DATA CENTER APPLICATIONS REFERENCE GUIDE

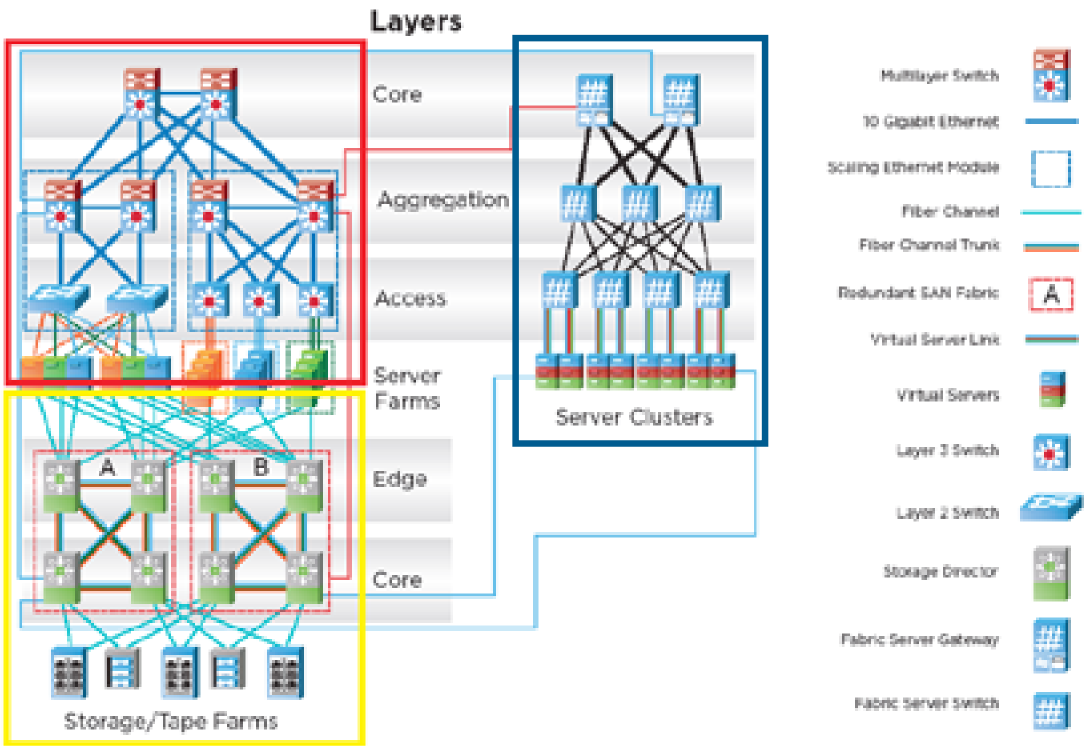
Networking & Storage

Scope

This technical paper provides an overview about the most dominant networking and storage applications in modern data centers. Additionally, it offers information about the different structured cabling infrastructures capable of running these applications in order to function as an application reference book for network cabling designers in data centers.

1. Introduction

The definition of the most dominant networking & storage applications in data centers used in this technical paper is derived from the following graphic (source: Cisco):



Graphic 1: Data Center Functional Elements and Applications

The applications can be grouped into:

Application	functional element
Ethernet	Networking area (red marked)
Fiber channel	Storage area (yellow marked)
Infiniband	High Performance server Cluster & Storage (blue marked)

Note: IP convergence is becoming more and more popular in DC's resulting in deployment of FibreChannel over Ethernet (FCoE) and Infiniband over Ethernet (IoE) applications. Although they are not listed here, they will be covered in latter chapters.

2. Data Center Cabling Standard ISO/IEC 24764

This standard has been released in April 2014 (ed 1.1) and defines together with the ISO/IEC 11801 (ed. 2.2 - Generic Cabling for Customer Premises; released in June 2011) the cabling systems for copper and fiber applications in data centers. These standards are used in this paper as reference for linking the mentioned data center applications to standard compliant cabling systems.

2.1 Copper cabling systems

ISO/IEC 11801 ed. 2.2 defines the following performance classifications for balanced cabling:

Class	Specified up to
Class D	100 MHz
Class E	250 MHz
Class E_A	500 MHz
Class F	600 MHz
Class F_A	1000 MHz

Table 1: Performance classifications for balanced cabling

The following copper connector definitions have been made for the equipment outlet (EO)

Category	Standard
Category 6_A unscreened	IEC 60603-7-41
Category 6_A screened	IEC 60603-7-51
Category 7 screened	IEC 60603-7-7
Category 7_A screened	IEC 60603-7-71
Category 7_A screened	IEC 61076-3-104

Table 2: Connecting hardware of the type used at the EO

2.2. Fiber optic cabling systems

For multimode fiber optic cabling systems, the following cabled fiber definitions are used:

		Minimum modal bandwidth MHz x km		
		Overfilled launch bandwidth		Effective modal bandwidth
Wavelength		850 nm	1300 nm	850 nm
Category	Nominal core diameter µm			
OM1	50 or 62.5	200	500	Not specified
OM2	50 or 62.5	500	500	Not specified
OM3	50	1500	500	2000
OM4	50	3500	500	4700

Table 3: Fiber types and bandwidths

Note: Modal bandwidth requirements apply to the optical fiber used to produce the relevant cabled optical fiber category and are assured by the parameters and test methods specified in IEC 60793-2-10.

