

IEEE 802.3 Single Pair Ethernet Enhancements

Call for Interest Consensus Building Meeting

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3/8/21

Supporters & Contributors

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Steve Carlson – High Speed Design
Clark Carty – Cisco Systems
John D'Ambrosia - Futurewei
Chris DiMinico – MC Communications
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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

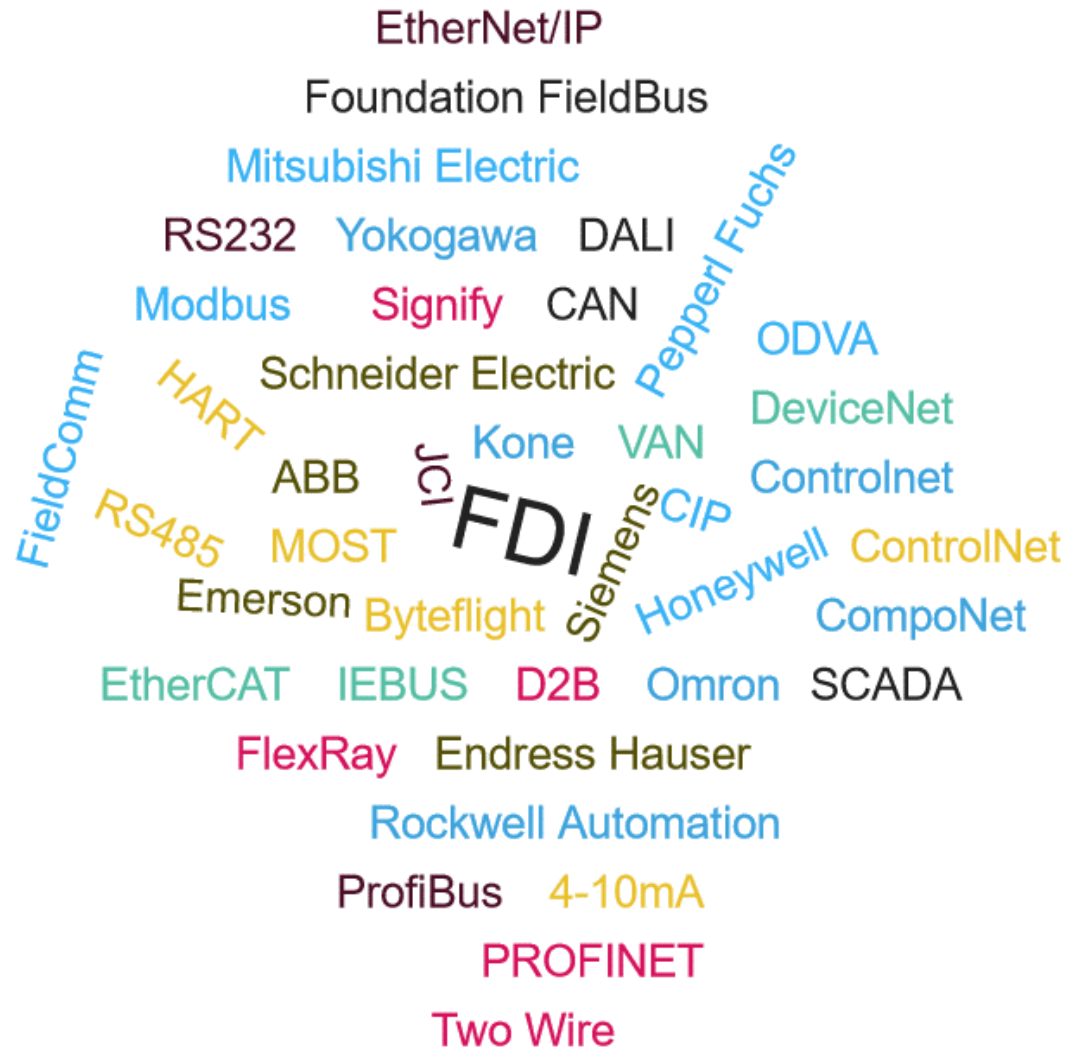
Token Ring Thick Net
Burroughs Poll/Select
Hewlett Packard Thin Net
HDLC VT100 Sperry X.25
MicroSoft DEC WANG Token Bus
Novell Netware IBM AppleTalk LU6.2 Telnet RS485
Novell TN 3270 Novell
Apple TD830 Olivetti Decnet
ISDN Burroughs SNA
Dial Up UUCP SDLC
ARCnet RS232
Banyan Vines



