Single balanced twisted-pair cabling infrastructure for IoT and M2M connectivity

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Executive summary

Twisted-pair cabling traces its roots back to the late 19th century when Alexander Graham Bell first used it to transmit voice traffic while overcoming interference.

Today, twisted-pair copper continues to play a crucial role in communications. Significantly improved from the first telephone wire that carried Bell's voice, twisted-pair is prevalent in ethernet networks, supporting commonly available equipment with data rates up to 10 Gbps. Engineers have also been able to tap the ability of balanced twisted-pair to deliver DC power, as well as data, over the same cable.

Concerning network cabling, the best solution is not always the fastest; it's the solution that most effectively meets all application requirements. One need only look at the increasing deployment of the internet of things (IoT) to understand the significance of this shift and the opportunities it is creating.

Enterprise IT professionals are challenged to connect a wide assortment of sensor/actuator devices into their structured cabling networks. Many require the power output and high-bandwidth capacity only four-pair ethernet cabling can support. But, for devices with lower power and bandwidth requirements—such as sensors and actuators used for building automation and manufacturing equipment, alarm systems and RFID readers—the use of single-pair ethernet cabling can provide a more cost-effective and space-efficient solution.

The industry is exploring possibilities for single-pair ethernet to efficiently support these applications. Standards bodies have ramped up the development of guidelines for a variety of applications involving single balanced twisted-pair as well as the components used in its deployment. Application specifications include 802.3bp 1000BASE-T1, 802.3bw 100BASE-T1, 802.3bu PoDL (0.5 watt to 50 watts) 802.3cg 10BASE-T1S (short reach), and 10BASE-T1L (long reach).

Single-pair ethernet is not meant to replace traditional four-pair ethernet cabling, but support emerging applications, such as interconnecting IoT and machine to machine devices, strengthen the business case for its growing use. When deployed in support of appropriate applications, single-pair ethernet provides significant economic, density, sustainability, and installation advantages.

Twisted-pair cabling traces its roots back to the late 19th century when Alexander Graham Bell first used it to transmit voice traffic while overcoming interference.

Some examples of single-pair use cases in buildings include:

1. Building automation systems
2. Lighting systems
3. Elevator and escalator control systems
4. Access control systems
5. Security and fire alarm systems

Industrial use cases include:

1. Industrial automation
2. Process control
3. Robotics
4. Server cabinets and switch connections
5. Industrial enclosures

IoT applications are opening the door for single-pair ethernet

IoT-based sensors and devices are expected to exceed mobile phones as the largest category of connected devices.[1] By 2020, there will be an estimated 200 billion connected objects in use worldwide[2]—or 26 devices for every person on Earth. See Figure 1 for IoT market projections.

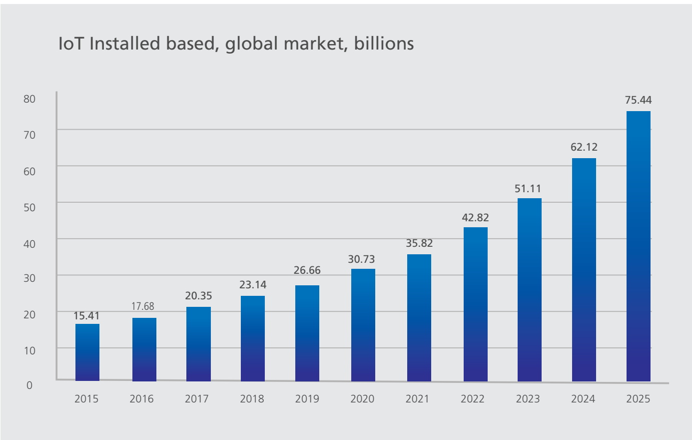


Figure 1: The IoT market will be massive

While consumer-based applications—wearables, home automation and automotive telematics—attract much of the general media attention, they pale in comparison to the industrial IoT (IIoT). By 2025, the total global worth of IoT technology could be as much as USD 6.2 trillion, with USD 4.8 trillion coming from healthcare (USD 2.5 trillion) and manufacturing (USD 2.3 trillion) as the two largest market segments.[3] Most of the growth will come from machine-to-machine (M2M) connections needed to drive manufacturing, distribution, agriculture, industrial processing, healthcare and other professional services.

Enterprise network engineers must determine how to connect the vast number of sensors, actuators, controllers, cameras and other devices in a way that makes sense, is easy to scale, and cost-efficient. Most of these connected devices—especially those used in industrial operations—are deployed at the edge of the network. Many require a wired data connection to the network; of those, some are battery powered, but most depend on a reliable dc power feed.

