

## IT@Intel

# Preparing Intel's Data Center Network Architecture for the Future

Upgrading our network architecture to support speeds greater than 10 GbE is essential in optimizing our data center infrastructure to more quickly respond to business needs while enhancing the services and value IT brings to the business.

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### Executive Overview

To accommodate the increasing demands that data center growth places on Intel's network, Intel IT is upgrading our data center network architecture to a combination of 10 GbE and 40 GbE connections. Existing 100 Mbps and 1 GbE connections no longer support Intel's growing business requirements. Our new 10/40 GbE data center fabric design will help to support current growth and accommodate increasing network demand in the future—which we anticipate will eventually involve upgrading to a 100 GbE fabric.

Intel IT is engaged in a verticalization strategy that optimizes data center resources to meet specific business requirements in different computing areas. Data center trends in these areas drove our decision to upgrade:

- Server virtualization and consolidation in the Office, Enterprise, and Services<sup>1</sup> computing environments
- Rapid growth in Design computing applications and their performance requirements
- Increase of 40 percent per year in our Internet connection requirements

While designing the new data center fabric, we tested several 10/40 GbE connection products and chose those that offered the best performance, reliability, and total cost of ownership.

The new data center fabric design provides many benefits:

- **Reduced data center complexity.** As virtualization increases, a 10/40 GbE network allows us to use fewer physical servers and switches.
- **Reduced total cost of ownership in a virtualized environment.** A 10/40 GbE fabric has the potential to reduce network cost in our virtualized environment by 18 to 25 percent, mostly due to simplifying

<sup>1</sup> Intel groups their data center infrastructure environment into five unique verticals that represent main business computing solution areas (referred to as DOMES) that include Design, Office, Manufacturing, Enterprise, and Services.

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## Acronyms

<b>CFP</b>	C Form-Factor Pluggable
<b>MMF</b>	multimode fiber
<b>MPO</b>	multifiber push-on
<b>MPT</b>	multiplex pass-through
<b>OM</b>	Optical Multimode
<b>OM3</b>	Optical Multimode 3
<b>OM4</b>	Optical Multimode 4
<b>QSFP+</b>	Quad Small-Form-Factor Pluggable
<b>SFP+</b>	Small-Form-Factor Pluggable
<b>SMF</b>	single-mode fiber
<b>Tbps</b>	terabits per second
<b>µm</b>	micrometer

the LAN and cable infrastructures. The new system also requires fewer data center space, power, and cooling resources.

- **Increased throughput.** Faster connections and reduced network latency provide design engineers with faster workload completion times and improved productivity.
- **Increased agility.** The network can easily adapt to changing business needs and will help enable us to meet future requirements, such as additional storage capacity.

Upgrading our network architecture to support speeds greater than 10 GbE is essential in optimizing our data center infrastructure to more quickly respond to business needs while enhancing the services and value IT brings to the business.

## Background

Intel IT operates approximately 55,000 servers in 64 data centers that support more than 104,000 employees.<sup>2</sup> For more than a decade, Intel IT has been virtualizing the servers in our Office, Enterprise, and Services data center environments. Additionally, we support 45 million compute-intensive Design workloads every week with high-performance computing.

Intel's rapidly growing business requirements place increasing demands on data center resources. Intel IT is engaged in a verticalization strategy that examines each application area and provides technology solutions that meet specific business needs. We have developed an Office, Enterprise, and Services private cloud environment, and we expect to expand cloud computing to support Manufacturing.

These strategies, combined with the following significant trends in several computing application areas, compelled us to evaluate whether our existing 1 GbE network infrastructure was sufficient to meet network infrastructure requirements.

- Large-scale virtualization in the Office, Enterprise, and Services computing domains.
- Increasing compute density in the Design computing domain.

In addition, high-performance Intel® processors and clustering technologies are enhancing file server performance. This means that the network, not the file servers, is the limiting factor in supporting faster throughput. Our Internet connection requirements are growing 40 percent annually as well, which requires faster connectivity than is possible with a 1 GbE data center fabric.

<sup>2</sup> See the whitepaper, "Intel IT's Data Center Strategy for Business Transformation."