TCP/IP



OT Modernization Challenge



TCP/IP



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

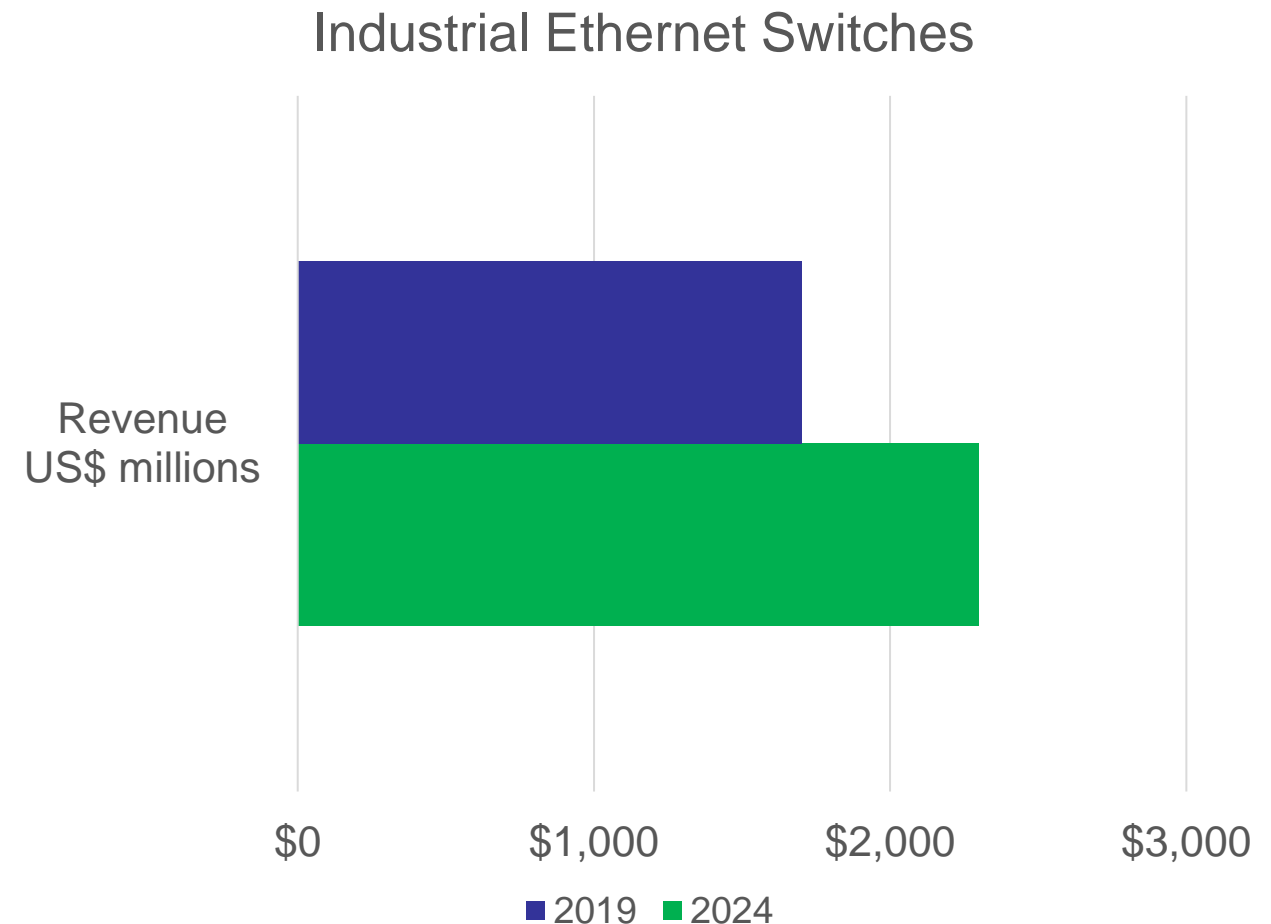
SPE Advantage

- Suited for the target environments and topologies.

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.

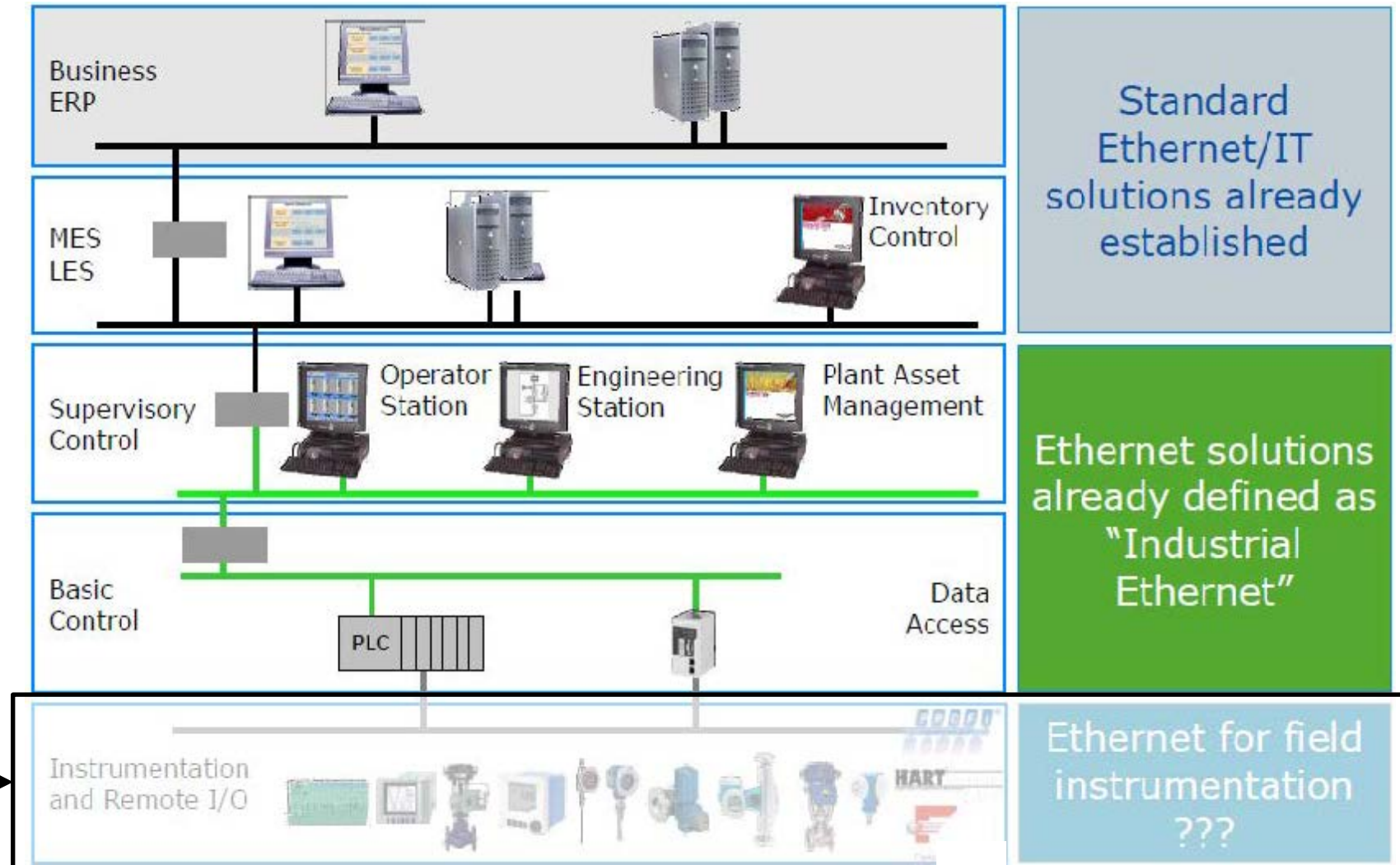


Data: Omdia - <https://www.cisco.com/c/dam/en/us/solutions/collateral/internet-of-things/omdia-industrial-edge.pdf>

