WEBINAR SUMMARY

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ElectronicDesign

Tackling PCI Express and Ethernet Increasing Bandwidth Demands

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KEY TAKEAWAYS

- Market trends are constantly moving toward faster, more powerful computing resources.
- PCIe standards improve performance over previous generations, but are backward compatible.
- 3M Twin Axial Cable solutions reduce cost and loss.
- Application demand for higher-bandwidth communication drives high-speed Ethernet adoption.
- 3M Twin Axial External Assemblies offer space-saving benefits without compromising performance.

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OVERVIEW

The evolution of technology, such as the emergence of 5G cellular, artificial intelligence (AI) and machine learning (ML), and next-generation applications, is placing intensive bandwidth demands on connectivity and communications infrastructure. PCI Express (PCIe) and Ethernet are two major connectivity technologies that share many problems and solutions to handle increasing bandwidth speed and performance requirements.

3M and TTI have developed cabling and connectors to address some of these challenges. The 3M Twin Axial high-speed cable solutions make connectivity work for internal and external cabling requirements. The thin, highly flexible cabling supports connectivity in smaller devices without sacrificing performance.

CONTEXT

The presenters explained trends in digital infrastructure and connectivity standards guiding hardware development. They also shared details of the 3M Twin Axial high-speed cabling solutions that meet current and next-generation connectivity requirements.

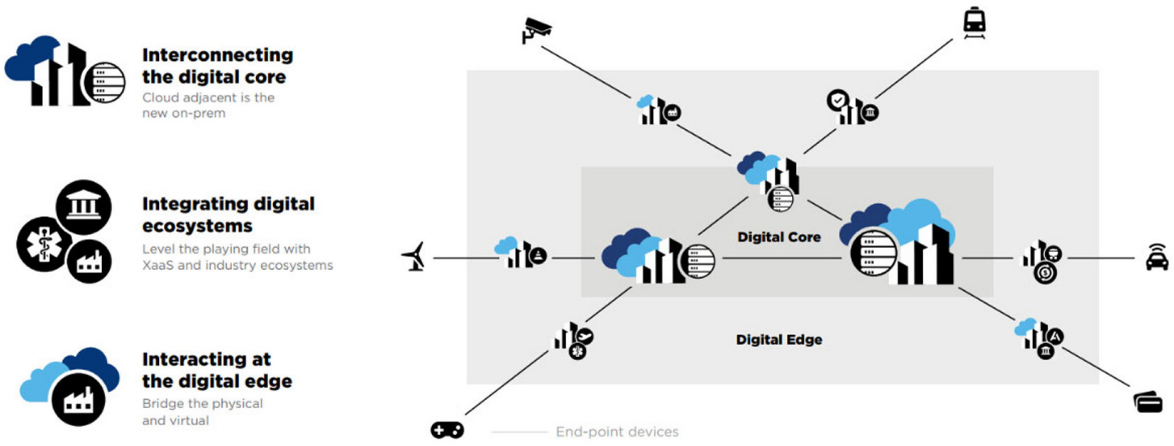
KEY TAKEAWAYS

Market trends are constantly moving toward faster, more powerful computing resources.

Equinix, Inc. defines the three elements of the digital infrastructure as:

1. **The digital core.** Enterprises are migrating away from on-premise data centers to cloud-based data centers, allowing businesses to achieve economies of scale and operational efficiencies, and to better serve customers.
2. **The digital ecosystem.** The cloud platform allows enterprises to focus on XaaS (anything "as a service") to provide revenue-generating services that serve various segments of the industry.
3. **The digital edge.** Cloud-based services have access to a fixed amount of network bandwidth; therefore, as these service offerings grow, enterprises are looking for ways to distribute computing away from network usage. By moving data closer to the user (the "edge"), data centers move closer to the users.

Figure 1: Three elements of digital infrastructure



Source: EQUINIX INC. (2021). Global Interconnection Index: Measuring the Growth of the Global Digital Economy (Vol. 5). EQUINIX Inc.