Cabled optical fiber attenuation (maximum) dB/km							
	OM1, OM2, OM3 & OM4 multimode		OS1 single-mode		OS2 single-mode		
Wavelength	850 nm	1300 nm	1310 nm	1550 nm	1310 nm	1383 nm	1550 nm
Attenuation	3.5	1.5	1.0	1.0	0.4	0.4	0.4

Table 4: Performance definitions for cabled optical fiber

The following fiber connector definitions have been made for the equipment outlet (EO):

- For the termination of one or two single-mode optical fibers the interface shall be IEC 61754-20 (the LC interface).
- For the termination of one or two multimode optical fibers, the interface shall be IEC 61754-20 (the LC interface).
- For the termination of more than two optical fibers, the interface shall be IEC 61754-7 (the MPO interface).

2.3. Minimum requirements for data center cabling

In order to ensure a future proof selection of the data center cabling systems, ISO/IEC 24764 specifies minimum cabling performance requirements for data centers as follows:

2.3.1 Balanced cabling

The main distribution cabling shall be designed to provide a minimum of Class E_A channel performance as specified in ISO/IEC 11801.

2.3.2 Optical fiber cabling

Where multimode optical fiber is used, the main distribution and zone distribution cabling shall provide channel performance as specified in ISO/IEC 11801 using a minimum of Category OM3.

Note: The scope of the cabling standard ends at a channel length of 2000 m. Lengths in this document that are longer than 2000 m are taken from the application standard.

3. Ethernet (IEEE 802.3)

Ethernet applications according to IEEE 802.3 are dominating the networking area in today's data centers. The server farms in the equipment distribution areas (access) use 1 Gigabit Ethernet (with 10 Gigabit Ethernet knocking at the door). In the aggregation and core areas, 10 Gigabit Ethernet using fiber optic cabling is the choice of cabling designers all over the globe. In mid 2010, the newest IEEE 802.3 has arrived: 40/100 Gigabit Ethernet.

3.1 Gigabit Ethernet over fiber (IEEE 802.3z)

There are 2 main data center applications: 1000BASE-SX and 1000BASE-LX

3.1.1 1000BASE-SX

1000BASE-SX is a fiber optic gigabit Ethernet standard for operation over 2 multimode fibers using a 770 to 860 nanometer, near infrared light wavelength. This standard is highly popular for intra-building links in large office buildings, co-location facilities, data centers and carrier neutral internet exchanges.

3.1.2 1000BASE-LX

1000BASE-LX is a fiber optic gigabit Ethernet standard using a long wavelength laser (1270 to 1355 nm). The application can be run on either two multimode or singlemode fibers.

	Channel length 1000Base-SX	**Channel length 1000Base-LX**
OM1, 62.5/125 µm	275 m	550 m*
OM2, 50/125 µm	550 m	550 m*
OM3, 50/125 µm	1000 m	600 m
OM4, 50/125 µm	1040 m	600 m
OS1/OS2, 9/125 µm	N/A	5000 m

* Mode Conditional PatchCords required

Table 5: Channel length definitions for Gigabit Ethernet depending on application and fiber type

As mentioned in 2.3.2, the minimum requirement defined by the data center cabling standard for cabled optical fiber in data centers is OM3. Other fiber types are listed for reference only.

3.2. Gigabit Ethernet over copper

1000BASE-T (also known as IEEE 802.3ab) is a standard for gigabit Ethernet over copper wiring.

Each 1000BASE-T network segment can be a **maximum length of 100 meters** and must offer a Class D channel performance as a minimum. 1000BASE-T requires all four pairs for transmission.

As mentioned in 2.3.1, the minimum performance class requirement defined by the data center cabling standard for copper cabling systems is Class E_A which is backward compatible to the Class D performance.

3.3. 10 Gigabit Ethernet

3.3.1. 10 Gigabit Ethernet over fiber

In 2002, 10GBE over fiber has been specified by IEEE 802.3ae with both WAN and LAN application focus. Because of the severe link length limitations of this application when using traditional 50/125 µm (OM2) and 62.5/125 µm (OM1) fibers, the international cabling standards had to define a new laser optimized 50/125 µm fiber (OM3) featuring a much more precise fiber core index profile. The much higher effective modal bandwidth of that fiber allows longer link lenghts meeting the building requirements.

