R&M Data Center
Handbook

R&M

Preface

The present Data Center Handbook serves as a current guide for planning and designing data centers. Many data centers around the world rely on our fiber-optic and twisted-pair cabling solutions as the physical foundation of their networks. R&M's Automated Infrastructure Management (AIM) system has also become the basis for automating and orchestrating all MAC processes and capacity planning functions required to operate a highly efficient data center. All this long and deep knowledge has now been brought together in this manual.

Ultimately, innovative cabling products can enable your data center organization to become more flexible and respond faster to your organization's critical IT needs. All decisions relating to the infrastructure of the physical layer are of the utmost importance, so that they are tailored both to today's needs and to the requirements of future networks. The data center handbook will help you to make the right decisions when planning, deploying and operating a data center with sound knowledge. It also helps you to identify the numerous challenges in these areas at an early stage.

We hope you enjoy reading this book and look forward to hearing your thoughts and questions about it at feedback_handbook@rdm.com.

Yours sincerely
Your R&M Team

Content

R&M

Aspects in Planning a Data Center

Aspects in Planning a Data Center

Areas on which to focus in preliminary planning include:

- The analytic phase, including an accurate determination of your current situation
- Definition of requirements
- Conception

These phases should also include estimation of the costs of constructing the solution as well as future operational costs. The following items should be included in the preliminary planning process:

- Corporate strategies
- Requirements resulting from IT governance policy
- Requirements resulting from IT risk management policy
- A realistic determination of performance specifications

In addition, answers to critical issues must be provided at an early stage:

- Construction of an entirely new data center, or expansion of the existing one or
- Outsourcing (housing, hosting, managed services, cloud services) or
- Some alternative data center concept

Two factors are of vital importance when selecting a site for your data center:

- Power supply
- IP connection

The selection of a data center location must of course also include a consideration of general economic conditions, available resources and requirements of physical security. These last should include:

- Potential risks due to activities carried out by neighboring companies
- Risks due to natural hazards (water, storms, lightning, earthquakes)
- Protection from sabotage

External Planning Support

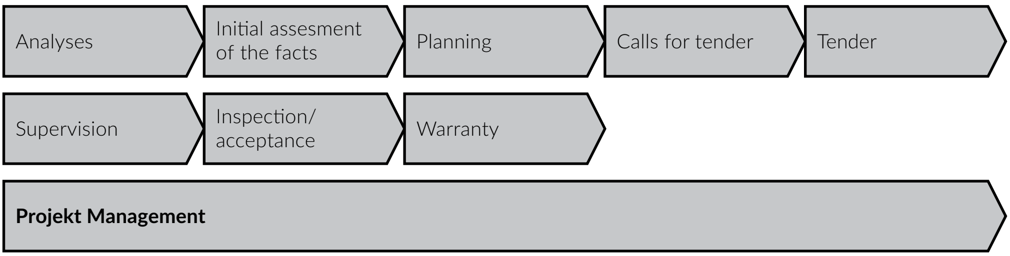
Planners and consultants are frequently brought into the planning process too late. Companies are often of the belief that server rooms and complex information systems can be realized without the help of specialized planners, or at least without professional consultants. The industry-wide experience these specialists bring to the table makes it possible to avoid and/or resolve a number of deficiencies and risks before they arise. It is therefore advisable that external partners providing support in the planning process themselves be evaluated at an early stage.

A perfect flow of communication between all project members is another requirement for project success; these parties must all speak the „same language“. As a result, the project leader must act as a focal point to tie together and integrate all the different area heads and trade groups. These parties include:

- Management
- IT and infrastructure experts
- Electrical and climate control engineers
- Supply technicians
- Architects
- Safety experts
- Network specialists, etc.

Consultants should meet with all project members to help them work out analyses and later requirements and technical specifications. This especially includes management, the IT department and infrastructure experts.

The conventional responsibilities of a data center planner include the following:



Conventional responsibilities of a data center planner

The demand for data center planners is constantly increasing, and the industry continues to show growth. Every planner brings a very different portfolio of services; they range from general contractors, who provide all services from planning up to final completion of the data center, up to experts who specialize in specific sub-tasks, as well as trade groups. The best way for a company to select the right planner is to focus on their own particular ideas and requirements, or the specific needs of the client. Companies are sometimes able to build upon their own experiences, in which case they might only need to invite certain trade groups to tender, or engage an expert assessor for quality assurance purposes.

Further Considerations for Planning

As data centers are often installed within the structure of a corporation, campus, production facility or building, areas in planning that go beyond mere infrastructure planning are gaining in importance. Such fields include structured cabling as well as application-neutral communications cabling (see EN 50600 series, TIA-942-B, EN 50173-5, EN50174, ISO/IEC 11801-5).

These integration tasks are often still not entrusted to data center planners. Experts estimate that more than 70% of all IT failures are based on faults in the cabling system infrastructure. Internal and external network are being required to transport increasing amounts of data. As a result, it is all the more essential for planners not to ignore how a data center is linked to the rest of the networked world.

From a data center standpoint, the following issues are essential to include in network planning:

- Security, availability
- Energy consumption, energy efficiency
- Redundancy
- Installation and maintenance efforts and/or costs
- Delivery times
- Flexibility for changes
- Productivity

Data Center Tiers

Data Center Tiers

The Uptime Institute, founded in 1993 and based in Santa Fe, New Mexico, is responsible for establishing specifications for the best-known classifications for data centers. These classifications define the availability of both physical structures and technical facilities. Tier classes I to IV describe the probability that a system will be functional over a specified period of time.

SPOF (Single Point of Failure) refers to that component in a system whose failure will cause the entire system to collapse. High-availability systems may not possess a SPOF.

Tier I – IV

The tier classification is based on all the components that are essential in a data center infrastructure, as well as some other factors. The lowest value of a specific component (cooling, power supply, communication, monitoring, etc.) determines its overall evaluation. Note that the classification also takes into consideration the sustainability of measures, operational processes and service processes in the data center. This is particularly evident in the transition from Tier II to Tier III, where the alternative supply path allows maintenance work to be performed without interfering with the operation of the data center, which in turn is reflected in the MTTR value (Mean Time to Repair).

Main Requirements	TIER I	TIER II	TIER III	TIER IV
Distribution paths power / cooling	Mutual	Mutual	1 active / 1 passive	2 active
Redundancy Active components	N	N+1	N+1	2 (N+1)
Redundancy Backbone	No	No	Yes	Yes
Redundancy Horizontal cabling	No	No	No	Optional
Double floor	12“	18“	30“–36“	30“–36“
UPS / Generator	Optional	Yes	Yes	Continuous
Servicing	No	No	Yes	Yes
Fault-tolerant	No	No	Yes	Yes
Availability	99.671 %	99.749 %	99.982 %	99.995 %

N: Need (required)
Source: Uptime Institute

Tier I

This class corresponds to the requirements of smaller companies. At this level extranet applications are not yet required, and use of the Internet is more passive. Availability is considered a secondary factor.

A Tier I data center operates with non-redundant capacity components and single non-redundant distribution networks. These centers do not require emergency power supply systems, uninterrupted power supply systems or double floors. Maintenance and repair work are based on schedules. Faults may paralyze operations.

Tier II

This second level corresponds to requirements of companies that are already processing business processes online during business hours. Delays where the data center is not available on occasion are acceptable. However, data losses may not occur. Delays should not be business-critical (non-time critical backups).

A Tier II data center has redundant capacity components (N+1) and single non-redundant distribution networks. An uninterruptible power supply as well as double floors is required.

Tier III & IV

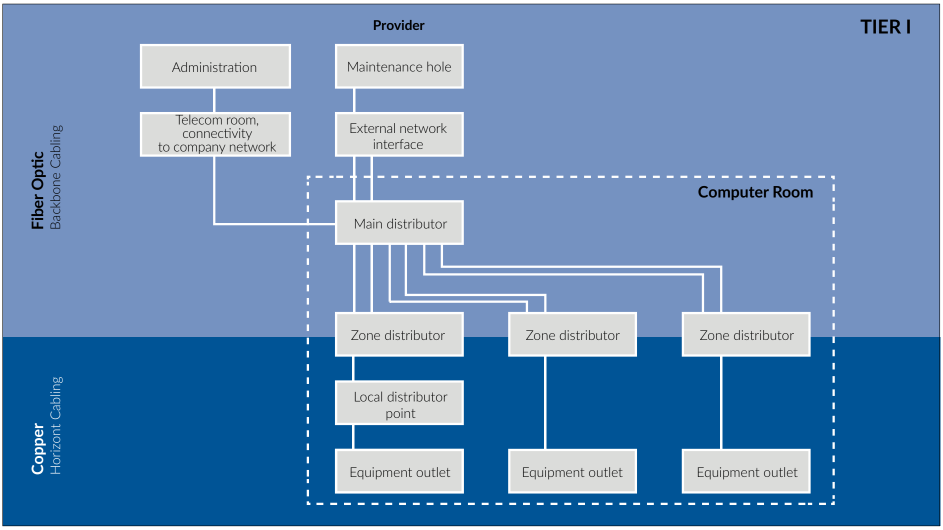
These higher levels correspond to requirements of companies that use their IT installations for internal and external electronic business processes. IT systems must be ready for operation and available around the clock. Times for maintenance and shutdowns must not lead to delays, operational interruptions or data loss. Tier III and IV requirements are the standard for e-commerce, electronic market transactions and financial services. High failure safety rates and security backups must be ensured at all times for organizations of these types.

A Tier III data center operates with redundant capacity components and multiple distribution networks. In general, only one distribution network supports servers at any one time.

A Tier IV data center must also possess so-called fault tolerance. It operates using redundant building components. Multiple distribution networks support servers simultaneously. All servers are dual powered and installed properly so as to be compatible with the topology of the site's architecture.

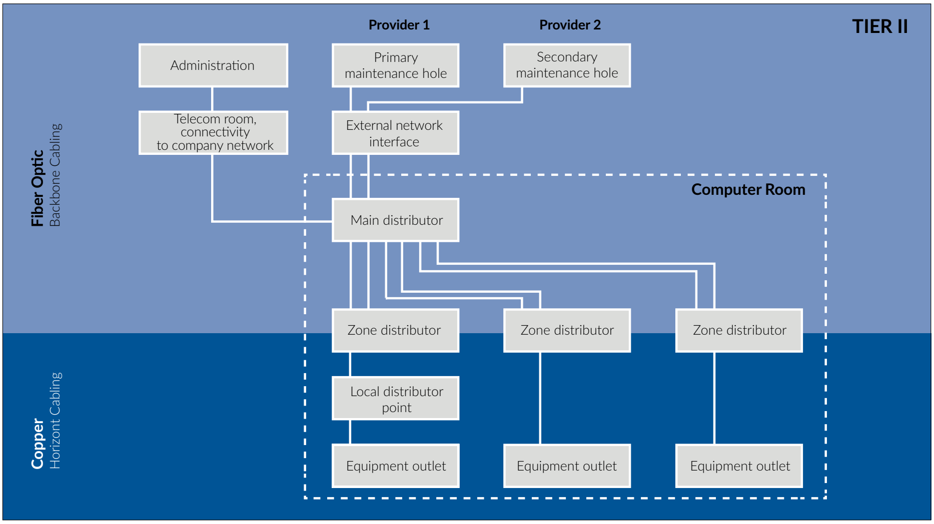
Classification Impact on Communications Cabling

Regardless of the corresponding tier level, cabling systems must be configured redundantly. This ensures availability and failure safety of the communication network in the data center. The following charts illustrate principles of cabling.



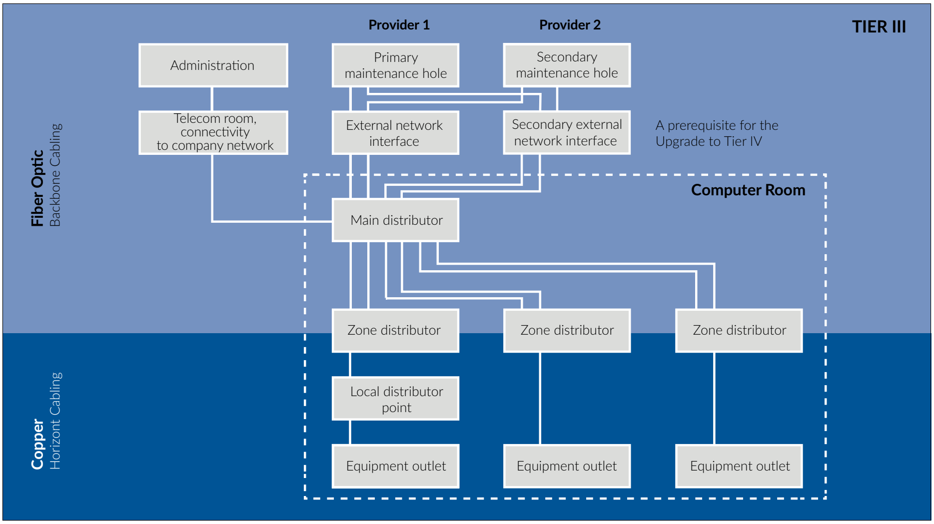
Principles of cabling TIER 1

A simple star topology or structured cabling system fulfills Tier I requirements. Neither backbone cabling systems, horizontal cabling systems nor active network components are redundant. Network operation may be interrupted. However, data integrity must be ensured.



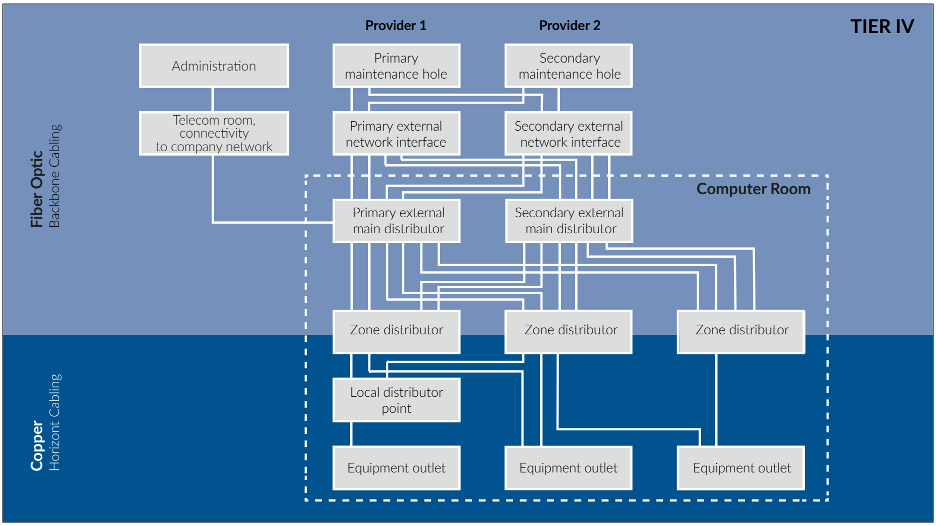
Principles of cabling TIER 2

Backbone cabling and horizontal cabling at the Tier II level are also in a star topology and not redundant. Redundancy must be planned for active network components and their connections. Network operation may only be interrupted at specified times or only minimally during peak hours of operation.



Principles of cabling TIER 3

Backbone cabling and active network components are configured redundantly in a star topology at the Tier III level. Network operation must be maintained without interruption within specified times and during peak hours of operation.



Principles of cabling TIER 4

The Tier IV level requires that backbone cabling and all active components as well as the uninterruptible power supply and the emergency power generator are redundant, 2 x (N+1). Horizontal cabling may also be configured redundantly if desired. Systems and networks must operate free of interruption. 24/7 operation is an absolute requirement. This means that the data center runs around the clock, on all days of the week. It must be planned to be fault-tolerant, without a SPOF (single point of failure). Maintenance and repair work may be carried out during continuous operation but must not lead to downtimes.

In conclusion, note the difference between the scientific classification and standard. The Tier classification of the Uptime Institute is based on a comprehensive analysis of a data center, from the point of view of the user and the operator. By contract, a Tier classification per is more a checklist for designing data centers. TIA-942-B specifies Tier classes using Arabic numbers, whereas the Uptime Institute uses Roman numbering.

In addition, the costs and time periods that are to be expected for implementing a Tier I and Tier IV data center may be of interest to planners and investors. The following table from the Uptime Institute gives an overview of sample values.

Implementation Time and Investment Costs

	TIER I	TIER II	TIER III	TIER IV
Implementation time	3 months	3 - 6 months	15 - 20 months	15 - 20 months
Relative investment costs	100 %	150 %	200 %	250 %
Costs per m^2	~ $ 4,800	~ $ 7,200	~ $ 9,600	~ $ 12,000

Source: Uptime Institute

Multi-Tenant Data Centers

Multi-Tenant Data Centers

A multi-tenant data center (MTDC), also known as a colocation data center, is a facility in which organizations can rent space to run their IT. MTDCs provide the space and network connectivity to connect an organization to service providers at low cost. Businesses can choose among various service schemes—from renting a server rack to a complete purpose-built module. The scalability of usage provides the business benefits of a data center without the high price.

The need to act regarding data centers is generally a consideration that can be assessed over the long term. IT departments, being aware of trends and critical time points, can make strategic considerations at an early stage. One question that faces data center operators, for example, is whether they should set up additional in-house resources, just outsource the entire data center, or find combined solutions.

The advantages of outsourcing data operations come down to three key factors: savings, availability, and security.

Outsourcing data center operations yield in drastic improvement of the IT team's capacity and ability to support the business. Any IT team managing its own data center must constantly be focused on maintaining and upgrading the data center. There must also be the capability to expedite work when demand spikes, along with addressing downtime and data loss. This constant focus of managing the data center results in a lack of IT resources dedicated to business strategy. By outsourcing to an MTDC facility, the company will be able to redeploy capital and resources into strategic growth initiatives.

Savings

By outsourcing data center operations, MTDC tenants can accomplish considerable CapEx and OpEx savings. Because MTDC companies have years of experience in the design, construction and operation of data center buildings, they are better able to optimize their operational efficiency. MTDC operators can not only build a data center lower in price, but also operate it more competitively. The ability to directly connect enterprises, content, and cloud providers in the same facility eliminates the need for WAN connections with accompanied backhaul and bandwidth costs.

Availability

MTDCs typically provide their own technicians to maintain the infrastructure and ensure that the hosted functions operate at maximum efficiency. MTDC operators offer their clients SLAs to ensure compliance with uptime and operational parameters. This enables customers to align their redundancy and performance needs with their cost options.

Security

An MTDC provides a multi-level security scheme to fend off external threats. By the same schemes, it can also provide thorough disaster recovery. The first security level consists of controlled entrance points to the facility. Commonly, these facilities are ringed with steel fences, often barbwire, and bollards. Only authorized persons can enter designated areas via biometric access. In addition, the entire campus is under CCTV control and can often be exposed to random security patrols.

Next, we take the case where a company decides against completely outsourcing its IT systems, and at best accepts housing and hosting them with external service providers. This approach is considered below:

The company must take the following issues into consideration:

- Continuing to develop its own data center further (own)
- Using housing or hosting services from a hosting provider (renting)
- Mixture between owning and renting

The arguments against outsourcing are mostly of a psychological or organizational nature.

Psychological Reasons

A fear of loss of control is the strongest reason for deciding against outsourcing. Typical arguments include:

- Fast responses to system faults are no longer possible
- You do not know who else has access to the computers you use

IT departments might also feel that they would become „less important" within the company since a core activity is now being outsourced.

This misgiving can easily be invalidated through appropriate processes and agreements with external data centers.

Organizational Reasons

Typical arguments against outsourcing from an organizational standpoint:

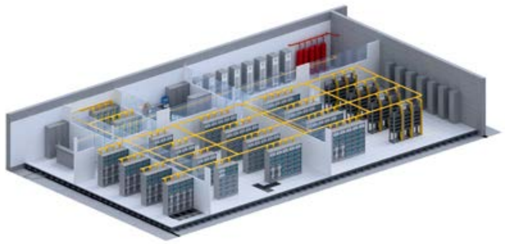
- Lack of transportation options for IT personnel
- Difficulty of coordinating internal and external staff
- Inability to carry out hardware operations at short notice
- Limited influence on scheduled maintenance work

However, upon careful review, one can see that not every visit into a data center is necessary. Many data center operators employ qualified technical staff on-site who can carry out simple hardware jobs on behalf of the customer. If an automated infrastructure managment (AIM) system such as R&M's inteliPhy is in use, these jobs can even be planned and monitered remotely by company personnel. Most of the other work can be carried out remotely. If company personnel themselves need to be on site more frequently, it might be possible to provide a local operator.

Nevertheless, with over 12 million square meters of white space and an annual expansion rate of 16 percent, MTDCs are amongst the fastest-growing verticals in the data center industry. The leading MTDC companies help clients through all stages of migration projects, from need assessment through migration through operation. They have the expertise to understand, meet and exceed clients' requirements.

Standards

Standards



090.6319
Illustration of a data center

Because of trends like cloud computing and virtualization and the increasing tendency of companies to outsource data center operations, requirements in terms of space are growing more complex. Functions must be defined and assigned to separate rooms. This leads to room structures that must be specially designed.

A typical data center is divided into an access area, computer room and work area for administrators. UPS batteries, emergency power generators and the cooling system are each located in separate rooms. Areas in the premises must also be made available for access control, video monitoring and alarm systems. And finally, sufficient space must be maintained for data cabling. Every area affects other areas. When planning how to divide up space, key goals are always to provide for smooth administration of the data center, to facilitate quick recoveries in the event of system faults, and to make it possible for the data center to be expanded and migrated as necessary – and all this without great administration overhead.

The data center layout, hierarchical structure and individual zones as well as their functions are described in detail below.

National as well as international committees have worked out standards that define data center structures as well as characteristics of the cabling systems that must be furnished for them. The three most important organizations in this area are:

- ISO/IEC (International Organization for Standardization / International Electrotechnical Commission), responsible for developing international standards
- CENELC (Comité Européen de Normalisation Électrotechnique), responsible for developing European standards
- ANSI (American National Standards Institute), responsible for developing American standards.

The following bodies of standards relate to data center cabling:

- ISO/IEC 11801-5
- EN 50173-5
- EN 50600
- TIA-942-B

Though these four standards focus on different areas, they all elaborate on the structure and performance of cabling systems. Their goal is to provide a flexible, scalable and clearly laid out structure for cabling systems. This will allow for rapid isolation of faults as well as system changes and expansions.

Delimiting Different Standards

These standards consider the variety of the data center types as well as the demands that are expected to result from future communication protocols and data rates. However, the different standards all treat these requirements, as well as interfaces to other system types, in a different manner. CENELEC has introduced the EN 50600 series as an overall standard in Europe. The Committee is already in the process of working out further standards.

