Generic Balanced Single Pair Cabling Infrastructure for Powering and Communication with IoT and IBS Devices

Masood Shariff

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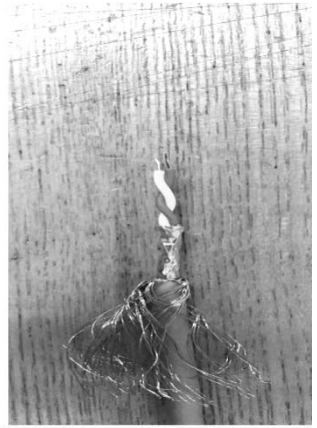
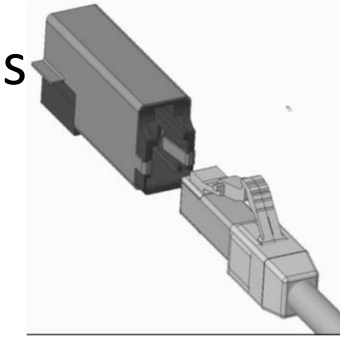
Outline

- What is generic single pair cabling infrastructure?
- Market trends and indicators
- Technology and Standards
- Design and Installation
- Cables and Connectors
- Quality metrics and testing
- How can BICSI members help?
- Conclusions and take away

What is generic single pair cabling infrastructure?

- Includes only 2 conductors in the cable and connectors
- Supports variety of indoor and outdoor spaces
- Easy installation and operation
- Supports multiple applications
- Reusable over several equipment and device life cycles





What are IoT and IBS?

- A part of an equipment or device that enables communication with other similarly enabled devices
- Networked communication allows devices to work together in unison towards a common purpose (e.g. energy efficiency, security, comfort, convenience)

Market Trends and Directions

- Office of the future
- Smart buildings and smart cities
- Internet of things (M2M communication)
- Efficiency and environmental sustainability
- Power and data over single pair cabling
- Convergence of IT and OT in some areas
- IoT market is predicted to be about USD 100 Billion in 4 years growing at about 10% CAGR (next few slides)

Communication Technology study

“According to the new market research report "Building Automation System Market by Communication Technology (Wired, and Wireless), Offering (Facilities Management Systems, Security & Access Control Systems, and Fire Protection Systems), Application, and Region - Global Forecast to 2022", the overall BAS market was valued at USD 53.66 Billion in 2016 and is expected to reach USD 99.11 Billion by 2022, at a CAGR of 10.73% between 2017 and 2022. The growth of this market is driven by the increase in demand for energy-efficient systems, growing need for the automation of security systems in buildings, and advancement of IoT in BAS”

Building Automation Systems Market

"The global **building automation system market** was valued at USD 44,067 million in 2017, and is expected to reach a value of USD 82,517.4 million by 2023, recording a CAGR of 11% over the forecast period (2018-2023). The scope of this study has been restricted to hardware and software components used in building automation systems. The service segment has not been considered as part of the study scope."

Orbis Research Study

"According to Statistics MRC, Building Automation Market is estimated at $35.9 billion in 2015 and is expected to reach $67.1 billion by 2022 growing at a CAGR of 9.6% from 2015 to 2022. Strict government initiatives, growing demand for energy efficient systems & solutions, and increasing cost saving needs of the building owners have played a key role in boosting the market growth"

Research and Markets Report

"According to this report, the Global Building Automation System (BAS) market is expected to grow from $59.43 billion in 2017 to reach $166.99 billion by 2026 with a CAGR of 12.1%. Rising in demand for energy-efficient systems, improvement of IoT in building automation system, growth of building automation-centric wireless protocols and wireless sensor network technology are some of the key factors fueling the market growth."

Global Building Management System Market Analysis

"The Global Building Management System Market accounted to USD 54.0 billion in 2016 growing at a CAGR of 11.0% during the forecast period of 2017 to 2024." (USD 112.11 billion in 2024)

Common Standards based OT/BAS networks

Characteristics of BAS standards

- Most Use RS 485 communications protocol, but, have proprietary interfaces, sub-systems, installation configurations, and functional layers
- Inconsistent security may not meet IT security guidelines
- Many different topologies, data rates, and configurations
- Interoperability made more difficult by proprietary implementations

BACnet

- Developed by ASHRAE
- Primarily for HVAC
- MS/TP: References RS-485 specs which in turn references TSB-89 for cables
  - Design is vendor dependent
- LONTalk: see next slide

LONTalk

- Primarily for Building Automation Systems TP/FT-10A @ 78 kb/s: 1-pr data
  - Bus (termination at both ends): 900 m with Cat 5 and better
  - Free (termination at one end, star wiring with branch): 450 m with Cat 5 and better
- TP/XF-1250 @ 1.25 Mb/s: 1-pr data, 1-pr transformer centre tap reference
  - 130 m with Cat 5 and better

MODBus

- Primarily for process controls
- Mainly RS-485 using 1-pr
- Up to 115 kb/s
- Cat 5 cable: Up to 600 m

ProfiBus/FieldBus

- Primarily for process controls
- Mainly RS-485 using 2-pr data
- Traditional Type A cable: per IEC 61158
- Balanced cable (Type A) : 22 AWG, Cat 5 cable supporting:
  - 12 Mb/s = 100 m
  - 1.5 Mb/s = 400m
  - 187.5 kb/s = 1000 m
  - ≤ 93.75 kb/s = 1200 m

KNX

- Primarily for BAS
- 1-pr for power & data
- Twisted pair: Up to 9.6 kb/s
- Difficult to support over Category cabling

DALI

- Primarily for lighting
- 1-pr data
- Cable: conductor size between 0.5 mm^2 (20 AWG) and 1.5 mm^2 (15 AWG)
  - 1.2 kb/s @ up to 300 m (20 AWG cable @ 100 m)

Examples of Company specific OT/BAS networks

Johnson Controls Metasys System

- N2 Bus family
  - Proprietary, based on modified RS-485
  - 3-conductor (data only), 26 AWG twisted pair
  - 9.6 kb/s @ 1520 m
- BACnet family
  - FC (Field Controller) Bus
    - ❖ 1-pr MS/TP (data only), 22 AWG stranded
    - ❖ Max 76.8 kb/s (38.4 kb/s recommended) @ 1220 m
  - SA (Sensor Actuator) Bus
    - ❖ 2-pr or 3-pr MS/TP (data and power), 22 AWG stranded
    - ❖ Max 76.8 kb/s (38.4 kb/s recommended) @ 365 m or 152 m between bus controller and network sensor
- LON family: see LONTalk

Honeywell Controls Excel System

- C Bus family
  - Proprietary, based on RS-485
  - 1-pr (data only), 18 AWG twisted pair
  - Max 76.8 kb/s @ 1200 m
- BACnet/IP family
  - Ethernet
    - ❖10/100BASE-T
- LON family: E-Bus - see LONTalk

Schneider Electric TAC

- InfiNet: Proprietary, based on RS-485
  - 1-pr (data only) MS/TP, 24/22 AWG twisted pair
  - Max 19.2 kb/s @ 1220 m
- Continuum System: BACnet family
  - 1-pr (data only) MS/TP, 24/22 AWG twisted pair
  - Max 19.2 kb/s @ 1220 m
- Vista Xenta System: LON family - see LONTalk

Siemens Building Technologies

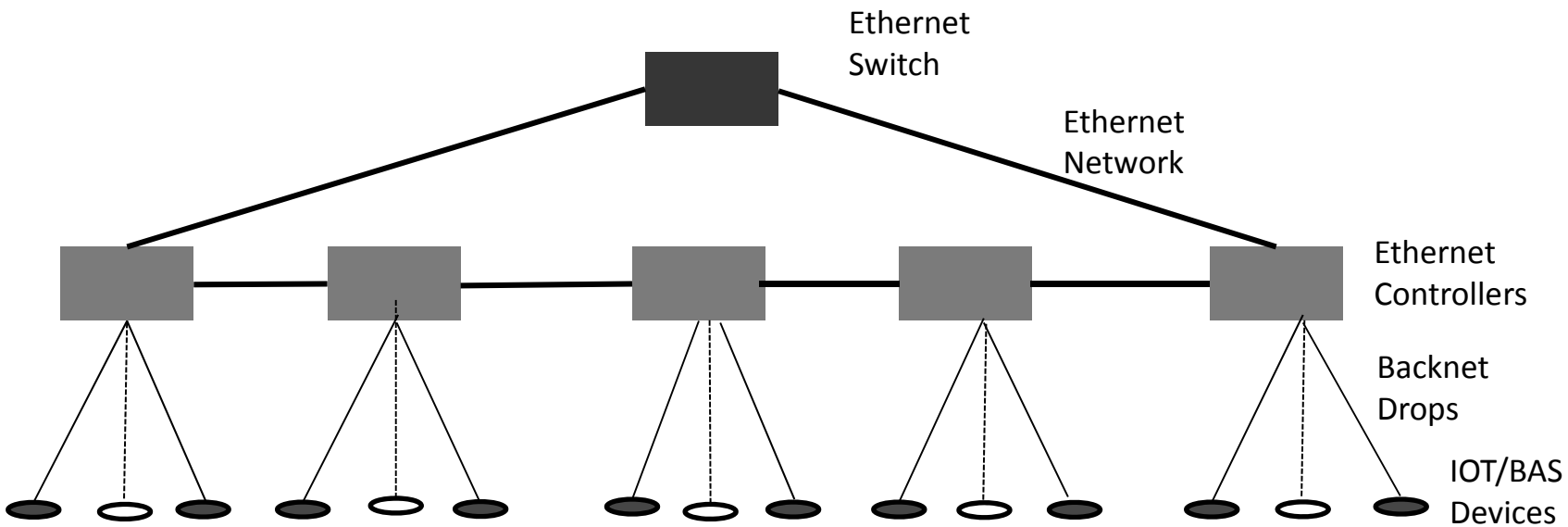
- Apogee
  - BACnet family
    - 1-pr (data only) MS/TP, 15 AWG twisted pair
    - Max 115.2 kb/s @ 750 m, ≤ 76.8 kb/s @ 1200 m
  - LON family – see LONTalk
  - KNX family – see KNX
- Desigo
  - BACnet family: see above
  - KNX family – see KNX
- Gamma & Synco (Residential)
  - Based on KNX – see KNX