There are two 10GBE multimode fiber applications used in data centers: **10GBASE-LX4** and **10GBASE-SR**. Both are dual fiber applications.

3.3.2. 10 Gigabit Ethernet over copper

10GBE over copper (10GBASE-T), defined as IEEE 802.3an in 2007, was similarily challenging for copper cabling systems as IEEE 802.3ae has been for fiber optic systems. Because of the link lengths limitations for Class E/Cat. 6 UTP systems to 37 m, the cabling standards had to define the new cabling performance Class E_A which is mentioned in 2.3.1 the minimum cabling requirement in data center cabling. **Class E_A cabling allows 100 m channels for 10GBASE-T.**

Ethernet 10GBase physical layer specifications					
Type	PMD	Technology	Connector	Media	Reach (m)
Copper	10GBase-T	4 pairs	RJ-45	Category 6 UTP	37
				Category 6 STP Category 6_A UTP/STP	100
Fiber	10GBase-SR	850 nm VCSEL, serial	Dual LC and SC	OM1/OM2/OM3/OM4 MMF	33/82/300/400
	10GBase-LRM	1310 nm LD, serial		OM1/OM2/OM3 MMF	220/220/300
	10GBase-LX4	1310 nm LD, WDM		OM1/OM2/OM3 MMF	300
				OS1 and OS2 SMF	10,000
	10GBase-LR	1310 nm LD, serial		OS1 and OS2 SMF	10,000
	10GBase-ER	1550 nm LD, serial			40,000

Note: OM1/OM2/OM3 = 200 MHz.km/500 MHz.km/2,000 MHz.km bandwidth respectively
OS1 = 9/125 singlemode; OS2 = 9/125 low water peak singlemode

Table 6: Application vs. media vs. link length for 10 GigaBit Ethernet

As mentioned in 2.3.2, the minimum requirement defined by the data center cabling standard for cabled optical fiber in data centers is OM3. Other fiber types are listed for reference only.

3.4. 40/100 GigaBit Ethernet

As the latest ethernet application, IEEE 802.3ba has been published in mid 2010. The standard defines both data rates (40 GBE and 100 GBE) simultaneously. There are 4 applications that are primarily defined for use in data centers:

- 40GBASE-CR4 100GBASE-CR10
- 40GBASE-SR4 100GBASE-SR10

While the -CR variants use a copper cable assembly with limited reach of 7 m, the –SR applications are using multimode fiber. 40GBASE-SR4 and 100GBASE-SR10 are the first ethernet applications that require more than 2 fibers for the transmission over multimode fiber. Based on multiple 10 Gb/s data streams in full duplex mode these applications are built, 40GBASE-SR4 (8 fibers) and 100GBASE-SR10 (20 fibers). Hence, these applications require the use of the multi fiber connector MPO. Although 40/100 GBE multimode applications dominate the data center, the following table also includes singlemode applications in order to give a complete overview about all of the 40/100 GBE applications.

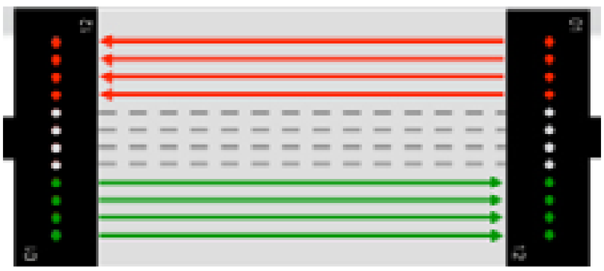
	Channel length 40GBASE-SR4	Channel length 100GBASE-SR10	Channel length 40GBASE-LR4	Channel length 100GBASE-LR4	Channel length 100GBASE-ER4
OM3, 50/125 µm	100 m	100 m	N/A	N/A	N/A
OM4, 50/125 µm	150 m*	150 m*	N/A	N/A	N/A
OS1/OS2 9/12 µm	N/A	N/A	10 km	10 km	40 km

* special link budget applies, see section 3.5

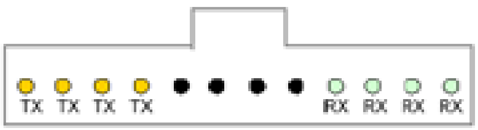
Table 7: Channel length definitions for 10GBE depending on application and fiber type

3.4.1. 40GBASE-SR4 (40GBE)

The following graphics illustrate the concept of the parallel data transmission on multi-fiber links using the MPO connector and the respective pinout for 40GBase-SR4 on the connectivity.