## Solution

In 2010, we decided to upgrade our data center network architecture from 100 Mbps and 1 GbE connections to 10 GbE connections to meet these computing demands. Today, we are expanding our network upgrade to a combination of 10 GbE and 40 GbE connections. This upgrade enables us to meet current needs and positions us to incorporate new technology to meet future network requirements—such as eventually upgrading to 100 GbE.

### Simplifying Virtualization for Office, Enterprise, and Services Applications

Intel's data center strategy for Office, Enterprise, and Services applications relies on virtualization and consolidation to reduce data center cost and power consumption, while reducing time to provision servers. Our current consolidation level is 20:1, and we are targeting a 30:1 consolidation level or greater with newer dual-socket servers based on Intel® Xeon® processors.

By upgrading our network design to support speeds of 10 GbE and beyond, we can simplify server connectivity. For example, we can reduce the number of LAN ports from dozens of 1 GbE connections to just two 10 GbE connections. This significantly reduces cable and infrastructure complexity. As we move to higher-density 10 GbE servers, which use more switch interconnects, we will need even higher speeds, such as 40 GbE and 100 GbE.

Higher network speeds are also required for storage. Presently, not all of our storage workloads run on the IP network; the SANs currently use fiber channel connections and HBAs. However, in the next phase of virtualization we will migrate the SANs to the IP network, which will put even more load on the Ethernet network.

In addition to simplifying physical infrastructure, a 10/40 GbE network fabric may also reduce the overall total cost of ownership for LAN components per server by about 18.5 percent compared to the 1 GbE fabric. Figure 1 shows the cost savings associated with a 10 GbE fabric. We anticipate that higher speeds, such as 40 GbE, will offer similar savings.

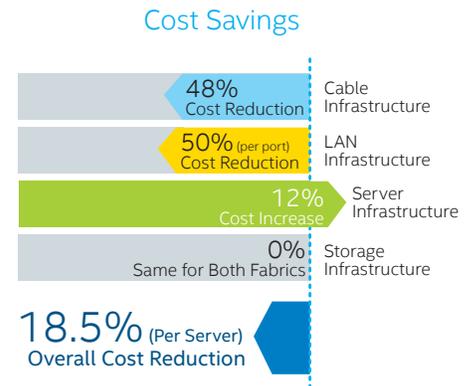
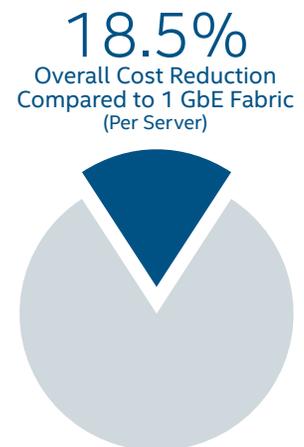


Figure 1. Cost savings associated with a 10 GbE fabric.



## Bandwidth Demand: Key Drivers, Projections, and Plan

As shown in Figure 2, Intel IT adopts higher-speed network technology almost as soon as it is available. For example, we introduced 10 GbE in 2010 and 40 GbE in 2013. The key drivers for this growth in bandwidth demand are different, depending on the computing environment. In our Design computing environment the demand is driven by about 35 percent growth in storage and about 30 to 40 percent growth in compute capacity year over year. In contrast, in the Office, Enterprise, and Services computing environment, the key drivers are a growing virtual machine count per host and 15 percent increase in the number of virtual machines.

Based on current and forecasted demand growth, we expect our data centers to need 100 GbE by 2015. However, we do not expect to convert all data center ports to high speed; we expect that 1 GbE and 10 GbE to remain the dominant ports within data centers for the next three years, as shown in Table 1. But, as we migrate to higher speeds, it is critical to develop the right physical infrastructure that can scale for even higher future speeds, such as 1 Tbps and 10 Tbps.

## Overview of Available Physical Cable Technologies

Transport speeds beyond 10 GbE use two methods: parallel optics or multi-strand copper. Transmission performance standards were developed by the IEEE in 2010 with the 802.3ba-2010 standard. Standard #5 describes parallel-optic and copper-based configurations and their associated performance requirements.

