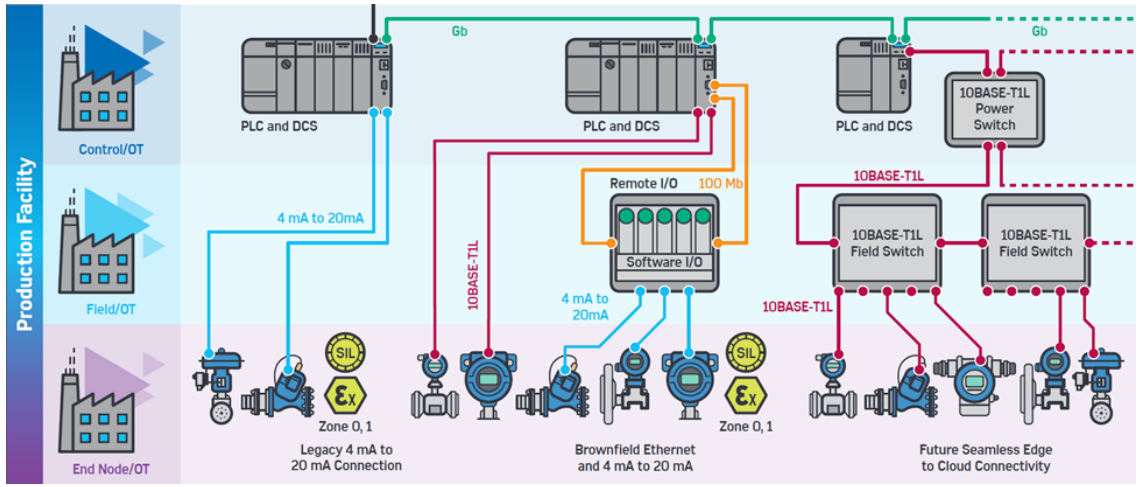



*This has two parts: Near-term (initial 10BASE-T1L deployments), and Long-term (providing for growth 4-5 years from now)*

# THE NEAR-TERM: PROVIDING FOR TSN ON SPE TRUNKS

# Process Automation (PA) Characteristics

- A PA system is used to control a process such as chemical, steel, oil refineries, petrochemical, paper or pulp factories.
  - Individual stations are spread over a large geographical area.
  - 10BASE-T1L is needed to provide connectivity over these distances.
- PA data consist of many analog values, such as temperature, pressure, flow, or level.
- Fast control cycle is NOT required (1 sec cycle is enough in many cases).
- A PA system operates 24x7x365 and requires procedures to stop safely.
- Hence, the extra high reliability and availability is required



# Communication Example (in a TSN domain)

- Application Scan Interval
  - HMI: 1,000ms
  - **Controller: Basic 1,000ms, Fast 100ms**
- Controllers to HMI (monitoring)
  - Data size: 1,400 Byte
  - Up to 3,000 subscribed signals per scan interval
  - Scan interval: 1,000ms
- IO Control Data Size (PV or MV)
  - 4 Byte data + 1-4 Byte status per IO item
  - Up to 1,024 Byte per IO-Station (which has up to 128 IO items)
  - Input vs. Output = 2:1 (typically)
- IO-Stations to Controllers (input)
  - Up to 2,000 published signals per scan interval (typical 1,500)
  - Scan interval: **100 - 1,000ms (typical 1,000ms)**
- Controllers to IO-Stations (output)
  - Up to 2,000 published signals per scan interval (typical 750)
  - Scan interval: **100 - 1,000ms (typical 1,000ms)**
- Controllers to Controllers
  - Up to 1,000 published signals per scan interval
  - Scan interval: **50 - 500ms (typical 500ms)**

# Minimizing Latency for important traffic

- In the presence of so many traffic sources, congestion is inevitable
- The 60802 Profile defines seven traffic types to accommodate traffic
  - Due to the comparatively slow control loop cycles, the added complexity of scheduled traffic is usually undesirable
  - However certain traffic types required minimized latency, making the MAC Merge sublayer desirable

| Traffic type name | Cyclic | Data delivery requirements | Time-triggered transmit | Traffic-type-category |
|---|---|---|---|---|
| Isochronous | Yes | Deadline | Yes | IA time-aware-stream |
| Cyclic-Synchronous | Yes | Latency | Yes | IA time-aware-stream |
| Cyclic-Asynchronous | Yes | Latency | No | IA stream |
| Alarms and Events | No | Latency | No | IA traffic engineered non-stream |
| Configuration & Diagnostics | No | Latency | No | IA traffic engineered non-stream |
| Network Control | Optional | Latency | No | IA traffic engineered non-stream |
| Best Effort | No | N/A | No | IA non-stream |