Data center cabling planners must examine a variety of different parameters. These parameters include: z.B. Space requirements, climate control, power consumption, redundancy, failure safety and access control. It is recommended that the different bodies of standards be applied as required and as they are appropriate to the given purpose at hand.

The following table provides an overview of the most important parameters covered by the relevant standards, as well as their areas of focus.

Criteria	ISO/IEC 11801-5	EN 50173-5	EN 50600	TIA-942-B
Structure		✓	✓	✓
Cabling performance	✓	✓	✓	✓
Redundancy	✓	✓	✓	✓
Grounding / equipotential	IEC 60364-1	EN 50310	EN 50310	TIA-607-B
Tier classification	×	×	✓	✓
Cable routing	IEC 14763-2	EN 50174-2 /A1	✓	✓
Ceilings and double floors	IEC 14763-2	EN 50174-2 /A1	✓	✓
Floor load	×	×	✓	✓
Space requirements	IEC 14763-2	EN 50174-2 /A1[3)]	✓	✓
Power supply / UPS	×	×	×	✓
Fire protection / safety	EN 50174-2 /A14)[4)]		✓	✓
Cooling	×	×	✓	✓
Lighting	×	×	×	✓
Administration / labeling	IEC 14763-1	EN 50174-2 /A1[5)]	EN 50174-2 /A1	TIA-606-B
Temperature / humidity	×	×	✓	✓

1) not data center-specific, 2) cable separation is covered in TIA-569-C, 3) door widths and ceiling height only,
4) refers to local standards, 5) refers to complexity level, 6) refers to TIA-569

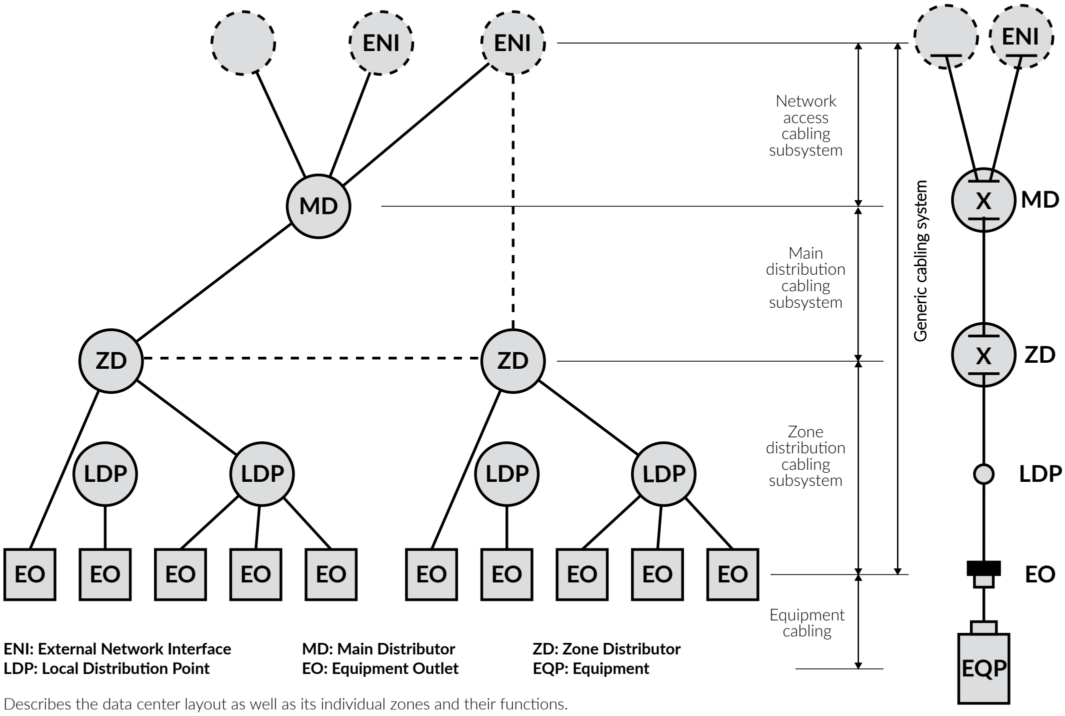
ISO/IEC 11801

Installations implemented in accordance with ISO/IEC 24764 require compliance with the following standards:

- Configuration and structure in accordance with ISO/IEC 24764 and/or ISO 11801
- Copper cabling tests as defined under IEC 61935-1
- Glass fiber cabling tests as defined under IEC 14763-3.
- Quality plan and installation guidelines as defined under IEC 14763-2

IEC 14763-2 refers to ISO/IEC 18010 in matters of cable routing. This standard not only contains descriptions for cable routing, but also various information on failure safety measures. Note, however, that data center requirements are not explicitly covered in either IEC 14763-2 or ISO/IEC 18010.

The tree structure concept, that makes use of a single central distributor, determines the structure of the cabling system. This concept allows for point-to-point connections in exceptional cases, when active devices in the immediate vicinity are arranged together or when communication via a structured cabling setup is impossible. The cabling systems in a local ISO 11801 distributor and at the interface to external networks are not considered part of this structure.



ENI: External Network Interface
LDP: Local Distribution Point
MD: Main Distributor
EO: Equipment Outlet
ZD: Zone Distributor
EQP: Equipment

Describes the data center layout as well as its individual zones and their functions.

The concept of spatial separation of the different areas of the data center is applied to its layout. The network structure in the data center must be separated from the building cabling system. A separate distributor connects the internal network. This must also be physically separated from the data center. The connection to the external network (ENI) can be established either within the data center or outside of it. All other functional elements should be permanent elements of the data center and should be accessible always.

The standard does not cover cabling components, patch cords or connection cables, nor distributors of the building network itself.

A data center must include at least one main distributor. However, the functions of different distributors may be combined, depending on the size of the data center. The standard does not explicitly stipulate any requirements regarding redundancy. However, for purposes of improving failure safety, it does provide information on options for redundant connections, cable paths and distributors. The local distribution point (LVP) should be housed within the ceiling or a raised floor. Patch cabling is not used in this area, since cables are through-connected.

ISO/IEC 24764 makes references to ISO 11801 regarding matters of performance. The latter standard contains further details on characteristics of transmission links and components. These standards differ in terms of their definitions of the minimum requirements for primary cables and area distributor cables.

Cabling classes for the network access connection correspond to the applications listed in ISO 11801.

Cabling infrastructure:

- Copper cable: category 6_A, category 7, category 7_A, category 8 / 8.2
- Copper transmission path: Class E_A, class F, class F_A, class I
- Multimode fiber: OM3, OM4, OM5
- Singlemode fiber: OS2

Plug connectors for copper cabling systems:

- IEC 60603-7-51 or IEC 60603-7-41 for category 6_A for shielded and unshielded respectively
- IEC 60603-7-7 or IEC 60603-7-71 for category 7 and 7_A respectively
- IEC 61076-3-104 for category 7 and 7_A
- IEC 60603-7-81 for category 8.1

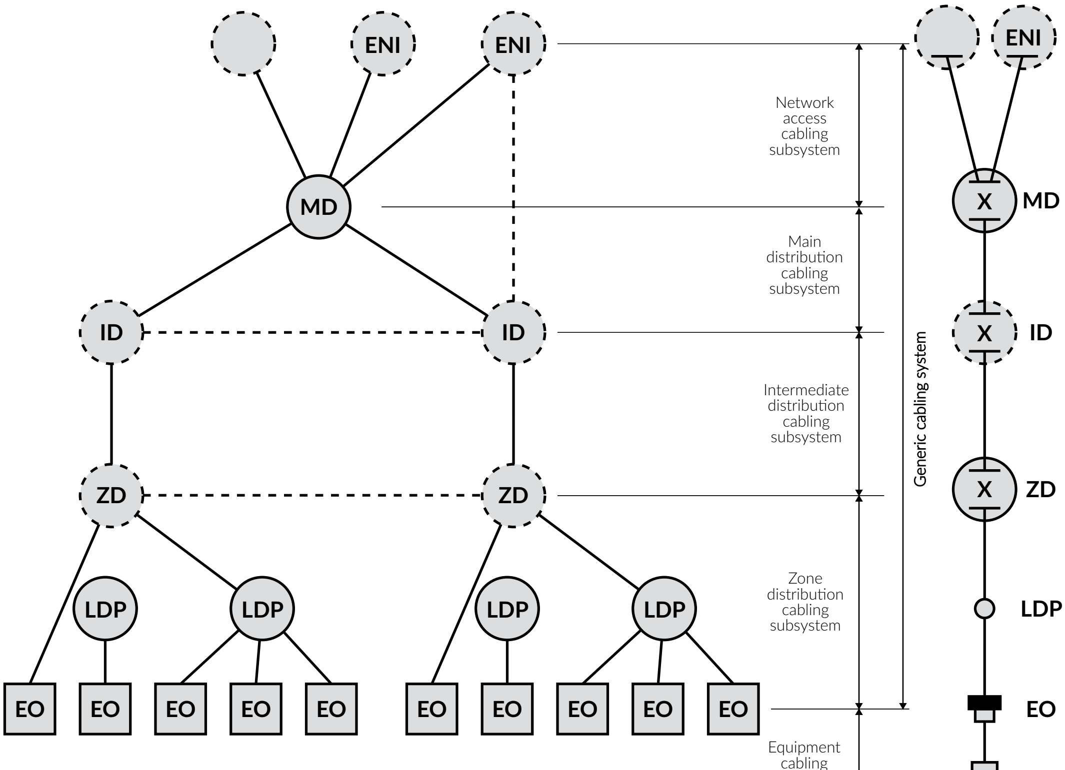
Plug connectors for optical fibers:

- LC duplex per IEC 61754-20 for GA and ENS
- MPO/MTP® multi-fiber connectors per IEC 61754-7 for 12 or 24 fibers

ISO/IEC 24764 refers to ISO 14763-2 regarding issues of multi-fiber connections. Keep in mind here that for the sender and receiver to be connected correctly, connection polarities must be strictly observed.

EN 50173-5

EN 50173-5 shows only minor differences from ISO/IEC 24764. Amendment 2 contains the latest changes. Planner should read EN 50173-5 and EN 50173-5/A2 as well as the other standards in the EN 50173 series. The hierarchical structure defined in EN 50173-1 & -2 also applies in EN 50173-5. One significant enhancement is the amendment is the additional distributors provided for structuring larger data centers.



ENI: External Network Interface
LDP: Local Distribution Point
MD: Main Distributor
EO: Equipment Outlet
ZD: Zone Distributor
EQP: Equipment

Describes the data center layout as well as it's individual zones and their functions

A standards-compliant installation must comply with:

- The EN 50173 series,
- The EN 50174 series,
- Their respective amendments and
- EN 50310 for earthing and equipotential bonding systems for cabling systems.

Additional information on the following data center topics was added in EN 50174-2/A1:

- Design proposals
- Cable routing
- Separation of power and data cables
- Double floors and ceilings
- Use of pre-assembled cables
- House interconnection point
- Room requirements

In contrast to ISO 11801, EN allows for optical fiber classes of not only OF-300, OF-500 and OF-2000, but also OF-100 through OF-10000. EN 50173-1 and EN 50173-2 establish requirements for cabling performance.

Minimum requirements for data center cabling are also established in these standards. EN 50173-5 provides for a cabling class for the network access connection in accordance with ISO 11801 applications.

EN 50600

EN 50600 was developed to adapt the contents of the TIA-942-B standard to European conditions. CENELEC divides the contents of TIA-942-B over a few standards. EN 50600 represents the first European standard that uses a holistic approach to make comprehensive specifications for the new construction and operation of a data center. It defines requirements for the construction, power supply, air conditioning & ventilation, cabling, security systems, and defines criteria for the operation of data centers. As one of a wide range of guidelines and best practices, this standard is valid throughout Europe.

EN 50600 has been rolled out since 2012 in ten parts and subsections:

- EN 50600-1: General aspects for design and specifications
- EN 50600-2-1: Building construction
- EN 50600-2-2: Power distribution
- EN 50600-2-3: Environmental control
- EN 50600-2-4: Telecommunications cabling infrastructure
- EN 50600-2-5: Security systems
- EN 50600-3-1: Management and operational information
- EN 50600-4-1: Overview of and general requirements for key performance indicators
- EN 50600-4-2: Power Usage Effectiveness
- EN 50600-4-3: Renewable Energy Factor

A forward-looking aspect of this series is the operational information part within EN 50600-3-1. It states that automated infrastructure management systems offering real time documentation and efficient management of the physical layer should be considered for availability and operational purposes. Furthermore, it categorizes following operational processes and defines KPIs for these:

- Operations management – infrastructure maintenance, monitoring and event management
- Incident management – responding to unplanned events, recovery of normal operations state
- Change management – logging, coordination, approval and monitoring of all changes
- Configuration management - logging and monitoring of configuration items
- Capacity management – monitoring, analysis, reporting and improvement of capacity

TIA-942-B

The encompassing body of standards TIA-942-B lays the foundations not only for cabling, but also for the building to house the data center, selection of the surrounding area and the geographic location, and more. One important building block is the availability classes, or „Tiers“, defined in the body (see section 2.2.1).

TIA-607-B covers topics of grounding and equiptential bonding. TIA-606-B describes administration. TIA- 569-C describes measures for separating telecommunications cables and power cabling. Cabling is the common theme that runs throughout all the data center standards listed above. TIA-942-A refers to the EIA/TIA-568 series for performance-related issues; here, minimum requirements for cabling system performance capacity were adapted to ISO/IEC 24764 and EN 50173-5.

TIA provides for an intermediate distributor between the MDA (main distribution area) and HDA (horizontal distribution area). If data center plans include a second entrance room, the cabling system will be better structured through use of an IDA (intermediate distribution area).

TIA-942-B establishes the following criteria for data center cabling:

Cabling infrastructure:

- Copper cable: Category 6, category 6_A, or category 8, with category 6_A or higher recommended
- Multimode optical fiber cable: OM3, OM4 or OM5, with OM4 or OM5 recommended
- Single-mode optical fiber cable: 9/125 µm, OS2
- Coaxial cables: 75 ohms

Plug connectors for optical fibers:

- LC duplex per TIA -604-10 (for less than 2 fibers)
- MPO multi-fiber connectors per TIA-604-5 (for more than 2 fibers)

Summary

Since no standard is complete all relevant standards should be consulted as the planning process begins. The most demanding and most advanced standard should then be used, considering the given requirements and the technical area under development. Example: In the case of cabling performance, the standard with the highest performance requirements for cabling components should be used as a basis for planning. The same applies for other parameters.

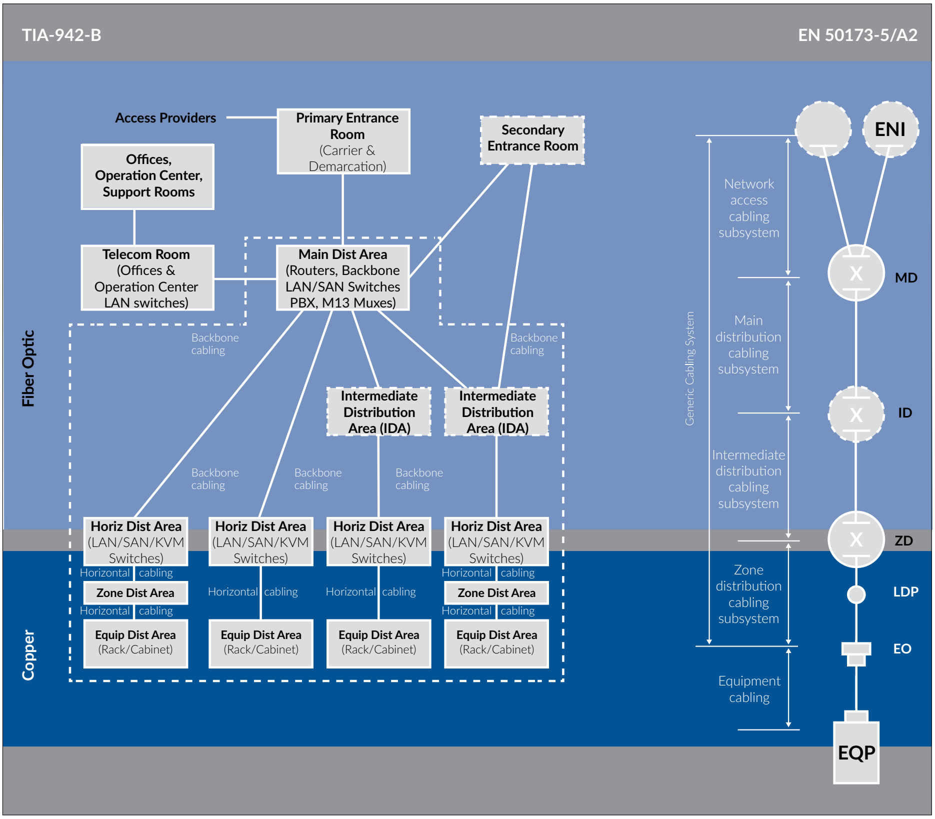
Recommendation:
The relevant standard should be listed in the technical specifications to ensure requirements are clearly defined!

Comparison

International standards on data center cabling differ from their European counterparts due to their areas of focus (also see section 3.1). One important thing to note is that the terms used to describe functional elements differ between international standards and European standards. A comparison of these terms appears in the following table:

ISO/IEC 11801-5	EN 50173-5	EN 50600-2-4	TIA-942-B
External Network Interface (ENI)	External Network Interface (ENI)	External Network Interface (ENI)	External Network Inter-face (ENI) Entrance Room (ER)
Network Access Cabling	Network Access Cabling	Network Access Cabling	Network Access Cabling
Main Distributor (MD)	Main Distributor (MD)	Main Distributor (MD)	Main Cross Connect (MC) Main Distribution Area (MDA)
Main Distributor Cabling	Secondary Cabling	Main Distributor Cabling	Backbone Cabling
Intermediate Distributor (ID) Intermediate Distributor Cable	Intermediate Distributor (ID) Intermediate Distributor Cable	Intermediate Distributor (ID)	Intermediate Cross Connect (IC) Intermediate Distribution Area (IDA)
Zone Distributor (ZD)	Zone Distributor (ZD)	Zone Distributor (ZD)	Horizontal Cross Connect (HC) Horizontal Distribution Area (HAD)
Zone Distributor Cable	Zone Distributor (ZD)	Zone Distribution Cabling	Horizontal Cabling
Local Distribution Point (LDP)	Local Distribution Point (LDP)	Local Distribution Point (LDP)	Consolidation Point (CP*) Zone Distribution Area (ZDA)
Local Distribution Point Cable	Local Distributor Cable	Equipment Cabling	Horizontal Cabling
Equipment outlet (EO)	Equipment outlet (EO)	Equipment Outlet (EO) Transmission Equipment (EQP)	Equipment Outlet (EO) Equipment Distribution Area (EDA)

CP* = LDP (Local Distribution Point)



Comparison between TIA-942-B and EN 50173-5 cabling topology

Functions are assigned to rooms. Note, however, that TIA-942-A focuses on the areas of the data center and not its functions. However, the topology on which that standard is based is the same as that in ISO/IEC 24764 and in EN 50173-5.

The individual areas of a data center are assigned the following functions:

- **Entrance Room:** Entrance area to the data center network. Access to the public network (Internet provider) is established at this point. This access may be a redundant connection, depending upon the „Tier" level. In smaller networks, the External Network Interface can be connected directly to the Horizontal Distribution Area (Area Distributor).
- **Main Distribution Area:** This is the core of the data center. It should be made secure through the implementation of redundant connections and components. Also, known as Core Layer, since all data traffic is managed from this point. The Aggregation Layer (or Distribution Layer) is part of this layer. It forwards bundled data traffic from the access layer on to the core, via aggregation / distribution switches.
- **Intermediate Distribution Area:** An IDA can be used to structure the MDA and HDA (main/horizontal distribution area) in larger data centers. Network operation may be interrupted. A second entrance room can be connected directly for purposes of redundancy.
- **Horizontal Distribution Area:** This area in the network is known as the Access Layer. Data traffic from access switches is passed to the aggregation layer between the backbone and horizontal cabling in the HDA.
- **Zone Distribution Area:** Used for intermediate distribution outside the Equipment Distribution Area. Is implemented for reasons of space, and placed in the double floor, for example. The Raised Floor Solution from R&M that was developed for this purpose provides up to 288 connections per box in a double floor segment format. It is freely configurable, thanks to its modular design concept.
- **Telecom Room:** Room for connection to the internal network
- Operation Center, Support Room and Offices are available as work rooms for data center personnel.

Cable type selection is a critical factor in determining the ability of the data center cabling system to grow with future needs. Definitions therefore exist both for possible communication protocols and the corresponding maximum transmission rates for various cable types. Fiber optic cable is usually the preferred medium for backbone cabling, while copper cable is used for horizontal cabling.

Data Center Infrastructures

Planning data centers is a challenge that is rewarding, but covers numerous facets and entails much responsibility. The purpose of this section is to provide the reader with appropriate guidance in this regard. It covers the key areas of data center infrastructures. This spectrum ranges from systems for power supply and climate control, includes concepts of interior design and cabling routing, and concludes with infrastructure management.

The main principles involved in a professional concept for data centers include: Conserving space and energy, providing support for efficient, economical operation, providing for expansions and changes, and achieving a maximum level of security. Factors such as room planning, the computer room layout and the technical environment must remain secondary to the requirements listed above as well as similar requirements.

Just small changes can translate into an increase in energy efficiency. It is essential that rack rows, hot and cold air routing systems, ventilation and climate control technology, structural elements and cabling routing systems be planned and installed in an optimal manner.

The overall design must take into account typical processes. For example, data center statics must be calculated in such a way that heavy active components and machines can be easily installed and removed. The room must have headroom of at least 2.6 to 2.75 meters as measured to the lowest installations. Floor loading capacity must be at least 750 to 1,200 kg/m2. Access doors must be at least 1 meter wide and 2.1 meters high, sealable, and have no thresholds. Cabinet rows must be optimized for cooling active devices. Aisles must also be sufficiently wide so that devices can be easily installed and removed. These installation depths require an aisle width of at least 1.2 m. If a hollow floor is used, it must be possible to keep least one row of base plates open per passageway.

These are just a few aspects that should be mentioned in advance. A discussion of the essential areas in the infrastructure is presented below.

Power Supply, Shielding and Grounding

All buildings must be properly earthed so that hazardous current is properly discharged and individuals as well as electrical installations in and around buildings are protected. National regulations stipulate how earthing systems are to be installed.