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*
- *Point to point, multidrop, trunk & spur*
- *Reach, cable type*

Power Delivery

- *Power small device (e.g., sensor, field switch)*
- *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)*
- Tracking events
- Coordinating actions

TSN – Latency

- *Frame Preemption (IET)*
- Credit Based Shaper
- *Scheduled Traffic*

TSN – Reliability

- Frame Replication and Elimination
- Path Control and Reservation
- Per-Stream Filtering and Policing

TSN - Resource Management

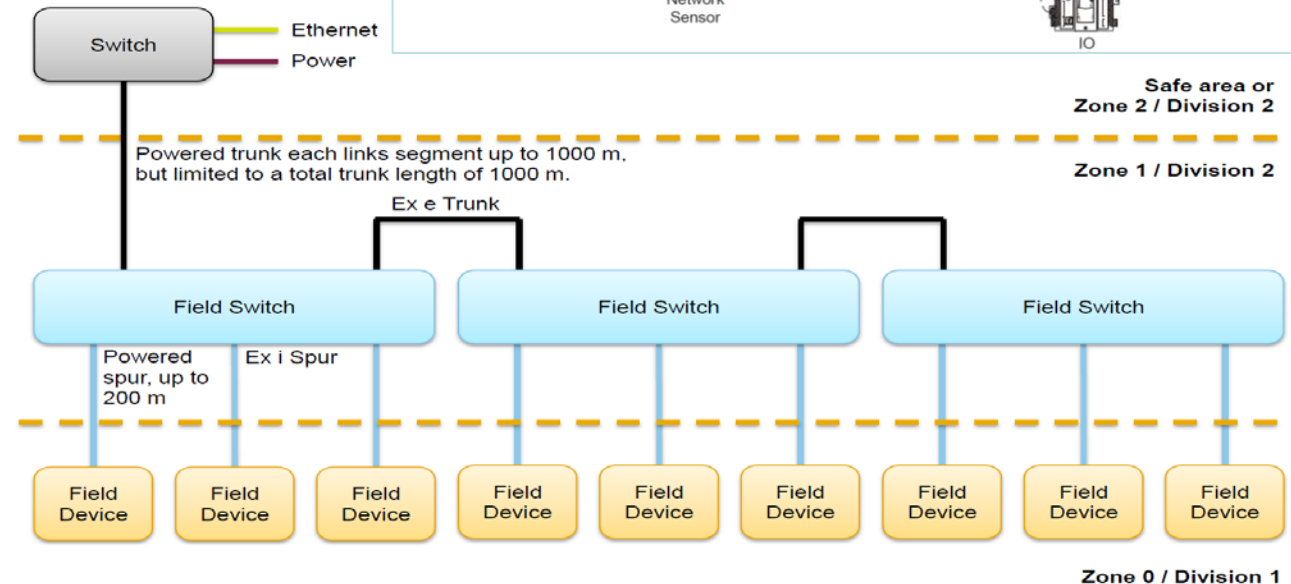
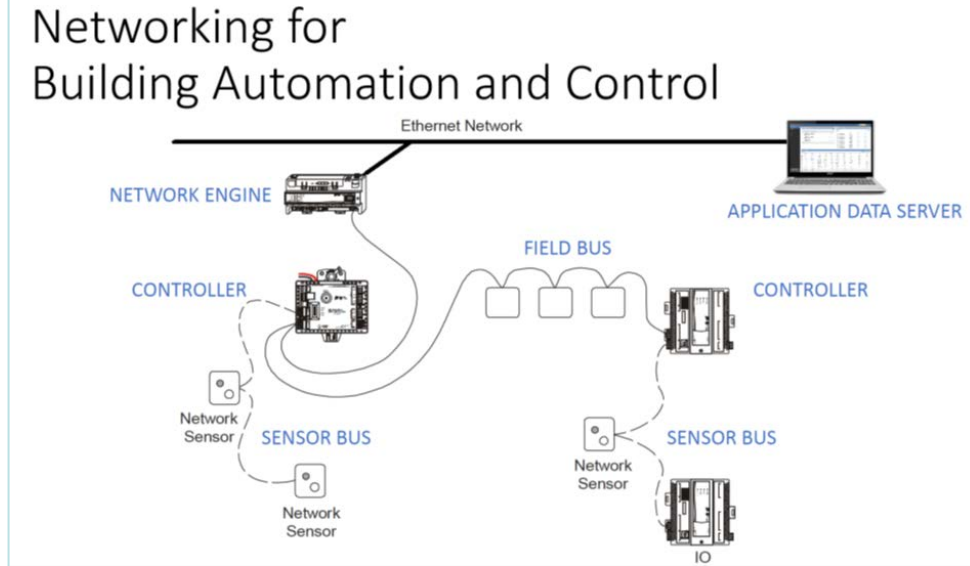
- Stream Reservation Protocol
- Link-local Registration Protocol
- LLDPv2 for MultiframeData Units
- Multicast and Local Address Assignment

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WHAT NEEDS ENHANCING?