# So, What's the Problem?

- Clause 99.1 in IEEE Std 802.3-2018:
  "specifies an optional MAC Merge sublayer for use with a pair of full-duplex MACs and a single PHY operating at 100 Mb/s or higher on a point-to-point link"
  - This makes perfect sense in that many 10 Mb/s PHY do not support the PCS and thus will not recognize the the SMD which is the Start of Mpacket Delimiter
  - However the newer 10 Mb/s PHY technologies (T1L and T1S) do support the PCS and will work with the MAC Merge sublayer
- Other TSN features (scheduled traffic, FRER, ATS, etc.) are already compatible with these PHY technologies.

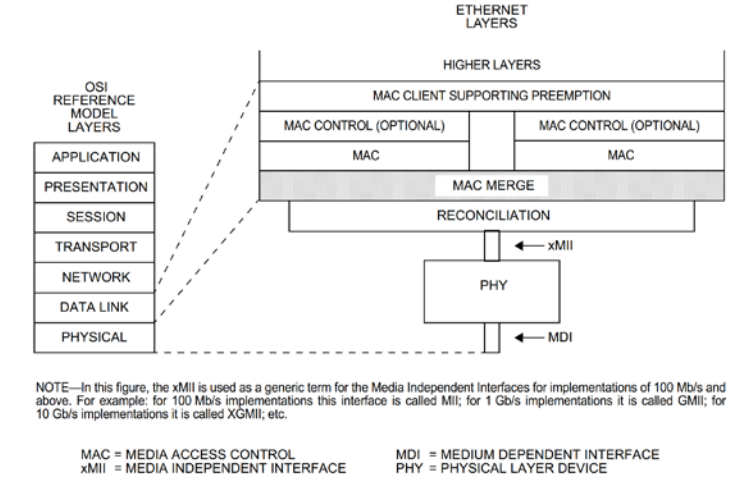



**Figure 99–1—Relationship of MAC Merge sublayer to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model**

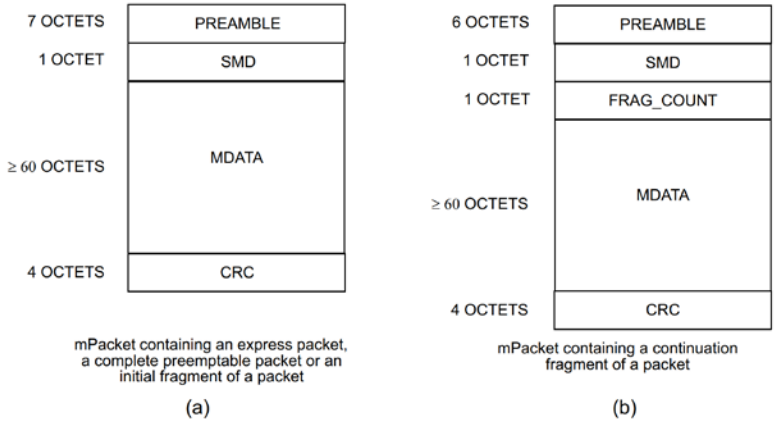



**Figure 99–4—mPacket format**

G. Zimmerman

# NEAR TERM NEED: MAKE 10 MB/S PT-TO-PT A “FULL CITIZEN” FOR TSN

# 10BASE-T1L and TSN

- 10BASE-T1L is included in the list of Common PHY and MAC Options (5.6.1) of IEC/IEEE 60802d1.2
  - For Process Automation, 10BASE-T1L is an essential technology to replace various legacy technologies for relatively long distances and in harmful environments
- There are some gaps that need to be discussed and addressed
  - 10BASE-T1L and Frame Preemption / MAC Merge sublayer

802.3!

