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Category 8 cabling:
supporting applications beyond 10 Gb/s

Introduction

Category 8 cabling specifications were published in July 2016 in ANSI/TIA-568-C.2-1, Balanced twisted-pair cabling and components standard, addendum 1: Specifications for 100 Ω Category 8 cabling. Similar cabling specifications are reaching maturity in ISO/IEC/JTC 1/SC 25/WG3 and CENELEC TC215 committees. In parallel, the IEEE 802.3bq task force has completed development of the 40GBASE-T and 25GBASE-T Ethernet applications that IEEE-SA approved for publication on June 30, 2016. This white paper describes the combination of application and cabling standards that quadruples the cabling bandwidth and data throughput capacity of Ethernet links.

The IEEE 25G/40GBASE-T standards utilize Category 8 cabling and have standardized on the RJ45 connector as the equipment interface connector (also referred to as the MDI connector). This helps make the cabling that supports 25G/40GBASE-T applications backward compatible and interoperable with the huge installed base of cabling and equipment using RJ45 connectors. Additionally, the 25G/40GBASE-T applications feature auto-negotiation, allowing them to automatically detect the lowest common speed between two pieces of equipment and negotiate to communicate over that speed.

This white paper describes recent advances in balanced twisted-pair cabling technology that enabled Category 8 and associated products matching these specifications. The interoperability of Category 8 components and the field testability of Category 8 channels are important considerations for end users—and this white paper includes practical examples demonstrating these features. Finally, the white paper covers use cases where Category 8 may be deployed in data centers and enterprise networks—allowing users a cost-effective, flexible option for upgrading their networks. CommScope, our customers, and other industry leaders continue to evaluate potential markets for 25G/40GBASE-T. As we determine the makeup of practical solutions, these considerations will continue to be important.

IEEE 802.3bq task force

At the March 21, 2013, IEEE 802.3 meeting, the working group approved the formation of the IEEE 802.3bq task force to develop the IEEE 40GBASE-T Ethernet standard.

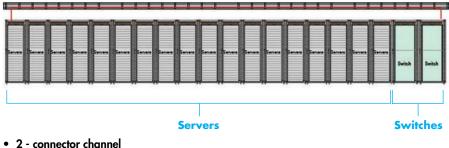The task force established the following objectives:

- Support full duplex operation only

- Preserve the 802.3/Ethernet frame format utilizing the 802.3 MAC

- Preserve the minimum and maximum frame size of the current 802.3 standard

- Support a BER better than or equal to 10^{-12} at the MAC/PLS service interface

- Support auto-negotiation (clause 28)

- Support energy-efficient Ethernet (clause 78)

- Support local area networks using point-to-point links over structured cabling topologies, including directly-connected link segments

- Do not preclude meeting FCC and CISPR EMC requirements

- Support a data rate of 40 Gb/s at the MAC/PLS service interface

- Define a channel model based upon copper media specified by ISO/IEC/JTC1/SC25/WG3 and TIA TR42.7 meeting the following characteristics:
  - o 4-pair, balanced twisted-pair copper cabling
  - o Up to two connectors
  - o A maximum channel reach of 30 meters
  - o A definition for a single 40 Gb/s PHY supporting operation on the channel model

The committee agreed to require cabling to be specified up to 2000 MHz and included link segment specifications based on ISO/IEC 11801-1 Class I and ANSI/TIA-568-C.2-1 Category 8. The task force also selected the IEC 60603-7-81 (RJ45) connector for the MDI (media dependent interface). This establishes the interoperability of 25G/40GBASE-T using auto-negotiation with previous IEEE BASE-T applications, including 10GBASE-T, 1000BASE-T, and 100BASE-TX. In addition to the economic advantages, the convenience and flexibility of auto-negotiation during upgrades are key reasons for the widespread adoption of Ethernet using twisted-pair cabling.

The IEEE 802.3bq task force amended the original objectives to add 25GBASE-T as an additional application. Following the detailed IEEE 802 process of task force ballot review, working group ballot review, and sponsor ballot review cycles, IEEE standards 25GBASE-T and 40GBASE-T were both approved for publication by the IEEE-SA on June 30, 2016.