Earthing is especially important in data centers since they house expensive, sensitive equipment that must be protected from surges and electromagnetic interference. Implementing shielded cabling systems in order to run 10 Gigabit Ethernet results in an additional need for earthing. In this case, not only the building, but also the entire data cabling system, must be provided with a reliable earthing system.

Importance of Earthing

An earthing concept guarantees functionality and electromagnetic compatibility (EMC) will be maintained for purposes of safety. The EMC characteristics of a device or system ensure that it will not interfere electromagnetically with any other equipment in operation.

A building with IT equipment makes the following demands on an earthing system:

- Safety from electrical hazards
- Reliable signal reference within the entire installation
- Satisfactory EMC behavior, so all electronic devices work together without trouble.

In addition to national regulations, the following international standards are useful tools in developing an earthing concept: IEC 60364-5-54:2011, EN 50310:2016, ITU-T K.73, EN 50174-2:2018, EN 60950 and TIA-607-C.

To reduce interference voltage, an equipotential bonding system must be designed to be suitable for high frequencies and also be low resistance. This is achieved through surface connections with all metal masses, housings (racks), machine and system components.

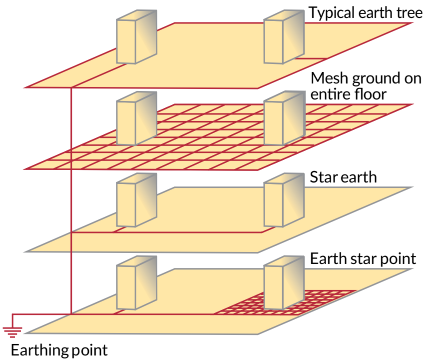
Alternating Current Distribution System

The neutral conductor of the alternating current distribution system should be separated from the earthing system. This function is best carried out through use of a TN-S system. TN-C systems are used in internal installations with PEN conductors (protective earth and neutral conductor combined). Note: These devices may not be used for IT equipment.

Two proven earthing methods for buildings are the tree structure and meshed structure:

Earthing System as a Tree Structure

This configuration comes from the field of telecommunications. Earthing conductors are connected together at a central earthing point. The configuration avoids ground loops and reduces the interference from low-frequency interference voltages (humming)

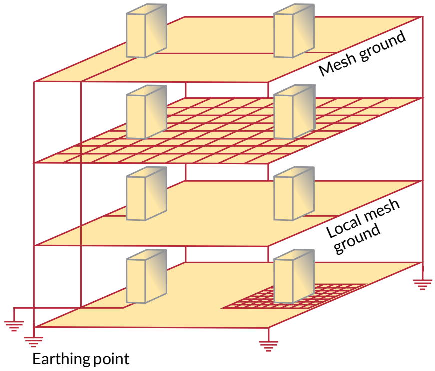


Earthing system as a tree structure

Earthing System as a Mesh Structure

The goal of the mesh structure is to distribute the currents in ground loops as evenly as possible and to minimize these loops. Mesh structures are mostly used for highfrequency data transmissions. This process requires that the building have as many earthing points as possible. All metallic building components must be connected to the earthing system.

If a continuous meshed structure for earthing cannot be installed in buildings, this structure can be approximated by installing cells. Metallic cable ducts, conductive double floor and parallel copper conductors are used for local meshed earthing.



Earthing system as a mesh structure

Grounding Options for Patch Panels

So that data center operators can work freely during planning and installation, all patch panels should be earthed using a tree structure as well as meshed structure. This installation feature should be specifically noted at evaluation time. The final selection of the earthing method to be used also depends upon the conductivity of 19“ cabinets or mounting rail.

Every patch panel is earthed individually in a tree structure, through the cabinet or to ground bus bars. Looping the earthing connection through from one patch panel to another is not recommended, since this increases impedance.

Cabinet Earthing and Earth Connection

The cabinet in a tree structure itself is earthed after the patch panels are earthed, via telecommunication main ground bus bars (TMGB) or telecommunication ground bus bars (TGB).

In the case of a meshed structure, the cabinet is connected to the next earthing point within the building structure. It is important in this case that the impedance (Z) from the current path to the earth is as low as possible. This value is based on ohmic resistance (R) and line inductance (L), as shown in the following term:

$$Z = \overline{\omega L} + \overline{R} \quad \text{with} \quad \overline{\omega} = 2\pi f$$

Impedance must be considered when selecting the earth connection for the cabinet. Flat cables, braided straps or copper strips with low impedance are the best choices for this purpose. If stranded conductors are used, these should be 4 to 6 mm^2 (16 mm^2 is even better).

It can be a good idea to use HF-shielded housing in applications with high-frequency field-related influences. The parameters for a standards-based housing unit are best determined through on-site measurements.

Cable Runs and Routing

Data center cabling is routed in hollow floors or hollow ceilings (see above) and is subject to the following requirements:

- Must not impair network performance
- Must not affect cooling
- Electromagnetic compatibility must be ensured
- Upgrades, changes and maintenance must be possible

The cable routing system in many data centers and server rooms has grown historically, and is therefore rarely at an optimal level. The reasons for this include:

- Connection cables were put in long after they were needed. As a result, no planned infrastructure existed.
- Documentation on the connection cables that were laid does not exist or is poor. As a result, connection cables that are defective or no longer required cannot be removed.

A double floor becomes overfilled quickly, and can no longer maintain its primary function of ventilation and cooling. The cabling system is constantly changing, making optimal dimensioning of data center cooling capacity difficult. Cabling solutions that take up less volume provide a solution: Glass fiber cables, multi-core cables or low profile cables. The use of cable routing systems such as conventional trays or mesh cable trays is recommended in all cases, since these bundle cables and route them in an orderly manner, and thus create space for air circulation. The advantages and disadvantage of both systems:

Tray

A tray provides better mechanical protection, but not always better electromagnetic protection. A tray is only a good option if edge protection is provided at incoming and outgoing threading points to preserve cables. There is the risk that cables will be damaged if threading points are added later. Cable covers prevent „third-party cables“ that may be installed later, such as power lines, from being packed onto data cables and impairing their operation.

Mesh Cable Tray

Cables in mesh cable trays have less protection. This is an issue especially for cables at the bottom of the tray. This risk can be reduced by placing a metal plate on the base of the mesh cable tray. An open mesh cable tray makes it easier for cables to be threaded out. Some manufacturers provide an extra cover for mesh cable trays.

Laying Patch Cords

One key question remains: Where should patch cords be installed? Can they be laid in the double floor? A device connection should always supply only one element (e.g. a server) in the same cabinet. Going by this principle, there should be no, or only a few, patch cords that extend beyond the cabinet. As a result, no patch cords should be stowed in the floor. Nevertheless, it can sometimes occur, when longer patch cords are in use, that connections must be made to other cabinets. It should be avoided putting these in the double floor whenever possible. One of the following options should be used instead:

- Conventional or mesh cable trays installed up above (see above).
- Trough systems such as the Raceway System from R&M. Like conventional trays or mesh cable trays, these are installed above cabinets. They also allow for customized configuration options, and preserve the cabling routing system, especially when fiber optic cabling is used.

Finally, it should be noted that a patch cabling system that is clearly laid out makes installation work as well as moves, adds, changes (IMAC) in the data center significantly easier. Therefore, patch cabling, like installation cabling, requires careful planning.

090.7368
The R&M Raceway system

Data Center Architectures

Data Center Architectures

Networking Architecture

Network infrastructure has changed so dramatically since the time when we first released our R&M Data Center Handbook back in 2014. The world is moving to the cloud model to achieve better agility and economy, following the lead of the cloud titans who have redefined the economics of application delivery during the last decade. Applications such as social media and Big Data, new architectures such as dense server virtualization and IP Storage, and the imperative of mobile access to all applications have placed enormous demands on the network infrastructure in data centers.

Network architectures that make the cloud possible are fundamentally different from the highly over-subscribed, hierarchical, and costly legacy solutions of the past. Increased adoption of high performance servers and applications requiring higher bandwidth is driving adoption of 10 and 25 Gigabit Ethernet switching in combination with 40 and 100 Gigabit Ethernet.

This section details three- and two-tier network designs and elaborates on the concept of fabrics, software defined networking, hyperconvergence, and software defined storage.

Legacy **three-tier** networks consist of:

- An access/storage layer: This layer includes switches for desktop computers, servers and storage resources.
- Aggregation/distribution layer: Switches combine streams of data from the access layer and protect these with components such as firewalls
- Core switch layer: Regulates the traffic in the backbone

The European and American standards for physical cabling structures in data centers use the following terms for these logical layers:

Logical architecture	EN 50173-5	TIA-942-A
Core & Aggregation Layer	Main Distributor (MD)	Main Distribution Area (MDA)
Aggregation Layer	Zone Distributor (ZD)	Horizontal Distribution Area (HDA)
Access & Storage Layer	Local Distribution Point (LDP)	Zone Distribution Area (ZDA)
	Equipment Outlet (EO)	Equipment Distribution Area (EDA)

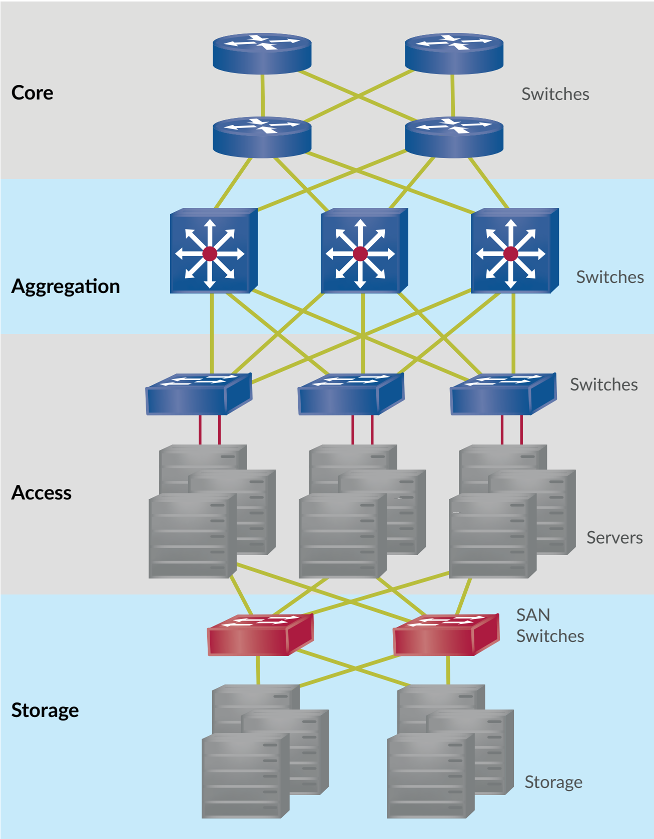


Illustration of a three-tier network

The server networks are highly oversubscribed. Moreover, major problems are faced by the three-tier architecture include, connected scalability, fault tolerance, energy efficiency, and sectional bandwidth. The three-tier architecture uses one of the enterprise-level network devices at the higher layers of acess layer topology that are very expensive and power hungry.

The aggregate layer switches interconnect multiple access layer switches together. All the aggregate layer switches are connected to each other by core layer switches. Core layer switches are also responsible for connecting the data center to the internet. Although, the three-tier architecture is still very common in data centers, it is unable to handle the growing demand of cloud computing.

A dramatic increase in the performance of virtualized servers was achieved through the systematic implementation of SRIOV (single root I/O virtualization). This technology allowed potential I/O performances of 20 to 30 Gbit/s to be achieved. Server blades that have the ability to support this technology must also be equipped with 2 x 10 GbE connections for them to make use of their full potential. Since blade systems can support up to 8 blade servers, this means planners must provide for 100 GbE network connections.

Up to this point, the performance required for the next highest layer in the hierarchy could be easily achieved through 10 GbE connections or aggregation through multiple connections. Servers just had to be fitted with 1 GbE LAN interfaces, and could be connected to top-of-rack switches over 1 Gbit/s. These days, however, congestion in uplink ports can quickly result given server performance increases to 10 Gbit/s and aggregation processes running in blade systems and transmitting in the core direction with 40 or 100 Gbit/s. This problem is solved with two-tier concepts. The two-tier architectural approach also reduces latency times, since data traffic flows through fewer switches.

For data center networks, the main goal is to connect many servers by using switches that only have a limited number of ports. By smartly connecting switching elements and forming a topology, a network can interconnect an impressive number of servers.

Two-tier, also known as fat-tree or spine-leaf networks were proposed by Charles E. Leiserson of the Massachusetts Institute of Technology (MIT) in 1985. The distinctive feature of the fat-tree idea is that for any switch, the number of downlinks is equal to the number of uplinks. Therefore, the links get "fatter" towards the top of the tree. However, this means that the number of ports would have to vary from switch to switch. For data center networks that connect servers, off-the-shelf switches are used, and they have a fixed number of ports. Hence, the theoretical concept is not very usable. Therefore, alternative topologies were proposed that can efficiently utilize existing switches with their fixed number of ports.

The example of this topology is given below:

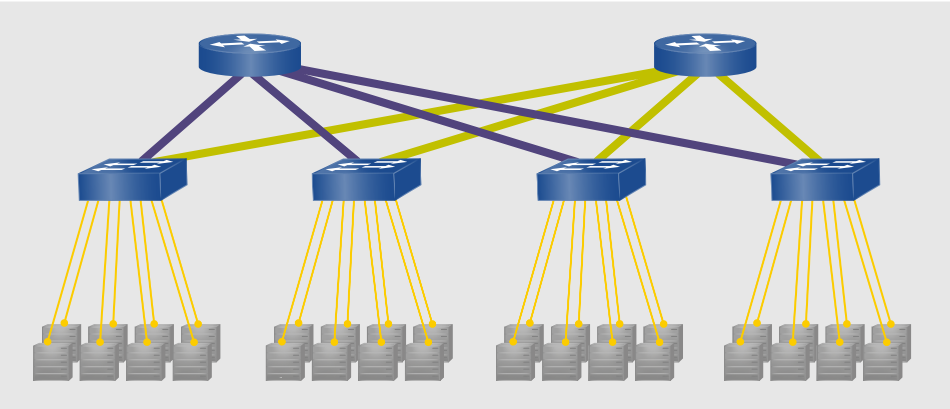


Illustration of a two-level fat-tree network

Here, a two-level fat-tree network is depicted. The lower and upper levels can be referred to as edge and core layers, or leaf and spine layers. Identical switches with 36 ports are used on both levels. Each of the four switches on the leaf level has 18 ports dedicated to connecting servers. The other 18 ports of each leaf switch are connected to the spine layer. In this case, two bundles of 9 links (represented by thick lines) go to the two spine switches.

The dynamic load distribution process used in virtualized environments and cloud environments automatically distributes virtual servers over several different hosts. This results in a load configuration that can overtax networks based on conventional structures. This is because in some cases data communication between virtual machines travels constantly over multiple networks nodes and layers. One solution to this problem is to slowly start replacing conventional north-south architectures (vertical communication) with east-west architectures (horizontal communication).

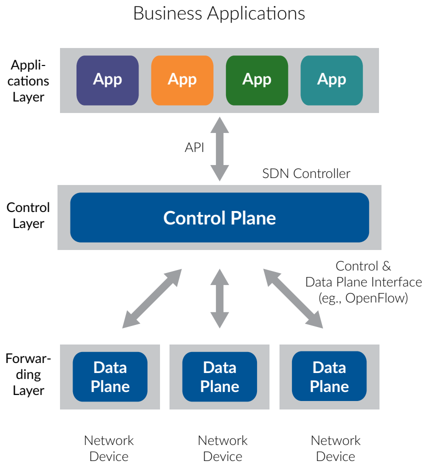
This goal can be achieved using data center fabrics. This will allow established three-layer networks to be eliminated and in turn allow for implementation of a simplified network model. A network of this type is also easier to manage. This new model can be viewed as one single, very large switch. This switch, however, is not actually installed physically but modeled logically.

All devices connected to the network are assigned the logical switch as a single access point through which system communication runs. This means it is no longer relevant on what physical host a virtual machine runs, or whether the virtual machine is moved onto a different host. The server always communicates with its partners over the one node, both before and after the migration. Using this approach for network design allows operators and planners to go forward with a virtualization concept that supports dynamic load distribution.

Another advantage of combining components into a single logical object in this way lies in its simplified management. The switch is configured only over a single interface and at a single location. All switches that are combined can be reached through a single administration access point. This greatly simplifies network analysis, querying of statuses and monitoring.

In addition, a single fabric is easier to scale. If you need more ports, you just add another fabric switch, which then adds itself into the existing combine of switches and is automatically configured from the top-level fabric.

Software-defined networking (SDN) provides for flexible packet control within a network. SDN's distinguishing feature lies in its separation of control and data paths – in other words, separation of the control plane from the data plane.



Software Defined Networking architecture

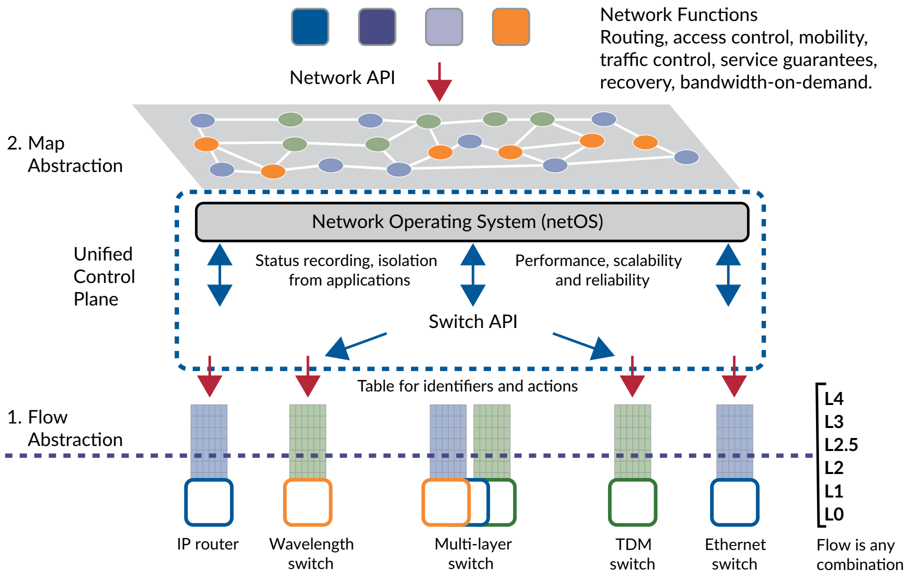
The control plane is responsible for configuring switches and routers and programming data paths. SDN moves the control plane into a separate system, so to speak, i.e. the SDN controller. This process also makes it possible to implement flexible tables, so-called flow tables.

This results in a single point of management for the entire infrastructure, with the controller regulating traffic in the entire network. The SDN controller can be installed as a physical server, virtual machine or hardware appliance. It specifies how the data plane is to handle data packets (priorities, destination ports, etc.).

The data plane in turn forwards these rules onto the application-specific integrated circuits in the switch or router. Software defined networking therefore separates out the decisions which affect the routing of packets and rules (policies) from the network topology and transport layer.

In the early days, the controller and data plane communicated primarily via the OpenFlow protocol, developed at Stanford University in California. In the last years however, for many companies OpenFlow is no longer an exclusive solution, they added proprietary techniques. These include Cisco Systems, Open Network Environment and the VMware N8X network virtualization platform.

Network Operating System (netOS)



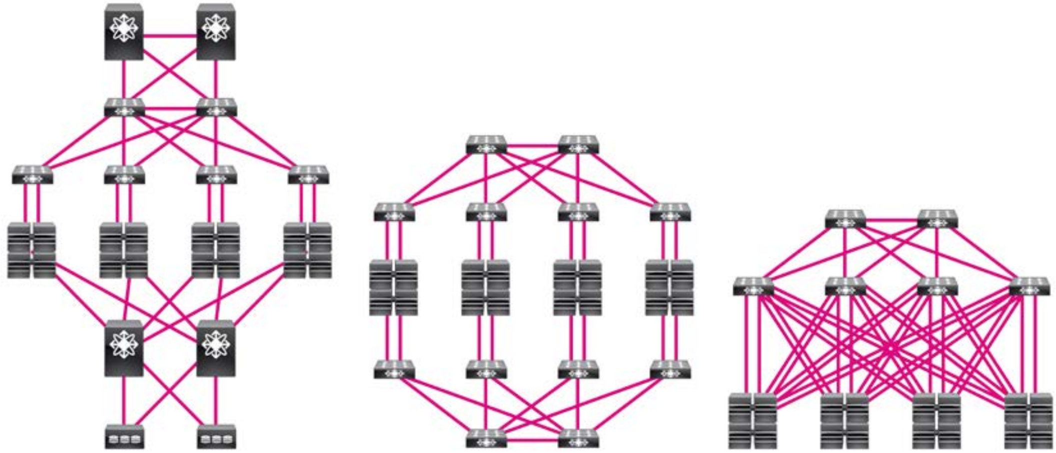
Source:
Stanford University

Software-defined storage (SDS) is a storage architecture that separates storage software from its hardware. Unlike traditional storage area network (SAN) systems, SDS is generally designed to perform on any industrystandard, removing the software's dependence on proprietary hardware.

Decoupling storage software from its hardware allows to expand storage capacity if needed, and when needed. It also allows to upgrade or downgrade hardware at any time. The introduction of SDS is changing network architectures in data centers. The cabling density is increasing. What does that mean for the design?

Suppliers of IT infrastructures have established the principle of SDS on the market. And they have created the technical prerequisites to be able to integrate storage tasks in the server infrastructure. Increasing virtualization means data traffic between servers is growing. At the same time, there is an increase in CPU and PCI performance. These advances should also get through to users. They expect acceptable latency.

Shifting storage into the server housing means networks are consolidated (see figure). Cabling density increases as a result, both at the server housing and at the switch or router. This needs to be considered during infrastructure planning.



050.6314
Left: classic design with Ethernet and fiber channel network.
Center: SDS alternative for enterprise data centers with two separated Ethernet networks.
Right: consolidated Ethernet network in which both data and storage traffic are distributed via the same switches.

The evolution of data center networks described can only be successfully implemented with more bandwidth and greater cabling performance. As a result, data centers should ensure their networks can cope with using 40/100 Gigabit Ethernet (GbE).

Hyperconvergence is an IT framework that combines storage, computing and networking capabilities into a single system to reduce data center complexity and increase scalability. In comparison with converged infrastructure, components of a hyperconverged environment cannot be physically separated. The software-defined elements are implemented virtually so that platforms include a hypervisor to run VMs, SDS, and virtualized networking on standard, off-the-shelf servers. The use of commodity hardware yields an infrastructure that is designed to be more flexible and simpler to manage than traditional enterprise storage infrastructure. This allows organizations to easily expand capacity by deploying additional modules.

