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White paper

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

Contents

Executive summary

Twisted-pair cabling traces its roots back to the late 19th century, when Alexander Graham Bell introduced this technology as a way 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. Meanwhile, engineers have been able to tap the ability of balanced twisted-pair to deliver dc power, as well as data, over the same cable.

Advancements in twisted-pair cabling coincide with a growing realization that the best cabling solution is the one that most effectively meets all application requirements. Faster is not necessarily better. 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.

"Today, the desire to bring the advantages of Ethernet into new applications necessitates a new approach where the needs of the application are considered first and foremost in defining new Ethernet incarnations."

—David Chalupsky, director, Ethernet Alliance Board of Directors

In the coming years, enterprise IT professionals will be charged with integrating a wide assortment of connected devices into their structured cabling networks. Some will require the power output and/or high-bandwidth capacity only four-pair Ethernet cabling can support. But, for devices with minimal 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.

To efficiently support these applications, the industry is beginning to explore the possibilities for single-pair Ethernet. Standards bodies have ramped up efforts to develop guidelines for a variety of applications involving single balanced twisted-pair as well as the components used in its deployment. Application specifications have been published or are under development in IEEE 802.3. These include 802.3bp 1000BASE-T1, 802.3bw 100BASE-T1, 802.3bu PoDL (0.5 watt to 50 watts) and 802.3cg 10 Mbps Ethernet.

While it is not meant to replace traditional four-pair Ethernet cabling, the business use case for single-pair Ethernet is emerging. When used in support of appropriate applications, single-pair Ethernet provides significant advantages.

IoT applications are opening the door for single-pair Ethernet

By 2018, IoT-based sensors and devices are expected to exceed mobile phones as the largest category of connected devices.[1] By 2020, estimates predict there will be about 200 billion connected objects worldwide[2] —or 26 devices for every person on Earth.

While consumer-based applications—think 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 health care (USD 2.5 trillion) and manufacturing (USD 2.3 trillion) alone.[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.

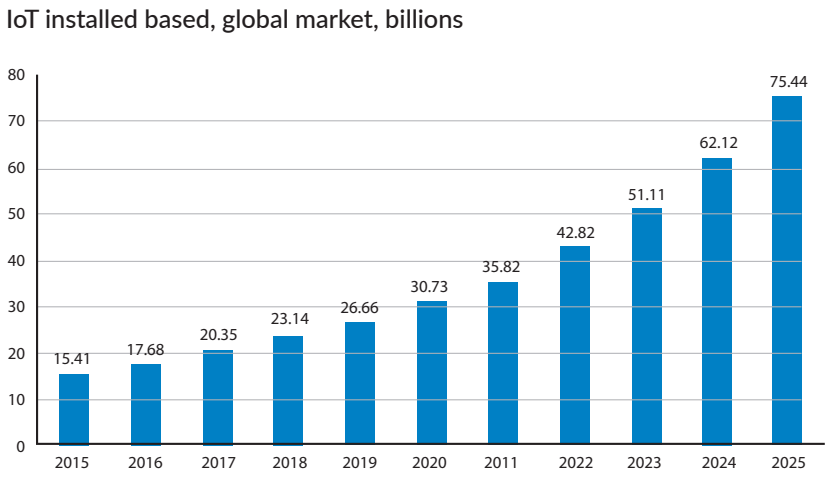


Figure 1: The IoT market will be massive

Enterprise IT teams are just now beginning to wrestle with how to connect the various sensors, controls, cameras and other devices in a way that makes sense, is easy to scale, and cost-efficient. By virtue of their function, most of these connected devices—especially those used in industrial operations—are deployed at the edge of the enterprise 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, these types of connections have been made using non-Ethernet links to a Fieldbus type interface. Due to the highly fragmented and proprietary nature of the Fieldbus sector, there are multiple protocols depending on the Fieldbus manufacturer and many different variations of Ethernet signaling, such as Ethernet/IP, PROFINET, FF HSE, ModbusTCP, and HART-IP.