The significant shift to remote work since 2020 has driven the demand for agile computing that scales up or down according to demand. Cloud hosting providers such as Microsoft, AWS, Cisco, Google, IBM, and others have developed cloud computing infrastructure to support enterprise data centers, vendor-specific economies of scale, and public, private, or hybrid offerings for enterprises to offload some or all on-premise data center operations to the cloud, with capacity scaling a key added benefit over traditional on-premise data centers. Specialized providers offer security, cost savings, flexibility, and scalability benefits.

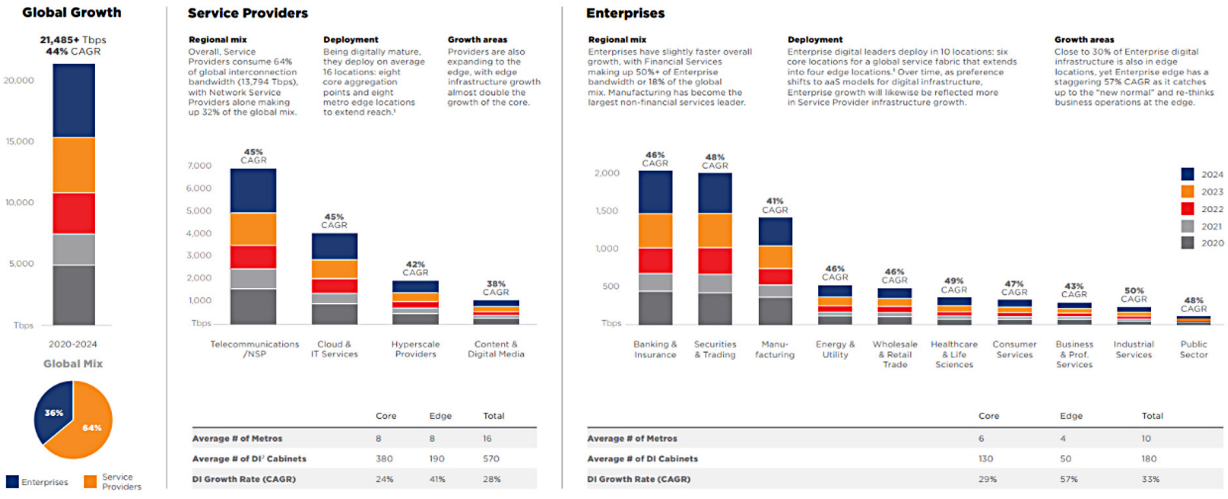
As part of this trend, while the data center has evolved from on-premise to a cloud-computing structure over the past decade, data processing resources are now shifting again—this time, toward edge computing, local processing, or networks of IoT devices. Local devices are using a decrease in chip size and increased computing power to support more intensive computing demands. Market demands such as streaming TV and online gaming require scalable, agile computing. Companies such as 3M are innovating in the digital edge space, using 5G networks to compute and communicate faster, thus moving computing power itself to the digital edge.

AI and ML are also driving increasing demand for data center resources. With today's computing power, ML can train servers to analyze tremendous amounts of data, calculate at an accelerated rate, and provide insights that would otherwise take a significant amount of time. Looking at market trends, 51% of enterprises have plans to implement AI, while 25% have already done so.

> We see this as, 'How do we make better decisions with the data we have?' AI is the tool for that. If we look at the forecast for spend and business value, by 2030, 44% will use AI and machine learning in some capacity. That's a significant use of this technology and tool to develop insights with a tremendous amount of data.
>
> *David Foresyth, 3M*

Devices have been developed to communicate faster as networks advance, to today's on-demand data and services to the user through a cell phone, with data typically pulled from a data center to the end user device. Because of the constant drive toward smaller, faster, more powerful networks and other infrastructure, there is significant projected growth rate of service providers and industries driving data center and communications expansion and improvement.