  - 10BASE-T1L and IEEE 802.1AS-2020 Link Delay Threshold
  - 10BASE-T1L and IEEE 802.1AS-2020 Performance Requirements

802.1

# What 802.3cg forgot: MAC Merge for 10BASE-T1L

**99. MAC Merge sublayer**

**99.1 Introduction**

This clause specifies an optional MAC Merge sublayer for use with a pair of full-duplex MACs and a single PHY operating at 100 Mb/s or higher on a point-to-point link. The two MACs are:

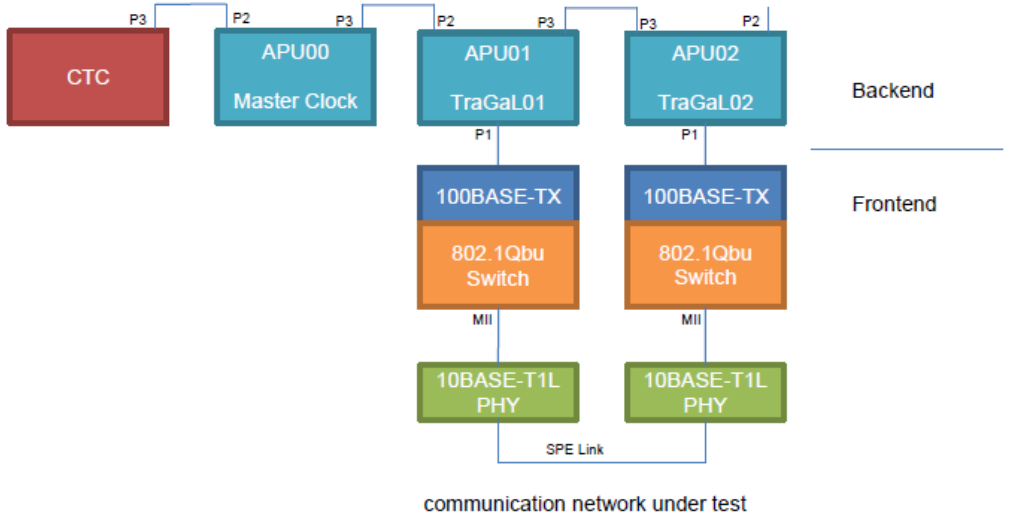
Source: IEEE Std 802.3-2018

- Speed limitation was an easy way for Clause 99 to avoid old, 'legacy' PHYs
  - ❖ BUT: 10BASE-T1L is architected like modern, >100 Mb/s PHYs (MII -> PCS -> PMA, full duplex)
- Why not Maintenance? – New feature
- Does it work? Did we forget anything else?

# What is left out of TSN for 10BASE-T1L?

- Addition of 10BASE-T1L to MAC MERGE clause should easy and straightforward

- Should be a simple project
- Study group should first look and make sure nothing else is missing




10BASE-T1L MACMERGE demonstration
Source: Martin Ostertag (private communication)

# Is there anything else?

- Notes on MII say 100 Mb/s and above
  - (802.3cg changed this in Fig 1-1,

NOTE—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 10BASE-T1L, 10BASE-T1S, and 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations it is called GMII; for 10 Gb/s implementations it is called XGMII; etc.

**Figure 1–1—IEEE 802.3 standard relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model**

  - but left out Fig 90-1 and 99-1)

NOTE 1—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations, it is called GMII; for 10 Gb/s implementations, it is called XGMII; etc.

- Any time sync issues?
  - None identified, but study group is the place to look

**90.4.1.1 Interlayer service interfaces**

Figure 90–1 depicts the TimeSync Client and the RS interlayer service interfaces.