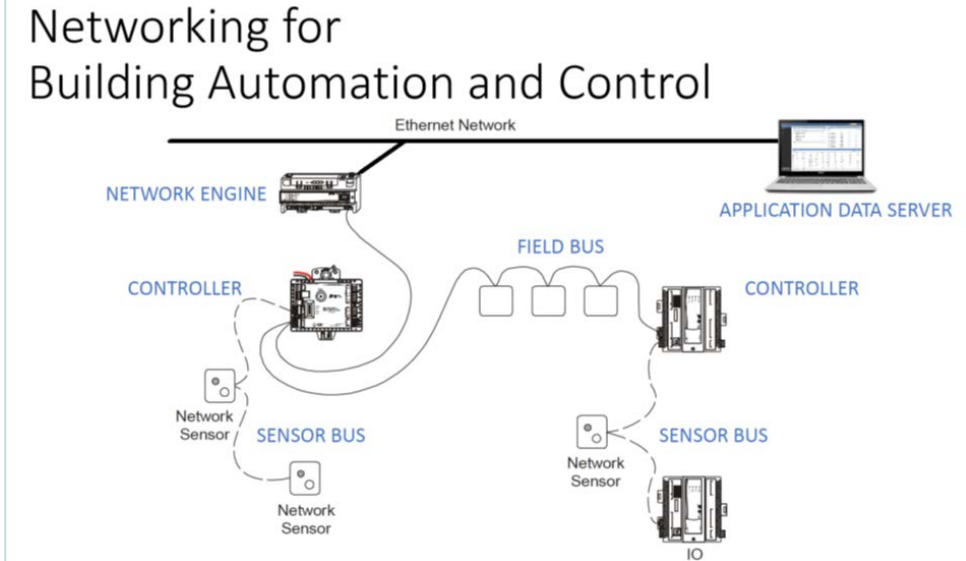
Example SPE Cases

- 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

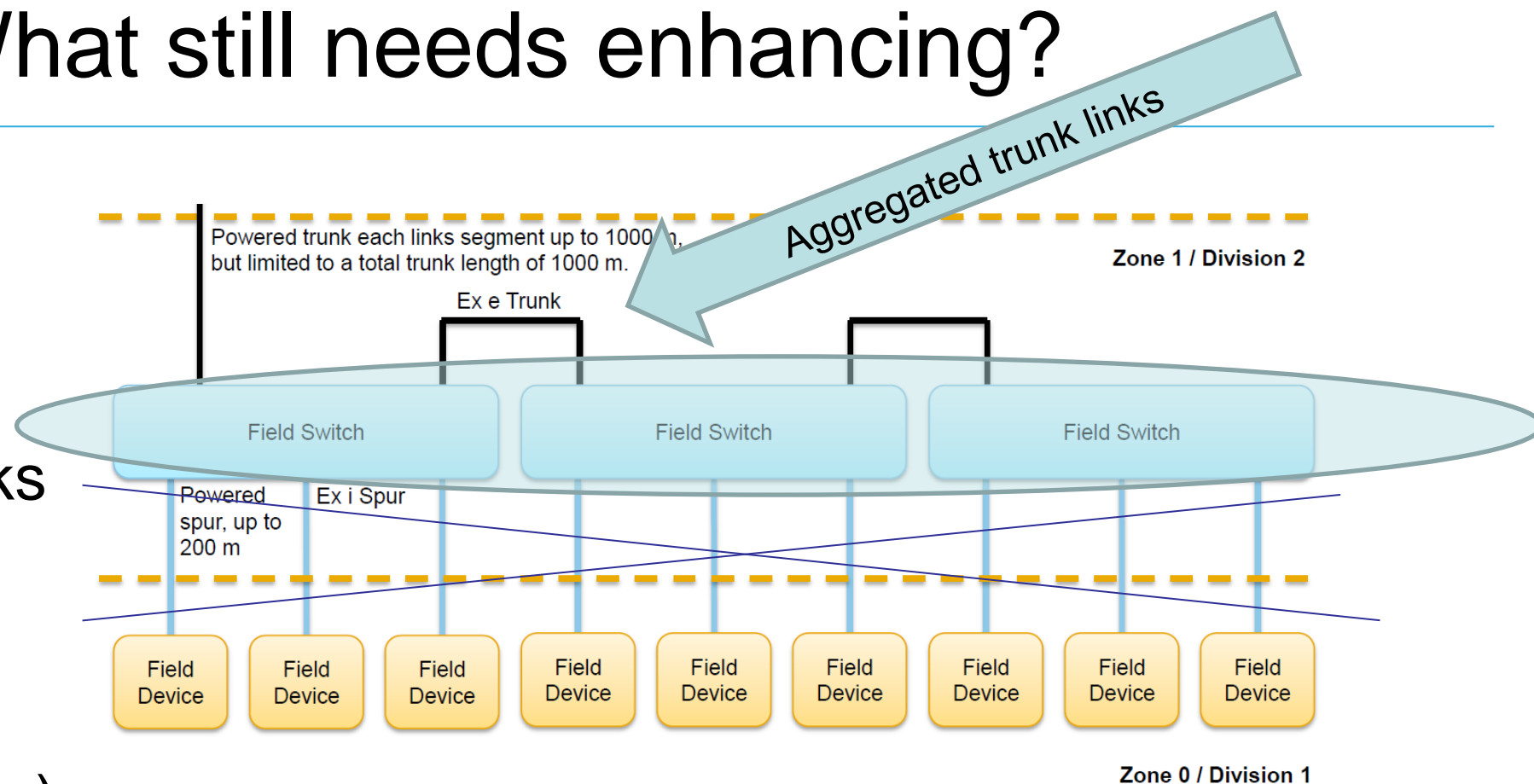
- Short:
 - In-cabinet, chassis
 - Vehicles
 - Multipoint topologies
- Medium:
 - Industrial pods (5-40m)
 - Building control networks (50-100m)



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

What still needs enhancing?