Delta Controls

- NET1
  - BACnet MS/TP
    - 1-pr (data only) MS/TP, twisted pair
    - Max 76.8 kb/s @ up to 1220 m
- NET2
  - LINKnet
    - 1-pr (data only) MS/TP, twisted pair
    - Max 76.8 kb/s @ up to 1220 m
- Ethernet & PoE: 10BASE-T

Creating an alternative single pair Ethernet Ecosystem for IT/OT/others

The move to Ethernet



Necessary Contents of an Ecosystem

Includes at least the following:

- Clear scope and extent
- Existing and emerging application standards
- Cabling and component standards
- Design and installation guidelines
- Quality metrics and testing
- Administration and Operations

Single Pair Standards and Technology

- IEEE 802.3 SPE projects
- TIA TR42 cabling systems and components
- ISO/IEC/JTC1/ SC25/WG 3 cabling systems
- IEC SC46C cables, cords, and test instruments
- IEC SC48B Connectors
- CENELEC TC215 cabling systems

NOTE: Standards have to fill in the details of the complete ecosystem including planning, design, installation, testing, and operations

ISO/IEC/JTC 1/ SC25/WG 3

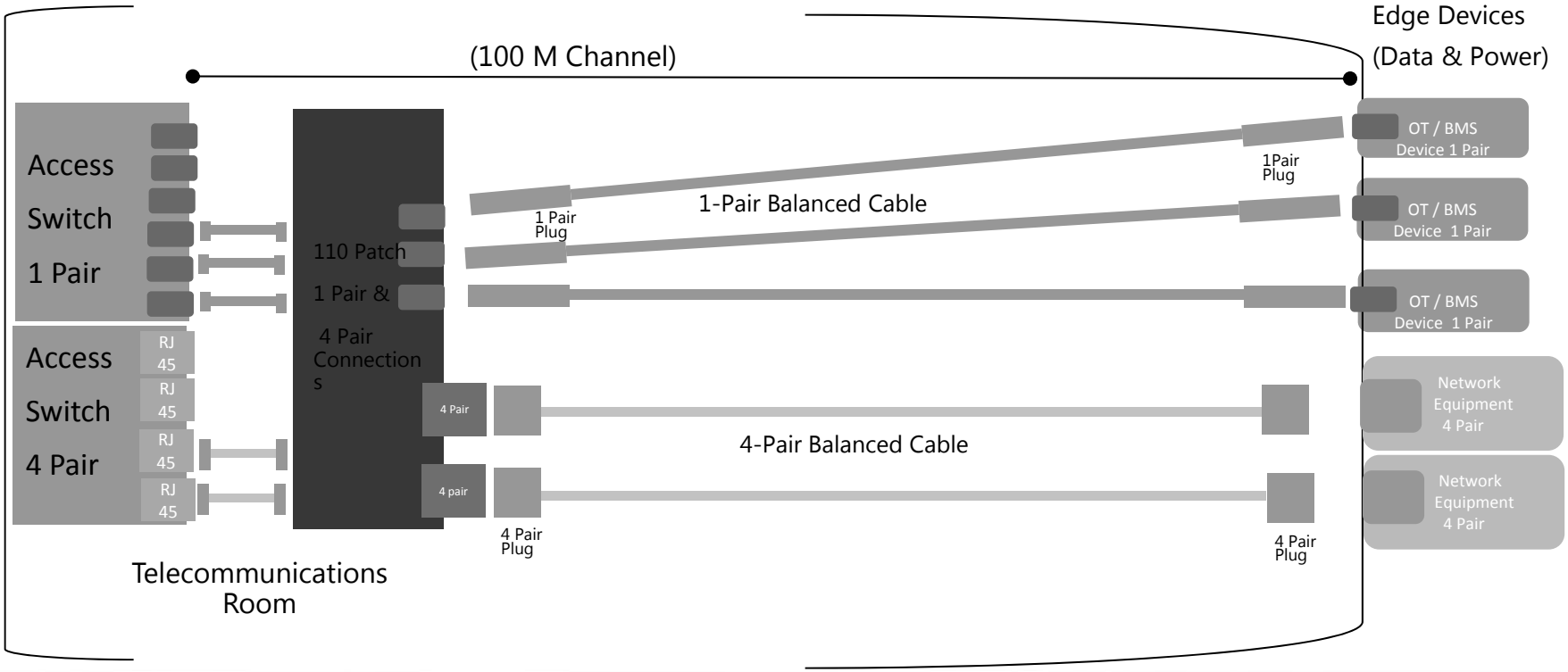
- Has 4 projects on single pair cabling infrastructure
  - ISO 11801-1 Amd1 Generic guidelines
  - ISO 11801-3 Amd1 Industrial
  - ISO 11801-5 Amd1 Distributed Services
  - ISO 11801-9906 SPE Application guidelines

TIA TR42

- TR42 has started 4 single pair projects
  - TIA 568.5 Generic cabling and components
  - TIA 568.0-D Amd 1 Generic architecture
  - TIA 862-B Amd 1 Intelligent building systems (IBS)
  - TIA 1005-A Amd 3 Industrial