Figure 2: Global trends in digital infrastructure



Source: EQUINIX INC. (2021). Global Interconnection Index: Measuring the Growth of the Global Digital Economy (Vol. 5). EQUINIX Inc.

PCIe standards improve performance over previous generations, but are backward compatible.

Founded in 1992, the Peripheral Component Interconnect Special Interest Group (PCI-SIG) is an association of over 800 industry companies all working toward the goal of defining a common specification for performance, or the PCI Express I/O bus specifications and related form factors.

One of the key features of PCIe standards is that each new generation is backward-compatible with the previous generation, supporting consumer- and industrial-level device interoperability. PCI-SIG works to double the bandwidth of interconnect technology every three years, releasing the specification for industry standards to inform hardware design processes.

From the initial standard PCIe 1.0 in the early 2000s that operated on the 3G cellular network, to the recently released PCIe 5.0 and the emerging PCIe 6.0 versions, communication and processing capabilities have evolved to leverage the capabilities of ever-improving cellular networks. Ethernet speeds have evolved from 100-gigabit Ethernet (GbE) to 400 GbE being implemented today, with some early adopters implementing 800 GbE.

Although PCI-SIG ensures backward compatibility, enterprises should consider performance tradeoffs for older devices. For example, with a PCIe 5.0 peripheral device used in a PCIe 3.0 system, where CPU and bus only support PCIe 3.0, the interface will default to the previous generation's speed (from 32 Gbps to 8 Gbps) even though the PCIe 5.0 device is compatible with the PCIe 3.0 motherboard.

Beginning in PCI Generation 6, the use of NRZ (Non-return to Zero) modulation was switched to PAM4 (Pulse Amplitude Modulation) with FEC (Forward Error Correction), enabling faster data transmission and error compensation. As the PCIe standard moves to version 7.0, increasingly data-intensive applications will drive a faster internal network or internal bus requirement and 800 GbE will be required to support the structure of the PCIe 7.0 protocol.

Figure 3: PCIe versions and their respective targeted applications

Source: https://pcisig.com/faq

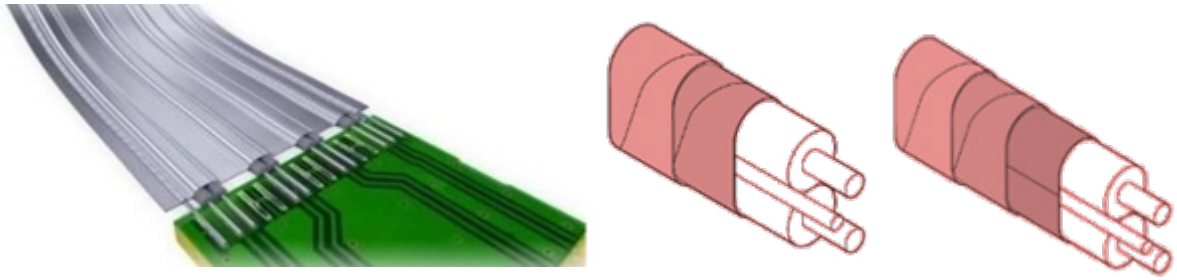
3M Twin Axial Cable solutions reduce cost and loss.

To support the faster speeds of PCIe 4.0, 5.0, and 6.0, 3M Twin Axial Cables are thin, flexible, and even foldable. The ability to bend the cables allows easy routing in between DIMM slots and fans, and because cable orientation can be manipulated to such a degree, the cables allow manufacturers to take advantage of the minimal space in dense servers and to route parallel to the airflow to maximize cooling efficiency, all without compromising signal integrity.

3M employs a unique, precision-formed, continuously laminated shield over the entire cable, to deliver the thinness and flexibility that enables tight folding and creasing without loss of performance. 3M Twin Axial Cables offer precision termination, allowing the stripping of the insulation, bending and forming, and soldering it to the PCB, all with uniformity, which increases efficiency and quality of devices.