Traditionally, such edge-based connections have been made using non-ethernet links using a Fieldbus type networking protocol. Due to the highly fragmented and proprietary nature of the Fieldbus sector, there are multiple implementations that are often not interoperable. The specific technology used—such as ethernet/IP, PROFINET, FF HSE, ModbusTCP, and HART-IP—depends on the Fieldbus manufacturer.

Integrating and coordinating devices into the network presents challenges. Issues include installation complexity, lack of sufficiently skilled labor, interoperability problems and a variety of maintenance procedures. As a result, demand for industry-standard end-to-end "industrial ethernet" network protocols has been steadily growing, with a significant focus now being placed on one-pair applications. In June 2016, the IEEE 802.3 Ethernet Working Group issued a call for interest (CFI) to discuss developing standards around industrial ethernet. The initiative—10 Mbps Extended Reach Single Twisted Pair ethernet PHY—envisions a unified network based on single-pair ethernet as an alternative to the hugely fragmented Fieldbus landscape. There are several reasons IEEE 802.3 Ethernet Working Group is organizing around single-pair cabling:

- Increasing capabilities regarding data and power: Advancing standards and technologies confirm that single-pair ethernet can support speeds beyond 10 Gbps. Additionally, single-pair cabling can support up to 50 watts of dc power, covering a wide range of devices that need both power and data.
- Efficient use of space and budget: At about 25 percent the mass and weight of traditional four-pair ethernet, single-pair cabling can help relieve the increasing congestion in cable pathways and enable more—and more flexible—routing options. This includes connecting to smaller high-density devices.
- Data security: A primary challenge in deploying wide-scale IoT is ensuring network protection. IEEE 802.3 applications have built-in security features to allow secure communications.

In its CFI presentation, the 802.3 Ethernet Working Group calls the use of single-pair "essential" due in part to its weight, cost, and mechanical benefits—as well as the ease of installation and maintenance, combined with the existing pool of ethernet knowledge.[4]

IEEE 802.3cg 10BASE-T1 standard

The IEEE 802.3 10 Mbps/single pair ethernet project has completed the final stage of balloting and the IEEE-SA Standards Board approved IEEE Std 802.3cg-2019 for publication. The project objectives cover industrial, automotive, and building automation use cases, with two physical layer PHYs supporting the following applications:

- IEEE 10BASE-T1S up to 15-meter reach, with optional 25-meter multidrop capability
- IEEE 10BASE-T1L up to 1,000-meter reach

The IEEE 10BASE-T1S PHYs include optional Physical Layer Collision Avoidance (PLCA) to improve collision performance for multidrop implementations. To support the longer reach of 10BASE-T1L, the Power over Data Lines (PoDL) specifications have been modified to include several additional power classes that can deliver up to 7 watts of power over 1,000 meters using a nominal 57-volt power supply. See table 2 for these additional classes.

ISO cabling standards around single-pair

The international standards bodies—ISO, IEC and CENELEC —are also modifying existing cabling standards to address the increased use of single-pair ethernet. In September 2016, the ISO/IEC/JTC 1/SC 25/WG 3 initiated several projects to address single-pair cabling, including:

1. ISO 11801-1 amendment 1 containing generic single-pair cabling requirements.
2. ISO 11801-3 amendment 1 containing additional single-pair requirements for industrial environments like factory automation and process control.
3. ISO 11801-6 amendment 1 with additional guidelines for single-pair cabling supporting distributed services such as building automation systems, alarms and access control.

These projects are progressing with documents in the committee draft (CD) balloting process and are likely to reach publication approval by the end of 2020.

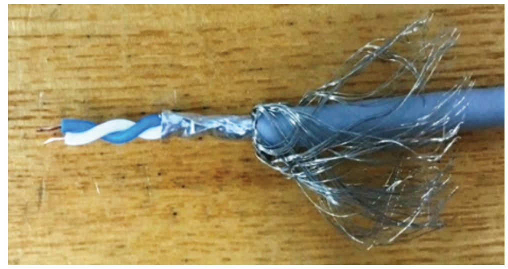


Figure 2: Example of IEC 61156-11 type shielded cable

IEC SC46C balanced single-pair cable standards

IEC SC46C started the following projects in coordination with ISO/IEC/JTC 1/SC 25/WG 3 to support IEEE 802.3 single pair ethernet (SPE) applications:

1. IEC 61156-11 horizontal cables specified up to 600 MHz
2. IEC 61156-12 drop cables specified up to 600 MHz
3. IEC 61156-13 horizontal cables specified up to 20 MHz
4. IEC 61156-14 drop cables specified up to 20 MHz

The first two projects typically use 26 AWG to 22 AWG conductors, while the third and fourth projects use larger conductor sizes from 20 AWG to 16 AWG. These projects are progressing with documents in various stages of balloting with publication likely by the end of 2020. Figure 2 shows a typical single-pair cable construction.