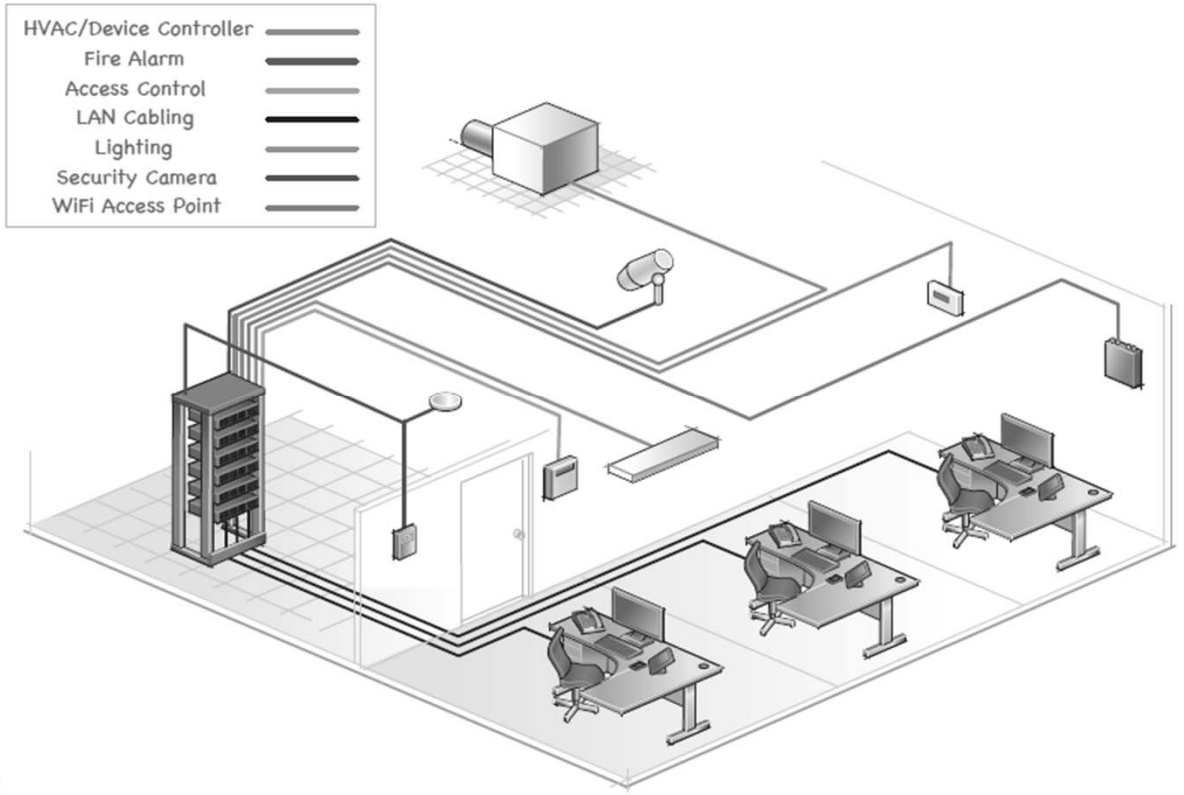
Designs and implementations

1-pair using the same topology as traditional 4-pair

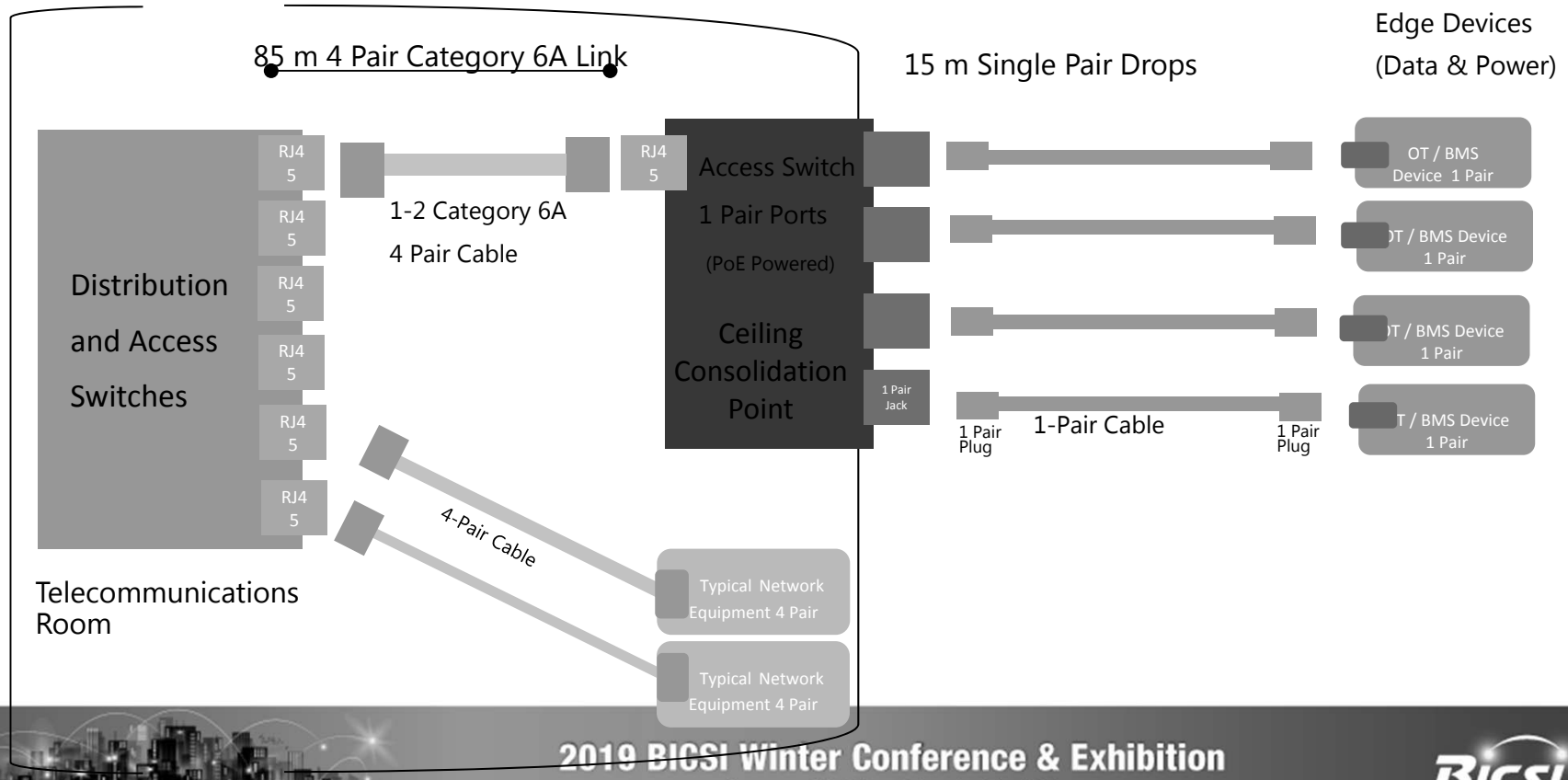


Conventional 4-pair Premises Architecture

- Horizontal cabling directly to application endpoints
- Fixed cabling impedes office dynamics and application convergence

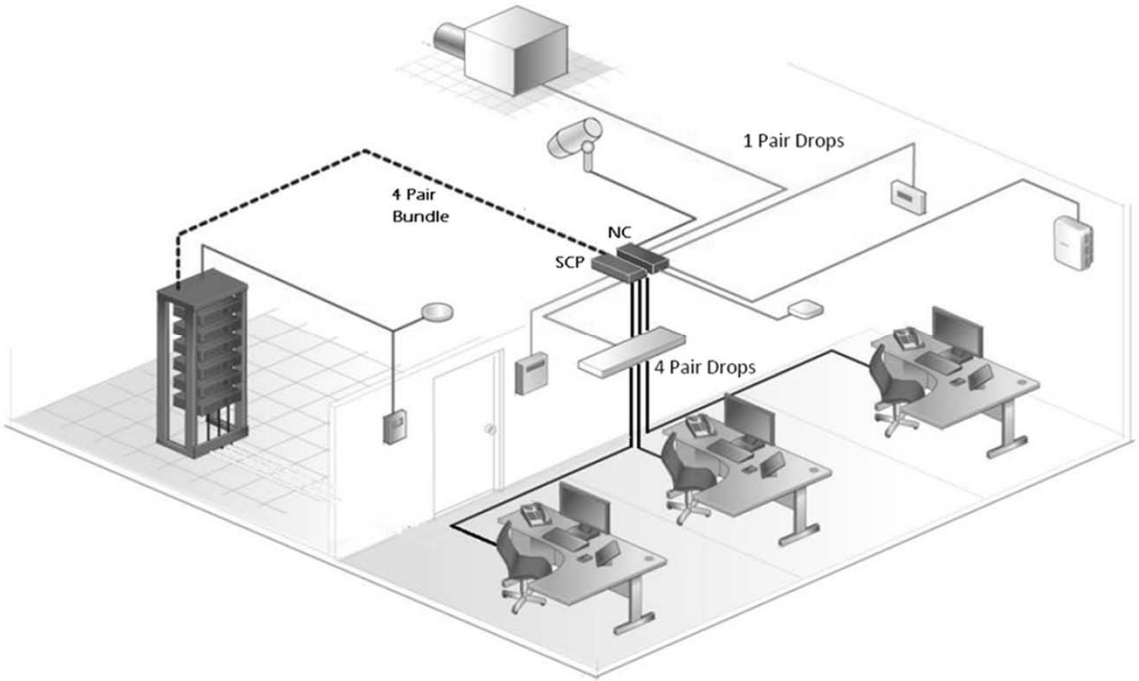


Distributed Active Architecture



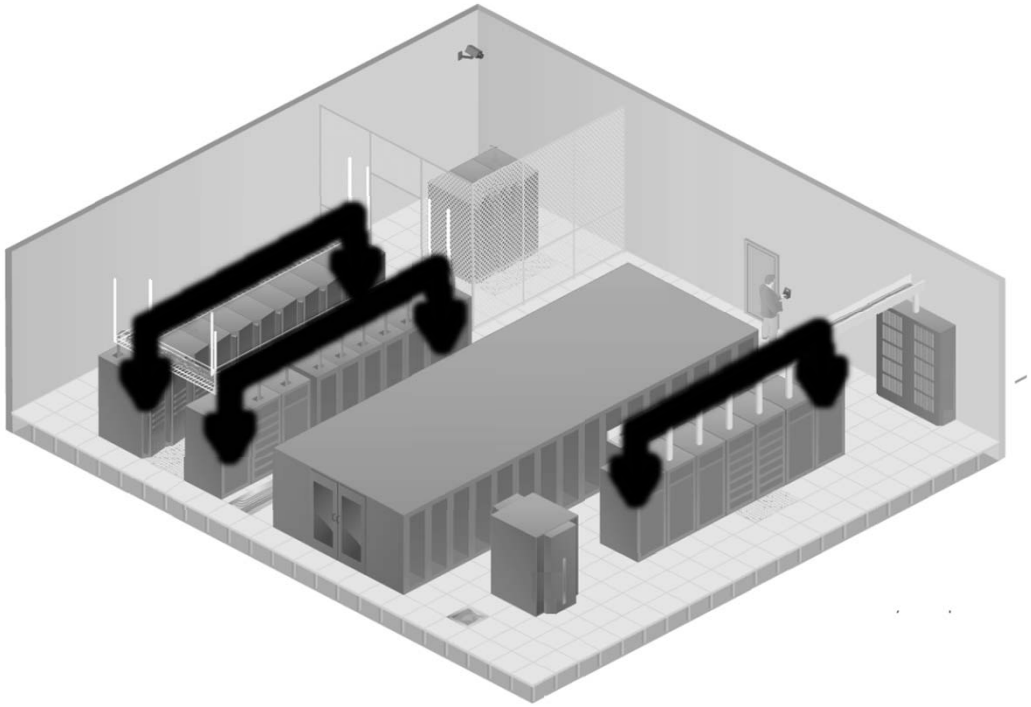
4-pair with 1-pair zone Architecture

- Service Consolidation Point allows connection to a 1-Pair Network Conversion Switch
- More flexible cabling for offices of the future
- IOT friendly supporting greater endpoint diversity
- Friendly to 15(+) meter 1-Pair PHY developments
- Provide for improved planning of cable bundling in support of POE