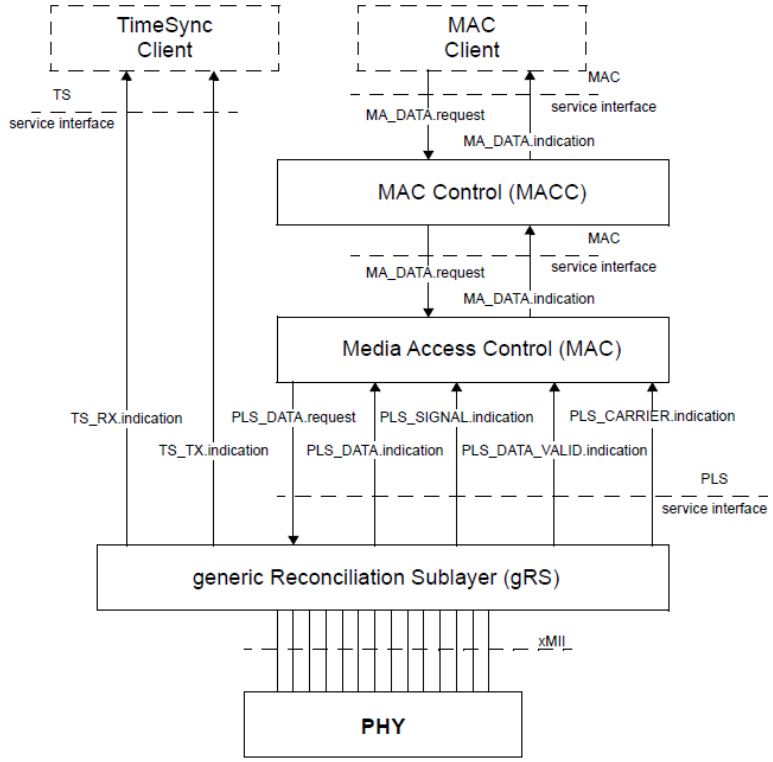



**Figure 90–1—Relationship of the TimeSync Client, TSSI and gRS sublayer relative to MAC and MAC Client and associated interfaces**

NOTE 1—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations, it is called GMII; for 10 Gb/s implementations, it is called XGMII; etc.

NOTE 2—Optional Low Power Idle (LPI) Client service interface not shown.

# LONG TERM: WHAT IS THE NEXT STEP IN LONG-REACH POINT-TO-POINT SPE

# The Next Speed? From 10 Mb/s?

- Filling in the SPE ecosystem
  - As SPE spur deployment fills out, this will put pressure on the trunks
  - Traditionally, Ethernet has provided a higher speed
- What is the right speed for long-reach SPE trunks as 10BASE-T1L deployment grows
- This is NOT about a new Ethernet Speed
  - But the time is now to begin the discussions for a new PHY speed to support needs 5 years from now as SPE grows

# Beyond 15m: Existing PHYs Don’t Come Close to 10BASE-T1L

- Clause 96: 100BASE-T1
  - Defined for automotive, link segment defined for 15m
  - No delay specification
  - How far can it really go?
  - Reach limited by design for automotive UTP
- Clause 97: 1000BASE-T1/Option B – 40m…
  - Reach limited by echo canceller, SNR, Automotive signalling design
- BUT – these are 26 AWG cables… T1L generally uses larger diameter cabling (16-18 AWG)

# What is the Next step for T1L?

- Desire to use existing cable/topologies
  - E.g., fieldbus type A (35 MHz), 16-18 AWG (1.5-0.75mm^2)
  - MUCH less insertion loss/meter than automotive cabling
- Differing views
  - Rate:  100 Mbps?  1 Gbps?
  - Reach: 100m, 200m, 500m, 1km
- Varying complexity solutions

*GETTING CONSENSUS ON THIS IS WHAT A STUDY GROUP IS ABOUT*

# One view of a path forward

- 100-200m short trunks and spurs with a reach extension to 100BASE-T1 (Cl 96) or similar technology
  - Minor modifications to existing standard
  - Consider needs of industrial, building & process automation vs. original target of automotive

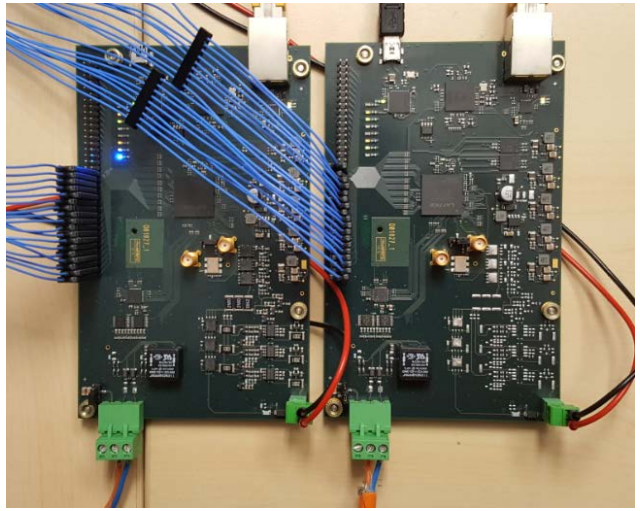
**SPE PHY : Measured Cable Reach with IEEE 802.3cg, IEEE 802.3bw PHYs**