Industry-wide, at higher speeds fiber-optic solutions are more generally accepted than copper-based solutions. While copper is less expensive, its adoption and use cases have been relegated to intercabinet connectivity due to its distance limitations. The IEEE standard specifies up to 7 meters for 40 GbE and 100 GbE transmissions. Fiber-optic solutions using parallel optics have better distance capabilities and design flexibility. Parallel-optic trunks comprise multiples of 12 strands of single-mode fibers (SMFs) or multimode fibers (MMFs), ranging from 12 to 192 strands.

### OM3 Compared to OM4 MMF

The MMF classification is based on its modal bandwidth performance, also called its Optical Multimode (OM) rating. The latest rating to be added to the ISO standard was OM4, ratified in 2009. 40 GbE and 100 GbE transmissions require a minimum of OM3 MMF. Performance comparisons of OM3 and OM4 MMF are shown in Figure 3.

Typical deployments at Intel today use OM3 MMF 50 μm, as shown in Figure 4. Intel has always implemented the industry standard for SMF, 8.2 μm. However, when we want to maximize distances for 40 GbE and 100 GbE deployments, we prefer OM4. For better performance, 40 GbE and higher speeds require OM4 parallel optics.

## Market Availability and Intel Adoption

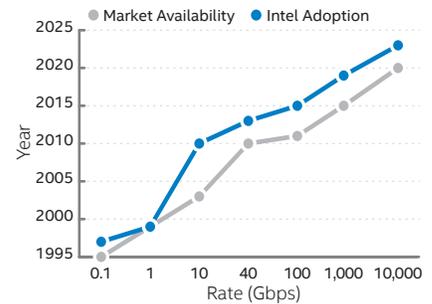


Figure 2. Intel IT adopts higher-speed network technology almost as soon as it is available.

Table 1. Estimated Distribution of Port Speeds over Time

	2013	2014	2015	2016
100 Mbps and 1 GbE	77%	71%	62%	58%
10 GbE	23%	28%	32%	31%
40 GbE	0.07%	0.71%	5.40%	10.49%
100 GbE	0.00%	0.00%	0.07%	0.33%

## Performance Comparison

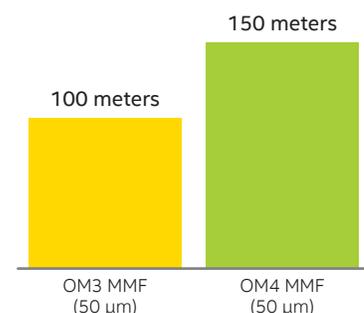


Figure 3. Performance comparison of OM3 and OM4 MMF parallel optics for 40/100 GbE.