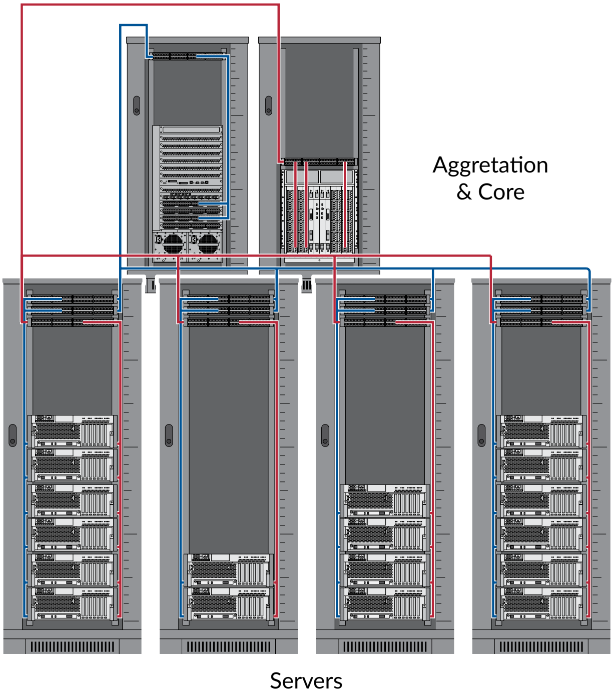
Hyperconverged infrastructure promises to deliver simplicity and flexibility when compared with legacy solutions. The integrated storage systems, servers and networking switches are designed to be managed as a single system, across all instances of a hyperconverged infrastructure. The inherent management capabilities enable ease of use, and softwaredefined storage is expected to yield greater scalability and resource efficiency. Companies can start small and grow resources as needed.

Current specialist vendors in the hyperconverged space include Nutanix and Pivot3. Big systems vendors that have entered the market include Cisco, Dell-EMC, NetApp and HPE (with the acquisition of SimpliVity).

Connection Methods

Data center networking architecture – the layout of the cabling infrastructure and the way servers are connected to switches – must strike a balance between reliability, performance, agility, scalability and cost. To optimize the data center investment, the architecture must also offer the ability to support both current and future applications and speeds.

The centralized network architecture is an appropriate model for smaller data centers of less than 500 m2. There are separate IP and SAN networks and each one leads from the servers to the core switches which are centralized in the main distributor.



Centralized architecture

This model provides very efficient switch port utilization and makes it easier to manage the network. Although it works well for smaller data centers, it does not scale up well and is therefore less suited with regards to future expansions. Due to the high port utilization, it is even in large data centers often employed for the SAN with its typically high cost switch ports. However, on the IP side, larger data centers usually avoid the centralized switching architecture with its long fiber runs. Downside being that it means a lot of cables in pathways and cabinets.

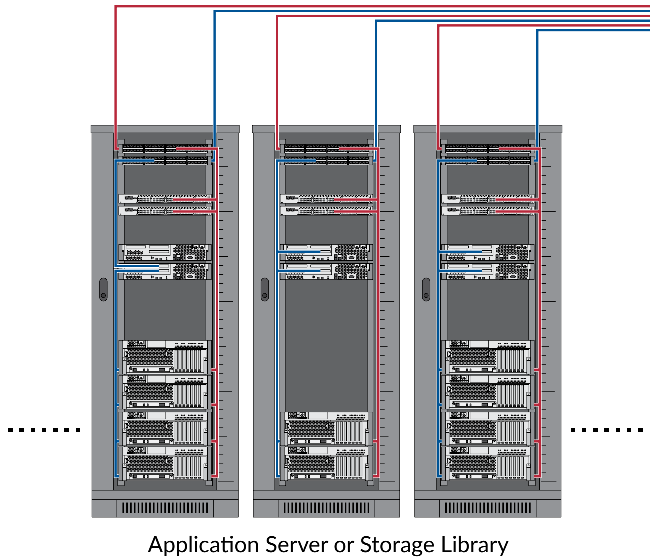
Advantages:

- High switch port utilization
- Concentration of switches simplifies MACs
- Optimal rack utilization

Disadvantages:

- Greater cable volume in horizontal cabling area
- Not scalable

The **zoned** network architecture consists of distributed switches. As depicted below, the switches can be distributed in an end-of-row (EoR) or middle-of-row (MoR) model. In these cases, the cabinet rows are opened into a star pattern. Switches sit in one cabinet and route data cables from that point to servers within the cabinet rows. This architecture is very scalable and repeatable. It reduces the number of network devices and improves the port utilization of the network. Zoned architecture is usually the most cost-effective, providing the best trade-off between switch port utilization and cabling costs.



Top of the Rack architecture

However, a large amount of cables is needed for the horizontal cabling. The major differences are that the switches are placed in the middle of the row and cable length is reduced.

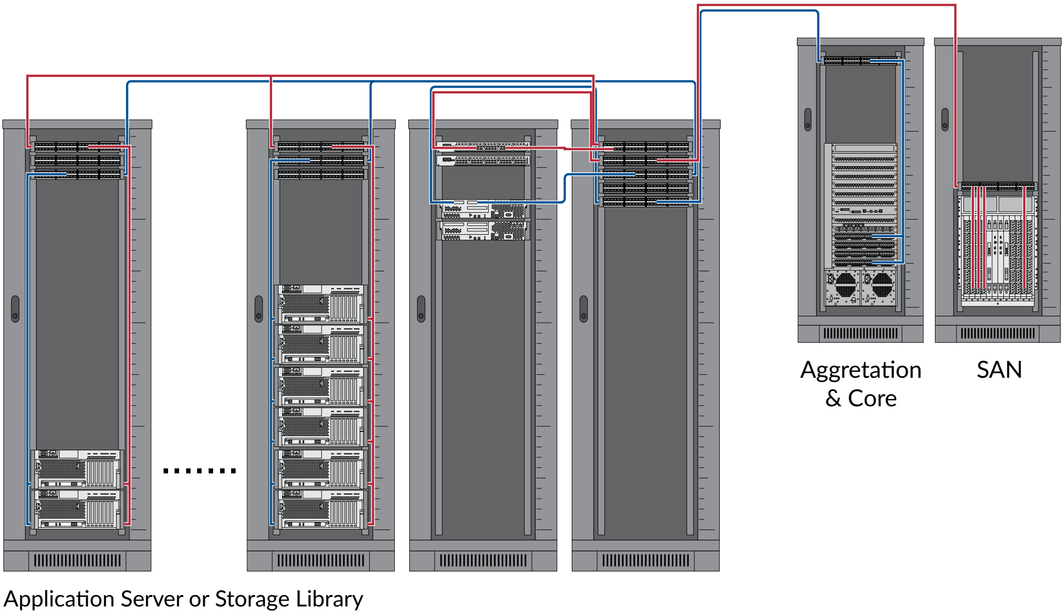
Advantages:

- Flexible, scalable, can grow with future needs
- Most cost-effective architecture

Disadvantages:

- Greater cable volume in horizontal cabling
- Many cable patches for EoR and MoR switches

Distributed switching typically consists of at least two switches in each server cabinet. This networking concept is also known as top-of-rack (ToR) switching. A ToR switch is installed in the top of racks as access or leaf switch. All servers in a rack are cabled to both switches for redundancy. The ToR switches have uplinks to the next switching layer – aggregation or spine switches as shown below.



End of Row architecture

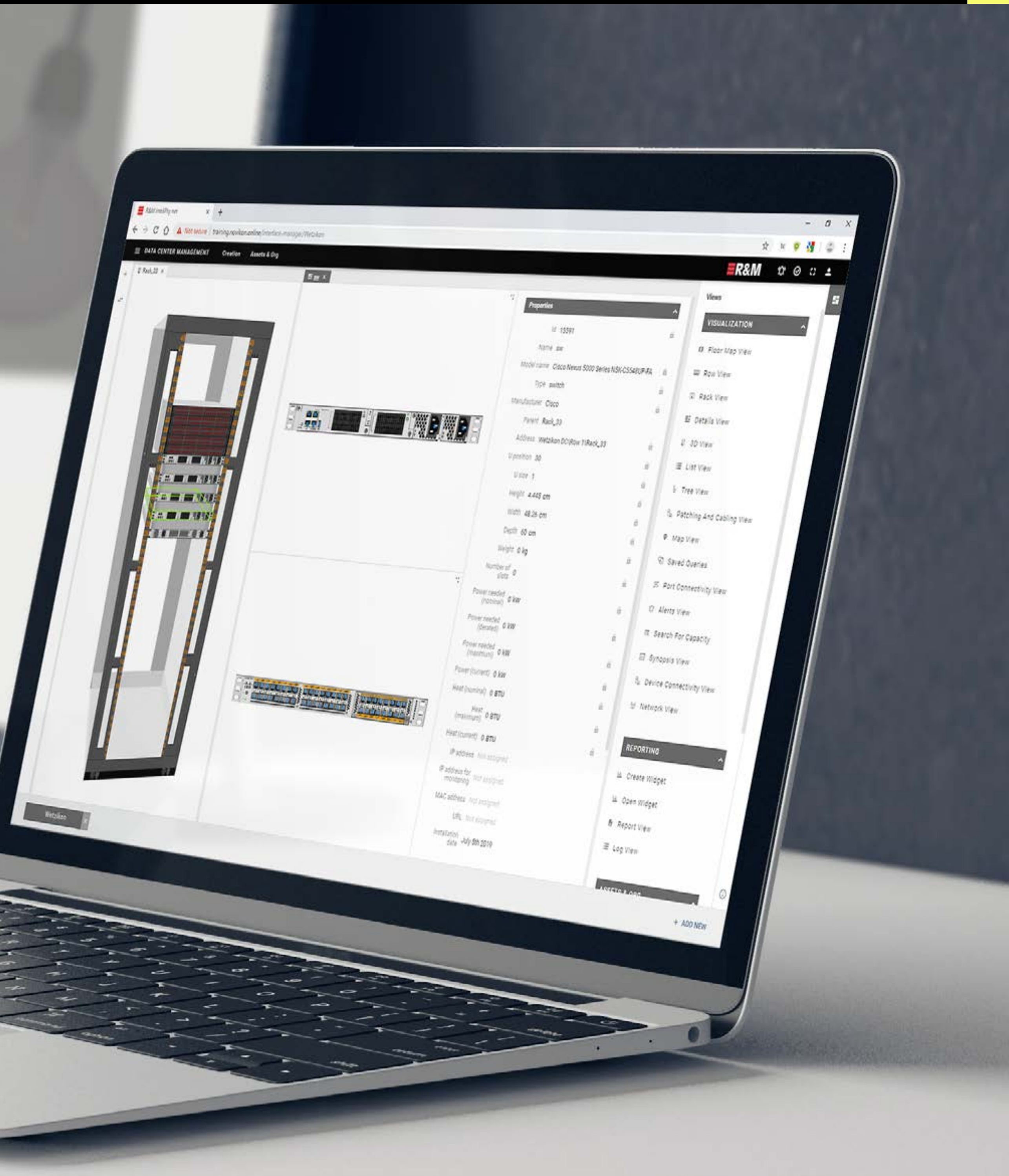
The distributed architecture significantly simplifies cable management in the cabinets. It also provides high-speed port-to-port switching for servers within the same cabinet and allows for an easy adding of servers. Although cabling is utilized more efficiently in a distributed architecture, it comes with an increase in cost of switches, as well as high costs for the underutilization of ports. Also, the network may be difficult to manage in large deployments.

Advantages:

- Smaller cable volumes, lower space requirements for horizontal cabling, lower installation costs
- Servers can easily be added

Disadvantages:

- Under-utilization of switch ports
- Sometimes unnecessarily many switches in operation (equipment and energy costs)
- Limitations in scalability and thus adaptability to future requirements


DATA CENTER MANAGEMENT
Creation
Assets & Org
R&M
Properties
Name sw
Model name Cisco Nexus 5000 Series N5K-C5548UP-FA
Type switch
Manufacturer Cisco
Parent Rack_33
U position 30
U size 1
Height 4.445 cm
Width 48.26 cm
Depth 60 cm
Weight 0 kg
Power (current) 0 kW
Heat (nominal) 0 BTU
Heat (current) 0 BTU
Installation date July 5th 2019
Views
VISUALIZATION
Floor Map View
Row View
Rack View
Details View
3D View
List View
Tree View
Patching And Cabling View
Map View
Saved Queries
Port Connectivity View
Alerts View
Search For Capacity
Synopsis View
Device Connectivity View
Network View
REPORTING
Create Widget
Open Widget
Report View
Log View
+ ADD NEW
Wetzikon

Automated Infrastructure Management

090.7810
R&M inteliPhy of the Netscale platform

Monitoring and managing the network's infrastructure has never been more challenging. Between ever-increasing fiber densities, complicated fanout connections, and meshed leaf-spine architectures, knowing the true state of the network cabling at any time has been extremely difficult. The reason for this challenge lies in the complexity of modern networks, which are often the result of expansions that occur over time and are carried out by third party operators to cope with growth and advances in technology.

Keeping track of network infrastructure is no small task in the presence of ultra-high density fiber environments which increase the risk of user error as technicians navigate crowded patching fields. To help minimize patching errors and downtime, many data center managers have turned to Automated Infrastructure Management (AIM) systems such as R&M*inteliPhy*.

An AIM system automatically monitors and documents the location and status of connections and connected assets, providing real time insight into, and control over, what is happening within the IT infrastructure. An AIM system uses intelligent hardware and software components to collect data regarding the identity, location and status of every port within the infrastructure and compare it to existing connectivity records. All this information about what is happening within the cabling infrastructure enables facility and IT managers to see and manage the connected environment in real time. AIM solutions also integrate with external applications and processes, enabling IT and facilities staff to manage and optimize network and building management systems. Integrated work order management allows the AIM system to generate trouble tickets and direct technicians to the precise location of a problem, saving the organization time and money.

To make sense of automating the management of the physical layer, it helps to break down individual tasks into distinct goals, functionalities and capabilities. The Maturity Model for AIM, developed by R&M, is a tool to describe the stages of controlled monitoring required to track, report, react to and resolve network cabling elements comprehensively, regardless of the complexity of the network.

The Maturity Model helps:

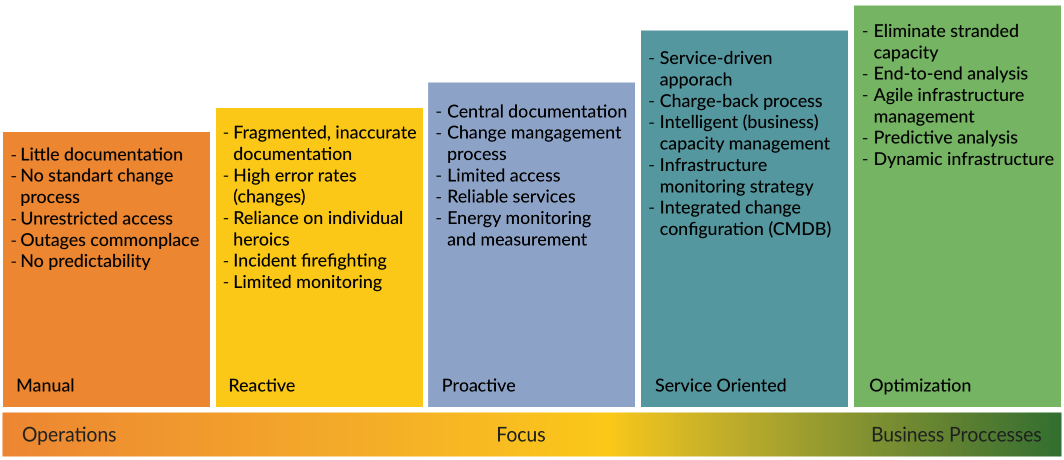
- Reduce risk by closing visibility gaps
- Assist data center staff to become more efficient and eliminate human error
- Decrease CAPEX and OPEX costs
- Reduce mean time to repair
- Provide a better handle on capacity management

The Maturity Model's five levels

Starting with the manual management tools in Level One and the reactive tools in Level Two, the Maturity Model describes the critical advances that come with the sophisticated standardization and consolidation found in Level Three, the advanced visibility that comes with Level Four, and the final optimized service delivery that results from the monitoring and management platform in Level Five.

What is at stake for an organization if it doesn't take steps to move to Level Five? Network availability, deployment agility and capacity planning, among other things. Data center staff workloads will inevitably become more demanding, and the amount of problems from human errors will continue to grow. Expansion and innovation will suffer.

The Maturity Model provides insight into how to gain control over all aspects of a network infrastructure while reducing both risk and costs. For example, achieving Level Five, as shown in Figure 1, will result in the elimination of stranded capacity and an end-to-end analysis of network infrastructure due to automated monitoring and work order management. And finally, visibility and real-time access at every rack gives the power to plan of the network.



The Maturity Model of Automated Infrastructure Management

The IT industry has recognized the positive impact AIM solutions can have on business processes and has developed standards that comprise the capabilities and functions of these systems. Using the term Automated Infrastructure Management or AIM, the TIA TR-42 and ISO/IEC WG3 SC25 groups have developed the following standards:

- TIA 606-B: Administration Standard for Commercial Telecommunications Infrastructure, published in 2012
- ISO/IEC 14763-2: Information Technology—Implementation and operation of customer premise cabling – Part 2: planning and installation, Amendment 1, published in 2015
- SO/IEC 18598: Automated Infrastructure Management (AIM) Systems—Requirements, Data Exchange and Applications, published in 2016

The AIM-compliant R&M*inteliPhy* system meets these existing and evolving standards

Level 1. Manual Management

As the average white space of data centers is currently between 1,000 and 2,500 m2, often with thousands of network ports, manual cable tracking is no longer a viable option. Yet all too many network managers still carry out inventory and management of physical infrastructure with paper, pencil and post-it notes. Developing realistic expansion plans and carrying out risk analysis are impossible, let alone complying with legislation and best practices governing data security and availability. Such an approach frequently results in significant application and service disruptions because it fails to account for the interaction of components within the network. Additionally, the lack of standardized change processes and unrestricted access makes capacity forecasting impossible.

In a typical Level 1 scenario, there is little documentation, and staff are highly focused on operations. Outages are commonplace. There is no predictability, no strategic capacity planning, and zero confidence that tools can be scaled to cover a larger infrastructure. At this level data center staff are operating blindly, completing everyday tasks at a slow pace, and dealing with significant, unplanned downtime and capacity issues. They find themselves frequently troubleshooting in the dark.

Three ways to move to Level Two:

- Abandon the paper notes to label the cable destination in favor of a simple digital documentation tool that provides a better overview and allows for the usage of Visio® stencils
- Put the documentation file on a shared folder to grant colleagues insight into the current state of the network infrastructure
- Implement a process to update this documentation after a change

Level 2. Reactive Management

Adding digital tools fills in the gaps caused by inadequate documentation tools, while a well-intended fix, actually results in more drastic problems. Demands on data center staff grow because they now must establish and adhere to a strict update management of the documentation files. And, as experience shows, documentation often remains fragmented and inaccurate. High error rates during changes lead to reactive incident firefighting with reliance on heroic acts by individuals, while unresolved problems continue to smolder. Here in Level Two, data center staff are mainly reactive. They are constantly putting out fires rather than detecting sparks, still at the mercy of limited monitoring and fragmented documentation. Staff are overworked, and job satisfaction is low. Innovation and new initiatives are distant dreams.

Three ways to move to Level Three:

- Introduce a centralized software tool such as inteliPhy net to document and manage the entire IT infrastructure down to the cabling plant
- Implement user access rights to this software tool to make sure that everybody is working with the current documentation and to prevent inadvertent modifications by staff
- Implement managed change processes based on work orders to ensure that the documentation is up to date

Level 3. Proactive Management

At this stage, there is end-to-end visualization of infrastructure, network, compute and storage, and it is possible to view the status of multiple sites on one screen. User-configurable reports provide valuable and up-to-date information because they derive from a single source of truth. To keep the data center always operating at normal levels, an overall maintenance plan for all infrastructure elements can be implemented that is compliant with the requirements of the individual equipment vendors.

A documentation process provides information about the status and the capacity of all data center infrastructure elements. Additional data for use in management processes such as energy and environmental management are acquired by sensors and logged in a central database.

Processes like capacity management or energy management register changes for the work order management process. The creator of a work order gives a description and its desired effects at registration. Work orders are planned to enable proper coordination. Downtime is minimized by coordinating changes relating to the same system. Resources can be planned to make sure that the change is completed successfully. Change management provides information about planned changes to operations management.

The last aspect to be mentioned in this section is capacity management which aims to optimize the usage of the data center's provisioned capacity. Therefore, it must monitor, analyze, manage and report the capacity of the data center's infrastructure. In capacity management, three categories of capacity must be distinguished:

a) Total capacity of the data center: the maximum capacity that it was designed for at full use;
b) Provisioned capacity: the capacity of the actual installed infrastructure;
c) Used capacity: the actual capacity used by the IT and facility.

Ideally, the granularity of capacity management is not limited to the room level but already allows gaining insight into the individual height units – or even better: the port level.

However, there's still room for improvement. For forecast needs and capacity planning, staff continue to gather data from several sources and manually enter them. The ability to scale to required monitoring demands has vastly improved, but at a significant price tag because of work load and discipline of everyone involved in the processes.

Three ways to move to Level Four:

- Deploy a monitoring system that provides a real-time visibility into the critical connectivity
- Integrate this monitoring system with work orders to ensure supervision and proper execution of changes
- Use searches, reports and automatic route finder functions to optimize the usage of installed capacity.

Level 4. Service Oriented Management

At Level Four, service-level views and cross-platform processes ensure that reliable metrics are the basis of business decisionmaking. And, mean time to repair (MTTR) is reduced significantly, resulting in higher service levels, fewer staff-hours devoted to troubleshooting and issue resolution. Incident Management is key to removal of failures and recovery to normal operational states.

Incidents are registered, monitored, solved and closed. Incident logging registers the beginning and the end of every failure for analysis in availability management. It is recommended to review each incident and the response to it, and – where possible – changes made to prevent the incident from re-occurring and to improve the response should the incident be repeated. Such an approach is only feasible if all changes are monitored and the creator is automatically informed about the status, esp. when the change is implemented successfully.