Data Center – Out of Band Admin Support

- Start servers
- Reset servers
- Log physical data
- Log statistics
- IEEE 802.3 10 SPE for internal and external networking of equipment



IEEE 802.3cg Backplane applications

- IEEE 802.3cg 10 Mb/s SPE management networks on server and switch circuit boards (backplane)
- Monitor physical and electrical characteristics
- Enable administration and management of circuit board components
- Can connect to external equipment using the same 10 Mb/s SPE network

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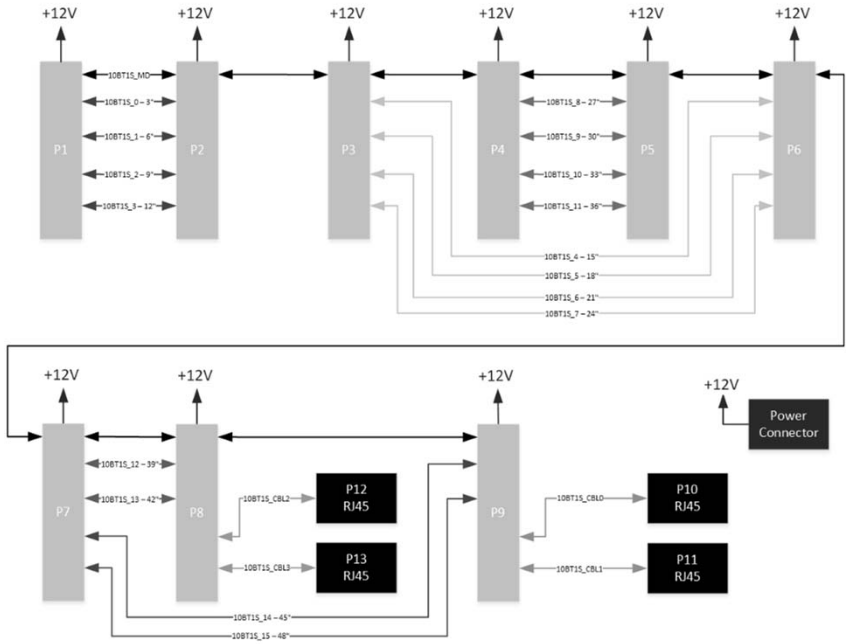
SPE Interoperability Testing

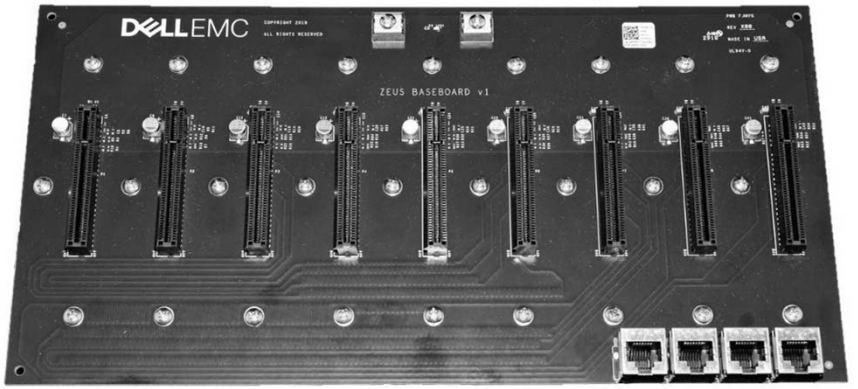
Jon Lewis & Jason Rock

Courtesy DELL-EMC

SPE Multi-site Baseboard



- Common PCIe x8 connectors for site insertion
- Varying P2P attenuation options
  - On board: 3” to 48” 100 ohm differential lengths
  - External ports for cable length testing (RJ45)
- Includes up to 9 multidrop sites
  - Multi-Drop “bus” routed with minimum spacing



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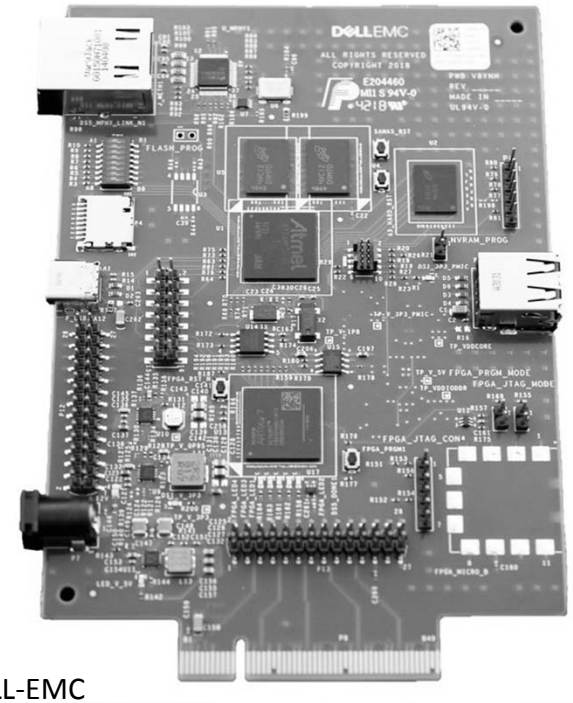
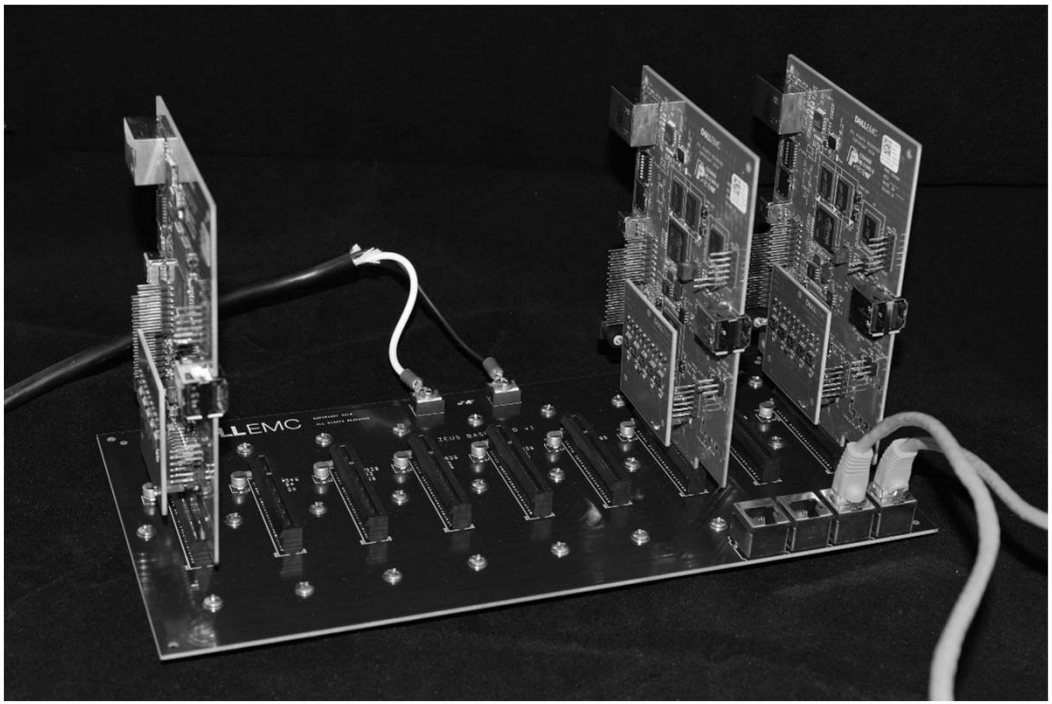
10 BASE-T SPE Emulator



Courtesy DELL-EMC

- PHY emulation via FPGA+AFE board
  - Up to five AFE channels
  - AFE modifiable depending on IP concerns
  - Test headers for debug
- Linux Yocto running on SAM A5 core
  - 100BT PHY for external traffic insertion
  - Serial USBs for console access
- Will be updated once silicon is available for interoperability testing.

Interoperability Testing Setup



- RJ45 connections for cable/connector testing.
  - Upcoming work: replace RJ45 with IEC63171-1 connector.
  - Feedback from silicon/system providers to adjust test fixture for better interoperability testing.
- Modification of the FPGA board to real 10 SPE silicon once available!