| IEEE Standard | 802.3bw 100Base-T1 | 802.3cg 10Base-T1L |
|---|---|---|
| Baud Rate | 66.66MHz | 7.5 MHz |
| Channel | 1 pair UTP | Profibus Standard PA Cable |
| Modulation | PAM-3 | PAM-3 |
| Tx-PSD/VoD | Lower & Upper Mask | Lower & Upper Mask/Vod min/max limits 2.4V p2p/1V p2p |
| FEC | NA | NA |
| Equalization | Receiver Based | Receiver Based |
| Echo Canceller | Yes | Yes |
| IEEE Design Cable Reach | 15m | 1000m |
| Ethernet PHY | DP83TC811 | DP83TD510E |
| Measured Cable Reach (Profibus PA Standard Cable) | 100 meters+ | 2000 meters + (for both 2.4V p2p and 1V p2p) |
| TSN IEEE 802.3br SMD compliant | Yes | Yes |

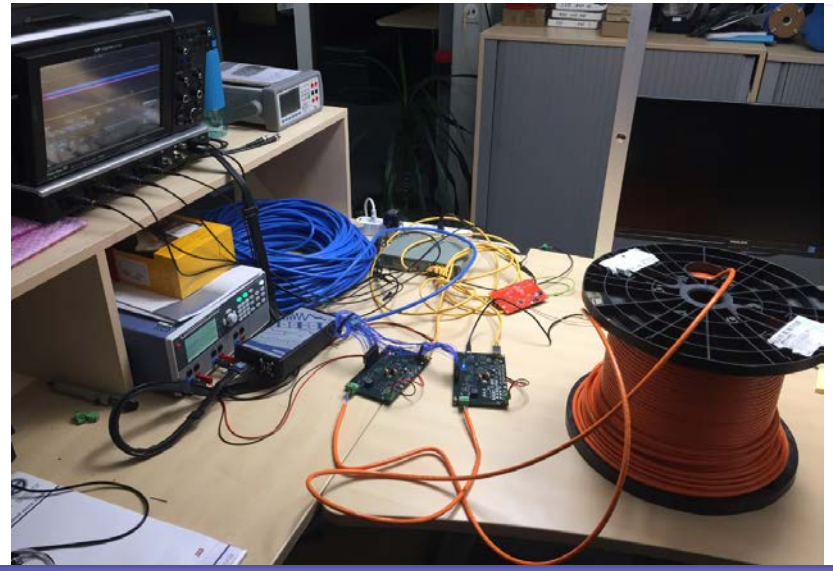
Technology exists with SPE PHY to reach the requirement of the long reach Industrial SPE 100M with appropriate noise and delay budgeting