Graphic 2: 40GBase-SR4 full duplex operation on 8 fibers

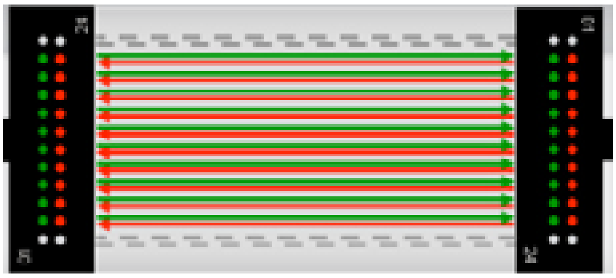


Graphic 3: MPO connector pinout for 40GBase-SR4

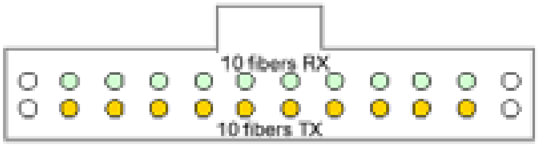
3.4.2. 100GBASE-SR10 (100GBE)

The following graphics illustrate the concept of the parallel data transmission on multi-fiber links using the MPO connector and the respective pinout for 100GBase-SR10 on the connectivity.

100GBASE-SR10 optical lane assignments



Graphic 4: 100GBASE-SR10 full duplex operation on 20 fibers



Graphic 5: MPO connector pinout for 100GBase-SR10

3.5. Channel power budgets for Ethernet applications

In addition to the link length definitions, the power budget definition for cabling systems is another critical parameter to monitor when deploying FO applications. The following table outlines the cabling system power budget for the above mentioned ethernet applications.

Network application	Max. channel insertion loss (dB)		
	Multimode[a]		Singlemode
	850 nm	1300 nm	1310 nm
IEEE 802-3: 10BASE-FLand FB	12.5 (6.8)**	–	–
IEEE 802-3: 1000BASE-SX	2.6 (3.56)**	–	–
IEEE 802-3: 1000BASE-LX	–	2.35	4.56
ISO/IEC 8802-3: 100BASE-FX		11.0 (6.0)	–
IEEE 802.3: 10GBASE-LX4		2.00	6.20
IEEE 802.3: 10GBASE-SR/SW	1.60 (62.5) 1.80 (OM2 50) 2.60 (OM3) 2.90 (OM4)	–	–
IEEE 802.3: 10GBASE-LR/LW	–	–	6.20
IEEE 802.3: 40GBASE-LR4	–	–	f.f.s.
IEEE 802.3: 100GBASE-LR4	–	–	6.3
IEEE 802.3: 100GBASE-ER4	–	–	18.0
IEEE 802.3: 40GBASE-SR4	1.9 (100m OM3/OM4) 1.5 (150m OM4)*	–	–
IEEE 802.3: 100GBASE-SR10	1.9 (100m OM3/OM4) 1.5 (150m OM4)*	–	–

* While all listed applications allocate 1.5 db insertion loss for splices and connections within a cabling channel, 40 and 100 GBE on OM4 requires a lower insertion loss of 1 db for all splices and connections in a channel, requiring an engineered link using a FO cabling system with highest performing connector technology.

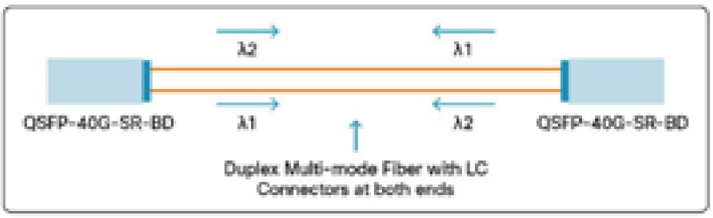
** Values shown are for 62.5/125 µm. Values in parenthesis represent 50/125 µm.

Table 8: Channel budget for ethernet applications depending on application and fiber type

NOTE: Several vendors have launched QSFP+ Transceivers for 40 Gb/s Ethernet offering extended power budget and channel lengths compared to the IEEE specification. Detailed specifications can be found in the specific data sheets of the suppliers.