Category 8 topology

The primary application area for 25G/40GBASE-T is in the server to access switch links in data centers. The IEEE 802.3bq task force, TIA and ISO have all accepted a maximum channel reach of 30 meters with a maximum of two connections as shown in Figure 1. This configuration can be used to serve as an end-of-row access switch configuration and a top-of-rack (TOR) access switch configuration. It is worth noting that the structured cabling paradigm that uses a modular subsystem approach is preserved and continues to offer easy moves, adds, and changes (MAC) to the network.

Servers   **Switches**

- **2 - connector channel**
- **30 - meter maximum channel length**

Figure 1: Two-connection 30-meter channel topology

TIA TR42.7 copper cabling systems

The published TIA-568-C.2-1 standard includes the following key provisions:

- Single-equipment outlet interface with the IEC 60603-7-81 RJ45-style connector

- Direct-attach cabling specifications for TOR implementations

- Length-scaling models to calculate transmission parameters at different lengths

- Improvements in return loss of the link and channel with a minimum of 8 dB

- Detailed measurement procedures for components, links and channels to improve the quality and robustness of Category 8 cabling

The interoperability of Category 8 components means end users have an open and competitive market in which to choose components to build links and channels. A contribution submitted to TIA TR42.7 by Psiber Data Systems shows interoperability where cords and modular RJ45 plugs from two different manufacturers were mated with links consisting of cable and modular RJ45 jacks from a third manufacturer.

This "mixed" channel was tested using the Psiber Wirescope field tester, and it showed good operational margin for the specified transmission parameters.

Interoperability test configuration

The following figures show the interoperability test configuration and results presented to TIA TR42.7. Figure 2 shows two setups with channel components from three different manufacturers. Both setups have a 26-meter link including RJ45 jacks provided by manufacturer X and cordage from manufacturer Y. Setup 1 has modular RJ45 plugs from manufacturer A; setup 2 has modular RJ45 plugs from manufacturer B.

The contribution from Psiber has detailed measurement results from both setup 1 and setup 2. For brevity (and since the results from setup 1 and setup 2 are very similar) only test results from setup 1 are presented.
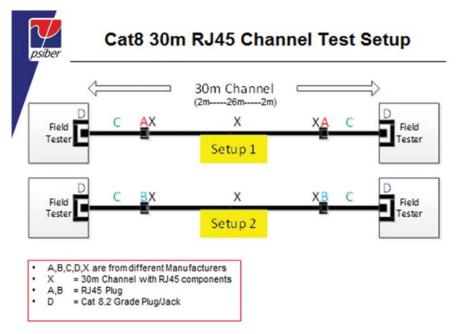

Figure 2: Category 8 interoperability test configurations using RJ45 connectors

Channel insertion loss

Insertion loss is the reduction of signal strength as the signal propagates from the transmitter to the receiver. This is a critical parameter in order to maintain good signal-to-noise ratio (SNR) at the receiver. Figure 3 shows a good margin up to 2 GHz for the channel configuration measured with field testers.
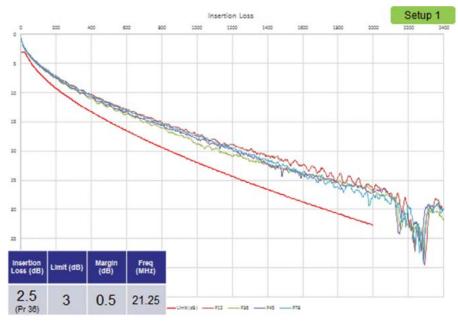

Figure 3: Category 8 channel IL measurement of test setup 1 using field testers

Channel return loss

Channel return loss specifies how much signal is reflected back into the transceiver and must be reduced by DSP (digital signal processing); otherwise, it impairs the decoding of useful information from the signal. The channel field measurement in Figure 4 shows good performance up to the maximum frequency of 2 GHz.
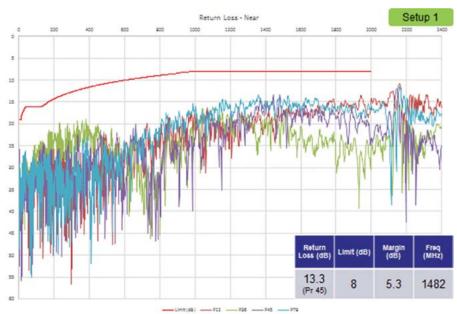