Of course, the aim of Incident Management is to minimize the time of outages. Therefore, the key performance indicator (KPI) mean time to repair (MTTR) shall be reported for every incident. Where a Service Level Agreement (SLA) is in place then compliance to the SLA is an advanced KPI for incident management. An AIM system now provides the solution, offering functions for mapping, managing, analyzing and planning cabling and network cabinets. The system improves operational efficiency and facilitates the ongoing management of the physical infrastructure. The integrated hardware and software system automatically detects when patch cords are inserted or removed and documents the changing cabling infrastructure, including connected equipment.

This enables ongoing, granular management of the infrastructure. Log analysis now triggers alerts, working with authorized and monitored changes. Single clicks get staff from metrics to work flows to logs within the same interface, greatly facilitating troubleshooting and reducing MTTR. In fact, the monitoring platform makes it possible to resolve issues in less than half the time, as the identification of problems is minimized. An organization knows what's happening on its network, where it's happening, and when it's happening – end to end.

090.7365
R&M*inteliPhy* set up with Analyzer

R&M*inteliPhy* deployed in Netscale, the world's highest density fiber solution, offering up 80 RFID-monitored LC-duplex or MPO ports per rack unit

The reporting capabilities support business decisions, offering insights based on KPIs defined by the organization. Data center strategy and operation has been streamlined and is now proactive. The effects are now being felt by customers and IT staff alike. Customers are seeing a consistently reliable service, and employees are experiencing the relief that comes with responsible automation.

A recent study carried out at large European and Middle Eastern installations has shown a reduction of 85% in the time required for tracking and documenting data center connectivity. Following the adoption of an AIM system such as R&M*inteliPhy*, accuracy was very close to 100%. The result is a positive impact on overall business. But there's still one more threshold to cross.

Three ways to move to Level Five:

- Start monitoring power consumption for the documentation and visualization of power utilization conditions, and the recognition and notification of faults or power disruptions
- Create dashboards to obtain a rapid overview of critical system resources and KPIs
- Use a tracking system to track the usage of resources over time, allowing you to identify potential hotspots well in advance.

Level 5. Optimization Management

Level Five is the ultimate goal in the Maturity Model for Automated Infrastructure Management. At this stage, a deployed AIM system enables organizations to optimize business processes from an IT infrastructure perspective. It eliminates stranded capacity, facilitates end-to-end analysis and agile infrastructure management and supports predictive analysis and dynamic infrastructure. Since the entire infrastructure is represented in a consistent database in an AIM system, inquiries into resources such as free ports in network cabinets ducting capacity, or cabinet space can be answered quickly and easily. There's full understanding and control of the entire infrastructure, end to end, including all the on- and off-premises components that make up the network.

With comprehensive automation and reliable real-time analytics, the infrastructure undergoes continuous improvement. The entire infrastructure is represented in a consistent database, offering precise, real-time information on the current state and future requirements of the data center. This 'single source of truth' brings benefits in several specific areas. Administration of cabling infrastructure and connected devices is always up to date. Furthermore, this approach provides a basis for efficient facilities and IT management processes and systems, as well as other networked management processes and systems such asintelligent building systems and business information systems. Constant asset tracking and asset management in combination with event notifications and alerts assist with physical network security. Everything can be monitored and administrated from a common software tool.

Visibility is now at maximum, so there is awareness of everything impacting the infrastructure resources. Organizations have insight into how environmental and energy consumption impact the underlying infrastructure. For example, the platform can monitor power strips to detect inefficient servers that draw more energy than is necessary or normal.

An often-overlooked aspect is stocking spare patch cords. It is best practice to keep a small stock of patch cords in multiple lengths. Experience tells that 1 m, 3 m, and 5 m are the most frequently used patch cable lengths. The types will depend on the specific application but generally, the stock should include RJ45 Cat 6A and OM4 LC-duplex cords and potentially 12-fiber OM4 MPO cords. With the predictive analysis function of AIM systems, a precise count on the installed cabling and port count usage can be used to forecast what spares need to be kept on hand.

At the end of the lifecycle, product lifecycle management shall select those equipment items for decommissioning that are affecting optimal operations, either by its behavior in monitoring and event management, or by its nonoptimal maintenance or energy costs.

At this stage, organizations have nearly fully automated the monitoring of their infrastructure performance, resulting in an unprecedented level of confidence. With a renewed sense of job satisfaction, staff can now spend time fine-tuning the and are free to create and pursue continuous improvement of the infrastructure and service delivery. Having maximized the value of the monitoring platform — and saved considerable CAPEX and OPEX funds in doing so — it's now possible to explore new revenue streams through savings-funded innovation.

Choosing a comprehensive performance monitor

When looking for a performance monitoring platform that will move an organization up the levels on the Maturity Model, it's important to find one that comprehensively covers all parts of the physical infrastructure. When moving through the levels, it is important to take full advantage of the various functionalities and capabilities of the AIM system implemented. Moving up one level can take as little as a couple of weeks. During this process, organizations can implement functionalities on their own or take advantage of technical help from system specialists.

By providing a fully automated, comprehensive solution, R&M*inteliPhy* is helping some of today's largest, most connected enterprises gain the security, cost savings and peace of mind that comes with approaching Level Five.


mirror object
operation == "MIRROR_X":
mirror_mod.use_x = True
mirror_mod.use_y = False
mirror_mod.use_z = False
operation == "MIRROR_Y"
mirror_mod.use_x = False
mirror_mod.use_y = True
mirror_mod.use_z = False
operation == "MIRROR_Z"
mirror_mod.use_x = False
mirror_mod.use_y = False
mirror_mod.use_z = True
selection at the end
_ob.select= 1
er_ob.select=1
ntext.scene.objects.act
("Selected" + str(modifi
irror_ob.select = 0
bpy.context.selected_ob
objects[one.name].se
("please select exact
OPERATOR CLASSES
types.Operator):
X mirror to the selected
mirror_x"


+56.45
+455

Networking Technologies

Protocols are used in the data transmission process to prepare information for transport from point A to point B, based on agreed rules. The use of protocols is a basic feature of the IT world, comparable to the use of envelopes for sending personal letters or cardboard packages for sending goods. These protocols are a basic component in transmission technology and transmission software.

030.6124
Network equipment with singlemode patch cords

The relationship between protocols and a network infrastructure and cabling is especially important factor in data center planning. The more complex and demanding the data transmission, the higher performance the cabling must be.

The purpose of this section is to provide a general overview of common communication protocols. Numerous sources are available in IT technical literature and on the Internet for those who wish to find out more about the origin,definition and technical details of protocols

Protocols can be divided into connection-oriented and connectionless protocols. A connection-oriented protocols establishes a connection before any data is transmitted, waits for confirmation and finally terminates the connection. A connectionless protocol is faster but unreliable, since it logs no information regarding establishment and termination of the connection or confirmation. Typical protocol types include:

- Transport-oriented protocols (OSI layer 1–4) & application-oriented protocols (OSI layer 5–7)
- Routable and non-routable protocols (concerning the ability to forward data through routers)
- Router protocols (decisions on data path selection, e.g. RIP, OSPF, BGP, IGRP)

Network protocols, also known as communication protocols or transmission protocols, regulate how data are transmitted between the computers or processes in a distributed system. These rules are based on interaction between syntax and semantics. Syntax = set of rules and formats which specifies the communication behavior (semantics) of the instances in the computers involved in the communication.

Various protocols, which are responsible for different tasks, are required for the data transmission process. In order to provide clear delimitation for these tasks, these protocols are organized into layers. Protocols structured in this way form a so-called protocol stack, the best-known of which is perhaps the TCP/IP protocol stack.

OSI Layer Model

The ISO standardization organization created the OSI model as a basis for communication standards (ISO 7498 of 1984). OSI stands for Open Systems Interconnection. The purpose of this model is to facilitate communication between different networks and computer worlds. OSI protocols define not only application data, but also information on structures and processes. The model makes use of seven protocol levels, or layers, with clearly delineated functions. Data packets run through all seven layers on both the sender and receiver machines.

Layer 1 – Physical Layer

Layer 1 controls the establishment and termination of connections. It is responsible for the protocol information pattern, the information on the voltage level through which the logical information „1“ and „0“ is described. Cables and plug connectors as well as electrical and optical signals are assigned to this layer.

Layer 2 – Data Link Layer

Layer 2, the data link layer, checks whether data was transmitted without error. Bitstream correction functions exist in this layer. In addition, flow control takes place here, as well as cell numbering, in the event cells are transmitted. In LAN applications, layer 2 is subdivided into the sublayers called logical link control (LLC) and media access control (MAC). Sender rights are assigned by MAC. The well-known communication protocol Ethernet (IEEE 802.3) also resides on this layer. Network adapters and layer 2 switches are assigned to this layer.

Layer 3 – Network Layer

Layer 3 is responsible for routing information. For the routing process to work, IP network addresses are read and evaluated, then this information is passed to the next stages (networks) using routing tables. To do this, router require communication parameters such as bit transmission rates, network load, threshold values and service quality. Routers and layer 3 switches are assigned to this layer.

Layer 4 – Transport Layer

Layer 4 controls end-to-end communication. When a connection becomes unstable or fails, this layer takes care of re- establishing the connection (handshake) as well as address conversions, if necessary. Devices with protocol functions specific to this layer are known as layer 4 switches.

Layer 5 – Session Layer

Layer 5 carries out and completes the session from the application layer. This layer also specifies whether the connection is full-duplex or half-duplex. Finally, it is responsible for monitoring and synchronizing the data stream.

Layer 6 – Presentation Layer

Layer 6 interprets the different data structures that arrive from different computer systems. This layer ensures that syntax is uniform or correct (regarding character set, coding language, etc.). The sender's data format is converted into a deviceindependent format. In addition, cryptography is incorporated in this layer when data security is a requirement.

Layer 7 – Application Layer

Layer 7 passes the data that was transmitted up to user programs. This layer must naturally have the ability to communicate with a wide variety of applications, which of course makes standardization difficult. Common application protocols include HTTP, FTP SMTP and DNS.

Order of Events in a Transmission

The sender begins the information transmission in layer 7. It passes data packets from layer to layer until they reach layer 1. The information gets a header in every layer. This header is added to the front of the data to be transmitted Layer 3 adds information including the IP source and destination addresses that allow routers to make appropriate selections for data paths. Layer 2 adds a checksum field as a basic security check for the information being transmitted. All additional information together form the frame.

As a result, significantly more information than just data runs over cables. The length of an Ethernet frame must be at least 64 bytes and may be a maximum of 1,518 bytes, or 1,522 bytes with frame extension. This extension contains additional identifying characteristics (tags) that are required for transmitting data in virtual local networks (VLAN).

Half- / Full-Duplex

Full-duplex and half-duplex describe the data transmission based on direction and time. Half-duplex uses only a single channel for transmission, which can either send or receive data. Data streams in full-duplex mode flow in both directions, at the same time and at the same speed. Example: Gigabit Ethernet (10 Gbit/s) in full-duplex mode has a transmission speed of 20 Gbit/s.

TCP/IP

The transmission control protocol/Internet protocol (TCP/IP) was developed to make reliable data transmissions possible over large networks and networks of different types, and to allow networks to connect with one another. TCP/IP provides the technical open standard that made development of the Internet possible in the first place. Typical tasks for protocols regarding data transmission in the Internet include:

- Retrieving and loading websites and hypertext files (HTTP and HTTPS)
- Sending and receiving e-mails (SMTP, POP3, IMAP)
- Uploading files to or downloading files from servers (FTP, HTTP and HTTPS)

Even though the OSI model is recognized around the world, it still has a somewhat academic nature. The TCP/IP reference model and the TCP/IP protocol stack lie closer to actual practice in the IT world and are based on the structure of tried and tested protocols. Both models function according to the principle of transmitting data down through the stack as it is sent, then up through the stack as it is received.

Comparison of both models:

OSI layers		TCP/IP layers		TCP/IP layers		Coupling elements
7	Application	4	Application	HTTP, HTTPS, FTP, SMTP, IRC, POP3	DHCP, BootP, NTP, TFTP, LDAP, CLDAP	Gateway, Content Switch, Layer 4 to 7 switch
6	Presentation					
5	Session					
4	Transport	3	Transport	TCP	UDP	
3	Network	2	Internet	IPv4, IPv6, ICMP, IGMP, etc.		Router, layer 3 switch
2	Data Link	1	Network access	Ethernet, wireless LAN, FDDI, etc.		Bridge, switch
1	Physical					Cabling, repeater, hub, media converter

Ethernet

Ethernet technology has been revolutionizing the world since 1973. In the beginning there only existed a single fascinating idea: computers should have the ability to talk to each other. Today it is natural for computers to exchange their information over networks and defined protocols – whether this is in local data networks or over long distances. At that time, the computer scientist Robert Metcalfe shaped the essential basics of this packet-switched network technology for cable-connected data networks that he called Ethernet (a combination of the words ether, or air, and network).

The reference to air is founded in the historical assumption that it is the medium for spreading waves, radio waves to be specific. The packet principle was selected since data packets are self-contained and can circulate networks independently and flexibly. Every packet knows its source and its destination. This way the process is not dependent on specific transmission speeds or failures on individual path segments.

Since February 1980, the IEEE 802 project maintained by the standardization organization IEEE has been stamping out further advanced principles for Ethernet. The 802.3 work group of the IEEE 802.3 handles specifications for local data networks. Ethernet activities in a data network run on layers 1 and 2 (see section 3.8.1). Ethernet protocols define cable types, plug connectors and forms of transmission for the physical connections between active components or stations in a network. One essential element of Ethernet is the regulation of asynchronous station access to common media: This is known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

The name Ethernet has become synonymous with a large portion of network and protocol technology. Ethernet has virtually dominated the market since the 1990s. The success of Ethernet is based on the favorable acquisition costs provided by standardized systems as well as reliability, ease of use and scalability. This has led to its wide popularity.

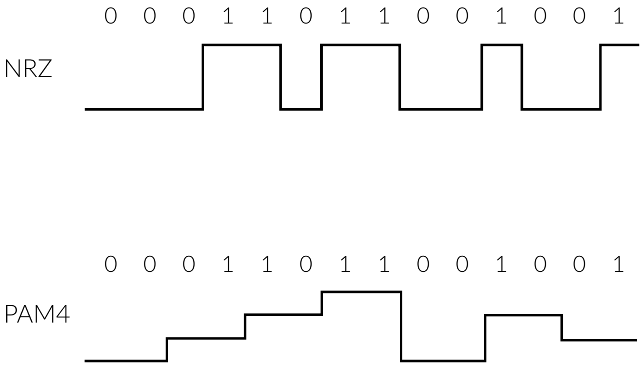
A key consideration in data center planning are the future being developed by IEEE 802.3 committees, now that they have established 25, 40 and 100 Gigabit Ethernet. The most important topics in this area include 50, next generation 100 Gigabit Ethernet, as well as 200 and 400 Gigabit Ethernet.

A central theme of higher speed Gigabit Ethernet is the search for cost-effective cabling solutions, cost-effective glass fiber cabling. This is because these technologies require a great deal more glass fiber technology to manage growth at all, in terms of bandwidth and data streams. Approaches for this are shown below.

090.6546
MPO trunk cable

25GBASE-SR, 50GBASE-SR and 100GBASE-SR4 technologies are designed to support maximum distances of 100 meters using OM4 glass fibers in accordance with the IEEE 802.3by, 802.3cd and 802.3bm standards. Cabling routes of just this length already allow for data center installation of most (> 85%) typical optical channels. Appropriate frames of reference can therefore be provided for data center planning. Restricting distances to these lengths, relatively short for glass fiber connection, is based on a very good reason: cost. Cost-effective transceivers can be implemented over these short distances and still ensure a quality signal transmission.

The biggest change in next generation Ethernet is the introduction of a new line code for multimode applications. While multimode Ethernet up to 100GBASE-SR4 was based on a non-return-to-zero (NRZ) line code, the latest Ethernet developments all employ four-level pulse amplitude modulation (PAM4). The NRZ line code represents a digital 1 by a high amplitude of the 850 nm laser, and correspondingly a 0 by a low amplitude, as it is depicted in the following illustration.



Non-return to Zero (NRZ) modulation (top) versus pulse-amplitude (PAM4) modulation (bottom)

PAM4 also modulates the laser amplitude but instead of only two states, uses four of them. The reasons for the move to PAM4 are plain: this modulation technique allows doubling of data rate while keeping the bandwidth by transmitting two bits in each symbol, as shown in the bottom part of the figure above. It is important to distinguish PAM4's data rate from its symbol rate.

The symbol rate is in baud (Bd) units. For example, a 50 Gbit/s PAM4 (data rate) signal is transmitted at the symbol rate of 26.5 GBd.

With PAM4, for 100, 200 and 400 Gbit/s Ethernet, parallel optical technology is still the medium of choice. The 100 Gbit/s solution uses two glass fibers in each of the two directions, and both the 200 and 400 Gbit/s solutions will use four fibers in each direction.

Fiber optic technology can therefore be tied to the historical success of Ethernet. The continued development of this technology into 200 and 400 Gigabit Ethernet is coming at the right time. It meets current needs and provides sufficient investment security for the future.

At the same time, the advantages of high-performance copper cabling should not be forgotten. It should continue to provide valuable services in the future in many data center areas for managing data volume. The Cat 6A and Cat 8.1 generations meet all conditions for fulfilling requirements of highly condensed Ethernet networks. With its copper data center assortment, R&M provides flexible, comprehensive solutions for copper cabling.

The following tables provide an overview of current Ethernet applications for copper and glass fiber cabling.

Ethernet Applications for Copper Cabling with Cat 6_A and Cat 8.1

Category & Class acc. ISO/IEC 11801		Cat 6_A – Class EA		Cat 8.1 – Class I	
		Shielded & unshielded		Shielded	
Topology		**PL** [1)]	**Channel** [2)]	**PL** [1)]	**Channel** [2)]
Installation Cable					
AWG	Wire type				
26	Solid	55 m	65 m		
26	Flexible	55 m	65 m		
23	Solid	90 m	100 m		
22	Solid	90 m	100 m	24 m	30 m [3)]

1) Permanent link and channel length reduction if patch cord (flexible cable) >10m
2) Channel calculation based on 2x5m patch cord (flexible)
3) Maximum patch cord length depends on gauge size: 3 m for AWG 22, this length is reduced to 2 m for AWG 26

Ethernet Applications for Glass Fiber Cables with OM4, OM5 and OS2

Fiber type accord ISO/IEC 11801							OM4		OM5		OS2	
Wavelength							850 nm		850 nm		953 nm	1310 nm
1550 nm												
Overfilled modal bandwidth (MHz*km)							3500		3500	1850		
Eff. Laser launch modal bandwidth (MHz*km)							4700		4700	2470	NA	NA
				y)	z)							
IEEE	802.3 VCSEL	Section Four	10GBASE-	S	R		400 m 2.9 dB [a]					
IEEE	802.3 Laser		10GBASE-	L	R						10 km 6.2 dB [a]	
IEEE	802.3 WDM		10GBASE-	L	X	4 [k]					10 km 6.2 dB [a]	
IEEE	802.3 OFL		10GBASE-	L	R	M					10 km 6.2 dB [a]	
IEEE	802.3 VCSEL	by-2016	25GBASE-	S	R		100 m 1.9 dB [a]					
IEEE	802.3 Laser		25GBASE-	L	R							10 km 6.3 dB [a]
IEEE	802.3 Parallel	Section Six	40GBASE-	S	R	4 [o]	150 m 1.5 dB [a]					
IEEE	802.3 WDM		40GBASE-	L	R	4 [k]					10 km 6.7 dB [a]	
IEEE	802.3 Parallel	Section Six	100GBASE-	S	R	4 [o]	150 m 1.5 dB [a]					
IEEE	802.3 WDM		100GBASE-	L	R	4 [k]					10 km 6.7 dB [a]	
IEEE	802.3 Parallel	bs-2017	200GBASE-	D	R	4 [o]					500 m 3 dB [a]	
IEEE	802.3 WDM		200GBASE-	F	R	4 [k]					2 km 4 dB [a]	
IEEE	802.3 WDM		200GBASE-	L	R	4 [k]					10 km 6.3 dB [a]	
IEEE	802.3 Parallel		400GBASE-	S	R	16 [o]	100 m 1.9 dB [a]					
IEEE	802.3 Parallel		400GBASE-	D	R	4					500 m 3 dB [a]	
IEEE	802.3 WDM		400GBASE-	F	R	8 [k]					2 km 4 dB [a]	
IEEE	802.3 WDM		400GBASE-	L	R	8 [k]					10 km 6.3 dB [a]	

y) Wavelength: S=short 850nm / L=long 1310 / D=parallel 1310
z) Encoding: R=64B/66B data coding method

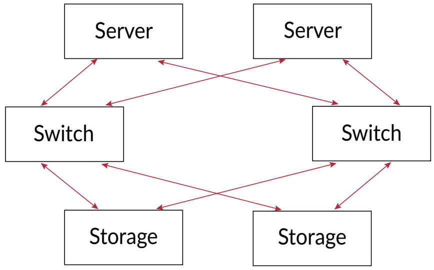
a) These channel insertion loss values include cable, connectors and splices
k) Wavelength division-multiplexed lane assignment
o) Number of fiber pairs

Fibre Channel

Fibre Channel is a protocol provided for serial, continuous high- speed transmission of large volumes of data. Storage area networks (SAN) run on the Fibre Channel standard. Transfer rates with this technology reach 32 Gbit/s with Gen6 Fibre Channel.

Fibre Channel assigns a WWNN (world wide node name) for each device, as well as a WWPN (world wide port name) for each port of a device. This 64-bit value therefore provides every Fibre Channel device with a unique identification feature.

Fibre Channel relies on other protocols such as SCSI or IP in the higher layers of the OSI layer model. This facilitates the use of existing drivers and software. Fibre Channel achieves a useful data capacity of over 90%, as opposed to Ethernet which only achieves 20% to 60%.



Example topology of a Fibre Channel switched fabric network

Topology

In general, Fibre Channel is mainly used in the Switched Fabric (FC-SW) topology. Multiple switches in a fabric usually form a mesh network, with devices being on the “leaves” of the mesh. Most Fibre Channel network designs employ two separate fabrics for redundancy The two fabrics share the leave devies, but are otherwise unconnected.

Broadcom LPe32002 32Gb Fibre Channel (FC) Host Bus Adaptor (HBA)

FC-SW allows the highest performance and most reliable Fibre Channel applications to be realized. The Fibre Channel switch, or director, in the center of the system connects all devices with one another. This way point to-point connections can be set up between any devices.

Reliability in Fibre Channel installations can be increased through redundancy, implemented by means of two independent switched fabrics. In the process, each storage subsystem and each server is connected to each of the two fabrics using at least one HBA. This configuration eliminates one single point of failure. In view of demands of high availability, all arguments generally speak in favor of using FC-SW.