4. Proprietary Cisco 40 Gb/s BiDi

Cisco has developed a proprietary 40 Gb/s technology using 2 fibers. This technology is not compatible with the IEEE standard for 40 Gb/s Ethernet. The Cisco QSFP 40 Gb/s BiDi transceiver has two 20 Gb/s channels, each transmitted and received simultaneously on two wavelengths. The result is an aggregated 40 Gb/s link over 2 fibers, connected with a LC-Duplex connector. The following graphic shows the technology



Graphic 6: Cisco 40 Gb/s BiDi technology

The channel loss budget for 40 Gb/s BiDi is 2 db. This results in the following cabling specifications

Wavelength	Cable Type	Core Size	Modal Bandwidth (MHz x km)	Cable Distance
850 to 900 nm	MMF	50.0 microns	500 (OM2) 2000 (OM3) 4700 (OM4)	30m 100m*1 125m*2

*1 Connector loss budget for OM3 fiber is 1.5dB
*2 125m over OM4 fiber is with an Engineered Link with 1dB budget for connector loss

Table 9: Channel lengths for Cisco 40 Gb/s BiDi

5. Fiber channel applications (INCITS, T11)

Fiber Channel (FC) is a gigabit-speed network technology primarily used for storage networking. Fiber Channel is standardized in the T11 Technical Committee of the InterNational Committee for Information Technology Standards (INCITS), an American National Standards Institute (ANSI)–accredited standards committee. It started primarily in the supercomputer field, but has become the standard connection type for storage area networks (SAN) in data centers

The following shows the FCIA (Fiber Channel Industry Association) technology roadmap for this application.

5.1 Fiber channel overview

Fiber Channel Speed Roadmap - FC (v1.8)				
Product Naming	**Throughput (MBps)**	**Line Rate† (GBaud)**	**T11 Spec Technically Completed (Year)‡**	**Market Availability (Year)‡**
1GFC	200	1.0625	1996	1997
2GFC	400	2.125	2000	2001
4GFC	800	4.25	2003	2005
8GFC	1600	8.5	2006	2008
16GFC	3200	14.025	2009	2011
32GFC	6400	28.05	2013	2015
128GFCp	25600	4x28.05	2014	2015
64GFC	12800	TBD	2016	Market Demand
128GFC	25600	TBD	2019	Market Demand
256GFC	51200	TBD	2022	Market Demand
512GFC	102400	TBD	2025	Market Demand
1 TFC	204800	TBD	2028	Market Demand

"FC" used throughout all applications for fiber channel Infrastructure and devices, including edge and ISL interconnects. Each speed maintains backward compatibility at least two previous generations (i.e. 8GFC backward compatible to 4GFC and 2GFC)
† Line Rate All "...GFC" speeds listed above are single-lane serial stream I/O's. All "...GFCp" speeds listed above are multi-lane I/Os
‡ Dates Future dates estimated

Table 10: Fiber channel speed roadmap

5.2. Fiber channel over copper

Although most users link the fiber channel application to transmission over fiber, there are also specifications available to run FC over copper. In 2007, INCITS 435 has been approved containing a set of specifications for the "FC-BaseT " applications, The rationale behind these copper definitions was the user perception of fiber optic being expensive. With the copper definitions T11 wanted to improve the fiber channel competitiveness in low cost environments.

Commonly used Fiber Channel physical layer specifications					
Type	PMD	Technology	Connector	Media	Reach (m)
Copper	4GFCBase-T	4 pairs	RJ-45	Class E/E_A	40/100
	2GFCBase-T			Class D/E/E_A	60/70/100
	1GFCBase-T			Class D/E/E_A	100

Table 11: Channel length definitions for fiber channel over copper depending on application and copper performance class

5.3. Fiber channel over fiber

As mentioned in the previous chapter, FC mainly runs on fiber optic cabling systems.

There are several length vs. media definitions depending on the specific fiber channel application to be deployed. The following table provides a complete overview.

Channel lengths / m						
Fiber type	**1 Gbps FC**	**2 Gbps FC**	**4 Gbps FC**	**8 Gbps FC**	**16 Gbps FC**	**32 Gbps FC**
OM1, 62.5/125 µm	300	150	70	21	15	N/A
OM2, 62.5/125 µm	300	150	70	21	15	N/A
OM2, 50/125 µm	500	300	150	50	35	20
OM3, 50/125 µm	860	500	380	150	100	70
OM4, 50/125 µm	min. 860	min. 500	400	190	125	100
OS1/OS2, 9/125µm	10000	10000	10000	10000	10000	10000

Note: Fiber channel specifies these lengths assuming an insertion loss of 1,5 dB (MM) and 2 dB (SM) for all connections and splices in the channel. See 5.5 for deviating multimode channel lengths depending on different connection/splice losses.

Table 12: Channel length definitions for fiber channel over fiber depending on application and fiber type

5.4. Fiber channel over Ethernet (FCoE)

Fiber channel over Ethernet (FCoE) is a new extension of the fiber channel storage protocol that uses Ethernet as it's physical transmission technology. FCoE combines fiber channel and Ethernet to provide end users with a "Converged" network option for storage SAN connectivity and LAN traffic. Combined with enhancements to Ethernet, FCoE allows datacenters to consolidate their I/O and network infrastructures into a converged network. FCoE is simply a transmission method in which the fiber channel frame is encapsulated into an Ethernet frame at the server. The server encapsulates fiber channel frames into Ethernet frames before sending them over the LAN, and de-encapsulates them when FCoE frames are received. Server input/output (I/O) consolidation combines the network interface card (NIC) and host bus adapter (HBA) cards into a single converged network adapter (CNA). Fiber channel encapsulation requires use of 10-Gigabit Ethernet transmission electronics.