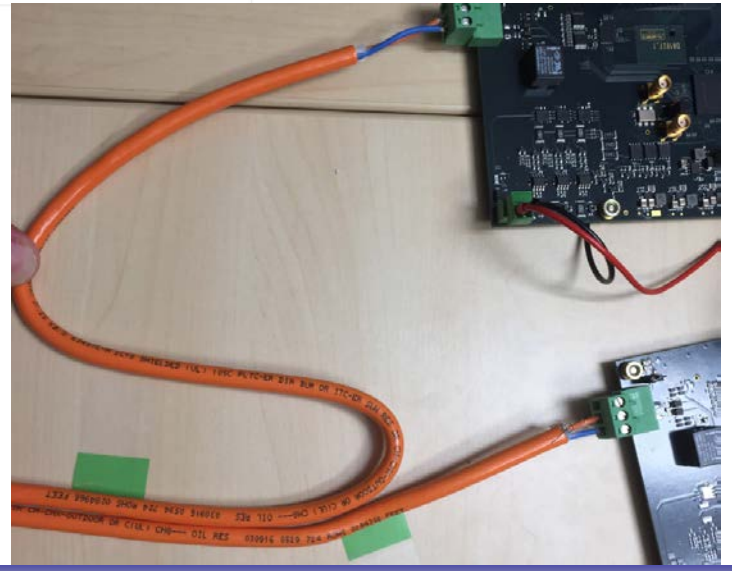
Source: Geet Modi/Texas Instruments

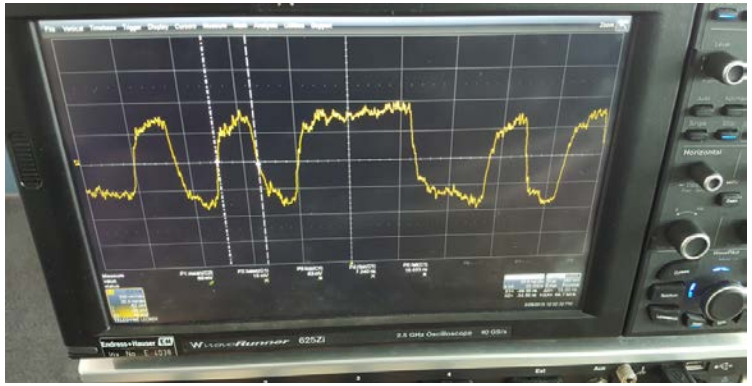
# Industry Moves Ahead: APL Phase 2 Project