Figure 4: Category 8 channel RL measurement of test setup 1 using field testers

Channel NEXT loss

Channel NEXT (near-end cross-talk) is the coupling of noise from an adjacent pair into the signal pair as measured at the near end. Figure 5 shows a good margin up to 2 GHz when measured with available field testers for Category 8 cabling.
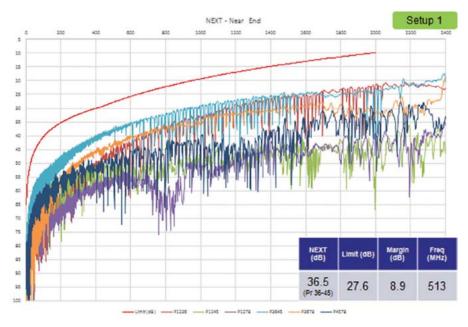

Figure 5: Category 8 channel NEXT loss measurement of test setup 1 using field testers

Channel ACRF

Channel ACRF (far-end cross-talk) is the coupling of noise from an adjacent pair into the signal pair as measured at the far end of the disturbed pair. Figure 6 shows good margin for the channel configuration tested up to 2 GHz using available field testers.
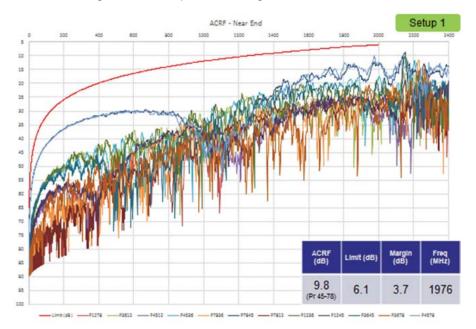

Figure 6: Category 8 channel ACRF measurement of test setup 1 using field testers

Interoperability study

The contribution from Psiber also includes the interoperability study for setup 2. This shows results similar to setup 1 with a good margin to the measured transmission parameters. The Psiber contribution draws the following conclusions:

- Field testing of Category 8 channels confirms the compatibility of RJ45 plugs and jacks from different manufacturers

- There is sufficient margin for most of the test parameters (except IL, which has 0.5 dB margin for the longest length)

Backward compatibility with Category 6A

Category 8 includes the whole suite of parameters specified for Category 6A. Backward compatibility with Category 6A supports 10GBASE-T and other lower speed applications up to 100 meters with four connections. This backward compatibility exists also at the physical level. A Category 6A equipment cord can be plugged into a Category 8 jack to yield, at minimum, Category 6A mated connection performance.

Channel PSANEXT and PSAACRF alien crosstalk parameters

Channel alien crosstalk parameters for Category 8 have improved 20 dB over Category 6A specifications, making them lower than the background noise seen by the transceivers. Since there are no easy ways to cancel alien cross-talk, this is a key improvement to support applications beyond 10GBASE-T.

Channel coupling attenuation

Coupling attenuation, which quantifies the effectiveness of the shield around the cable, has improved by 10 dB relative to Category 6A type F/UTP. This leads to better immunity from external noise sources.

ISO/IEC/JTC1/SC25/WG3 developing generic cabling for customer premises

In 2014, ISO/IEC/JTC 1/SC 25 Working Group 3 published the ISO/IEC TR 11801-99-1 technical report intended to support 40G applications. However, since this document specifies cabling only up to 1600 MHz, it is superseded by the requirement to specify link segments up to 2000 MHz, per the IEEE 802.3bq task force. As a result, this document cannot be referenced by the task force for its link segment requirements.

To accommodate the IEEE task force requirements, ISO/IEC/JTC 1/SC 25/WG3 agreed to incorporate Class I and Class II from the ISO/IEC TR 11801-99-1 technical report into the ISO/IEC 11801-1 generic document. The committee also agreed to extend the frequency from 1600 to 2000 MHz to comply with IEEE 802.3bq specifications for the link segment. It is important to know that WG3 generally does not develop component specifications, but refers these to IEC 46C (for cables) and IEC 48B (for connecting hardware). Accordingly, the IEC 46C and 48B have completed or reached maturity in developing Category 8.1 and Category 8.2 components to build Class I and Class II channels. Class I can be achieved by a reference implementation approach using Category 8.1 components. Class II can be achieved by a reference implementation approach using Category 8.2 components.