Fiber Channel Speed Roadmap (v11)					
	Product Naming	Throughput (MBps)	Equivalent Line Rate (GBaud)	T11 Spec Technically Completed (Year)	Market Availability (Year)
FCoE	10GFCoE	2400	10.3125	2008	2009
	40GFCoE	9600	41.225	2010	Market Demand
	100GFCoE	24000	100.3125	2010	Market Demand

Table 13: Fiber channel speed roadmap

FCoE tunnels FC through Ethernet. For compatibility all FCFs and CNAs are expected to use SFP+ devices, allowing the use of all standard and non standard optical technologies and additionally allowing the use of direct connect cables using the SFP+ electrical interface. FCoE ports otherwise follow Ethernet standards and compatibility guidelines.

5.5. Channel power budgets for FC applications

Channel Budget / dB						
Fiber type	1 Gbps FC	2 Gbps FC	4 Gbps FC	8 Gbps FC	16 Gbps FC	32 Gbps FC
OM1, 62.5/125 µm	3	2.1	1.78	1.58	-	N/A
OM2, 50/125 µm	3.85	2.62	2.06	1.68	1.63	2.02
OM3, 50/125 µm	4.62	3.31	2.88	2.04	1.86	1.87
OM4, 50/125 µm	4.62	3.31	2.95	2.19	1.95	1.87
OS1/OS2, 9/125µm	7.8	7.8	7.8	6.4	6.4	6.21

Table 14: Channel budget for fiber channel over fiber depending on application and fiber type

The multimode channel lengths given in 5.3 are based on an allocation of 1,5 dB insertion loss of all connectors and splices within a channel. However, a connector/splice loss in a channel deviating from the 1,5 dB results in different max. channel lengths. The following table gives an overview.

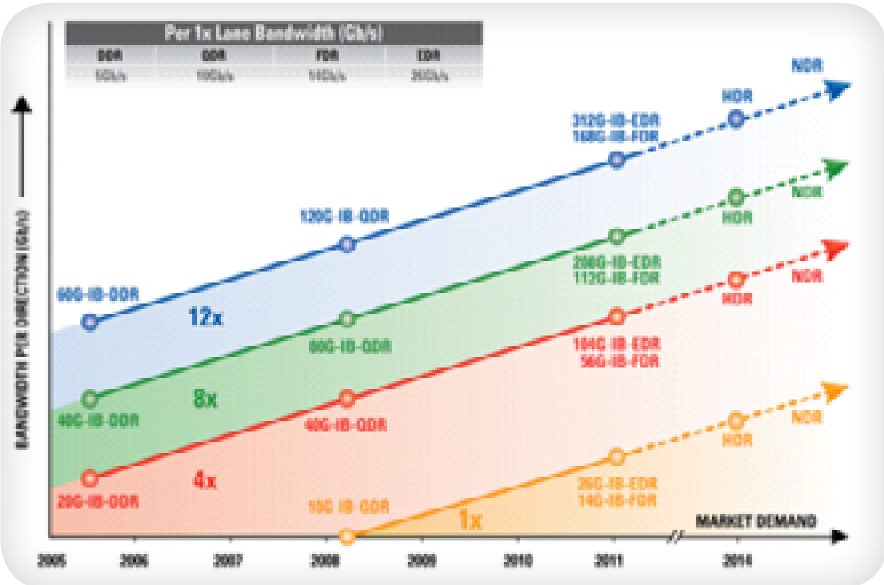
400-SN max operating distance & loss budget for different connection losses					
	Distance (m) / Loss Budget (dB)				
Fiber Type	Connection Loss				
	3.0 dB	2.4 dB	2.0 dB	1.5 dB	1.0 dB
M5F (OM4)	200 / 3.72	300 / 3.49	370 / 3.34	400 / 2.95	450 / 2.63
M5E (OM3)	150 / 3.54	290 / 3.45	320 / 3.16	380 / 2.88	400 / 2.45
M5 (OM2)	70 / 3.26	120 / 2.85	130 / 2.49	150 / 2.06	170 / 1.64
800-SN max operating distance & loss budget for different connection losses					
	Distance (m) / Loss Budget (dB)				
Fiber Type	Connection Loss				
	3.0 dB	2.4 dB	2.0 dB	1.5 dB	1.0 dB
M5F (OM4)	50 / 3.18	120 / 2.83	160 / 2.58	190 / 2.19	220 / 1.80
M5E (OM3)	35 / 3.13	110 / 2.80	125 / 2.45	150 / 2.04	180 / 1.65
M5 (OM2)	N/A	35 / 2.53	45 / 2.16	50 / 1.68	60 / 1.22
1600-SN max operating distance & loss budget for different connection losses					
	Distance (m) / Loss Budget (dB)				
Fiber Type	Connection Loss				
	3.0 dB	2.4 dB	2.0 dB	1.5 dB	1.0 dB
M5F (OM4)	N/A	50 / 2.58	100 / 2.36	125 / 1.95	150 / 1.54
M5E (OM3)		40 / 2.54	75 / 2.27	100 / 1.86	120 / 1.43
M5 (OM2)		N/A	25 / 2.09	35 / 1.63	40 / 1.14
3200-SN max., operating distance & loss budget for different connection losses					
	Distance (m) / Loss Budget (dB)				
Fiber Type	Connection Loss				
	3.0 dB	2.4 dB	2.0 dB	1.5 dB	1.0 dB
M5F (OM4)	20 / 3.04	65 / 2.64	80 / 2.36	100 / 1.86	110 / 1.48
M5E (OM3)	15 / 3.03	45 / 2.64	60 / 2.24	70 / 1.87	80 / 1.41
M5 (OM2)	N/A	15 / 2.52	15 / 2.52	20 / 2.02	25 / 1.29