- Long:
 - Process control trunks (1km)
 - Building automation trunks (500m)

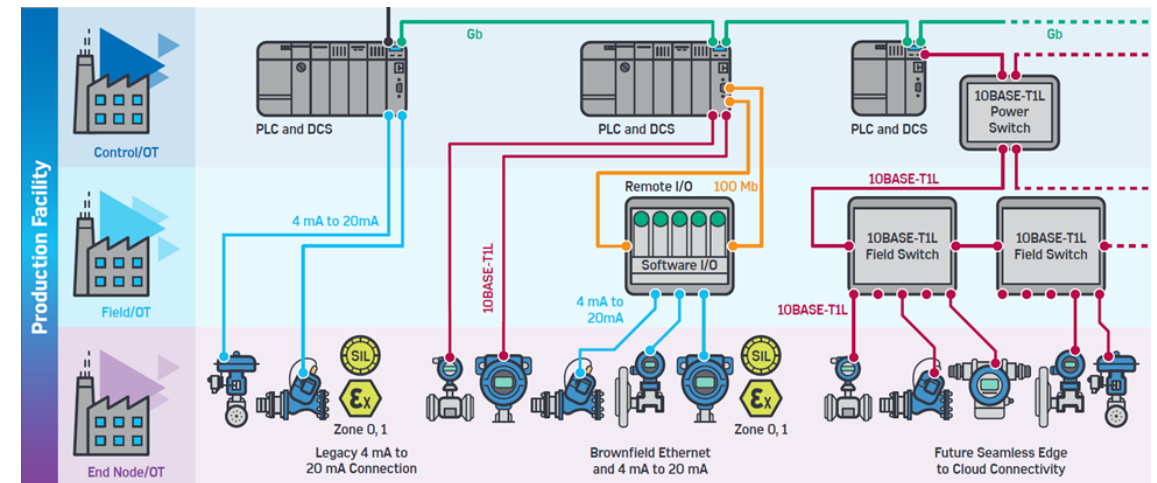


This has two parts: Near-term (initial 10BASE-T1L deployments), and Long-term (providing for growth 4-5 years from now)

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.

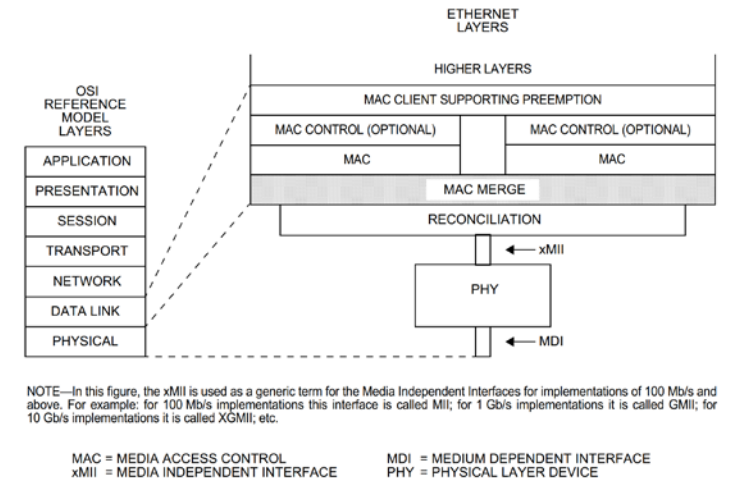


Figure 99–1—Relationship of MAC Merge sublayer to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

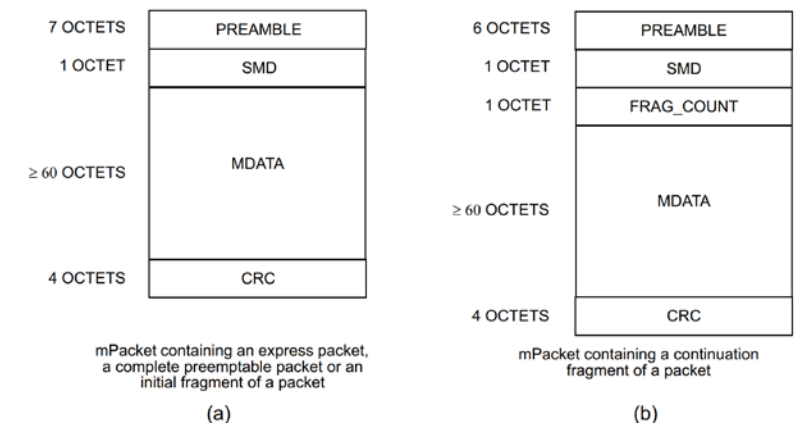

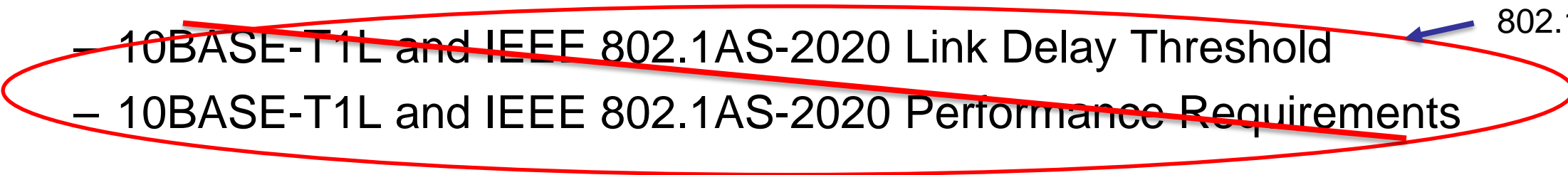


Figure 99–4—mPacket format

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**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  802.1
 - 10BASE-T1L and IEEE 802.1AS-2020 Performance Requirements