Fibre Channel Applications for Glass Fiber Cables with OM4, OM5, and OS2

Fibre type accord ISO/IEC 11801	OM4		OM5		OS2	
Wavelength	850 nm	NA	850 nm	953 nm	1300 nm	
1490 nm						
Overfilled modal bandwidth (MHz*km)	3500		3500	500		
Eff. Laser launch modal bandwidth (MHz*km)	4700		4700		NA	NA
8G Fibre Channel 800-M5F-SN-I	190 m 2.19 dB					
8G Fibre Channel 800-SM-LC-I					1.4 km 2.6 dB	
8G Fibre Channel 800-SM-LC-L					10 km 6.4 dB	
16G Fibre Channel 1600-M5F-SN-I	125 m 1.95 dB					
16G Fibre Channel 1600-SM-LC-L					10 km 6.4 dB	
16G Fibre Channel 1600-SM-LZ-I						2 km 2.6 dB
32G Fibre Channel 3200-M5F-SN-I	100 m 1.86 dB					
32G Fibre Channel 3200-SM-LC-L						10 km 6.34 dB
64G Fibre Channel 64GFC-SW	100 m 1.86 dB		100 m 1.86 dB			
64G Fibre Channel 64GFC-LW						10 km 6.3 dB
128G Fibre Channel 128GFC-SW4	100 m 1.36 dB					
128G Fibre Channel 128GFC-PSM4						500 m 3.01 dB
128G Fibre Channel 128GFC-CWDM4						2 km 4.1 dB

Fibre Channel provides the following advantages for storage networks:

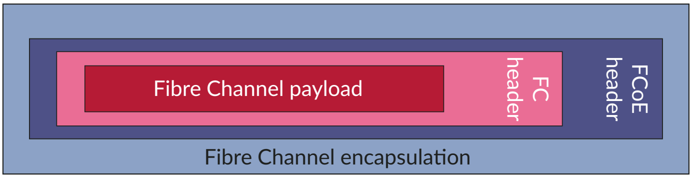
- Broad support by hardware and software manufacturers
- Higher level of technological maturity
- High performance
- High-availability installation (redundancy)

Fibre Channel over Ethernet

A classic data center design features a dedicated Ethernet LAN and a separate, dedicated Fibre Channel (FC) SAN. With FCoE, it is possible to run a single, converged network. This means that one can especially play off the advantages of Ethernet – flexibility, scalability and bandwidth. FCoE is used in networks with full-duplex Ethernet. However, it does use the Fibre Channel framework.

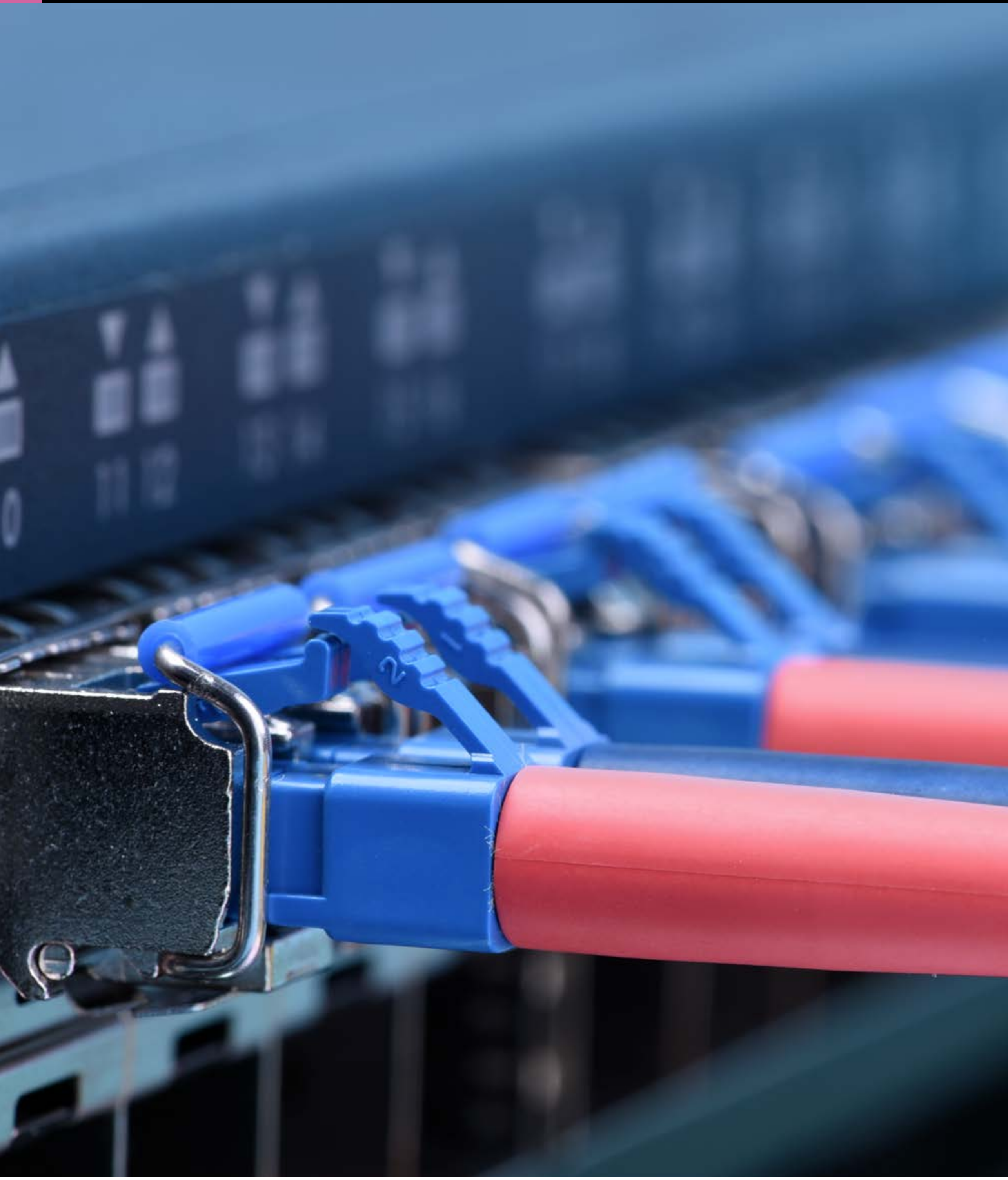
Disadvantages of the classic Ethernet protocol lie in its low reliability, e.g. when frames are lost because of overloading. To improve this situation, the system runs on data center bridging. FCoE can contribute to reducing the complexity of network structures since it can be considered a form of virtualization based on physical media that extend up to host systems for virtualized servers.

The combination of 10 Gbit/s Ethernet and Fibre Channel has led to Converged 10 GbE, which includes FCoE. In this process, FC packets are encapsulated in the header of the Ethernet frame. This solution allows for the use of a converged Ethernet topology. Now, FCoE technology can be used to extend convergence networks beyond the leaf layer. The higher speeds, such as 40 Gigabit FCoE to day, or the 100 Gigabit FCoE in the future, help enable higher-speed Inter-Switch Links (ISLs) in the network core.



030.6134
FCoE ports

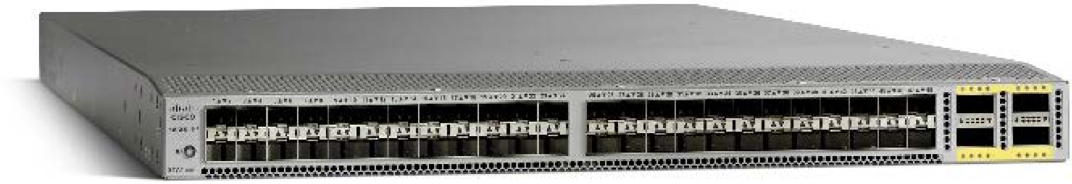
Transceivers



Transceivers

Two options exist for connecting IT components to a network:

- Permanently installed interfaces (the network technology is already defined by the time the purchase decision is made) which is usually the case for RJ45 ports
- Exchangeable interfaces which is equal to say fiber optic transceivers



Cisco Nexus 6001 Series 48-Port 10 Gigabit Ethernet SFP+ ports

Companies first decide, during the data center/network planning stage, whether data center and network connections will be based on copper or glass fiber cabling, and if so, in what areas this will be implemented and what interfaces to use. This decision will provide planners with the possible communication protocols they can use for the system.

In the past, data center operators relied on 10 Gigabit Ethernet, given the normal requirements of distance and performance in LANs. With the deployment of 40 and 100 Gigabit Ethernet, fiber optics links have become the de facto standard in dat a communication networks. This technology requires the use of top-quality OM4 and OM5 optical fiber cables.

MPO connectors with twelve fibers are required for 40 and 100 Gigabit Ethernet transmission. The four outer fibers on each connector are used to send and receive signals.

030.6127
SFP+ transceiver

SFP+

SFP+ modules make use of a single, serial data stream. Areas of application for SFP+ modules include 10 GbE and 16 gigabit Fibre Channel. The corresponding fiber optical plug is the LC-Duplex connector.

SFP+ adapts signals to the type of a given transmission. So, for example, an SFP+ module can convert an electrical interface into an optical connection. Given its separate sending and receiving units, it has both electrical as well as optical interfaces available. SFP+ support wavelengths of 850 nm, 1310 nm and 1550 nm as optical interfaces.

030.6125
SFP transceiver plugged into an switch port

Third-party suppliers also offer transceivers equipped with an intelligent configurator for flexible use in any system. Switch/ router manufacturers may block these „open“ systems. In any case, these systems should always be checked before they are implemented in any application.

Example of an SFP+ switch Juniper Networks (Source: Juniper Networks)

The QSFP+ module

QSFP+

The QSFP+ module is an evolution of SFP+ interfaces. This transceiver solution is suitable for 40 Gigabit Ethernet. QSFP+ stands for quad small form factor pluggable. It increases port density over SFP+ and reduces total costs. The corresponding fiber optical plug is the MPO8 or MPO12 connector.

The front of the QFX5110 data center switch from Juniper is shown as an example of this technology. This device combines a total of 32 QSFP+ ports into a single height unit.

Juniper Networks QFX5110 switch with 32 QSFP+ ports (Source: Juniper Networks)

An SFP28 transceiver

SFP28

SFP28 stands for small form-factor pluggable 28. It is the third generation of the SFP interconnect systems designed for 25Gbit/sperformance per the IEEE 802.3by specification. It has evolved from 100 Gigabit Ethernet, which is typically implemented with 4 × 25 Gbit/s data lanes. SFP28 is backwards compatible with SFP+ ports. The corresponding fiber optical plug is the LC-Duplex connector.

A QSFP28 transceiver

QSFP28

QSFP28 is the next generation of the QSFP form factor, delivering 100GbE. QSFP28 may also be used to break out a single 100GbE switch port into four individual 25GbE server connections with SFP28 transceivers. The corresponding fiber optical plug for singlemode devices is the LC-Duplex connector, and for multimode the MPO8 or MPO12.

CFP4

A CFP4 transceiver

The CFP4 is the third generation of the C form-factor pluggable (CFP), a multi-source agreement to produce a common formfactor for the transmission of high-speed digital signals. The C stands for the Latin number 100 (centum), since the standard was primarily developed for 100 Gigabit Ethernet systems.

It has four parallel lanes of each 25 Gbit/s and consumes less than 6 W. The corresponding fiber optical plug for singlemode devices is the LC-duplex connector, and for multimode the MPO8 or MPO12.

QSFP+ and QSFP28 SWDM4

The QSFP+ and QSFP28 SWDM4 transceiver modules are designed for use in 40GbE, 100GbE links respectively, over duplex multimode fiber. SWDM4 stands for shortwave wavelength division multiplexing over four wavelengths. Such connections are powered by VCSELs operating at 850, 880, 910, and 940 nm. In a QSFP+, these VCSELs are modulated at 10 Gbit/s, whereas they are modulated at 25 Gbit/s in QSFP28 transceiver modules. This is the same concept that is used in the Coarse Wavelength Division Multiplexing (CWDM) standards used in the longwave 1310 nm region operating over single mode fiber, except that SWDM is generated by VCSELs, which are a lower cost technology.

In an SWDM module, multiple SWDM VCSELs produce optical signals that are multiplexed onto a single fiber. All the VCSELs and the optical multiplexing occur within the optical module. On the receive side of the module, the wavelengths are demultiplexed and then converted to parallel electrical signals.

Summary

The very nature of a data center is complex as it consists of a variety of devices and technologies from different vendors. Increasing bandwidths and data rates have made fiber the preferred technology to enable speeds beyond 10 Gbit/s. In the past, development of optical transceivers was guided by technical specifications and interoperability requirements by IEEE 802.3 Ethernet working groups.

With ever-accelerating technical developments, brought Multisource Agreements (MSA) into the focus. An MSA is an agreement between several manufacturers to make devices interchangeable by defining common physical forms. In the case of optical transceivers, there are MSAs that cover both the specification and implementation from different vendors.

At the time of writing this handbook, Ethernet work groups include fourteen new cabling applications, of which eight are fiber optic.

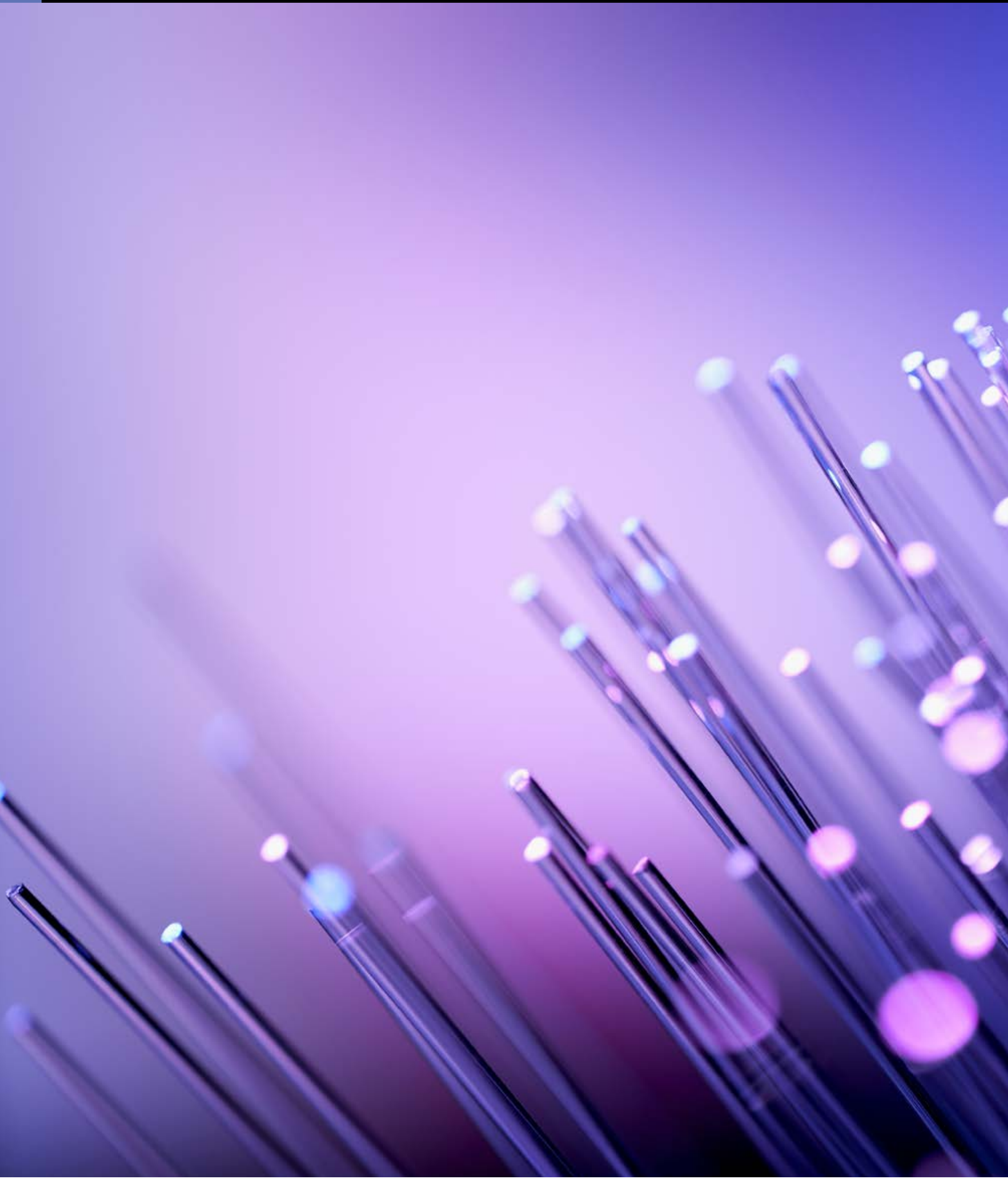
At the same time, many different MSAs have recently been announced which manifest the dynamics within the data center industry:

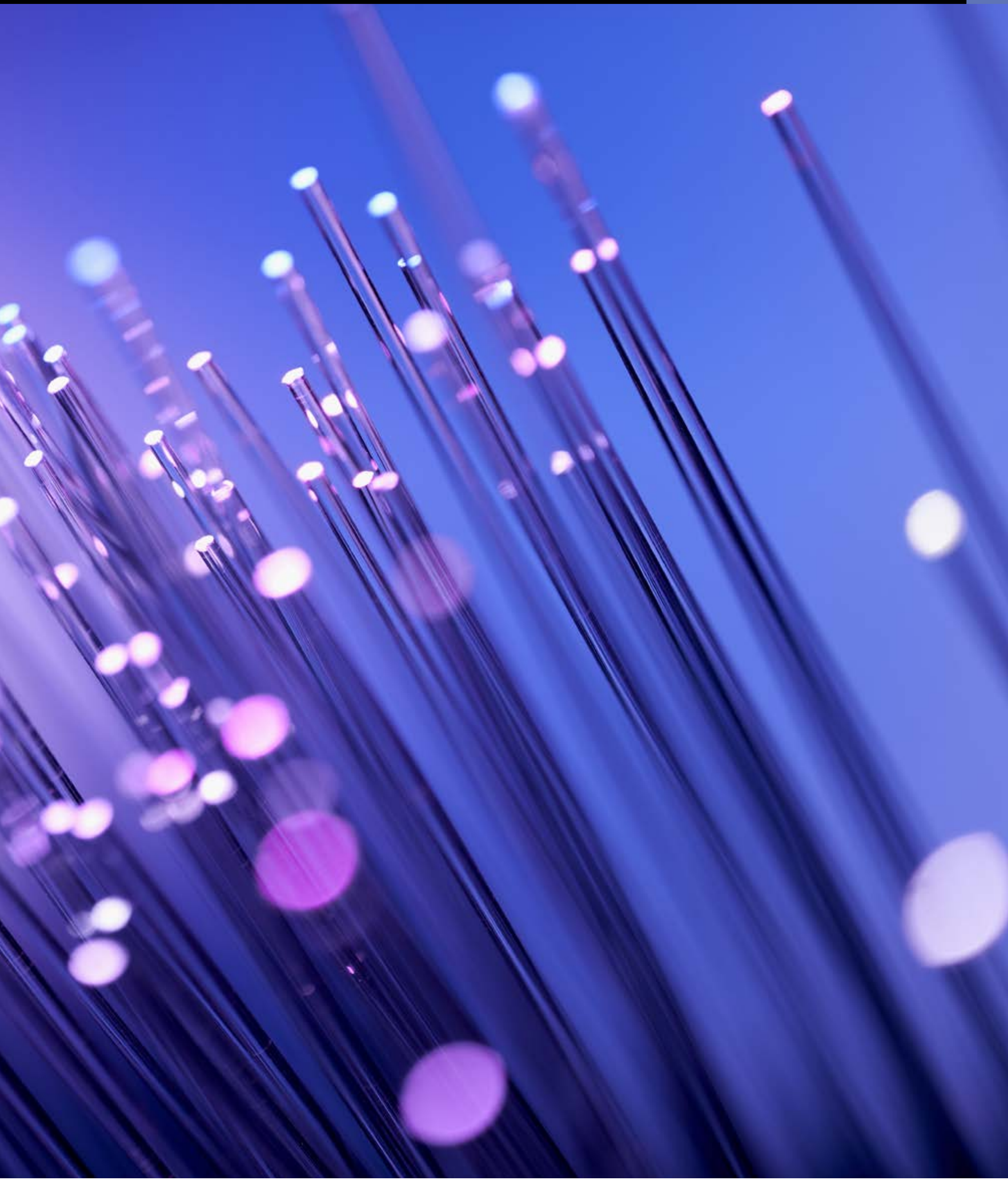
- 100G CWDM4, www.cwdm4-msa.org
- 100G PSM4, www.psm4.org
- 40G and 100G SWDM, www.swdm.org
- Consortium for On-Board Optics (COBO) of which R&M is a Member, www.onboardoptics.org
- 200G and 400G QSFP-DD, www.qsfp-dd.com
- 400G OSFP (Octal Small Form Factor Pluggable), www.osfpmsa.org
- 400G BiDi, www.400gbidi-msa.org
- 100G Lambda, www.100glamda.com
- 400G CFP8, www.cfp-msa.org
- 400G CWDM8, www.cwdm8-msa.org

The clear trend in this development has been towards both higher speeds and densities. Higher speeds are the result of new applications standards that specify higher line rates. Higher densities have largely been driven by technology advances which enable the transceiver to make use of lower power, which allows for smaller packaging.

Each of the data center cabling standards (TIA 942, ISO/IEC 11801-5, EN 50173-5, EN 50600-2-4) has standardized two optical connectors which cover all the MSAs mentioned above: the LC for single or duplex applications and the MPO for applications requiring more than two fibers. And while connector standardization has helped simplify cabling, it has also become very important to provide a very flexible and flexible connectivity that meets the ever-increasing speeds and higher densities driven by higher front panel densities.

Physical Layer Media





Physical Layer Media

The selection of transmission media and connection solutions plays a central role in network planning. This process requires foresight, since the passive infrastructure is often not easily replaced and must provide useful service for many years.

Indeed, the physical network infrastructure in the data center is essentially based on common principles of structure communication cabling.

The best approach in selecting transmission media and connection solutions, whether you are planning a new data center or redesigning an existing one, is to consider the future as far as possible, then to strive for acquiring the equipment that has the best specifications possible. In the process, proven standards for structured cabling can still serve as guides. This is because these standards support the usual criteria for success such as scalability, profitability, quality, operational reliability, etc.