Table 15: Channel length for fiber channel over fiber depending on application, fiber type and connection/splice loss

6. InfiniBand

InfiniBand is a technology that was developed to address the performance problems associated with data movement between computer input/output (I/O) devices and associated protocol stack processing. The InfiniBand Architecture (IBA) is an industry-standard architecture for server I/O and inter-server communication. It was developed by the InfiniBandSM TradeAssociation (IBTA) to provide the levels of reliability, availability, performance, and scalability necessary for present and future server systems, levels significantly better than can be achieved with bus-oriented I/O structures. Although InfiniBand was developed to address I/O performance, InfiniBand is widely deployed within high performance compute (HPC) clusters and storage networks due to the high bandwidth and low latency transport characteristics it offers.

The following graph shows the InfiniBand Roadmap taken from the homepage of the InfiniBand Trade Association www.infinibandta.org



SDR - Single Data Rate
DDR - Double Data Rate
QDR - Quad Data Rate
FDR - Fourteen Data Rate
EDR - Enhanced Data Rate
HDR - High Data Rate
NDR - Next Data Rate

Graphic 7: InfiniBand Technology Roadmap from the IB Trade Association homepage www.infinibandta.org

The SDR-application for multimode (IB 1x-SX)and all singlemode applications (IB 1x-LX) use 2 fibers with LC connectors for transmission while all other applications starting with DDR use the multi-fiber MPO connector.

Application	Connector Type
IB 1x-SX	2 x LC
IB 4x-SX	1 x MPO 12f
IB 8x-SX	2 x MPO 12f
IB 12x-SX	2 x MPO 12f
IB 1x-LX	2 x LC
IB 4x-LX	2 x LC

Table 16: InfiniBand applications and fiber optic connector types

6.1. Channel lengths

The maximum channel length depends on the data rate, the number of parallel lines and the optical fiber type. The following table summarizes this.

Channel lengths / m						
Fiber type	**IB 1x-SX SDR/DDR/QDR**	**IB 4x-SX SDR/DDR**	**IB 8x-SX SDR/DDR**	**IB 12x-SX SDR/DDR**	**IB 1x-LX SDR/DDR/QDR**	**IB 4x-LX SDR**
OM1, 62.5/125 µm	125/65/33	75/50	75/50	75/50	N/A	N/A
OM2, 50/125 µm	250/125/82	125/75	125/75	125/75	N/A	N/A
OM3, 50/125 µm	500/200/300	200/150	200/150	200/150	N/A	N/A
OM4, 50/125 µm*	500/200/300	200/150	200/150	200/150	N/A	N/A
OS1/OS2, 9/125µm	N/A	N/A	N/A	N/A	10km for all	10km

* IB physical spec does not mentioned OM4. Hence OM4 is treated as OM3 in this table