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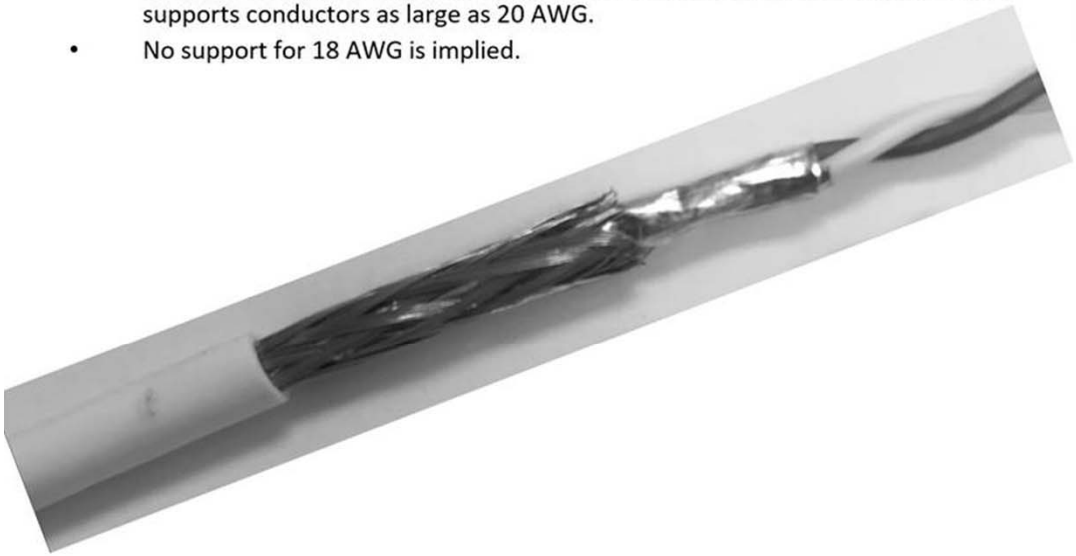
Single pair cable specifications

- As of April 12, 2018: Section 5.3 of IEC 61156-11 states that the conductor shall be a solid annealed copper conductor, in accordance with 5.2.1 of IEC 61156-1 and should have a nominal diameter between 0,4 mm and 0,65 mm. A conductor diameter of up to 0,8 mm may be used.
- In other words, the standard is targeted toward 22 to 26 AWG conductors but supports conductors as large as 20 AWG.
- No support for 18 AWG is implied.

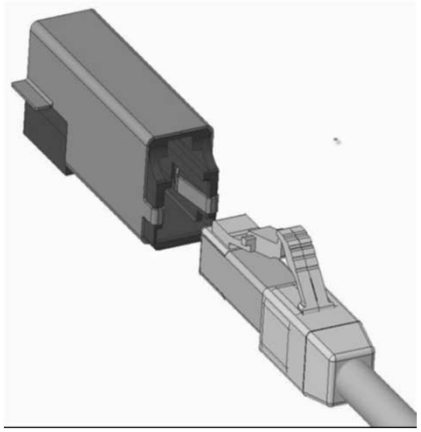


AWG #	Diameter (mm)	Diameter (inch)
18	1.0237	0.0403
19	0.9116	0.0359
20	0.8118	0.032
21	0.7229	0.0285
22	0.6438	0.0253
23	0.5733	0.0226
24	0.5106	0.0201
25	0.4547	0.0179
26	0.4049	0.0159
27	0.3606	0.0142
28	0.3211	0.0126

The “interface” connectors selected by ISO and TIA

IEC 63171-1

LC style for $M_1I_1C_1E_1$ environments .
e.g. office buildings and data centers



IEC 61076-3-125

Industrial style for $M_2I_2C_2E_2$ and $M_3I_3C_3E_3$
environments e.g. industrial spaces and harsh conditions

What does cabling interface connector mean ?

- Applies only at the two ends of the link segment
- Does not apply to any other connectors in the link segment
- Interface connectors need larger number of mating cycles (> 750)
- Interface connectors can be subject to mating and un-mating under load (2 A per contact)
- Need to have repeatable and consistent electrical & mechanical plug and jack interoperability from multiple suppliers

Advantages of using the same interface for cabling and MDI

- Connector specifications are developed by IEC SC48B experts with considerable expertise in mechanical specifications, electrical specifications, reliability specifications, testing and EMC specifications
  - IEC SC48B is the expert committee for detailed connector specifications
- Do not need multiple adapter cords for connection to equipment from the installed cabling
- Improves the volume economics of both MDI and cable interface connectors
- Shared knowledge and technology will improve both cabling interfaces and equipment interfaces leading to positive benefits for both

Usability considerations and advantages

- Cord can be plugged in without concern for end orientation making it easier to administer.
- Avoids mix ups, where one is choosing a cord by looking at the plugs. With the same plug on both ends, a look at either end means it is the same on the other end.
- Reduces the number of plug combinations (experience with the USB cord variants with USB on one end and different equipment connectors at the other end).
- Advantage of plug designed for the “cabling interface” application at the outlet, will also be capable of repeated “mating” at the equipment.

Interoperability – A key standards requirement

IEC 63171-1 Copper LC connector interoperability

IEEE 802.3cg Task Force
September 2018
Related to draft 2.0 ballot comments 572, 573, 618, 619, 653

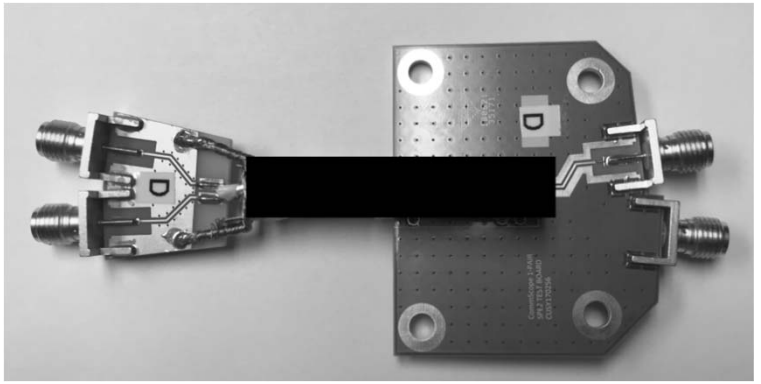
Antoine Pelletier, Intertek
Masood Shariff, CommScope
Jeff Oberski, CommScope
Mike Borgman, Panduit

Test plan overview

- Two (2) manufacturers submitted four (4) pairs of copper LC plug and jack (MDI).
- Each connector pair from both manufacturer was measured (resulting in 8 measurements).
- The plug and jack specimen were interchanged between both manufacturers and the mated performance measured (resulting in another 8 measurements).
- The IL, RL, TCL and TCTL results were compared against the IEC 63171-1 draft standard.

Test specimens and preparation

- The test specimens are prototype samples (not yet in production).
- The test specimens are shielded.
- Each specimen was mounted on a test board.
- Test boards of the same design and manufacturer were used for both connector manufacturers.
- The test boards are part of the whole DUT.



Network analyzer settings

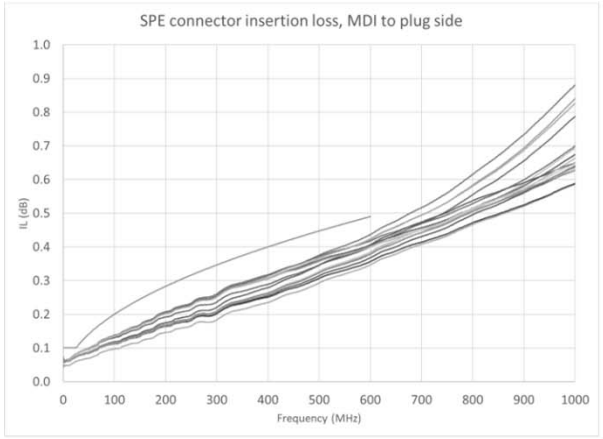
- Network analyzer: Keysight E5071C
- IF BW: 200 Hz
- Sweep type: Segment
  - 300 kHz – 900 kHz, 7 points
  - 1 MHz – 1 001 MHz, 1 001 points
- Power level: 10 dBm
- ECAL was used for calibration
- Note: The particular network analyzer used has a start frequency of 300 kHz which is greater than the 100 kHz minimum frequency of the draft standard. The connectors are expected to meet the requirements below 300 kHz.

Test results

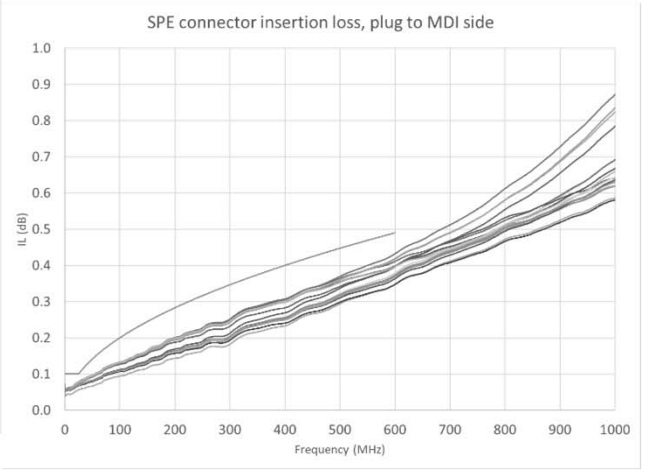
- The test results are presented in the following eight (8) slides (4 parameters * 2 directions).
- For each parameters, all sixteen (16) test results are superimposed.
- The test results are not identified as to which manufacturer combination they belong to.