Integrating and coordinating devices into the network, therefore, presents challenges. Issues include installation complexity, lack of sufficiently skilled labor, interoperability problems and a variety of maintenance protocols. 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 a number of reasons IEEE 802.3 Ethernet Working Group is organizing around single-pair:

- **Increasing capabilities regarding data and power:** Advancing standards and technologies enable single-pair Ethernet to currently support speeds of 1 Gbps. Additionally, single-pair cabling is capable of supporting up to 50 watts of dc power simultaneously to cover a wide range of devices that need both power and data.
- **Efficient use of space and dollars:** 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 that will 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, and the existing pool of Ethernet knowledge.[4]

Application standards around single-pair are evolving quickly

The 10 Mbps Extended Reach Single Twisted Pair Ethernet PHY is just one of many standardization initiatives focused on enabling the potential LAN applications of single-pair Ethernet. In September 2016, the IEEE 802.3 Working Group created the 10 Mbps Single Pair Ethernet Study Group to develop a project authorization request (PAR) and criteria for standards development (CSD) responses for 10 Mbps single twisted-pair Ethernet, including optional power.[5]

The PAR and CSD were approved in March 2017, enabling the group to push forward in developing a working standard to support 10 Mbps operation in automotive, industrial and enterprise environments (e.g., commercial buildings, data centers, education, and healthcare) using single balanced twisted-pair cabling—with or without power transmission. The schedule for what will be known as IEEEC 802.3cg anticipates the standard will be ready by late 2018 and approved by June 2019.

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 33 adopted several updates to ISO/IEC 11801-6 (cabling for distributed building services). Among them was an agreement to start work on an amendment to allow a service consolidation point (SCP) to transition from four-pair to one-pair cabling using active equipment located at the service concentration point (SCP). The CENELEC EN 50173 standards, which typically follow ISO/IEC 11801 standards, will likely adopt similar language. This will allow four-pair Ethernet to extend from the telecommunications room to the SCP, with the option of connecting directly to devices requiring four-pair cabling. Alternatively, the four-pair cable could transition to single-pair at the SCP using active conversion equipment, then connect to devices that only need single-pair cabling.

TIA cabling standards around single-pair

Meanwhile, two addendums are in development to expand the scope of ANSI/TIA-1005-A, which specifies telecom cabling to support industrial applications. The first addendum will provide specifications for cables, connectors, cords, links and channels using one-pair connectivity in industrial premises telecommunications networks. It focuses on MICE2 and MICE3 environments and includes cabling and component performance requirements and test procedures, reliability requirements and test procedures, as well as guidelines for adaptations to four-pair cabling.

The second addendum defines the transmission and environmental requirements for industrial cabling and components in support of 1000BASE-T1 over one-pair link segment type B, including MICE2 and MICE3 environments. It would also define components that meet the transmission and environmental requirements for these same applications.

At the June 2017 meeting, TIA TR42 approved an addendum to add single balanced twisted-pair use cases, topology and architecture to ANSI/TIA-568.0-D. The addendum provides guidelines for deploying single-pair cabling in buildings; separate efforts are also underway to address its use in intelligent building systems (IBS). The standard will include installation requirements and additional guidelines for transitioning from four-pair to single-pair cabling, including sheath sharing. The standard will also provide single balanced twisted-pair cabling guidelines in accordance with ANSI/TIA-568.5 for emerging IOT and M2M applications that will require higher density, reduced size and greater flexibility. TR42 also approved a second project to add an addendum regarding single-pair to ANSI/TIA-862-B—the intelligent building systems standard.

In June 2017, TIA TR42.7 also addressed the need for detailed requirements for components, links and channels. The group approved a single twisted-pair cabling and components standard that provides specifications for cables, connectors, cords, links and channels using single-pair connectivity in non-industrial premises telecommunications networks. The standard focuses on MICE1 environments and includes requirements and test procedures for cabling and component performance and reliability, as well as guidelines for adaptations to four-pair cabling.

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

The standards bodies have also continued to strengthen the case for single pair as a capable power conductor. In 2016, IEEE approved the 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 physical layers, using unshielded twisted-pair cable. It defines a power delivery protocol that supports multiple voltages, and multiple classes of power delivery at each voltage, with assured fault protection and detection capabilities for identifying device signatures, as well as communicating directly with devices to determine accurate and safe power delivery.