Since it is intended to support the 8-pin IEC 60603-7-81 (RJ45 interface) connector, Category 8.1 is specified to be backward compatibile with Category 6A. This ensures plug-and-play mechanical interoperability and also ensures Category 8 is fully backward compatible to all previous standardized applications.

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Use cases for IEEE 25G/40GBASE-T

In traditional data center topologies, Category 8 enables high-speed applications to use mid-span and end-span switch placements with structured cabling between the switches and servers. This allows for better port utilization and more flexible changes to both equipment and servers. Since the cabling is independent of the network equipment, this topology supports multiple types and generations of equipment.

The TIA TSB-5019 application published by TIA engineering sub-committeeTR42.7 in April 2015 describes the different use cases of Category 8 in data center and enterprise networks. The following excerpts from TIA TSB-5019 illustrate the use cases for Category 8 cabling. Essentially, 25GBASE-T and 40GBASE-T will work anywhere in a data center where 30-meter connections are applicable, including:

- Anywhere in the classic three-level hierarchy

- Fat-tree , leaf-and-spine, and interconnected fat-tree fabric architecture

- Full-mesh, interconnected meshes, and centralized switch or virtual switch

Figures 7 through 10—derived from ANSI/TIA-942-A-1 data center fabric architectures— show where Category 8 cabling may be used to extend the server link speeds to 25 and 40 Gb/s.
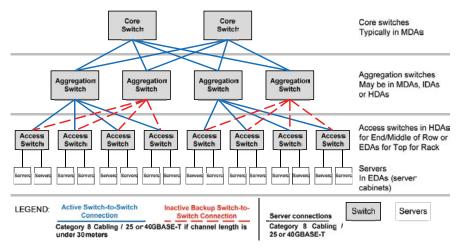

Figure 7: Category 8 use case for traditional 3 tier data center architecture
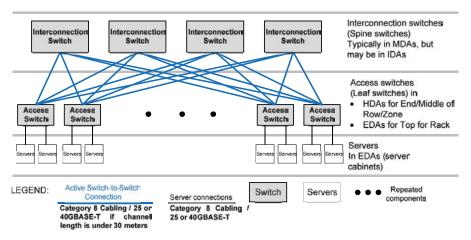
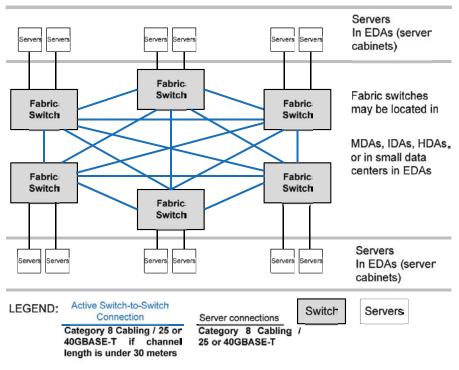Figure 8: Category 8 use case for leaf-and-spine data center architecture

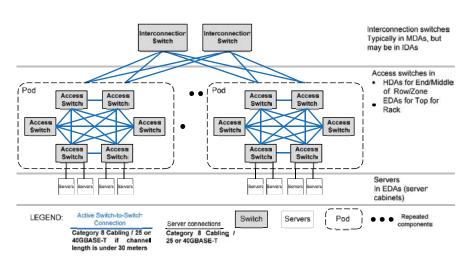Figure 9: Category 8 use case for full mesh data center architecture

Figure 10: Category 8 use case for interconnected mesh data center architecture

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Observations and conclusions

The TIA-568-C.2-1 Category 8 standard supports many use cases for higher capacity throughput in data centers and equipment rooms. This includes the new data center fabric architectures like leaf-and-spine, full mesh, and interconnected mesh that have multiple connections between active equipment. Category 8 cabling is a viable, cost-effective option in these new high-connection, high-speed topologies.

Additionally, Category 8 cabling requirements are intended to support backward compatibility with existing cabling and equipment to allow auto-negotiation between 100 Mb/s, 1 Gb/s, 10 Gb/s, 25 Gb/s and 40 Gb/s BASE-T Ethernet applications. This will enable the gradual evolution of LAN networks to higher speeds without a forklift upgrade, making the change cost effective and less disruptive for both existing and new data centers.

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