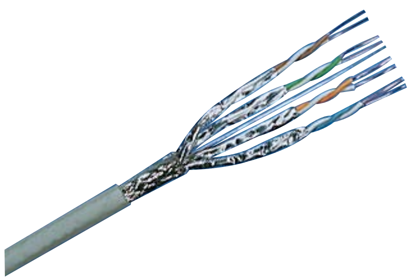
The various kinds of different data center media are considered in more detail below.

Twisted-Pair

The classic widespread variant of copper cabling is twisted pair. This is usually the most cost-effective and universally usable transmission medium from an economic standpoint. With the advent of 40GBASE-T, data centers can cover cabinet rows with twisted pair copper cabling when they select high-quality solutions for this purpose.

The most essential copper cabling components include:

- Category 6_A / 6_A (specified up to a bandwidth of 500 MHz)
- Category 7 (specified up to a bandwidth of 600 MHz)
- Category 7_A (specified up to a bandwidth of 1,000 MHz)
- Category 8.2 (specified up to a bandwidth of 2,000 MHz)



020.0983
A shielded twisted pair cable

Frequency	IEEE	EIA/TIA		ISO/IEC	
	Channel etc.	Channel	Components	Channel	Components
	10GBASE-T	Cat. 6A	Cat. 6A	Class E_A ISO/IEC 11801	Class E_A ISO/IEC 11801
1-500 MHz	IEEE 802.3 Section Four	EIA / TIA 568B.2-10 (2008)	EIA/TIA 568B.2-10 (2008)	Amendment 1 (2008)	Amendment 1 (2010)
1-600 MHz					
1-1'000 MHz					
1-2'000 MHz Class I	25GBASE-T Cat 8.1 interface	25GBASE-T 40GBASE-T		Cat. 8 Cat. 8.2 cable	IEEE 802.3 bq

Current cabling standards for typical data center requirements

Cable Selection

The general principle that maximum bandwidth normally allows a maximum data rate applies in the selection of cable. It therefore follows that companies that eventually expect to implement 10, or even 40 Gigabit, Ethernet should go with the highest quality cabling type, i.e. category 8.2.

Since old cabling designations related to shielding were not standard, were inconsistent, and often provided for confusion, a new naming system of the form XX/YZZ was introduced in ISO/IEC 11801 (2002).

- **XX stands for the overall shielding provided**
  - o U = no shield (unshielded)
  - o F = foil shield
  - o S = braided shield
  - o SF = braid and foil shield
- **Y stands for the shielding provided for the core pair**
  - o U = no shield (unshielded)
  - o F = foil shield
  - o S = braided shield
- **ZZ always stands for TP = twisted pair**

Twisted pair cables in the following shield variants are available on the market:

Shielding		U/UTP	F/UTP	SF/UTP	U/FTP	S/FTP	F/FTP
Overall shield	Foil		✓	✓			✓
	Wire mesh			✓		✓	
Core pair shielding	Foil				✓	✓	✓

Lightweight low-profile cables (AWG26 cables) with a diameter of 0.405 mm (as compared to 0.644 mm in AWG22) and other advances in shielding and cabling technology are leading to savings in cabling solutions. At the same time, these solutions can increase performance and efficiency in passive infrastructures. A maximum savings of 30% in cabling volume and weight is possible using these cables. However, some details may come into play regarding planning, product selection and installation. These involve achieving sufficient attenuation reserves in the channel and permanent link, and in turn full operational reliability of the cabling system.

AWG stands for American Wire Gauge and is coding systems for wire diameter. The following core diameters are used for communication cabling:

- AWG22 / Ø 0,644 mm
- AWG23 / Ø 0,573 mm
- AWG24 / Ø 0,511 mm
- AWG26 / Ø 0,405 mm

The network planning process must also consider any requirements where devices need to be supplied with power through data cabling. The IEEE 802.3 Section Two standard (Power over Ethernet/ PoE, Power over Ethernet Plus/PoEplus) standards define ways in which data cables can be used to supply devices with the electrical power they need. Common applications of this technique include wireless access points, VoIP phones and IP cameras.

Pre-Assembled Systems / Plug-and-Play Solutions

Installing systems and components in data centers requires precision work and complex measurements that must be carried by an enormous number of highly qualified personnel. In addition, producing the countless connections required in networks by hand is a lengthy operation. Quick, spontaneous changes to the positions of connections – a typical requirement in data centers –are only possible under certain conditions, and are relatively expensive.

Manufacturers like R&M therefore offer the following pre-assembled solutions:

- Multi-core cables consisting of multiple twisted-pair cables or multi-fibrous cables, both ends sealed with normal plug connectors or outlets or even a special unique manufacturer-specific plug. The manu facturer provides a measurement report with all connections.
- Modular terminal blocks which can be mounted in the cabinet using 19“ technology or in double floor systems. Multi-core cables can be connected to this block at the input side using the special plug, and then RJ45 outlets or glass fiber adapters are available on the output side.

Cabling systems pre-assembled at the factory allow data center availability to be increased. This is because, given a best-case scenario, installation is reduced to a simple plug and play, saving time and money. In addition, plug-and-play solutions allows systems enhancements to be implemented in no time at all. Plug-and-play solutions mean that no waste accumulates in the security area during installation, and third-party personnel or a company‘s own technicians only have the enter the security area for a short time, maybe even not at all.

090.5862
Pre-assembled shielded cable with category 6A modules

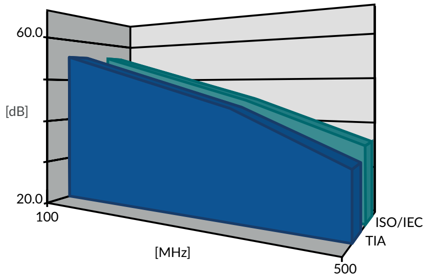
The supplier provides units that have been inspected and are onehundred percent flawless and immediately ready for operation. These units have uniform quality and transmission properties throughout. Furthermore, these solutions provide high investment protection, since in general they can be kept up-to-date, upgraded and reused.

030.5279

Only plug-in modules that were optimized with respect to contact geometry satisfy standards up to categories 6A and 6A. As in Channel technology (see above), higher performance can also be achieved using a 6A connector designed in accordance with ISO specifications than with a Cat. 6A plug connection designed in accordance with EIA/TIA specifications.

A 40- d B attenuation drop should be allowed for in Cat. 6A starting from 250 MHz, and a 30 dB drop for Cat. 6A. In the case of 500 MHz, this means that a Cat. 6A module must achieve NEXT performance that is 3 dB better than a Cat. 6A module (see graphic to the right).

The RJ45 plug connection system is the universal connection solution in twisted-pair copper cabling. The eight-pin miniature plug-in system for shielded and unshielded cabling is used in virtually every IT environment. Its transmission properties are determined through its small dimensions. Parameters like frequency range, attenuation and crosstalk also play an important role in determining the plug's transmission behavior, and must be taken into consideration in planning and evaluation processes. Crosstalk is especially critical, since core pairs that are guided into the cable separately must still run together in the body of the connector. The low contact distances of the RJ45 plug as well as certain other factors have proven to be problematic for high-frequency behavior.



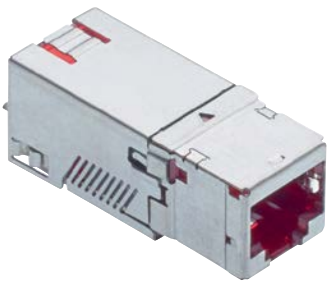
Connecting Hardware NEXT Values

Because the required attenuation reserve cannot be achieved through a change in the existing design alone, this performance increase will require a radical change in how new modules are developed. Above all, more compensating elements are required to balance out the additional coupling effects like cross-modal couplings. Greater effort is required to separate core pairs at the end from one another. The connecting or contacting process must be performed in a very precise manner and guaranteed to be without error, to ensure consistent signal transmission.

R&M has succeeded in doing just that with its Cat. 6A ISO module. It features enormous safety reserves that even go beyond those defined by the strict international standards (an example of the product appears below).

Category 6_A ISO

R&M's category 6_A solution, with its distinctive, innovative red connection module, has proven itself to be one of the most outstanding copper connection technologies ever offered in RJ45 format, and features the highest performance ever shown. Its wiring technology that features an automatic cutting process guarantees its cores are always wired precisely, no matter how they are handled by electricians.



090.7076
R&M's Cat. 6A module with X Separator

The inside of the module is provided with metal pyramids that divide wire cores to all four sides, and with an X separator component that provides insulation. This design provides maximum protection against crosstalk.

The Cat. 6_A ISO module from R&M has a radical design that makes it easy to use but at the same time offers unbeatable performance.

The module is also subject to a strict quality control process – R&M production-tests every single module over relevant parameters.

Category 6_A EL

Productivity is increased with the Cat. 6_A EL module because it is so easy and fast to terminate. Hence the addition to its name: Easy Lock (EL). The RJ45 connection can be installed without errors in just a few easy steps. Insulation displacement contacting (IDC) from R&M ensures the reliable termination of the wires. The integrated clamping ring takes care of strain relief and with shielded twisted pair (STP) cabling also provides 360° shield termination. There is no need for specialized knowledge, specific tools or cable ties.

090.7179
R&M's Category 6_A EL module

The module is available shielded (STP) in the die-cast version and unshielded (UTP) in the plastic version. The housing of the UTP module is made from a special plastic which reduces electromagnetic emissions (crosstalk) and thus controls the Alien NEXT of the module. This means the module can be installed anywhere without any additional protective measures.

Category 8.1

Category 8.1 is designed to connect server uplinks to the leaves of the network. It offers big benefits for data center and network managers with support for 25GBASE-T and 40GBASE-T, auto negotiation, and the universal RJ45 interface. The auto negotiation of BASE-T allows to connect two Ethernet devices of differing speeds. Both devices will choose a common transmission speed that both devices support. In this way, 25GBASE-T switches can already be deployed although servers still run on 10GBASE-T.

030.5970
R&M's Category 8.1 module

Based on our award-winning Cat. 6_A design a new dimension is ready – Cat. 8.1. Full capability in an easy to handle, installer friendly setup. The well proven design is improved for Cat. 8.1 to ensure maximum performance. After years of development in the high-performance data center environment, R&M sets out to offer the new twisted-pair category for future proof installations. Not only is bandwidth a crucial thing but also the overall costs of any installation.

Using the appropriate installation cable, one can use the jack and categorize the network in three zones: 24 m for 40 Gbit/s, 50 m for 25 Gbit/s, and 90 m for 10 Gbit/s LAN applications.

Fiber

Growing demands on data centers are forcing operators to use fiber optic cabling. This is because the fiber optic medium offers the most resources over the long term and can also support virtually any required bandwidth. Glass fiber makes extremely short access times possible. Cabling systems are easily scaled and require little space. Optical transmission technologies are clearly a technology of the future. Ethernet requires glass fiber infrastructures, especially for speeds above 40 Gigabit Ethernet.

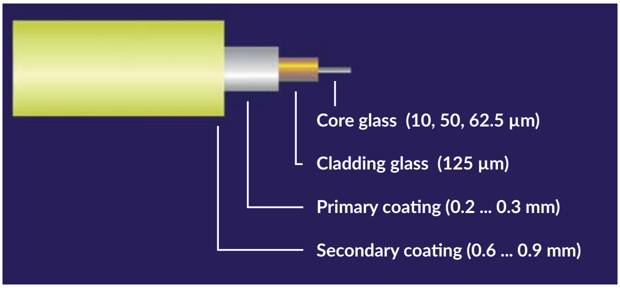
030.5923
Optical fiber

An overview is presented below of the fundamental topics, terminologies and issues that play a role in planning a glass fiber cabling system in a data center. We then present an orientation for decision makers, and information on some progressive glass fiber solutions that are currently available on the market.

Multimode, OM3/OM4

Glass optical glass fibers can be grouped into two different types:

- Multimode glass fibers with gradient index profile
- Singlemode glass fibers



Structure of a glass fiber (core: 9 µm single mode, 50 µm multimode)

The modes in multimode glass fibers with a gradient index profile run in a wave shape around the fiber axis, which provides for an extensive compensation of signal delay differences. This glass fiber type has an attractive costbenefit ratio, and has established itself as the standard fiber for high-speed connections over short to medium distances.

Attenuation, measured in dB/km, and bandwidth length product (BLP), specified in in MHz*km, represent the key performance indicators for glass fibers. A BLP of 1000 MHz*km means that the usable bandwidth is 1000 MHz over 1000 m, or 2000 MHz over 500 m.

OM3 and OM4 are laser-optimized 50/125 µm multimode glass fibers. The cost-effective VCSEL is usually used in data centers. Lasers have the advantage that, unlike LEDs, they are not limited to a maximum frequency of 622 MBit/s and can therefore transmit higher data rates.

OM4 fibers play a crucial role in data centers and thus deserve special attention. They offer additional leeway for insertion loss over the entire channel, which allows for more plug connections. Use of OM4 results in higher reliability of the overall network, a factor which is important for 40/100 Gigabit Ethernet applications.

Multimode, OM5

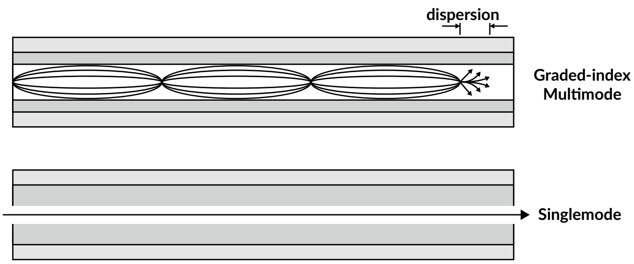
With internal data center traffic continuously increasing, network managers are now going to have to support increased bandwidth by implementing fiber optic cables which will facilitate simplified network transformation. To date there have been two solutions: LC Duplex with singlemode fibers (LR4) or a parallel optical solution with multimode fibers and MPO connectors (SR4). Both variants are expensive and complex. Now there is an alternative with OM5 and SWDM4.

Advances in laser technology and multiplexing are making this possible. Now, multimode VCSELs are taking care of multiplexing on the four short wavelengths 850, 880, 910 and 940 nm (Shortwave Wavelength Division Multiplexing, SWDM4). The corresponding transceiver modules transmit 10 or 25 Gigabits per wavelength. This clears the way for 40 or 100 Gbit/s on a single bidirectional multimode fiber pair. The category OM5 eliminates the disadvantages of chromatic dispersion.

041.0312
OM5 LC-QR ports in Netscale 120 platform

With OM5 and SWDM4, data center managers can opt for more favorably priced multimode cabling. The cables are easy to distinguish with their lime green color.

Singlemode, OS2



Illustrations of multimode (top) and singlemode (bottom) fiber

Only one light path exists in single-mode glass fibers. The reason for this is their extremely thin core diameter of 9 µm. As a result, no multi- path propagation with signal delay differences between modes exists in these fibers. The advantage of this is that single-mode glass fibers can maintain extremely high transfer rates over long distances.

Singlemode glass fibers demand extremely precise light injection and consequently topquality connection technology. This medium is used in high-performance areas like MAN and WAN backbones.

Dispersion-optimized monomode fiber technology, including non-dispersion shifted fibers (NDSF), dispersion -shifted fibers (DSF) and non-zero-dispersion shifted fibers (NZDSF) are available for applications based on WDM and DWDM technology (dense wavelength division multiplexing) technology. These fibers were standardized by the ITU in its G.650 ff. recommendations.

The following table shows the specifications of all standardized multi-mode and single-mode glass fiber types:

Fiber Types and Categories				
Modes	**Multimode**			**Singlemode**
ISO/IEC 11801 class	**OM3**	**OM4**	**OM5**	**OS2**
Core/cladding (typical)	50/125 µm	50/125 µm	50/125 µm	9/125 µm
Attenuation dB/km (typical)				
at 850 nm	3.5 dB/km	3.5 dB/km	3.5 dB/km	–
Bandwidth length product (BLP) MHz*km				
Effective modal bandwidth at 850 nm	2000 MHz*km	4700 MHz*km	4700	–
Effective modal bandwidth at 953 nm	Not specified	Not specified	2470	–

What is true for glass fibers also applies for fiber optic plug connectors – i.e. quality, performance and profitability are the decisive factors for what solutions are possible for a given data center. In contrast to copper connection technology, glass fiber plug connectors offer a wider assortment of formats and mating faces. This makes proper component selection a little more difficult. Basic knowledge in this area of quality grades for fiber optic connectors is indispensable for planners and installers. The following section provides information on current standards and discusses their relevance for product selection.

Connector Quality and Attenuation

The primary goal in the development, manufacture and application of fiber optic connectors is to eliminate causes of loss at fiber junctions. The small diameter of glass fiber cores requires a maximum degree of mechanical and optical precision in the manufacturing process. Tolerances of 0.5 to 0.10 µm (much smaller than a grain of dust) mean that manufacturers are approaching the limits of fine mechanics.

A plug connection is made up of a connector / adapter / connector combination. The fiber ends must meet each other precisely in the inside of the plug connection so that as little light energy as possible is lost or scattered back (return loss).

030.5776
An LC-QR uniboot connector

One can of course determine on site whether a plug connector has been snapped into place correctly. However, the quality of the connection can only be determined by measurement equipment alone. Users must be able to rely on manufacturer specifications for specifications like attenuation, return loss, or mechanical strength.

The quality of a fiber optic connector is usually characterized by two values:

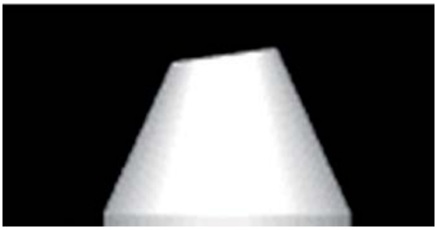
- Insertion loss **(IL)**
  Ratio of light output in fiber cores before and after the connection
- Return loss **(RL)**
  Amount of light at the connection point that is reflected to the light source

The smaller the IL value and the larger the RL value, the better the signal transmission in a plug connection will be.

Standards require that fiber ends come with a PC (physical contact) or APC (angled physical contact) polished surface. In a PC polished surface, the front of the fiber end gets a convex ground end surface so fiber cores can make contact at their highest elevation points. As a result, the creation of reflections on the connection point is reduced. An additional improvement in return loss is achieved by means of APC bevel grinding technology. Here, the convex end surfaces of the ferrule are ground with a bevel of 8° to the axis of the fiber.

PC Physical Contact

Different amounts of light or modes – depending on the physical properties of the fibers – are diffused and scattered back at the transition point of the two fibers. APC connector that is well-ground and cleaned has about 14.7 dB RL against air and 45 to 50 dB in when plugged in. With APC connectors, modes are also scattered back because of the 8° grind, though at an angle that is greater than the angle of acceptance for total reflection. Modes which have an angle of greater than 7.5° are decoupled after a few centimeters and therefore do not reach the source and interfere with it. A quality APC connector has at least 55 dB RL against air and 60 to 90 dB when plugged.



APC Angled Physical Contact

Plug Connector Types

LC and MPO connectors were defined for data center applications in accordance with ISO/IEC 24764, EN 50173-5 and TIA-942 standards for fiber optic cabling systems.

MPO Connector (IEC 61754-7)

MPO (multipath push-on) is based on a plastic ferrule that provides the ability to house up to 32 fibers in a single connector. This connector stands out because of its compact design and easy operation, but brings disadvantages in optical performance and reliability.

This connector type is of crucial importance because of its increased packing density and ability to migrate to 100 Gigabit Ethernet and above.

030.5782
MPO-QR patch cord

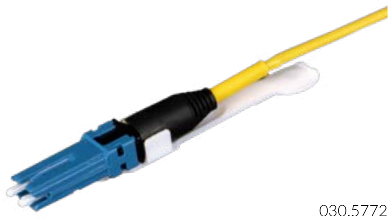
LC Connector (IEC 61754-20)

This connector is part of a new generation of compact connectors. It was developed by Lucent (LC stands for Lucent Connector). Its design is based on a 1.25 mm-diameter ferrule. As a result, it can achieve extremely high packing densities, which makes the connector the most often used one in data centers.

030.5772
Example of an LC connector

CS Connector

The CS connector is a miniature single-position plug which is characterized by two cylindrical, spring-loaded butting ferrules of a 1.25 mm typical diameter, and a push-pull coupling mechanism. The optical alignment mechanism of the connectors is a rigid bore sleeve or a resilient sleeve. It is specifically designed for 200G and 400G applications. Intended to complement the form factor of the next generation of QSFP-DD transceiver modules, the CS connector brings a 36 % reduction in size. The pitch is reduced to 3.8mm from LC standard of 6.25 mm resulting in 1.8 times higher patch panel density.



030.5772
Example of a CS connector

030.6151
Example of CS adapter

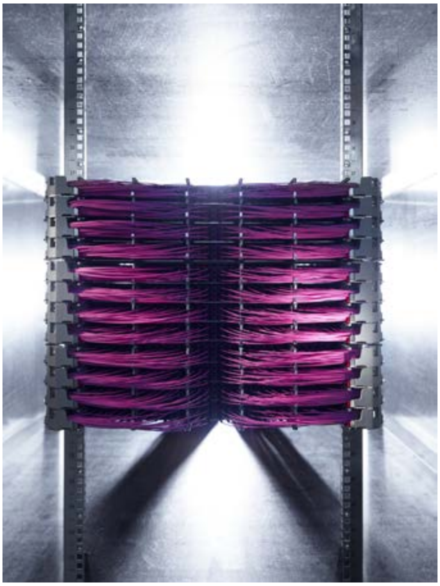
Next-Generation Structures Cabling

Next-Generation Structured Cabling

Generation 40/100 Gigabit Ethernet will continue keeping data centers busy in the coming years. The question arises, how can the infrastructures and components that have already been presented in this handbook be implemented in data centers elegantly and with justifiable expense? This section will show a few promising methods, by presenting the reader with some basic information as an introduction to parallel optic connection technology.

As internal data center traffic will increase by 80 % over the coming three years, there are bound to be bandwidth bottlenecks. To be prepared for the upcoming traffic, network managers are now going to have to support increased bandwidth by implementing fiber optic cables which will facilitate simplified network transformation.

To date there were two ways of migrating network infrastructure to 40 Gbit/s: LC Duplex with singlemode fiber (LR4) or a parallel optical solution with multimode fibers and MPO connectors (SR4). Both variants are expensive and complex. Now there is an attractive alternative with OM5 and SWDM4.
Advances in laser technology and multiplexing got the ball rolling. To date, Wavelength Division Multiplexing (WDM) was reserved for expensive singlemode lasers. In the meantime, multimode VCSELs have also become multiplexing-capable.