The following shows the current 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: Power at the PoDL-powered device

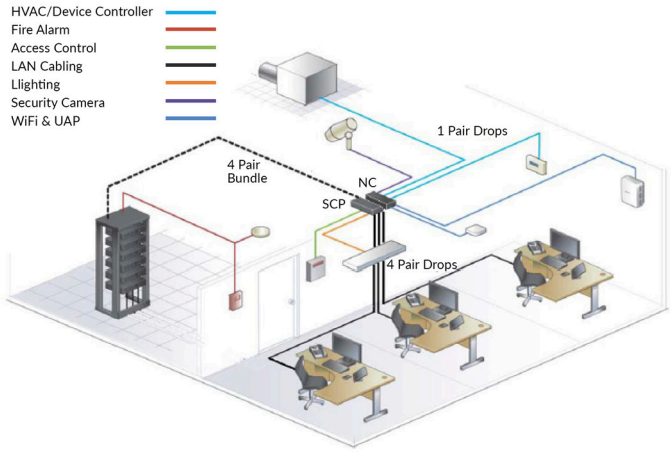
When deployed with 100BASE-T1 or 1000BASE-T1, PoDL-enabled single-pair Ethernet delivers reliable power and data up to 15 meters over a single 24-gauge twisted pair.[6] PoDL technology is generic enough that it will work with future speeds and reaches. As its power capacity—which currently maxes out at 50 watts—continues to grow, it can be extended to longer reaches 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 applications and standards involving the use of single-pair Ethernet are much further along than those in the industrial arena. But 802.3bu also holds a good deal of promise for further applicability across a wide range of industries and within a rapidly growing Internet of Things ecosystem.[7] Among other things, it creates opportunities for manufacturers of single-pair cable and connectors to leverage their experience from automotive across industrial applications.

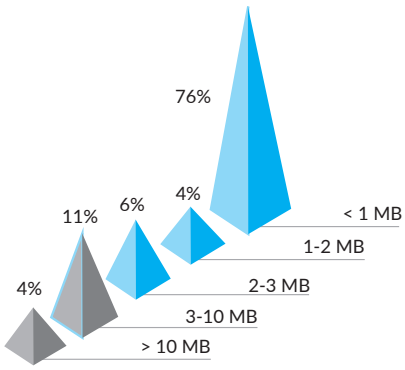
Finally, IEC and TIA are currently working on component standards in support of single-pair connectivity. These are being developed to support the link segment requirements for the different use cases in industrial, automotive, and enterprise environments. In-cabinet connections can use IP20 RJ45 Ethernet connectors. On-machine connections utilize the IP67 M8 connectors that are common in industrial applications, while automotive companies generally have their own proprietary array connectors that have been used with automotive wiring harnesses.

When and where will single-pair make sense?

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



Increasing power efficiency among a growing range of connected devices may further encourage the widespread use of single-pair Ethernet. A major 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 power savings across the facility, 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.



86%
of M2M/IoT Devices Consume less than 3Mb/Month

Source: John Brehm & Associates, 2015

Research also seems to indicate that the data transmission capabilities of single-pair Ethernet will be 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.

None of this, however, is meant to suggest that the discussion between four-pair or single-pair requires an "either/or" decision. These 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 consolidation point and four-pair can be used between the consolidation point and equipment room. Both types of cabling fit well within existing network design models such as CommScope's universal connectivity grid.

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 greater impact than in the workplace. There is no way to know exactly what the connected landscape will look like in 15 years—or even five. We do know that enterprises of all of shapes and sizes will look to their IT and facility management teams to figure out how to connect and support the billions of sensors, controls and other devices that will be needed.

The answer is not any single technology or platform, but an array of highly efficient infrastructure solutions that can be mixed and matched depending on the requirements of the enterprise and applications. Within this toolbox will certainly be the traditional four-pair Ethernet cabling, as well as a range of low-voltage connectivity components that complement it.

Network engineers should also consider single, balanced twisted-pair cabling. Over the past several years, single-pair Ethernet has won over a number 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 1000 Mbps) and emerging higher data rates. Light and thin, it provides a highly efficient way to connect the low-power, low-data devices that make up much of the IoT—exactly the type of targeted, smart solution network engineers will need at their disposal in order to meet the challenges on the horizon.

[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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