IEC SC48B single-pair connector standards

Currently, IEC SC48B has six single-pair connector projects underway within the IEC 63171 family; among these are the IEC 63171-1 copper LC-style connector from CommScope—which has been incorporated in IEEE 802.3, ISO/IEC/SC 25/WG 3, IEC SC 48B, and TIA TR42.7—and the IEC 63171-6 industrial connector from Harting. IEEE 802.3cg references these two connectors as optional MDI connectors for their 10BASE-T1S and 10BASE-T1L equipment. Figure 3 shows the plug and MDI socket version of the IEC 63171-1 copper LC style connector.

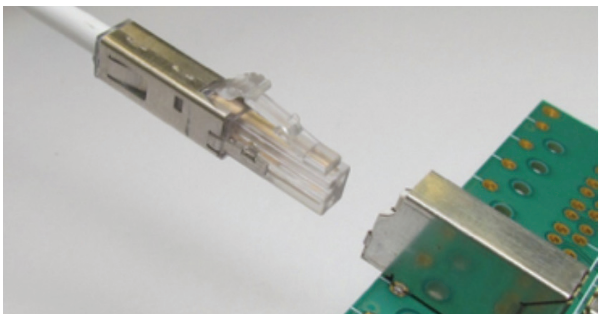


Figure 3: IEC 63171-1 plug and MDI style connector

The IEC 63171-1 copper LC connector has been tested for interoperability between several combinations of plugs and jacks from CommScope and Panduit. Testing was conducted in two phases. Phase one occurred in September 2018, when third-party testing by Intertek confirmed key transmission parameters for mechanical and electrical interoperability. In phase two, September 2019, engineers from CommScope and Panduit tested the IEC 63171-1 connections for EMC performance using active IEEE 802.3cg 10BASE-T1L prototype equipment. A 1,000-meter long channel, including several IEC 63171-1] connectors, passed IEC 61000-4-6 EMC conducted noise requirements with the noise level of 10 volts root-mean-squared (rms). This qualifies the IEC 63171-1 connector as an E3 industrial-capable connector, as defined by IEEE 802.3cg. Figure 4 shows the IEC 63171-1 MDI interface and cords connecting to live 10BASE-T1L prototype equipment during IEC 6 1000-4-6 noise immunity testing.

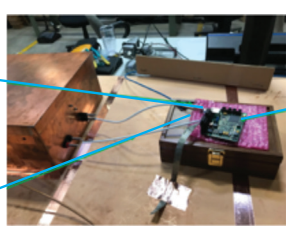


Figure 4: Detail of cords connecting the Coupling De-Coupling network (CDN) to the transceivers

TIA cabling standards around single-pair ethernet

TIA TR42.1: At its June 2017 meeting, TIA TR42 approved an addendum to add single balanced twisted-pair use cases, topology and architecture to the ANSI/TIA-568.0-D generic cabling standard. The addendum offers guidelines for deploying single-pair cabling in buildings. The amended standard also provides single balanced twisted-pair cabling guidelines per ANSI/TIA-568.5, addressing emerging IoT and M2M applications requiring higher density, reduced size and greater flexibility. TR42 also approved a second project to add an addendum with single-pair cabling to ANSI/TIA-862-B—the intelligent building systems standard.

TR42.7: Since June 2017, TIA TR42.7 has been working on ANSI/TIA-568.5, which contains detailed requirements for components, links and channels. This project is focused on cabling to support IEEE 100BASE-T1L applications using 23 AWG cabling up to distances of 400 meters and 18 AWG cabling between 400 and 1,000 meters.

TIA TR42.9: Two addendums in development would expand the scope of ANSI/TIA-1005-A, which specifies telecom cabling to support industrial applications. The first addendum provides specifications for cables, connectors, cords, links and channels that use one-pair connectivity for 10BASE-T1L applications in industrial telecommunication networks. It focuses on performance requirements, test procedures, and reliability guidelines for cabling and components in MICE2 and MICE3 environments.

The second addendum defines the transmission and environmental requirements for industrial cabling and components in support of 1000BASE-T1 deployed over one-pair, type-B link segments, up to 40 meters in length in MICE2 and MICE3 environments. It also defines the components that meet the transmission and environmental requirements for this application.