Test results

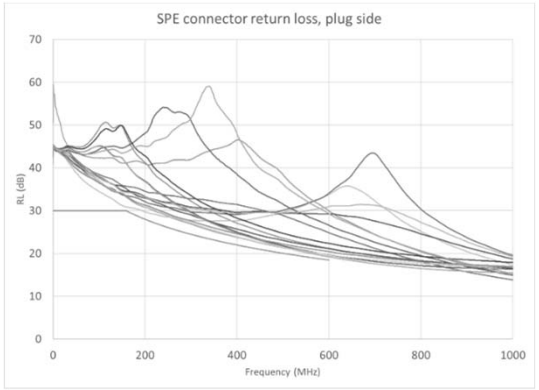
Insertion Loss forward



Insertion Loss reverse



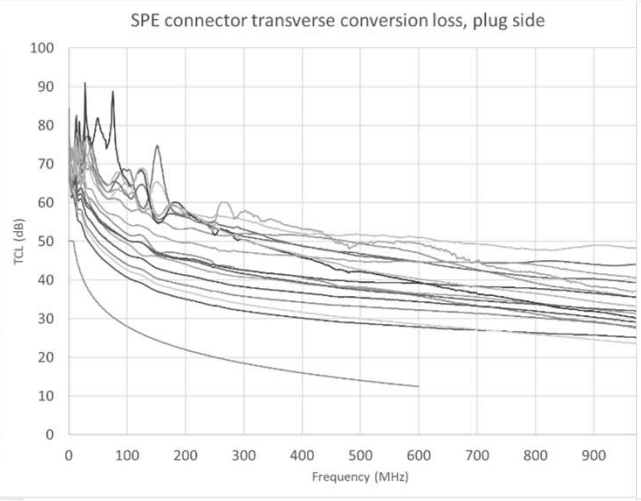
Return Loss forward



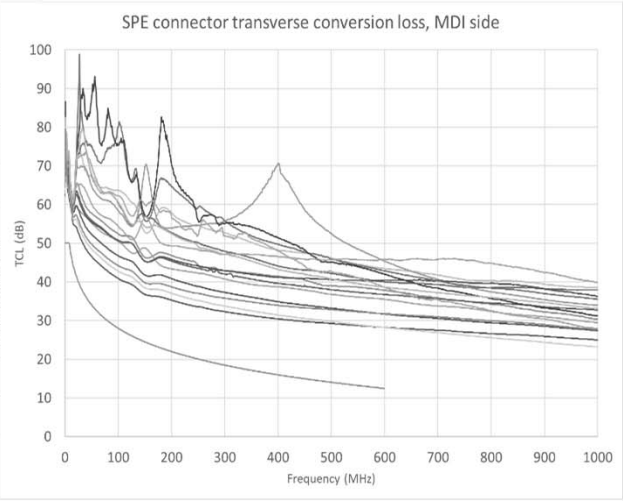
Test results

Return Loss reverse

TCL forward

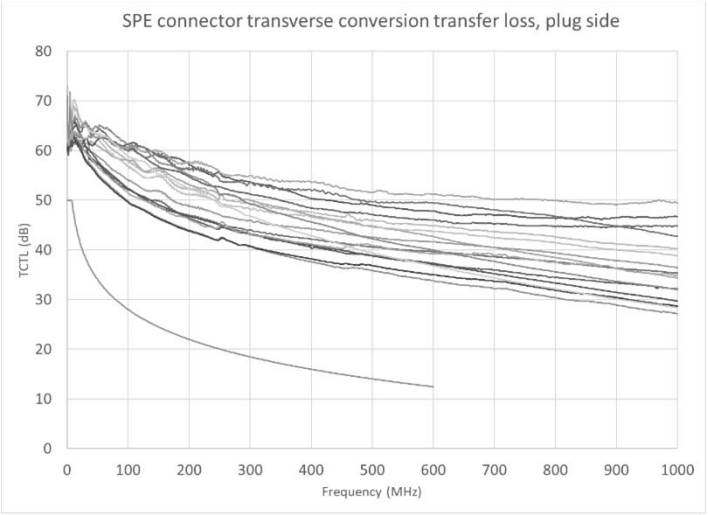


TCL reverse

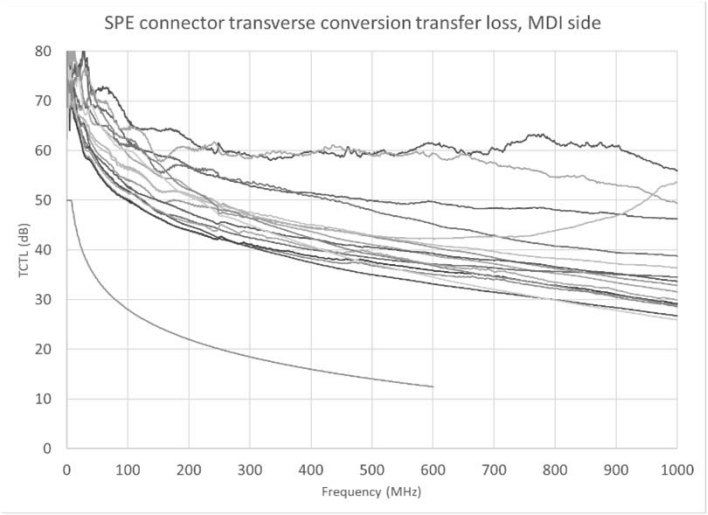


Test results

TCTL forward



TCTL reverse



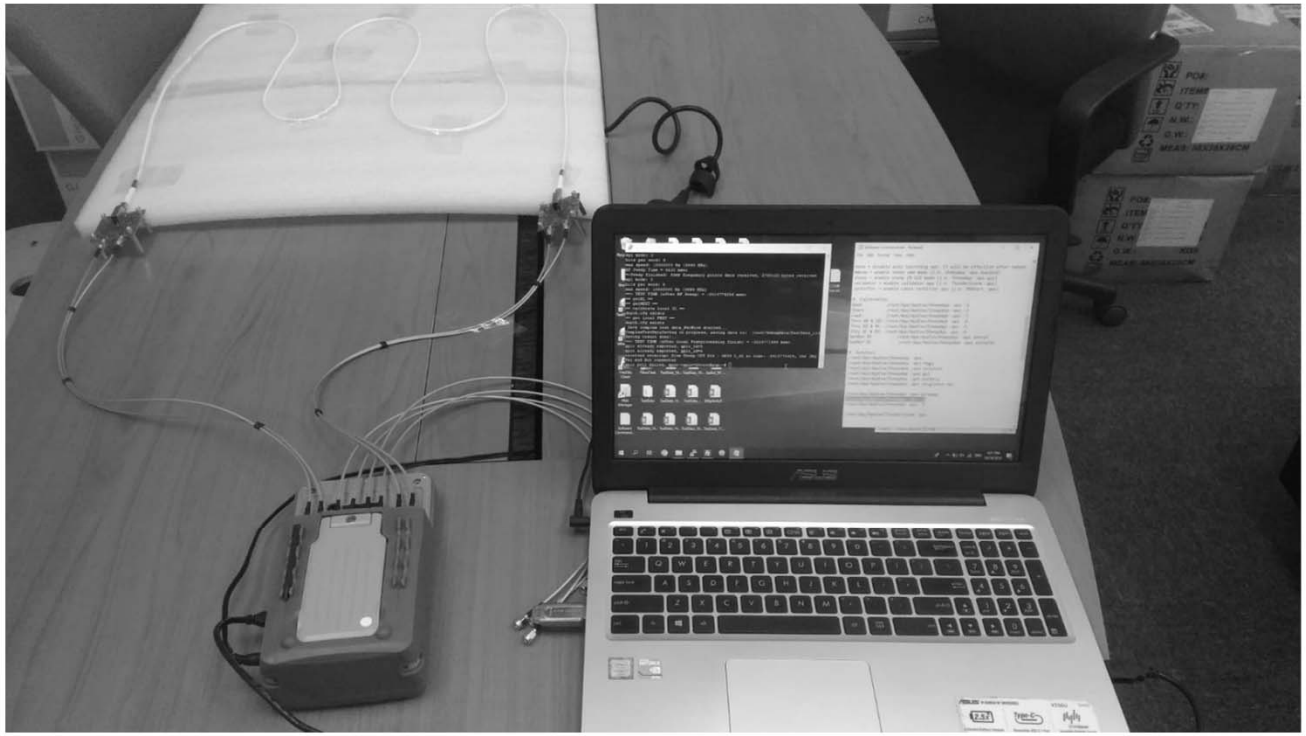
Conclusion

- Two (2) different manufacturers made compliant copper LC connectors.
- The IEC 63171-1 limits for IL, RL, TCL and TCTL are met when plugs and jacks from the two (2) manufacturers are interchanged.