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

99. MAC Merge sublayer

99.1 Introduction

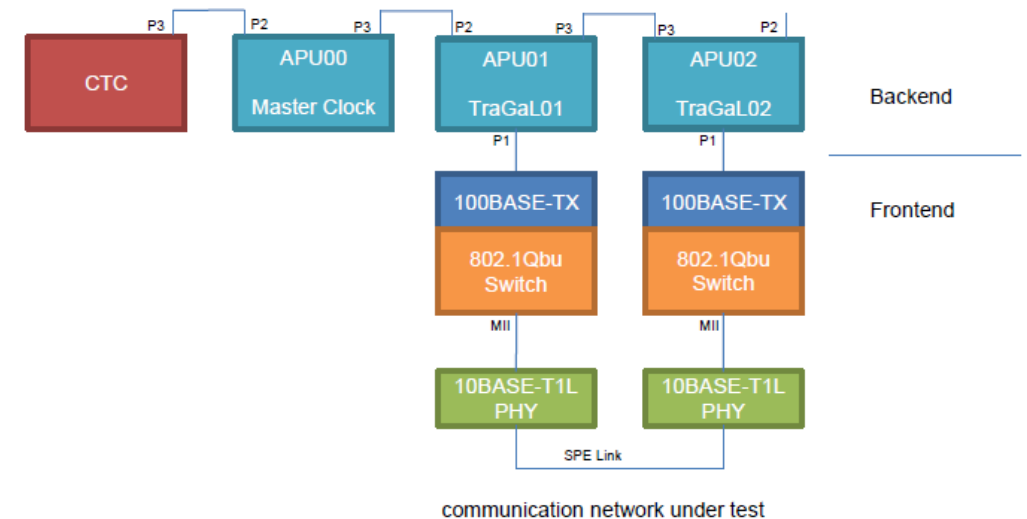
This clause specifies an optional MAC Merge sublayer for use with a pair of full-duplex MACs and a single PHY operating at 100 Mb/s or higher on a point-to-point link. The two MACs are:

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 be 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.

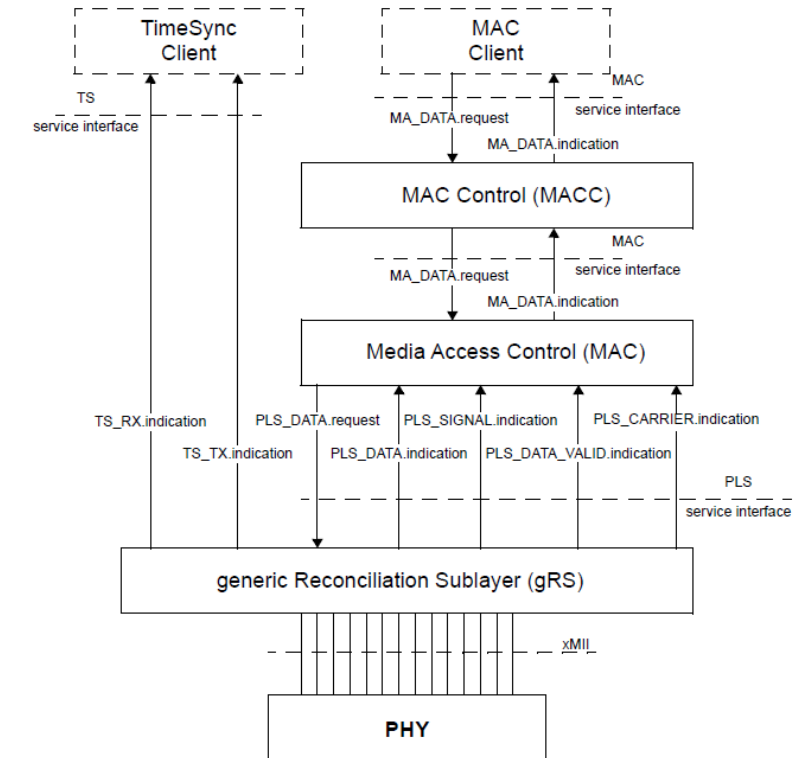


Figure 90–1—Relationship of the TimeSync Client, TSSI and gRS sublayer relative to MAC and MAC Client and associated interfaces

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 (1.5-0.75mm²)
 - 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 (CI 96) or similar technology
 - Minor modifications to existing standard
 - Consider needs of industrial, building & process automation vs. original target of automotive

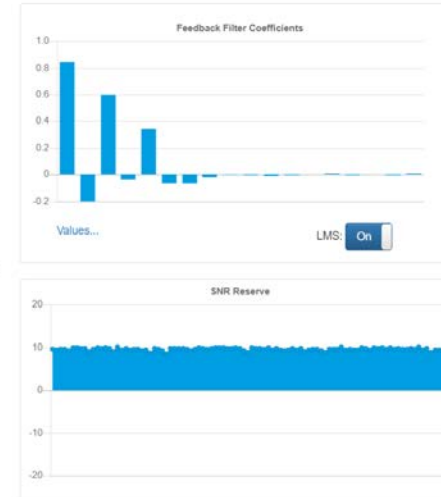
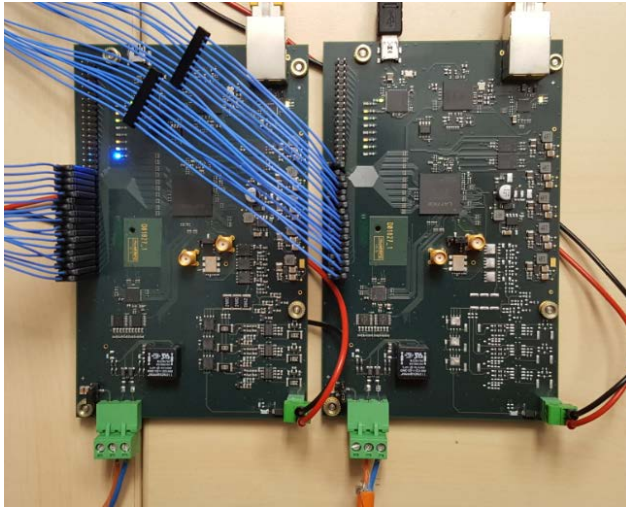
SPE PHY : Measured Cable Reach with IEEE 802.3cg, IEEE 802.3bw PHYs