Other companies' spiral/longitudinal wrapped shield around individual pairs renders those cables thicker and less flexible, which leads to performance degradation in tight bends and not resonance-free.

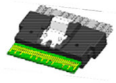
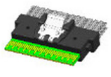
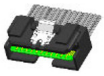
Figure 4: 3M Twin Axial Cable (left) versus competitors' spiral wrapped shield around individual pairs



3M offers a variety of form factors for cable termination, as well as the 3M Extender and Jumper product family, which allows connections between the board to a peripheral device located off the motherboard.

In addition to custom lengths and custom folding of cable assemblies, 3M offers hybrid assemblies that combine different connectors on each end and can be mixed and matched in the pinout, such as a SlimLine termination on one end with a Multi-channel I/O termination on the other.

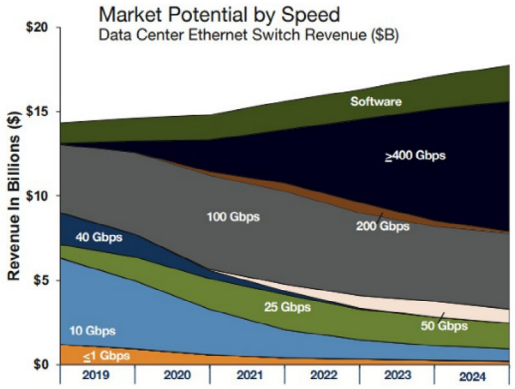
Figure 5: 3M Twin Axial Cable form factors

	3M SlimLine assembly	3M Mini-SlimLine assembly	3M Compact SlimLine assembly	3M Low Profile I/O assembly	3M Multi-Channel I/O assembly	3M Scalable High-Speed assembly	3M PCIe Extenders and Jumper assembly
							
# of Lanes	4, 6, 8 or 12	8, 12	8, 12	8, 12	8, 12	4, 8 or 16 (1C, 2C, or 4C)	8, 16
Protocol	SATA, SAS, PCIe®	SATA, SAS, PCIe®	SATA, SAS, PCIe®	SAS, PCIe®	SAS, PCIe®	SAS, PCIe®	PCIe®
Speeds	SAS 3.0: 12 Gbps PCIe® 4.0: 16 Gbps PCIe® 5.0: 32 Gbps	SAS 3.0: 12 Gbps PCIe® 4.0: 16 Gbps PCIe® 5.0: 32 Gbps	SAS 3.0: 12 Gbps PCIe® 4.0: 16 Gbps PCIe® 5.0: 32 Gbps	SAS 3.0: 12 Gbps PCIe® 4.0: 16 Gbps	SAS 4.0: 24 Gbps PCIe® 5.0: 32 Gbps	SAS 4.0: 24 Gbps PCIe® 5.0: 32 Gbps	PCIe® 3.0: 8 Gbps PCIe® 4.0: 16 Gbps PCIe® 5.0: 32 Gbps
Types of Application	Motherboard or controller to drive backplane	Motherboard or controller to drive backplane	Motherboard or controller to drive backplane	Motherboard or controller to drive backplane	Motherboard or controller to drive backplane, midboard	Motherboard or controller to drive backplane, midboard	Ext: Flexible "riser" Jmp: Motherboard to motherboard
Specification	SFF-8654	SFF-8654	SFF-8654	Industry compatible	SFF-TA-1016	SFF-TA-1020	PCIe® -CEM

Application demand for higher-bandwidth communication drives high-speed Ethernet adoption.

The IEEE (Institute for Electrical and Electronics Engineers), founded in 1963, writes the Ethernet standard for external devices communicating from the server to the switch, and the switch to the network. Similarly to the PCIe market, the majority of the Ethernet market is 100 Gbps, with most 400 Gbps enterprises having opted to move from 100 Gbps directly to 400 Gbps or even 800 Gbps.