Standards for power delivery over single twisted-pair are also progressing

The case for single-pair as a capable power conductor has continued to be strengthened by the standards bodies. In 2016, the IEEE approved 802.3bu-2016—Standard for Physical Layer and Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair ethernet. The standard supports 100BASE-T1 and 1000BASE-T1, the latest single-balanced twisted-pair ethernet solution to use balanced twisted-pair cabling. 802.3bu-2016 defines a power delivery protocol that supports multiple classes of power delivery across a range of voltages. The standard includes assured fault protection and detection capabilities for identifying powered device signatures, as well as communicating directly with powered devices to determine accurate and safe power delivery.

Table 1 shows the power classifications at the PoDL-powered device:

Class	0	1	2	3	4	5	6	7	8	9
Voltage	5.5-18	5.5-18	14-18	14-18	12-36	12-36	26-36	26-36	48-60	48-60
Current amps	0.1	0.22	0.25	0.47	0.10	0.34	0.21	0.46	0.73	1.3
PD power (watts)	0.5	1	3	5	1	3	5	10	30	50

Table 1: Available power at the PoDL-powered device

Currently, IEEE is close to publishing a related standard, IEEE 802.3cg, which includes six additional classes of PoDL-powered devices to those llisted in Table 1, to cover other use cases. See Table 2 for the new PoDL classes.

Class	10	11	12	13	14	15
Voltage	20-30	20-30	20-30	50-58	50-58	50-58
Current amps	0.092	0.240	0.632	0.231	0.600	1.579
PD power (watts)	1.32	3.2	8.4	7.7	20	52

Table 2: Extended PoDL classes 10 through 15

When deployed with 100BASE-T1 or 1000BASE-T1, PoDL-enabled single-pair ethernet delivers reliable power and data up to 15 meters over a single 24-gauge twisted pair.[6] PoDL technology is generic enough to work with future speeds and link spans. As its power capacity—which currently maxes out at 50 watts—continues to grow, it can be extended to longer reaches over thicker gauge conductors and can support future PHYs operating at different speeds.

Much of the impetus behind 802.3bu is the interest from the automotive industry, which has been moving toward a single-pair ethernet standard for automotive wiring. Backed by industry initiatives like the One-Pair Ether-Net (OPEN) Alliance and the Open DeviceNet Vendors Association (ODVA), automotive and industrial applications using single-pair ethernet are gaining traction in these market segments. Additionally, 802.3bu holds promise for further applications across a wide range of environments and within the rapidly growing internet of things ecosystem.[7]

When and where will single-pair make sense?

Given the significant degree of promise single-pair ethernet offers, it is essential to realize that the technology is no panacea. It has data rate and power carrying capacity limitations that restrict the maximum segment and link span. These variables must be taken into consideration when deciding how and where to deploy single-pair ethernet; applications like LED lighting, for example, require higher power but lower data speeds. In contrast, applications like multi-band and multi-antennae wireless access points are data intensive and require high power.

Research also indicates that the data transmission capabilities of single-pair ethernet are more than sufficient to satisfy the needs of most connected devices—or, at least, those currently known. According to IoT consulting firm James Brehm & Associates, 86 percent of IoT devices consume less than 3 MB a month.

A significant focus in the development of smart buildings and process automation has been on reducing the power requirements of connected devices. This not only enables significant OpEx savings, it allows the use of a low-voltage structured cabling network. As a result, the dc power requirements for many of the connected devices that will be deployed in the coming years can be met by the 50-watt maximum established by today's PoDL standards. Alternatively, Figure 5 shows an example single-pair cabling serving edge IoT/M2M devices with the same home run "star" topology as the four-pair cabling that serves the data terminal equipment (DTE).

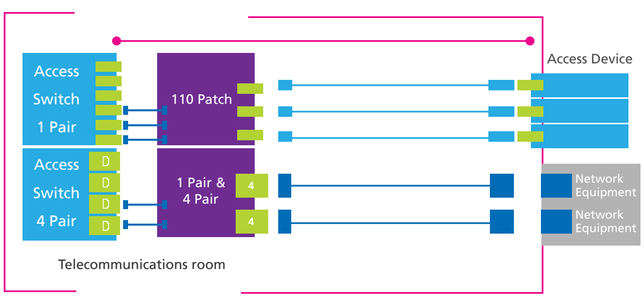


Figure 5: One-pair serving edge IoT/MTM devices with four-pair cabling serving data terminal equipment (DTE) from the same location