| 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 |

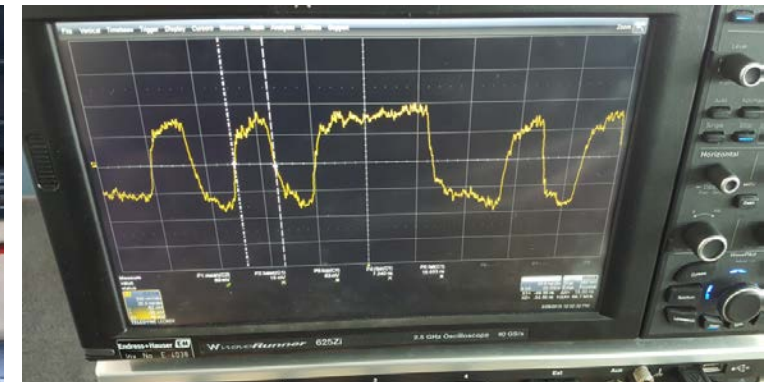
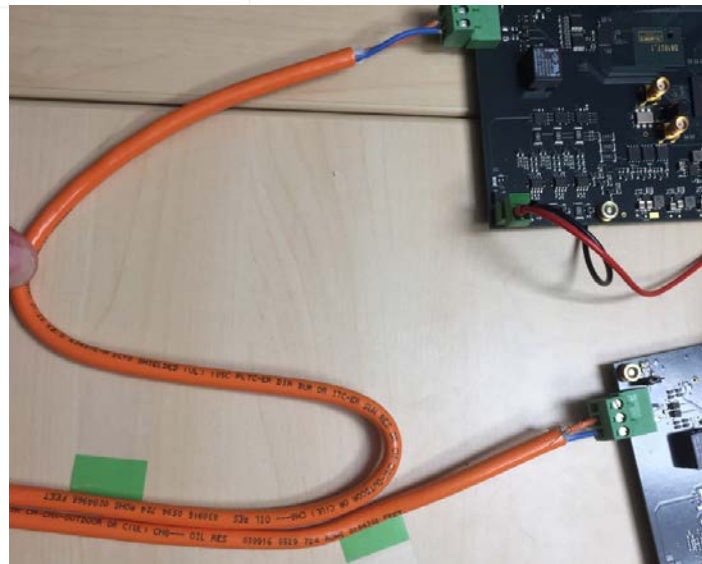
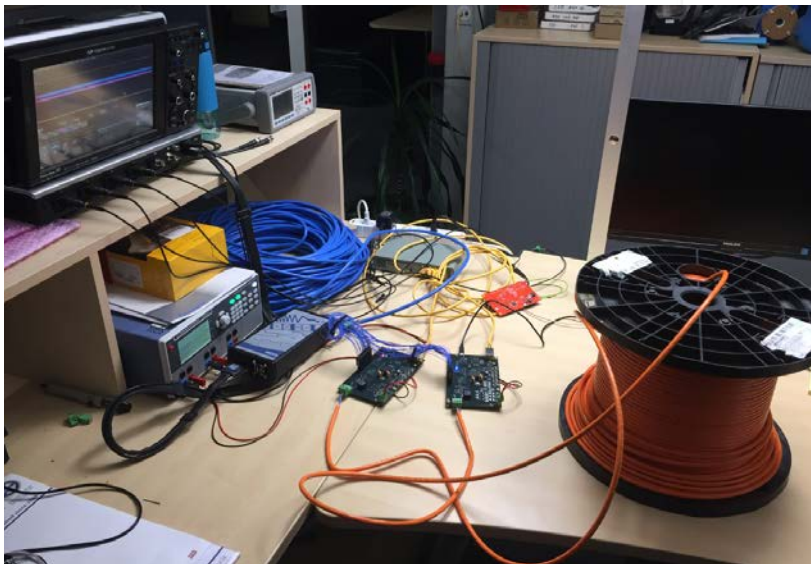
Technology exists with SPE PHY to reach the requirement of the long reach Industrial SPE 100M with appropriate noise and delay budgeting

Source: Geet Modi/Texas Instruments

Industry Moves Ahead: APL Phase 2 Project



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



APL Phase 2 (cont'd)