Working Prototype 200 m
Fieldbus Type A Cable
@ 100Mbps / PAM 3

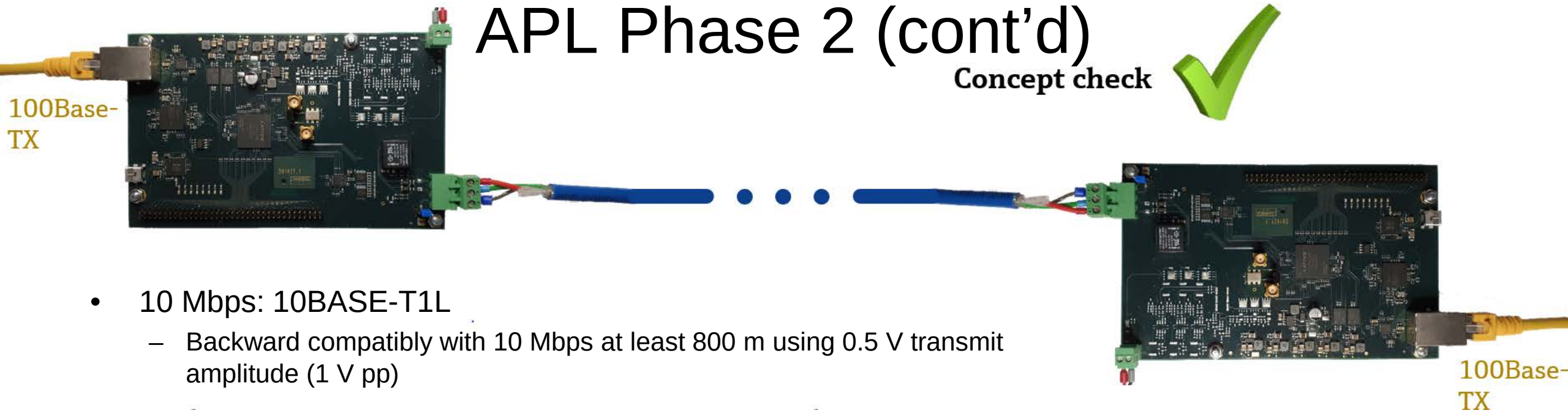






Source: Harald Mueller, Endress+Hauser

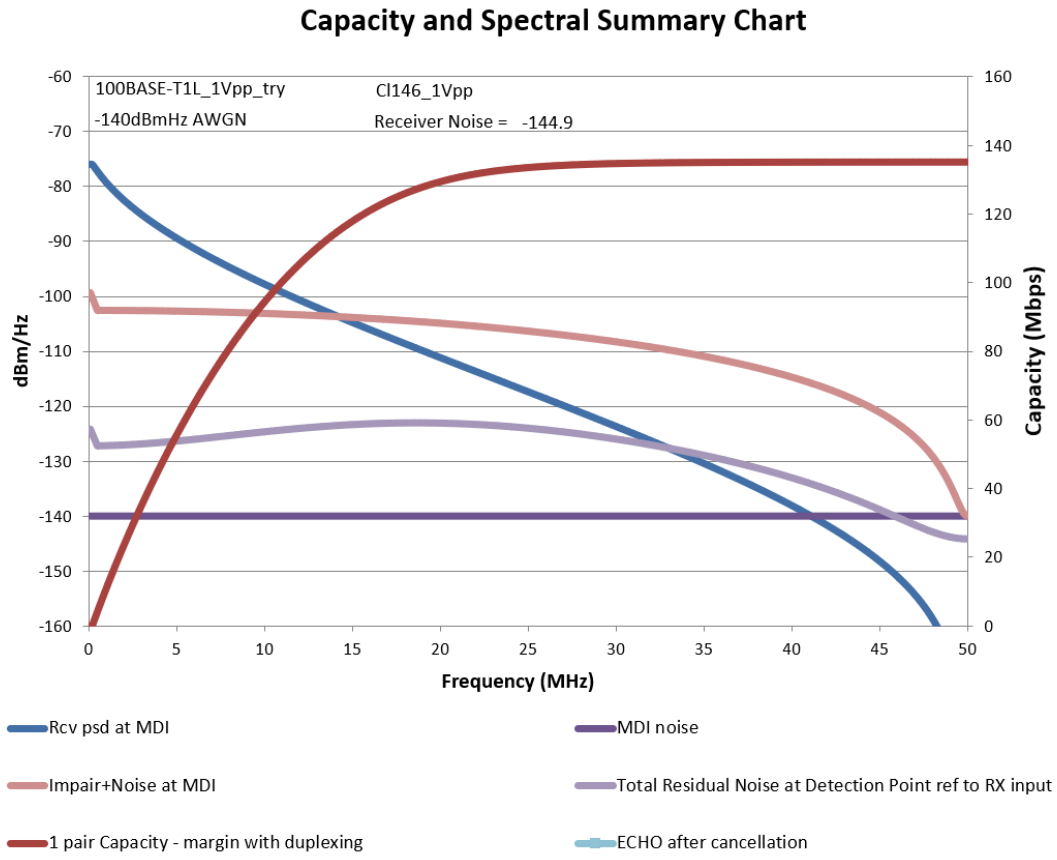
# APL Phase 2 (cont'd)




- 10 Mbps: 10BASE-T1L
  - Backward compatibly with 10 Mbps at least 800 m using 0.5 V transmit amplitude (1 V pp)
- 100 Mbps:
  - 300 m cable by using 1 V transmit amplitude (2 V pp), without bit errors
  - 220 m cable by using 0.5 V transmit amplitude (1 V pp), without bit errors
    - 3B2T encoding was tested for 100Mbps and achieved the same maximum reach -> 4B3T is more applicable for intrinsic safety applications due to its disparity observing encoding

# Other views – longer reach?

- New PHY design
  - Utilize shielded cabling common in industrial applications
    - Improved alien crosstalk over specification
  - E.g., 500m, 100 Mbps PHYs example
    - Minimal 4 dB coded gain
    - E.g., PAM-5, 50 MBd, 4dB coding gain
  - New phy designs possible