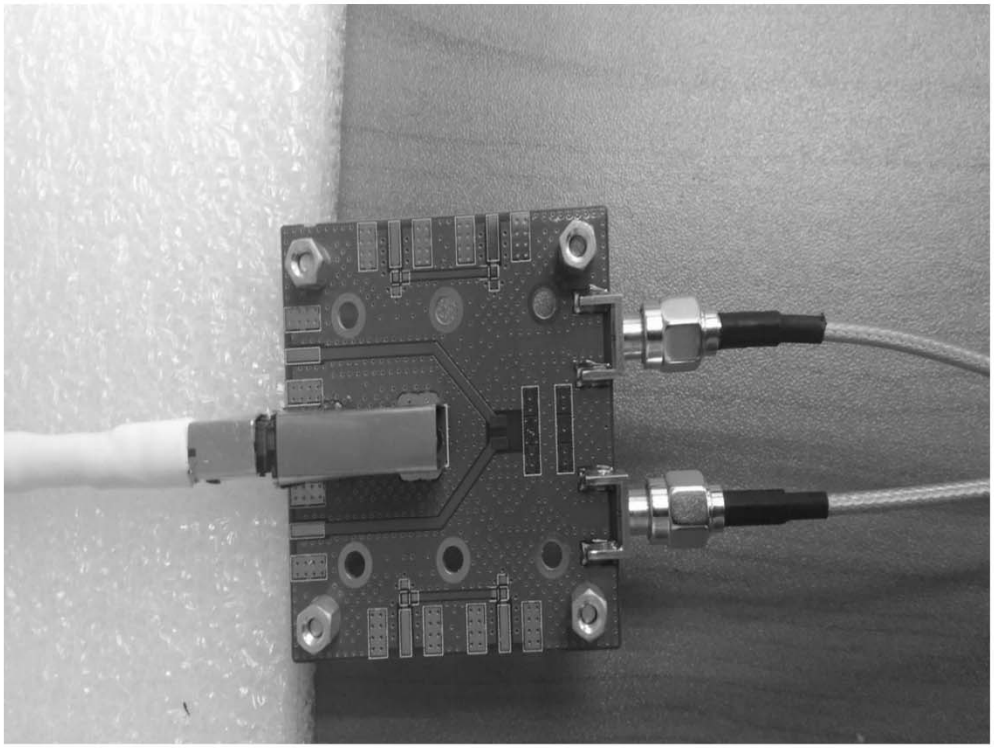
Field testing – An important quality metric

Setup 1

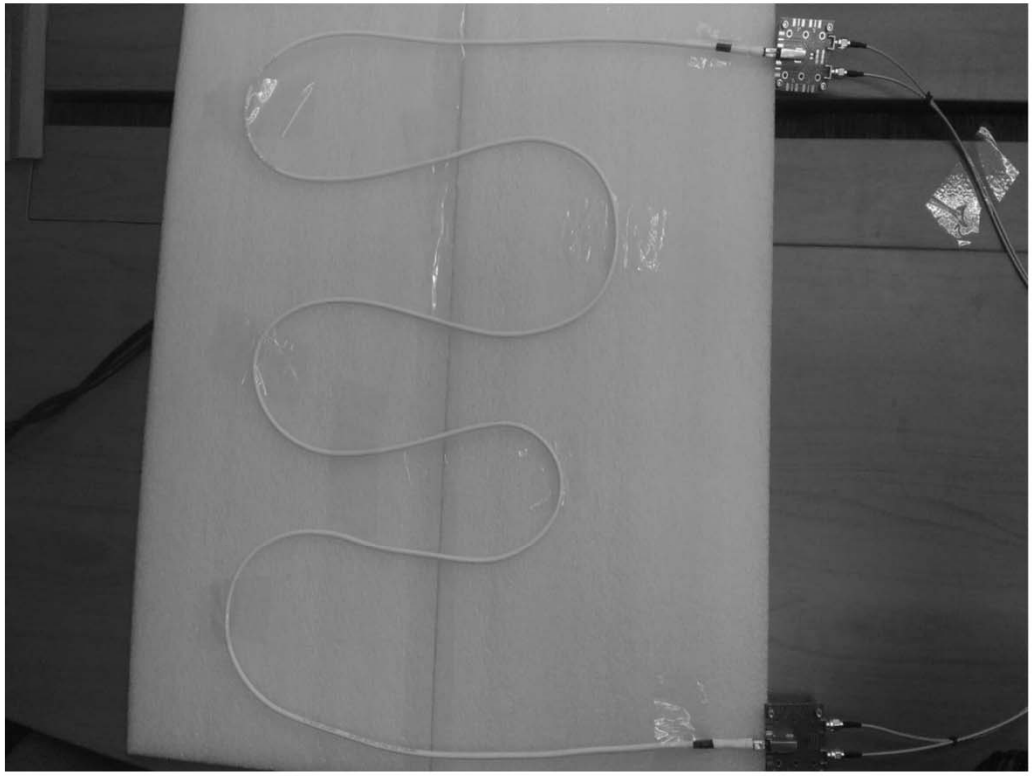
(End A and End B connected to Tester)



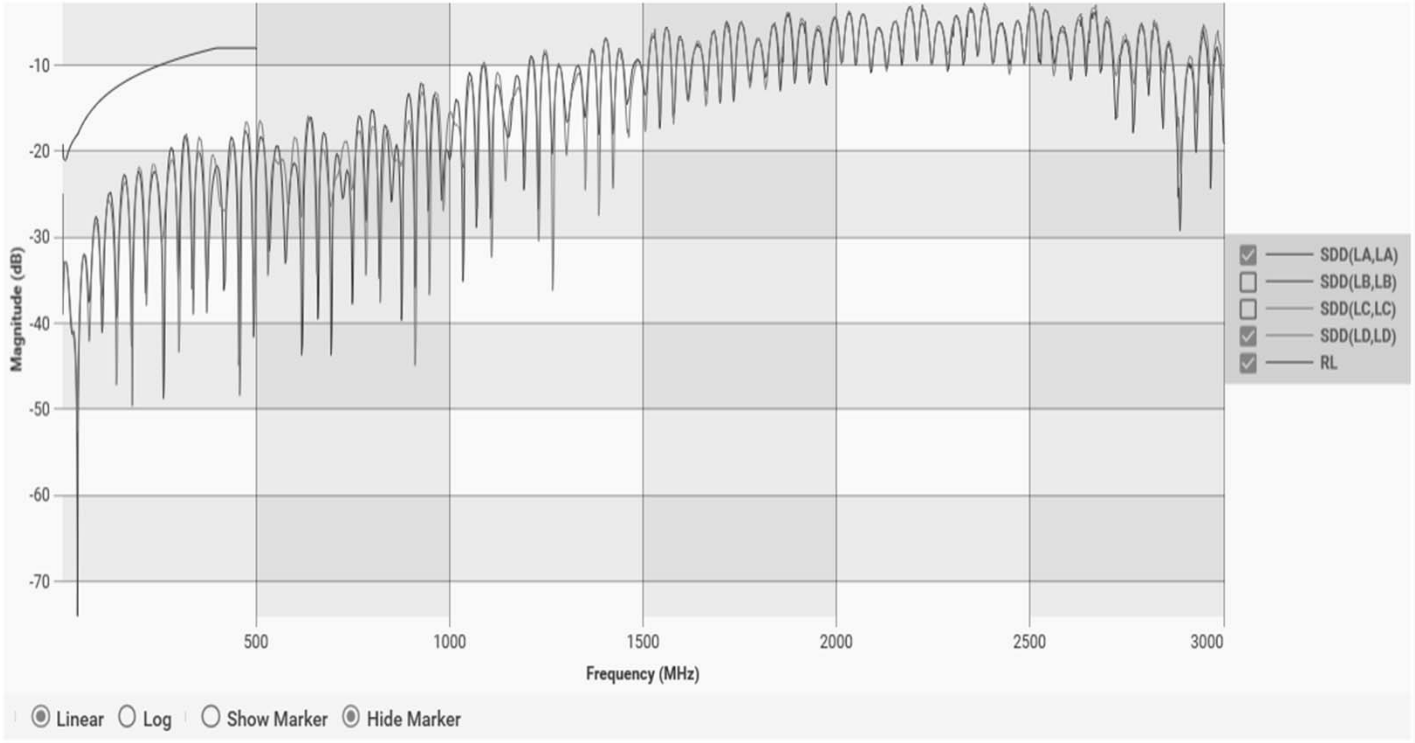
AEM Singapore Setup 1
(End A and End B connected to Tester)