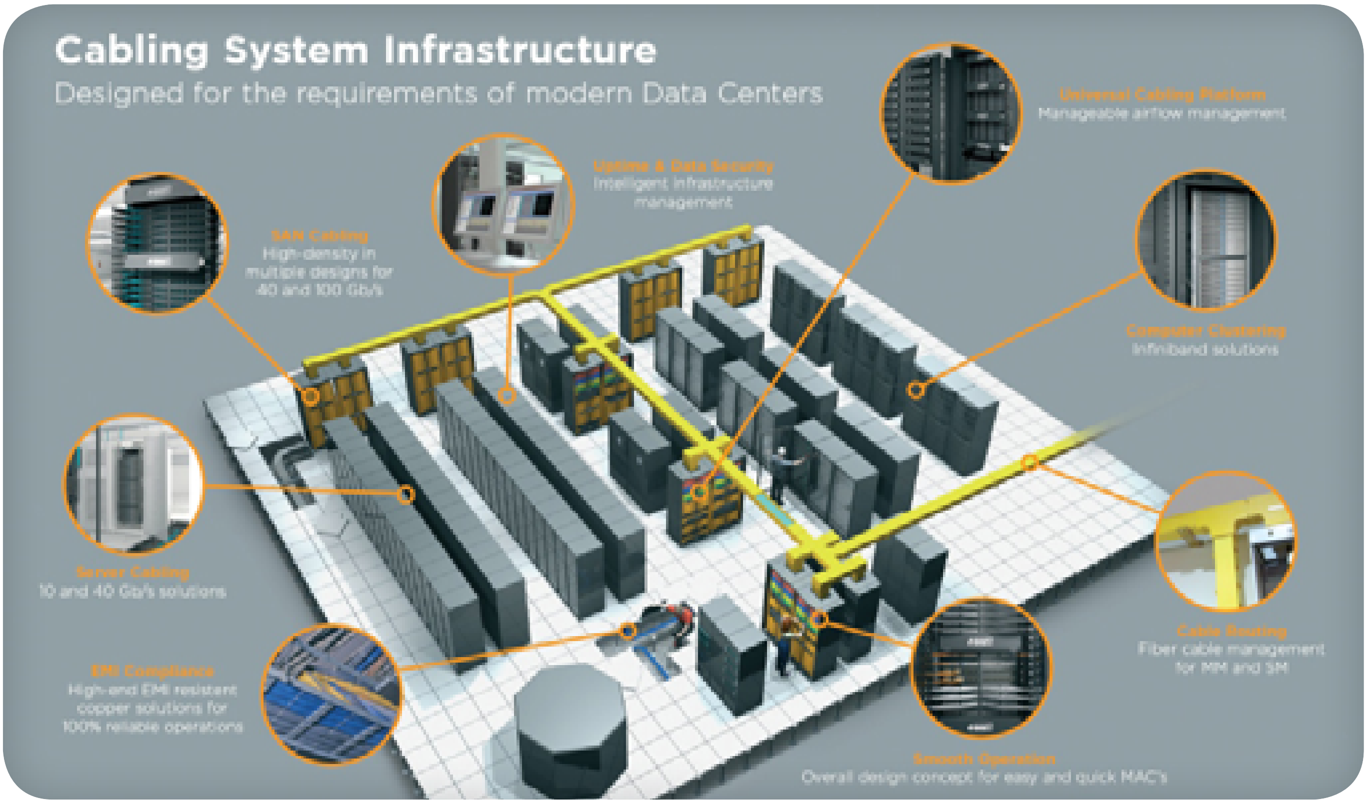
Table 17: InfiniBand channel lengths depending on applications and fiber types

6.2. Channel power budgets for IB applications

Channel Budget / dB						
Fiber type	**IB 1x-SX SDR/DDR**	**IB 4x-SX SDR/DDR**	**IB 8x-SX SDR/DDR**	**IB 12x-SX SDR/DDR**	**IB 1x-LX SDR/DDR**	**IB 4x-LX SDR**
OM1, 62.5/125 µm	6/7.93	4.8/6.25	4.8/6.25	4.8/6.25	N/A	N/A
OM2, 50/125 µm	6/7.93	4.8/6.25	4.8/6.25	4.8/6.25	N/A	N/A
OM3, 50/125 µm	6/7.93	4.8/6.25	4.8/6.25	4.8/6.25	N/A	N/A
OM4, 50/125 µm*	6/7.93	4.8/6.25	4.8/6.25	4.8/6.25	N/A	N/A
OS1/OS2, 9/125µm	N/A	N/A	N/A	N/A	9/9.8	6.2

* IB physical spec does not mentioned OM4. Hence OM4 is treated as OM3 in this table

Table 18: Channel Power Budgets



Graphic 8: Cabling system infrastructure

TE Connectivity

TE Connectivity is a $13 billion technology company that designs and manufactures the electronic connectors, components and systems inside the products that are changing the world. Our dedication to innovation, collaboration and problem solving helps engineers worldwide solve some of their biggest challenges, so they can create products that are smarter, safer, greener and more connected. Our components are found in almost every product in the world that uses electronics, making us a small part of millions of big ideas.

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