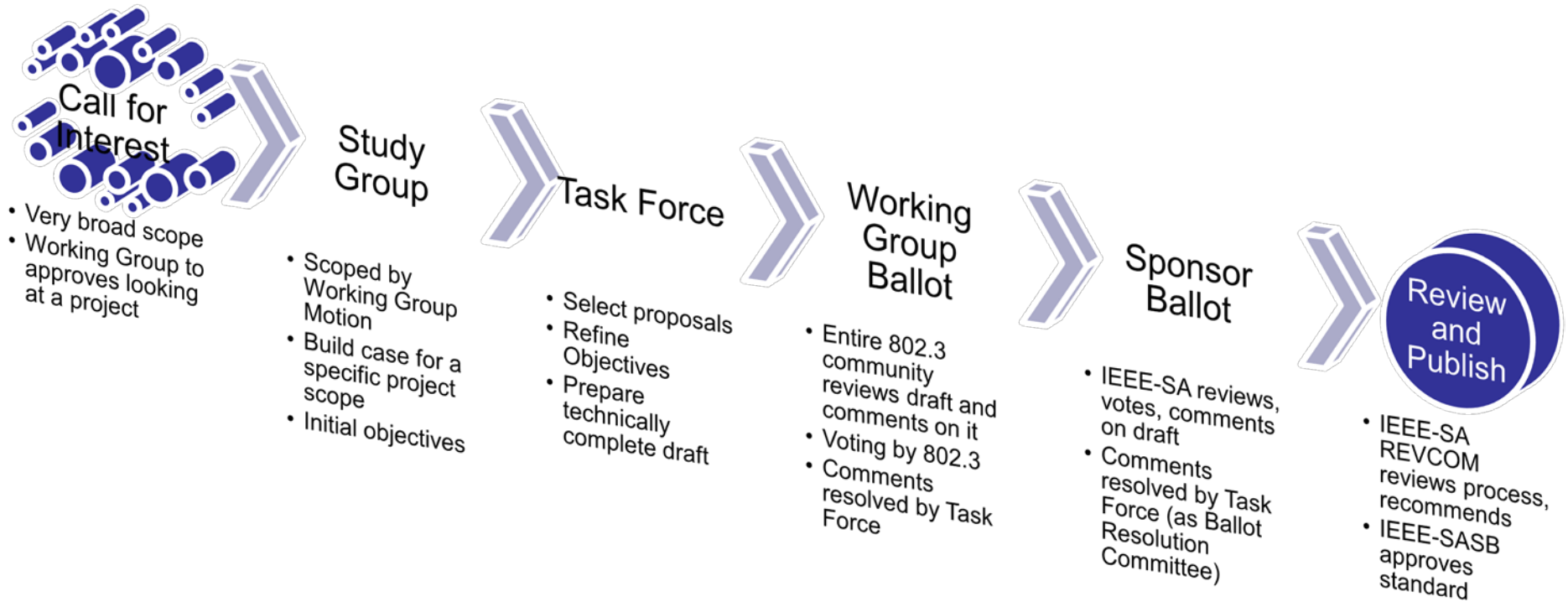

*GETTING CONSENSUS ON THIS IS WHAT A STUDY GROUP IS ABOUT*

# Why Now

- SPE (10BASE-T1L) chipsets/eval boards available now from multiple vendors
- SPE system products in 2021
  - APL certification
  - APL demo in June 2021 at ACHEMA
- Standards timeline is longer for next generations
  - More options, learning feedback
    - Next generation needed 2025-2026

# For Next-Gen products in 2H 2025, Start Now

| | | | | Approved | Products |
|---|---|---|---|---|---|
| 802.3cg: | Start: July 2016 | (Sept 2016) | (Jan 2017) | Nov 6, 2019 | 2021 |
| Possible next-gen: | Start: March 2021 | (May 2021) | (Jan 2022) | Nov 2023? | 2025? |



# WRAP UP

# What are we planning

- (At least) Two potential PARs from this CFI:
  - Short term – TSN Enhancements
  - Long term – Next generation point-to-point SPE (T1L)

- Specifically, multidrop, and hence PLCA would be out of scope of the proposed *point-to-point* effort
  - (see IEEE Std 802.3cg-2019 Clause 148 introduction)
  - Multidrop enhancements are 802.3da

# Study Group Question…

- Should a study group be formed to study Enhancements to point-to-point Single Pair Ethernet to:
  - support TSN
  - And support increasing traffic and speed needs with long reach point-to-point higher-speed single-pair PHYs

  - Y: 104
  - N: 1
  - A: 13
  - Call Count: 153

Results as of 9:12 AM PT

# Straw Polls

- I would participate in the “Enhancements to point-to-point Single Pair Ethernet” Study Group in IEEE 802.3
  - Tally: 54

- I believe my affiliation would support my participation in the “Enhancements to point-to-point Single Pair Ethernet” Study Group in IEEE 802.3
  - Tally: 46

Results as of 9:12 AM PT

# Future work

- Ask 802.3 WG for approval at Nov 2020 Closing Meeting
- If approved, request formation of “Enhancements to point-to-point Single Pair Ethernet” Study Group by IEEE 802 EC
- If approved, Creation of Study Group page /reflector
- Anticipated first Study Group meeting (teleconference), if approved by 802.3, will be announced at the closing 802.3 plenary.