Concept check



100Base-TX



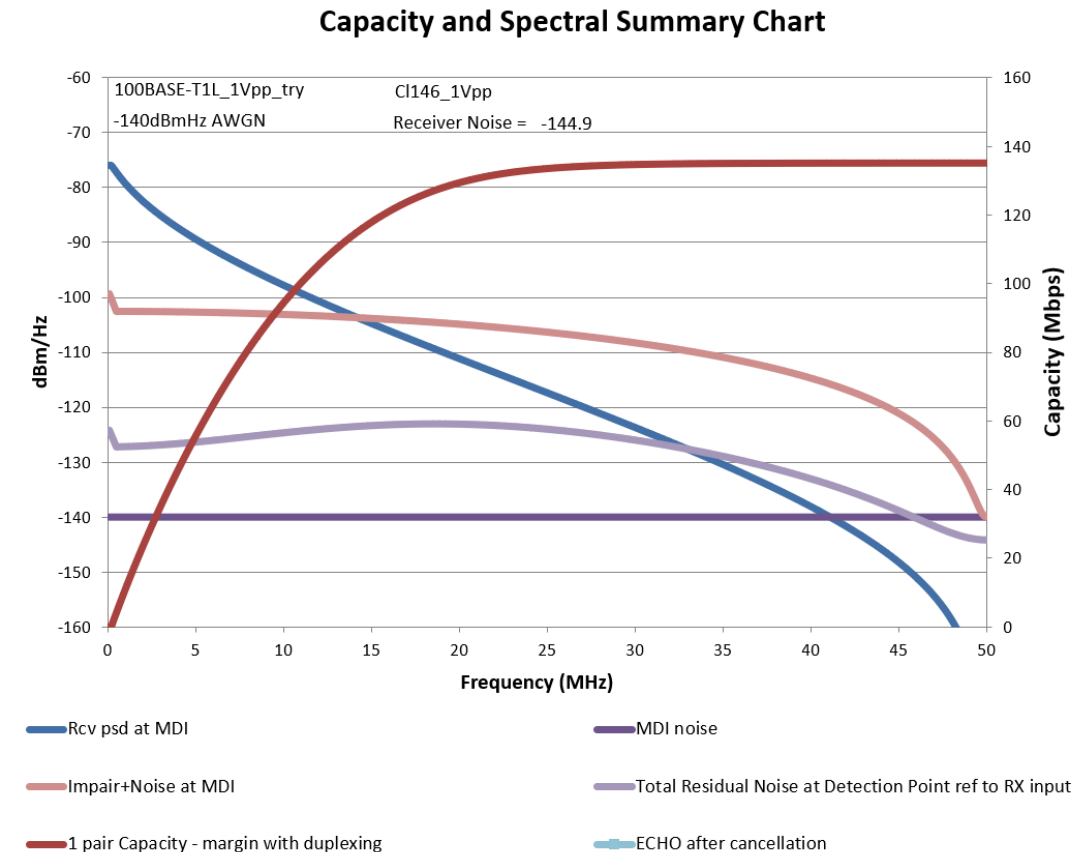
- 10 Mbps: 10BASE-T1L
 - Backward compatibly with 10 Mbps at least 800 m using 0.5 V transmit amplitude (1 V pp)
- 100 Mbps:
 - 300 m cable by using 1 V transmit amplitude (2 V pp), without bit errors
 - 220 m cable by using 0.5 V transmit amplitude (1 V pp), without bit errors
 - 3B2T encoding was tested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

100Base-TX



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

802.3cg: Start: July 2016 (Sept 2016) (Jan 2017)

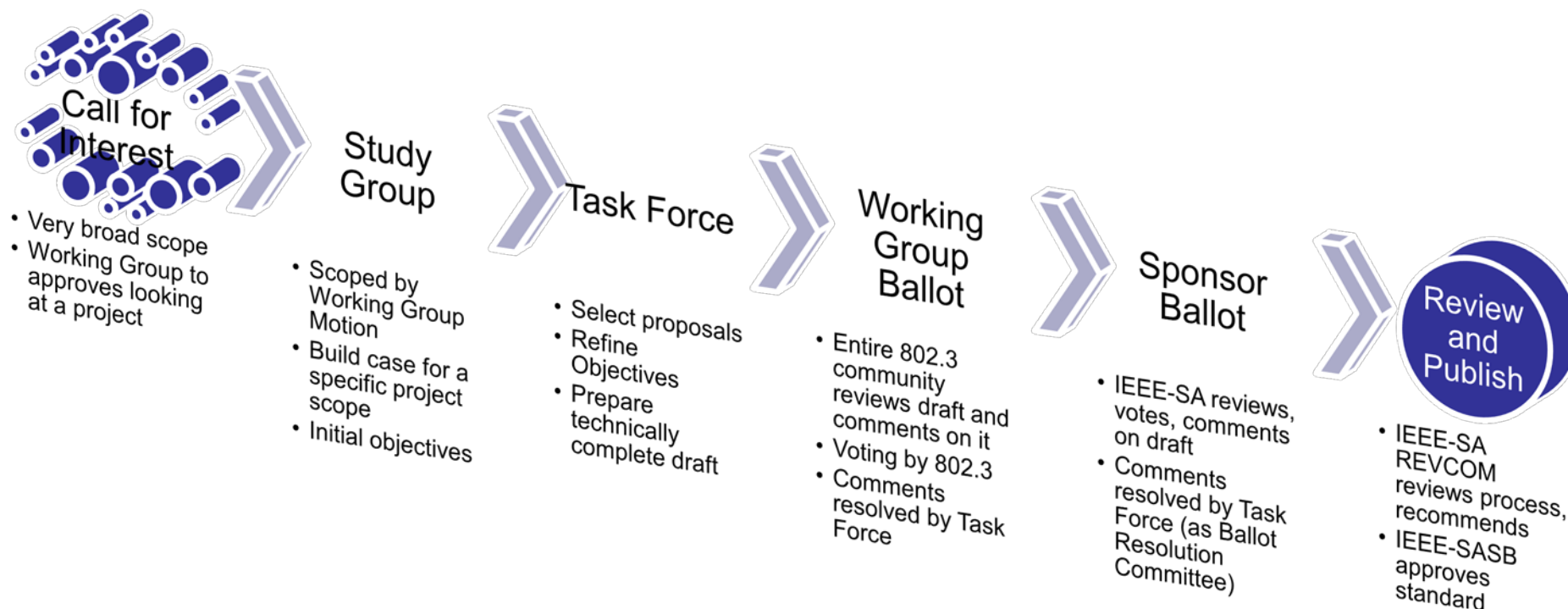
Approved
Nov 6, 2019

Products
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:
 - N:
 - A:
 - Call Count:

Straw Polls

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

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.