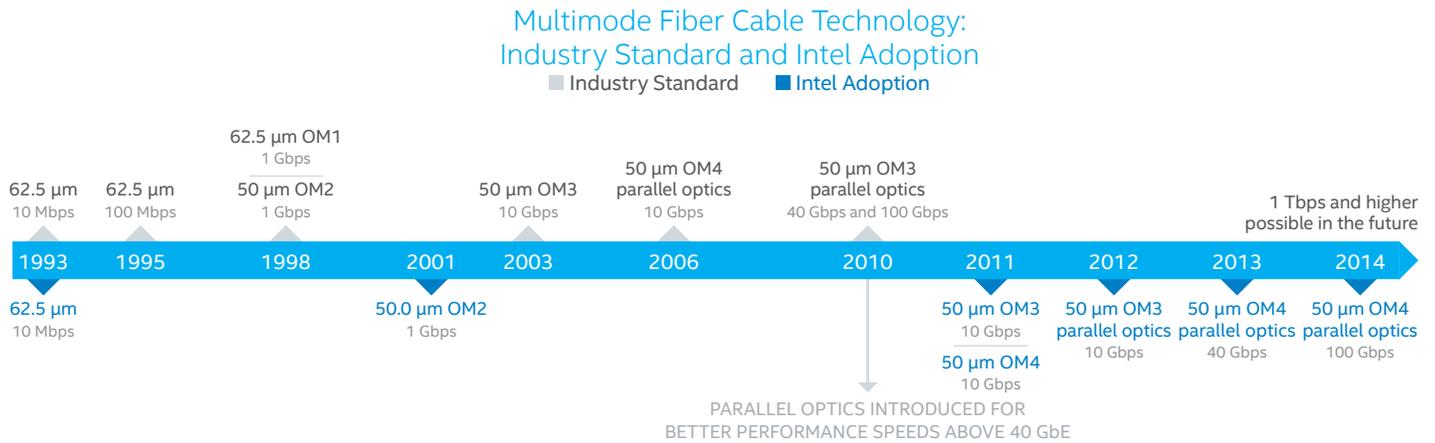


Figure 4. Intel adoption of cable technologies vs. industry standard. 40 GbE and higher speeds require OM4 parallel optics.

### 40 GbE Terminations

40 GbE connections in active equipment use a Quad Small-Form-Factor Pluggable (QSFP+) transceiver terminated to receive the multifiber push-on/multiplex pass-through (MPO/MPT) trunk. QSFP+ transceivers rated for short-range use multimode MPO trunks. Polarity becomes a consideration when implementing 40 GbE switch-to-switch interconnects over multi-strand MMF. These connections need to be Method B polarity for the link to function.

A long-range QSFP+ transceiver option is also available to run on SMF. This transceiver houses additional electronics which mux/de-mux the parallel transmits—that is, receive signals into a pair of SMFs. These links are Little Connector terminated and can run up to 10 km and are used for 40 GbE interbuilding connections.

The QSFP+ transceiver can also be used for MMF 40 GbE to 4x10 GbE partitioned applications. One end of the connection is terminated using an MPO/MPT configuration with four individual pairs terminated with Little Connectors at the other end. This configuration can support distances up to 150 meters using OM4 MMF. This type of connection is used to support channelized 10 GbE uplinks to distribution and core layer switches and to maximize the number of 10 GbE client attachments at the access layer.

### 100 GbE Terminations

100 GbE connections use a C Form-Factor Pluggable (CFP) transceiver. This transceiver family is the 100 GbE equivalent of the QSFP+ transceiver for 40 GbE. There are several optical interface options available, although no single one has yet to emerge as an industry standard. Two CFP options are dominant in the industry: CFP2 and CFP4. The primary differences between the two are physical density and transmit/receive lane configurations. CFP2 supports 100GBASE-SR10, 100BASE-LR4, and 100GBASE-ER4 optical interfaces. CFP4 doubles the port density on the line card and supports 100GBASE-SR4, 100GBASE-LR4, and 100GBASE-ER4 optical interfaces.

# Intel Use Cases Require Specific Solutions

In addition to 10 GbE, Intel is also actively deploying 40 GbE connections; the typical use cases are switch-to-switch interconnects and 40 GbE port partitioning to support server connectivity. Copper is used in some special cases, primarily for intercabinet switch-to-switch connections, with the majority of 40 GbE connections being optic fiber-based. Intel does not currently have 100 GbE deployed but is in the process of active component evaluation. From a cable plant standpoint, continued investment in fiber parallel-optic technologies will position the physical infrastructure for eventual migration to 100 GbE and beyond.

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“It took us 5 to 6 years to transition from 1 GbE to 10 GbE. We’ll move from 10 GbE to multiple GbE even faster.”

– **Sanjay Rungta**  
Senior Principal Engineer,  
Intel IT

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## Switch-to-Switch Interconnects

A 40 GbE switch-to-switch interconnect uses one of three methods. Intel IT uses all three methods, depending on the use case.

- **QSFP+ transceivers and MMF MPO trunks.** This configuration must use a Method B polarity MPO trunk.
- **Long-range QSFP+ transceiver and standard 2-strand SMF connections.** At Intel, this configuration is used where switch-to-switch interconnects span between data centers or buildings within a campus.
- **Active optical cable.** This is a preterminated parallel-optic solution which incorporates a 12-strand MMF bundle connected on each end with a QSFP+ transceiver. This type of cable is available in standard lengths up to 100 meters. At Intel, this configuration is used for 40 GbE connections that span rows within the data center.