090.7602
Netscale 120 with the highest fiber density in the world

In the most recent evolution phase, signals are transmitted on the four short wavelengths 850, 880, 910 and 940 nm (Shortwave Wavelength Division Multiplexing). Therefore, the technology is called SWDM4. The corresponding SWDM4 transceiver modules transmit 10 or 25 Gigabits per wavelength.
This would clear the way for 40 or 100 Gbit/s on a single bidirectional multimode fiber pair. But the four colors move at different speeds through the fibers. With conventional OM3 or OM4 fibers this would result in chromatic dispersion. The new category OM5 will solve this problem. It was detailed and published in TIA-492AAAE and is now standardized as OM5.

OM5 fibers facilitate future standards such as 40GBASE-SR, 100GBASE-SR, 200GBASESR and 400GBASE-SR4 over four fibers. The new category is backward compatible with OM4 and OM3.

Connectivity for Network Fabrics

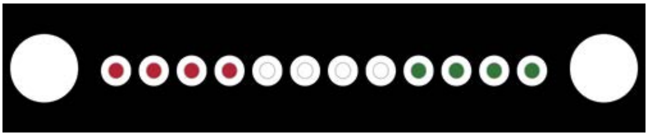
Parallel optical connection technology with OM4, OM5 and even OS2 fibers are paving a way to 40, 100, 200 and 400 Gigabit Ethernet (GbE) in terms of cabling. While generally, data rates of up to 20 0G can already betransmitted via LC connector , most IEEE applicationsrealizing such datarates are based on the multi-fiber MPO connector. This component can contact 8, 12, 24 or 32 fibers in just a tiny amount of space. This connector type is described in greater detail below.

030.5781
MPO connector with 12 glass fibers

The MPO connector (multi-fiber push-on or multi-path push-on) is a multi-fiber connector defined under IEC 61754-7 and TIA/EIA 604-5. Today, MPO connectors with 8, 12 or 24 fibers are generally used in applications.

The connector is provided with a push-pull locking device with a sliding sleeve and two alignment pins allowing the component to be precisely positioned. It is designed for more than 1,000 mating cycles. Contacting can be implemented as PC (physical contact) or APC (angled physical contact).

Eight fibers are required for 40 GbE and 100 GbE. This leaves four contacts unwired, as the following connection diagram shows:



12- fiber MPO connector. Color highlighting shows fibers for sending (red) and receiving (green).

As in any connector, the quality of a connection that uses MPO connectors depends on precision contacting – in this case, however, the same whether the 8-, 12-, 24-, or 32-fiber version is used. Fibers are stuck into a bore hole in the connector body. This hole must be larger than the fiber itself so that the fiber can be inserted. As a result, the fiber always has a certain amount of play in the bore hole.

MPO-QR

With the MPO-QR patch cord, R&M has launched a solution combining maximum packing density with simple handling. The trick: The MPO-QR can be locked and unlocked via the boot. The MPO-QR is designed so it can also be operated on its own at the end of the connector, i.e. at the boot. This is how the MPO adapters can be installed close together. Thanks to the MPO-QR, the packing density increases by 50% to up to 120 ports per height unit. A highly efficient solution. Welcome progress for all those seeking to pack more ports into the rack. The boot is the same color as MPO adapters: gray for polarity B and black for polarity A. Facilitates fast and simple unique identification during installation.

LC-QR

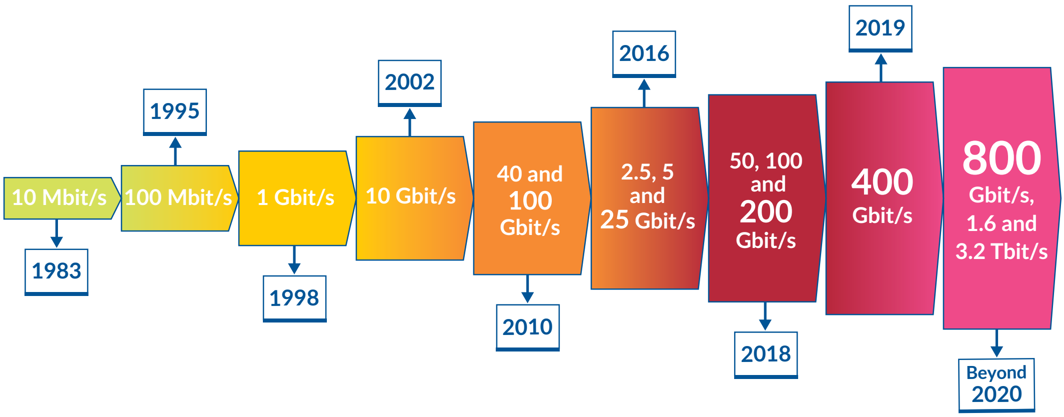
The LC-QR patch cord is R&M's idea of merging the highest packing density with a convenience of handling. The trick: The LCQR can be locked and unlocked via the boot. With LC-QR, the operation functions move to the rear. Now, the LC adapters can snuggle up close together. With LC-QR, packing density increases by 67% to up to 120 connections per rack unit. A highly efficient solution. Welcome progress for all those seeking to pack more ports into the rack. In just a few easy steps, you can even change the wiring polarity, on site without tools. During the change, the connector remains closed and the fibers remain well protected.

To meet the rapid growth of cloud-based storage and computing services, traditional enterprise data centers are evolving and adapting their existing architectures to new, agile, cloud-based designs. These new architectures differ from the traditional three-tier switching topologies, and are resembling hyperscale architectures instead.

Data center designers are using the leaf-spine architecture to achieve an optimized server-to-server comm nication path that can easily grow in connections to further servers. Additionally, such a design also allows to migrate to high data rates as the network grows. The leaf and spine design, often known as data center fabric, enables predictable, scalable communication between any computing and storage device, regardless of its physical location in the data center.

The performance of this network structure is appropriate to establish universal cloud services that allow for any connectivity with predictable capacity and lower latency. The fabric has inherent redundancy, with n merous switches interconnected throughout the data center to ensure better availability of running applications. These meshed network designs can be implemented and scaled much more economical than the traditional, large-scale switching platforms. The design of high-bandwidth connections is more complex as the number of connections and connection speeds both increase. Providing more data center capacity means exceeding the limits of existing media and communications channel technologies. As shown below, the Ethernet Alliance Roadmap shows both existing application standards and predictions for application rates beyond 1 terabit second. This will further challenge the complexity as application speeds move from duplex transmission to parallel transmission. With the onset of new transmission technologies such as shortwave wavelength division multiplexing (SWDM), chromatic dispersion compensating multimode fiber (OM5), bidirectional transmission, and more efficient line coding, a renaissance of the LC connector is expected.

Timeline of data rates



Timeline of Data rates

The combination of SWDM and OM5 paves the way to this renaissance and provides an opportunity to lengthen the use of multimode technology.

Fundamentals of Fiber Assemblies

By way of introduction, we first present all fiber components that are required for network fabrics.

030.6136
Example of an MPO key-up-to-key-down adapters

Connectors

Since MPO connectors generally contact up to 24 fibers in only one connection, it is extremely important that the connection be both stable as well as correctly aligned so it maintains the required transmission parameters. A faulty connection can lead to component damage or even complete link failure. MPO connectors come in both male versions (with pins) and female versions (without pins). These pins guarantee that the fronts of plug connectors match up exactly so that fiber ends do not shift out of place. The catches or guide grooves (keys) located on the top of plug connector units are clearly recognizable, and ensure connectors are correctly aligned when they are inserted in an adapter.

030.6137
Example of an MPO key-up-to-key-up adapters

Adapters

MPO adapters can be divided into two types, depending on how the guide groove (key) is positioned:

Key-up to key-down

The groove lies at the top on one side of the adapter and at the bottom on the other side, so that the two connectors are shifted by 180° toward one another when they are connected.

Key-up to key-down

Both grooves are at the top, so both connectors are in the same position when connected.

030.6139
MPO Connectors female

030.6143
MPO Connectors male

Connection Rules

- Always create an MPO plug connection using one male plug and one female plug, as well as an MPO adapter.
- Never create a male-to-male or female-to-female connection. The fiber cores of the two connectors in a female-to-female connection will not be exactly at the same height, since guide pins are missing. This will result in performance losses. A male-to-male connection experiences even a greater loss in performance, since in this case guide pins bump up against guide pins. Not only does this prevent contacting, but plugs may also be damaged
- Do not disassemble MPO connectors. The pins in an MPO plug can be removed only with great difficulty, and fibers can become broken in the process. Not only that, the warranty becomes invalid when the connector housing is opened!

Cables

MPO cables come pre-assembled when delivered, so careful planning of these components is required. However, this additional effort is outweighed by the technology's clear advantages – shorter installation times, quality that is inspected and guaranteed, and increased reliability.

Trunk Cables/Patch Cables

Trunk cables are used to establish the connection between MPO modules, as a permanent link. These cables are available in fiber counts of 8, 12, 24, 48, 72, 98 and 144, with their ends fitted with either 12-fiber or 24-fiber MPO connectors. MPO patch cords are used only in applications with QSFP+, QSFP28 or CFP-type transceivers. The ends of MPO patch cords are likewise fitted with either 12-fiber or 24-fiber MPO connectors.

Illustration of MPO cables

Harness Cables

Harness cables make it possible for multi-fiber cables to transition to single fibers or duplex connectors. The 12-fiber harness cables provided by R&M, for example, come pre-assembled with MPO-side male or female connectors; fanout legs are available with LC-QR or LC connectors.

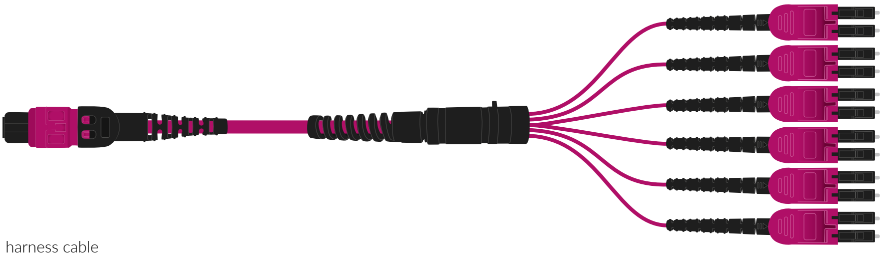
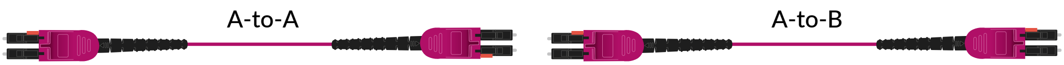


Illustration of a harness cable

LC-QR Patch Cables

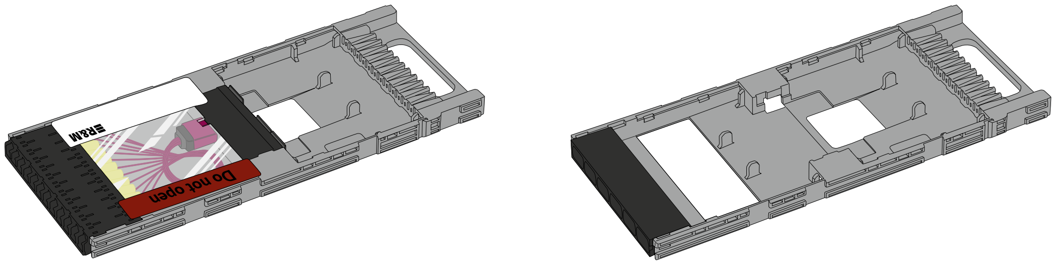
These cables are not MPO cables, just conventional duplex cables. They are available in crossed (A-to-A) and uncrossed (A-to-B) versions, and come pre-assembled with LC-QR or LC connectors.



LC-QR crossed and uncrossed

Modules and Adapter Plates

These devices represent the connection between permanent links and patch cords. The MPO module makes it possible to distribute the fibers supplied by trunk cables to duplex cables. Pre-assembled MPO modules come fitted with 12 or 24 fibers, front-side LC and rear-side MPO.



Illustrations of Netscale modules and casettes

A cassette connects MPO trunk cables with MPO patch cord or harness cables, LC trunks with LC patch cords respectively.

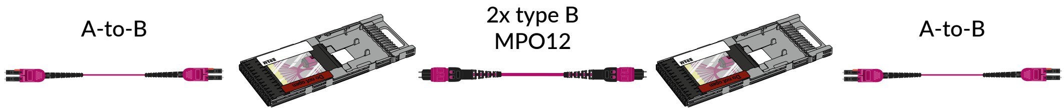
Polarity Methods

While the coding on MPO connectors and adapters are intended to ensure that the connection is always oriented correctly, the polarity method employed by R&M guarantees the bidirectional assignment is correct. This section contains a brief explanation of R&M's patented Type S polarity method.

Method S

Method S (designation defined by R&M) has been available since April 2013. This method requires only one patch cord type (A-to-B). The fiber cross-over for duplex signal transmission (10GBASE-SR, 25GBASE-SR, 40G SWDM, 100G SWDM) takes place in the pre-assembled case.

As the twelve LC ports are divided up by Tx and Rx, all Tx fibers are routed to one 12-fiber MPO and all Rx fibers to the other 12-fiber MPO. These two MPOs can be bundled, for example into one X cable. This makes symmetric cabling for 10G, 25G, 40G, and 100G possible when the method is implemented in combination with Type B trunks. As a result, a direct upgrade can be realized cost-effectively and completely without complication, since cases just need to be replaced with adapter plates

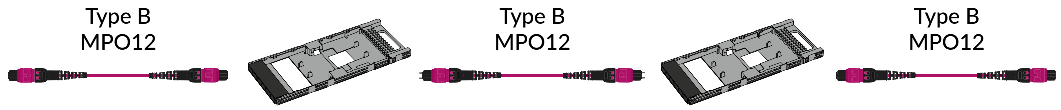


030.6130
Illustration of a link based on Type S moduls before migration

Duplex transmission – MPO trunk cables (Type B, male-male) replace the duplex trunk (center), MPO modules (Type S, female) enable the transition to the existing A-to-B LC duplex patch cords (left, right). Since the Type S module divides Tx and Rx up onto one MPO each, an X cable, or two trunks, is required.

If the next step involves replacing duplex transmission with parallel optics, the next adaptation can be carried out very easily by using MPO cassettes in place of MPO modules. In addition, the polarity method in use must be observed.

Replacement of MPO modules with Type B adapter plates and LC duplex patch cords by MPO patch cords of Type B, female- female (left, right). When this configuration is compared to the TIA-568.C standard, we notice immediately that methods S and B are identical for parallel optical signals. An existing X cable can serve two 40G links in this case as well.



030.6131
Illustration of a parallel-eptical link after migration

Summary

The implementation of MPO components and parallel optical connections translates into new challenges for data center planners and decision makers. Cable lengths must be carefully planned, MPO types correctly selected, polarities maintained over the entire link and insertion loss budgets calculated precisely. Short-term changes are either barely possible or are not possible at all, while errors in planning can be expensive.

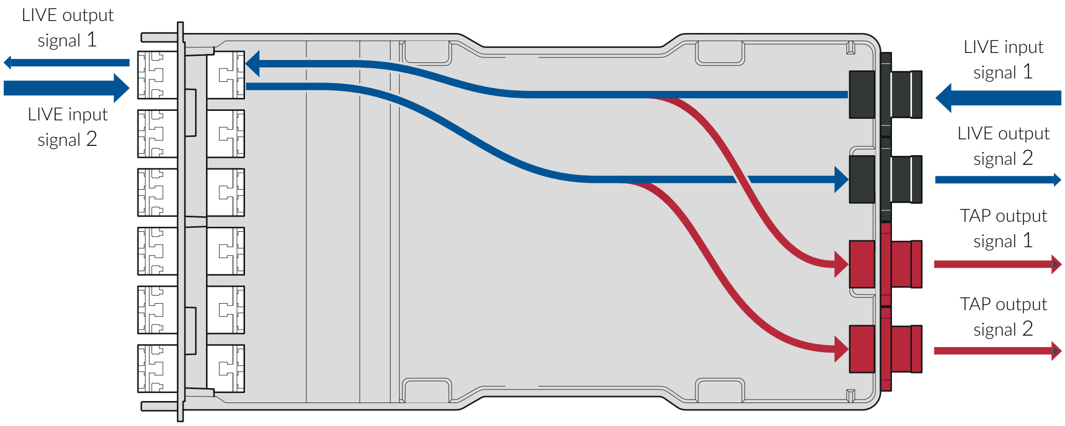
Nevertheless, it is very worthwhile to switch to the new technology, especially since it is already becoming a technological necessity over the medium term. It therefore makes sense to have switch points already placed early on, and to at least adapt passive components to future requirements. The high expense is more than offset by the technology's short installation times, quality that is inspected and documented for every single component, and operational reliability and investment security that will bring peace of mind for years to come.

Real-Time Network Visibility with Optical TAPs

As the cloud and software-defined everything continuously dissolve the concept of individual devices and device management, application traffic and end-user experience becomes more and more difficult to monitor and manage. Data center network managers are challenged with gaining superior visibility of their networks, enhancing application performance, and ensuring integrity of the security system.
To maintain extensive visibility in this environment, traffic access points (TAPs) are the most accurate, reliable and OpEx-saving way to access the data. A TAP is an optical splitter that divides the light transmitted through a fiber optic cable. TAPs can be integrated into the fiber cabling infrastructure to easily and passively monitor a network link without the introduction of latency of packet loss. Once the optical signal is out of band, it can then be analyzed without affecting the live applications.

A TAP is a passive fiber optic splitter to establish an identical copy of the optical signal passing through it. The fiber optic cable with the incoming signal is connected to the splitter input. The split signal is then separated into the live output which is connected to the receiving in-band device, and the monitor output which is connected an out-of-band device. Since a TAP utilizes such splitters in a duplex fashion, a complete copy of all traffic between two devices can be produced.

Figure 1 depicts the signal path schematics of 24-fiber multimode TAP Modules. The MPO connectors on the right side of the illustration provide two connections for serving the live traffic channels via trunk cables, and two MPO connectors (red) serve the TAP channels for connecting to monitoring equipment via MPO trunk or MPO-LC harness cables. The left side of the illustration shows the front surface of the modules providing 12 LC-duplex ports for patching.



Schematics illustration of a TAP module

The integrated splitters are unidirectional components and are arranged in an alternating sequence to allow for duplex transceiver connectivity at the LC ports. As shown in the upper part of the figure, the signal of Tx1 of the LC connectors, which serves only for signal input, is split between Tx1 of the Live MPO and the TAP MPO connectors. Other "Tx-fibers" of the LC connectors follow the same signal flow. The lower part of the figure shows Rx1 of the LC connectors, which receives traffic from Rx1 of the Live MPO port after a portion of its optical signal is split into Rx1 of the TAP MPO connector. Other "Rx-fibers" of the LC connectors follow the same signal flow.

The proportion at which the splitter divides the incoming optical signal between the two outputs is called "split ratio", and can vary anywhere between 10/90 and 90/10. R&M's standard TAPs use a 50/50 ratio, meaning that 50% of the incoming light goes to the live port and 50% to the TAP port. Clearly, a split ratio of 50/50 represents a loss of 3dB. With these additional losses, the overall fiber budget needs to be carefully assessed.

Besides the losses associated with the division of the optical signal, the splitter introduces no latency or other alteration of the signal. Its performance prevails whether monitoring equipment is connected to the TAP port, so that one can "deploy and forget" these TAP Modules.

Notes

Headquarters

SWITZERLAND
Reichle & De-Massari AG

www.rdm.com
Please choose your country on our global website

Europe

AUSTRIA
Reichle & De-Massari Austria GmbH

BELGIUM
Reichle & De-Massari Benelux Sales Office

BULGARIA
Reichle & De-Massari EOOD

CZECH REPUBLIC
Reichle & De-Massari Czech Republic a.s.

FRANCE
Reichle & De-Massari France Sàrl

GERMANY
Reichle & De-Massari GmbH

HUNGARY
Reichle & De-Massari (Mo.) Kft

ITALY
Reichle & De-Massari Italia Srl

NETHERLANDS
Reichle & De-Massari Netherlands B.V.

NORDICS
Reichle & De-Massari Nordics Sales Office

POLAND
Reichle & De-Massari Polska Sp. z o.o.

PORTUGAL
Reichle & De-Massari Portugal Sales Office

ROMANIA
Reichle & De-Massari Romania Sales Office

RUSSIAN FEDERATION
Reichle & De-Massari Russia Sales Office

SERBIA
Reichle & De-Massari Serbia Sales Office

SLOVAKIA
Reichle & De-Massari Slovakia Sales Office

SLOVENIA
Reichle & De-Massari Slovenia Sales Office

SPAIN
Reichle & De-Massari Iberia SL

SWITZERLAND
Reichle & De-Massari AG, Sales Office

UNITED KINGDOM
Reichle & De-Massari (UK) Ltd

North America

UNITED STATES
R&M USA Inc.

Latin America

BRASIL
Reichle & De-Massari Brasil Ltda

COLOMBIA
Reichle & De-Massari Colombia Sales Office

Asia Pacific

AUSTRALIA & NEW ZEALAND
Reichle & De-Massari Australia Pty Ltd

GREATER CHINA GROUP
Reichle & De-Massari China Co. Ltd.

INDIA
R&M India Pvt Ltd

INDONESIA
Reichle & De-Massari Indonesia Sales Office

JAPAN
R&M Japan K.K.

MALAYSIA
Reichle & De-Massari Malaysia Sales Office

PHILIPPINES
Reichle & De-Massari Philippines Sales Office

SINGAPORE
Reichle & De-Massari Far East (Pte) Ltd

THAILAND
Reichle & De-Massari Thailand Sales Office

Middle East, Turkey & Africa

EGYPT
Reichle & De-Massari Egypt Sales Office

JORDAN
Reichle & De-Massari Jordan Sales Office

KENYA
Reichle & De-Massari Kenya Sales Office

KUWAIT
Reichle & De-Massari Kuwait Sales Office

MOROCCO
Reichle & De-Massari Maroc Sàrl

OMAN
Reichle & De-Massari Oman Sales Office

QATAR
Reichle & De-Massari Qatar Sales Office

SAUDI ARABIA
Reichle & De-Massari Saudi Arabia Ltd

TURKEY
Reichle & De-Massari Elektronik Sanayi
VE Ticaret Ltd Sirketi

UNITED ARAB EMIRATES
Reichle & De-Massari MEA FZE

H_Data-Center_Handbook_01.20_EN_HQ

We are represented by more than 100 qualified partners worldwide.
Find your local partner at: www.rdm.com