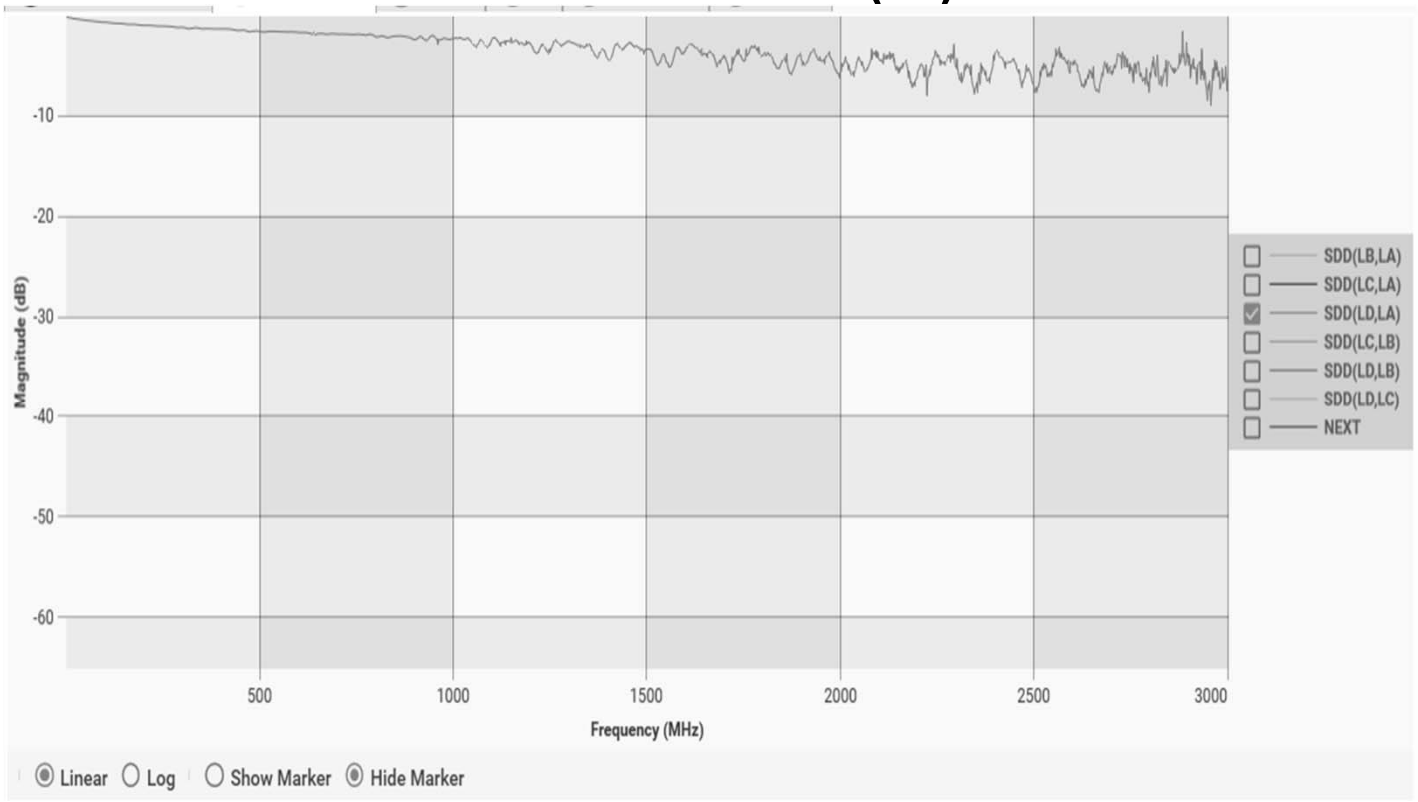
Setup 1 End A and End B connected to Tester



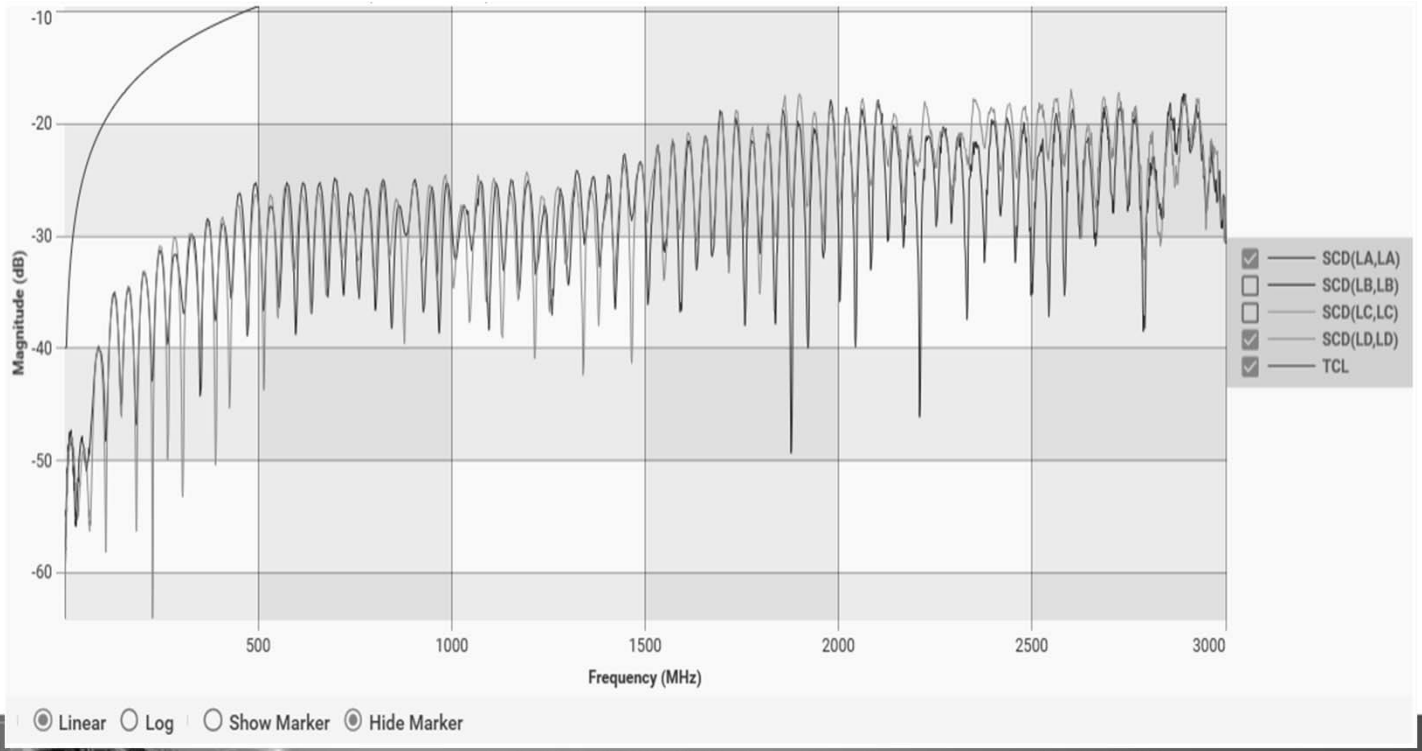
Return Loss (IL)



Insertion loss (IL)



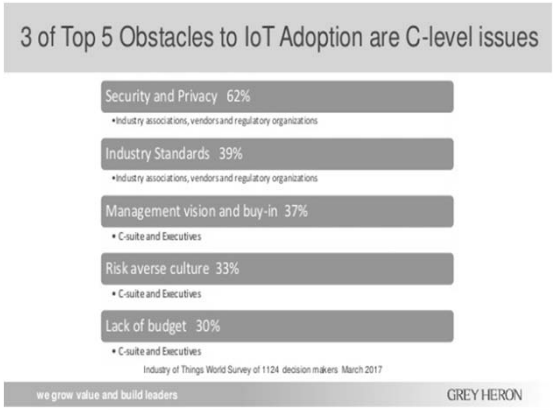
Transverse Conversion Loss (TCL)



Top Hurdles for IoT Deployment

Accenture Healthcare Report 2017

Privacy concerns 55%
Legacy systems and equipment 55%
Security concerns 54%
Technology immaturity 53%
Lack of budget 53 %



IEEE

Security, standardization & connectivity are at the TOP of all the lists.

How can BICSI members help?

- BICSI members can help existing common 1-pair use cases to migrate to Single Pair Ethernet supported by generic structured cabling to improve relative costs, usability, maintenance, and operations
- Move to structured 1-pair generic cabling will enable existing and emerging IEEE 802.3 1-pair applications to be used for data and control networking, bringing extra security, reliability, and robustness to these existing 1-pair applications
- BICSI members understand IT networks and OT networks and can help bridge the gap between these networks

Conclusions and Take Away

- Single pair Ethernet applications for communications and power are happening now
- ISO, IEC, TIA, and CENLEC cabling standards are following suit with several projects
- Need for low cost, high density infrastructure will lead to widespread adoption and growth in the next 3 to 6 years
- Need engagement from BICSI as a key stakeholder of the single pair cabling/applications ecosystem

Thank You!