## 40 GbE Port Partitioning

The switches deployed by Intel support logical partitioning of 40 GbE ports into 4 x 10 GbE. This enables Intel to increase 10 GbE port density with a minimum physical footprint. This type of connection requires a fan-out cable, which is made up of a 12-strand MMF bundle terminated with an MPO connector on one end and broken out to four 2-strand connections. This cable is available in standard lengths up to 100 meters.

## 10 GbE Cable Technologies

Higher transmission speeds require us to implement new cable technologies to optimize our 10 GbE infrastructure:

- **10GBASE-T.** This connection over unshielded or shielded twisted-pair cables can support distances over 100 meters (330 feet) with Category 6a cable, 55 meters with Category 6 cable, and 45 meters with Category 5e cable. We are using limited 10GBASE-T to serve the high-density connectivity within racks. 10GBASE-T has some cost advantages but it also consumes more power than optical technology.

- **Small-Form-Factor Pluggable (SFP+) direct-attach cables.** These twinaxial cables support 10 GbE connections over short distances of up to 7 meters. Some suppliers are producing a cable with a transmission capability of up to 15 meters.
- **Connectorized cabling.** We are using this technology to simplify cabling and reduce installation cost because it is supported over SFP+ ports. One trunk cable that we use can support 10 GbE up to 90 meters and provides six individual connections. This reduces the amount of space required to support comparable densities by 66 percent. The trunks terminate on a variety of options, providing for a flexible system. We also use an MPO cable, which is a connectorized fiber technology comprised of multistrand trunk bundles and cassettes. This technology can support 1 GbE and 10 GbE connections and can be upgraded easily to support 40 and 100 GbE parallel-optic connections by simply swapping a cassette. The current range for 10 GbE is 300 meters on OM3 MMF and 10 kilometers on SMF.

To maximize the supportable distances for 10 GbE, and 40 GbE/100 GbE when it is available, we have changed Intel's fiber standard to reflect a minimum of OM3 MMF and OM4 where possible (see [Figure 4](#)) with energy-efficient SFP+ ports.

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When I/O convergence on Ethernet becomes a reality, multiple traffic types, such as LAN, storage, and interprocess communication, can be consolidated onto a single, easy-to-use network fabric.

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## Future Plans for Office, Enterprise, and Services I/O and Storage Consolidation

Historically, Ethernet's bandwidth limitations have prevented it from being the fabric of choice for some application areas, such as I/O, storage, and interprocess communication. Consequently, we have used other fabrics to meet high-bandwidth, low-latency, no-drop needs, such as fiber channel. The advent of 10 GbE is enabling us to converge all our network needs onto a single, flexible infrastructure.

Several factors contribute to the increase of I/O demand on our data centers. First, when more servers are added to the data center, it increases IOPS, which creates a proportional demand on the network. In addition, as each generation of processors becomes more complex, the amount of data associated with silicon design also increases significantly—again, increasing network demand. Finally, systems with up to 1 TB of memory are becoming more common, and these systems also need a high-speed network to read, write, and back up large amounts of data.

Upgrading beyond 10 GbE products will help enable us to consolidate storage for Office, Enterprise, and Services applications while reducing our 10 GbE per-port cost. When I/O convergence on Ethernet becomes

a reality, multiple traffic types, such as LAN, storage, and interprocess communication, can be consolidated onto a single, easy-to-use network fabric. We have conducted multiple phases of testing, and in the near future these 10 GbE ports will be carrying multiple traffic types.

## Conclusion

A high-performance data center infrastructure capable of network speeds of 10 GbE and beyond can simplify the virtualization of Office, Enterprise, and Services applications and reduce per-server total cost of ownership.

Our analysis shows that for a virtualized environment, a 10 GbE infrastructure can reduce our network TCO by as much as 18 to 25 percent. And, for Design applications, where low latency is required, 10 GbE can increase throughput without requiring expensive low-latency technology. We project that we will need 100 GbE by 2015 in our data centers, but the majority of the ports over the next three years will remain 1 GbE and 10 GbE. At higher speeds, physical infrastructure plays a critical role. The new fabric will reduce data center complexity and increase our network's agility to meet Intel's growing data center needs.

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