This does not mean the discussion between four-pair and single-pair requires an "either/or" decision. The two wiring options are not necessarily mutually exclusive; in many cases, they can coexist in support of the same application. Single-pair ethernet can be used to connect the device to the nearest service consolidation point (SCP), and four-pair can link the service consolidation point and equipment room. Both types of cabling fit well within existing network design models, such as CommScope's universal connectivity grid. See Figure 6 for an example of four-pair cabling to the SCP with one-pair drops to building BAS devices. The NC (network conversion) point represents active equipment to convert high-bandwidth four-pair cabling into multiple low-bandwidth single-pair drops

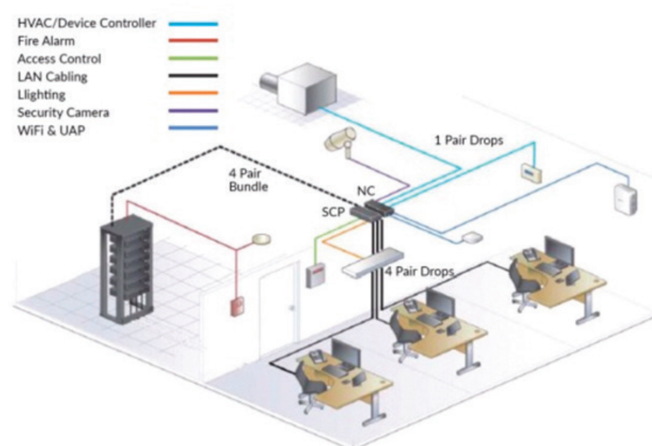


Figure 6: Example topology with four-pair cabling and one-pair drops from the service consolidation point (SCP)

Conclusion

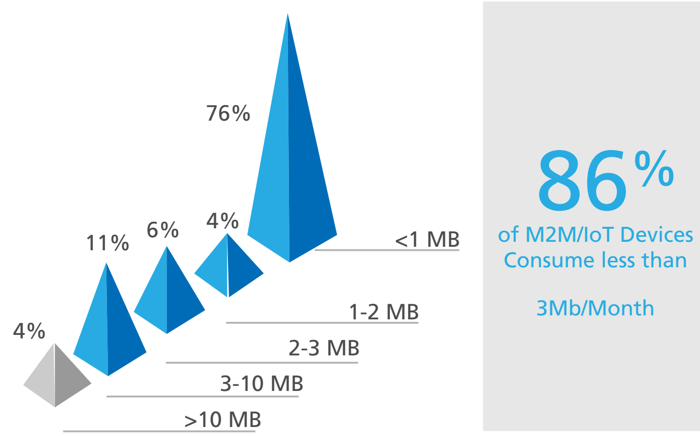
Perhaps no other trend or technology has been anticipated with as much excitement or anxiety as the internet of things. Nowhere will it have a more significant impact than in the move toward smart buildings and smart cities. There is no way to predict what the connected landscape will look like in 15 years—or even five. We do know that enterprises of all types rely on their IT and operational technology (OT) facility management teams to figure out how to connect and support the billions of sensors, controllers and other devices that will be needed.

The answer is not a single technology or platform but in an array of highly efficient infrastructure solutions that can be mixed and matched depending on the requirements of the enterprise and applications.

Yes, traditional four-pair ethernet cabling plays an important role, but so does the range of single-pair connectivity components that complement it.

Network engineers should, therefore, consider single, balanced twisted-pair cabling. Over the past several years, single-pair ethernet has earned the support of OEMs, cabling providers and standards organizations that see it as an efficient solution when used in the right applications.

Single-pair ethernet is robust, capable and growing in popularity because of the variety of existing data rates (10, 100, and 1,000 Mbps) and emerging higher data rates (10 Gbps, beyond 10 Gbps). Light and thin, it provides a highly efficient way to connect the low-power, low-data devices that make up much of the IoT—precisely the type of targeted, smart solution network engineers must have at their disposal to meet the challenges on the horizon.



Source: John Brehm & Associates, 2015

[1] Ericsson Mobility Report; Ericsson; June 2016

[2] A guide to the Internet of Things; Intel, infographic; December IDC, Intel, United Nations

[3] Strategy Analytics M2M Strategies advisory service, McKinsey Global Institute, NYTimes.com

[4] 10Mb/s Extended Reach Single Twisted Pair Ethernet PHY, Call for Interest; IEEE 802.3 Ethernet Working Group; May 2016.

[5] Agenda and General Information; IEEE 802.3 10 Mbps Single Pair Ethernet Study Group; September 17, 2016

[6] IEEE P802.3bu Power over Data Lines Tutorial; IEEE 802.3, plenary presentation; November 2015

[7] IEEE Publishes IEEE 802.3bu™ for Provisioning Power over Data Lines (PoDL) of Single Balanced Twisted-Pair Ethernet; Business Wire; March 15, 2017

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WP-111821.1-EN (11/19)