Figure 6: Ethernet market forecast by speed



	IEEE 802.3ba	IEEE 802.3bj	IEEE 802.3cd	IEEE 802.3ck
Speed	40 Gbps	100 Gbps	400 Gbps	800 Gbps
Commercialized (Year)	2015	2016	2019	2022/23

Source: Morgan, T. P. (2020, May 14). *This Switcheroo Doesn't Get Old.* The Next Platform. https://www.nextplatform.com/2020/05/07/this-switcheroo-doesnt-get-old/

3M Twin Axial External Assemblies offer space-saving benefits without compromising performance.

3M Twin Axial External Assemblies, otherwise known as Direct Attach Copper Assemblies (DACs), offer similar functionality and benefits to 3M internal cable assemblies. These 3M Twin Axial External assemblies are flat and can be bundled for easy organization in a rack. Bundling and moving the cables to the side also increases the airflow into the server and rack area for more efficient cooling. With no minimum bend radius, the cables can be bent and folded without sacrificing signal integrity performance.

Using 3M Twin Axial External Assemblies facilitates routing in dense environments, as it requires less space in front of the port, saving space and improving serviceability.

> Optical has taken over in the fabric of the network, but going from the neck to the top of the rack, copper is still the dominant solution. As we evolve to 800 Gbps and maybe 1.6 Tbps, even though the reach of the Direct Attach Copper cable is shortening, the cost-performance ratio is still a higher benefit over optical—so much so that we see customers redesigning the typical rack configuration and moving the switch where needed to maximize the performance of the deck cables. Eventually, as onboard optics becomes available, that might change, but the cost-power-thermal aspects of using copper are all still benefits that outweigh the performance and the costs of the optical.
>
> *David Foresyth, 3M*

Figure 7: 3M Twin Axial External Assembly cable portfolio

	3M™ 400G QSFP-DD Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ Twin Axial Cable Assemblies for QSFP+ Applications, 40GbE
					
Form Factor	QSFP-DD	QSFP28 Q28-Q28[1]	QSFP28 Q28-1Q28[2]	QSFP28 Q28-4SFP28[2]	QSFP+
Aggregate Data Rate	400G	100G	100G	100G	40G
Channel Data Rate	56G/channel (8x50)	25G/channel (4x25)	25G/channel (4x25)	25G/channel (4x25)	10G/channel (4x10)
Lengths	30 AWG: 0.50 - 2.0 m 26 AWG[3]: 2.25 - 3.50 m	30 AWG: 0.5 to 2.0m 26 AWG: 2.0 to 4.0m	30 AWG: 0.5 to 2.0m 26 AWG: 2 to 4.0m	30 AWG: 0.5 to 2.0m 26 AWG: 3.0 to 4.0m	30 AWG: 0.25 to 3.0m
Series	9V	9QJ0, 9QH6, 9QN0, 9QM6	9SR-Bxx	9SR-Axx	9QA0
Standards	QSFP-DD MSA IEEE 802.3 cd	SFF-8436, 8661 8665, 8661, 8662 IEEE 802.3bj	SFF-8661, 8662, 8665 IEEE 802.3bj	SFF-8661- 8662,8665,8431 IEEE 802.3bj	SFF-8436 IEEE 802.3ba

1: Q28-Q28 cable assembly - Cable and PCB are halogen free
2: Q-2Q and Q-4S - Cable is halogen free, PCB is not halogen free, CL2 Flame Rated
3: QSFP-DD - 3.25meter meets 802.3cd,3.50meter does not meet 802.3cd standard, however, passes COM

Additional products available in:
- 25G, 10G and miniSAS

ADDITIONAL INFORMATION

To learn more about 3M and TTI, visit www.tti.com/content/ttiinc/en/manufacturers/3m.html

BIOGRAPHY

David Foresyth

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David Foresyth is a senior global portfolio manager in the Electronic Materials Solutions Division at 3M Company. His career started as a manufacturing engineer and transitioned to product marketing. In his current role, David is responsible for twin axial cable products for high-speed applications and industrial connector products. He has a B.S. and M.S. in Manufacturing Engineering from Boston University.