All-optical switching for data centers

Fundamentals and applications

White Paper

HUBER+SUHNER

Bring software-controlled all-optical switching in data centers

Your data center needs to be streamlined, automated and reliable. With all-optical (OOO) switching solutions in your data center, you will benefit by efficiently automating complex connections remotely while reducing MACs and providing maximised uptime.

And this is why:

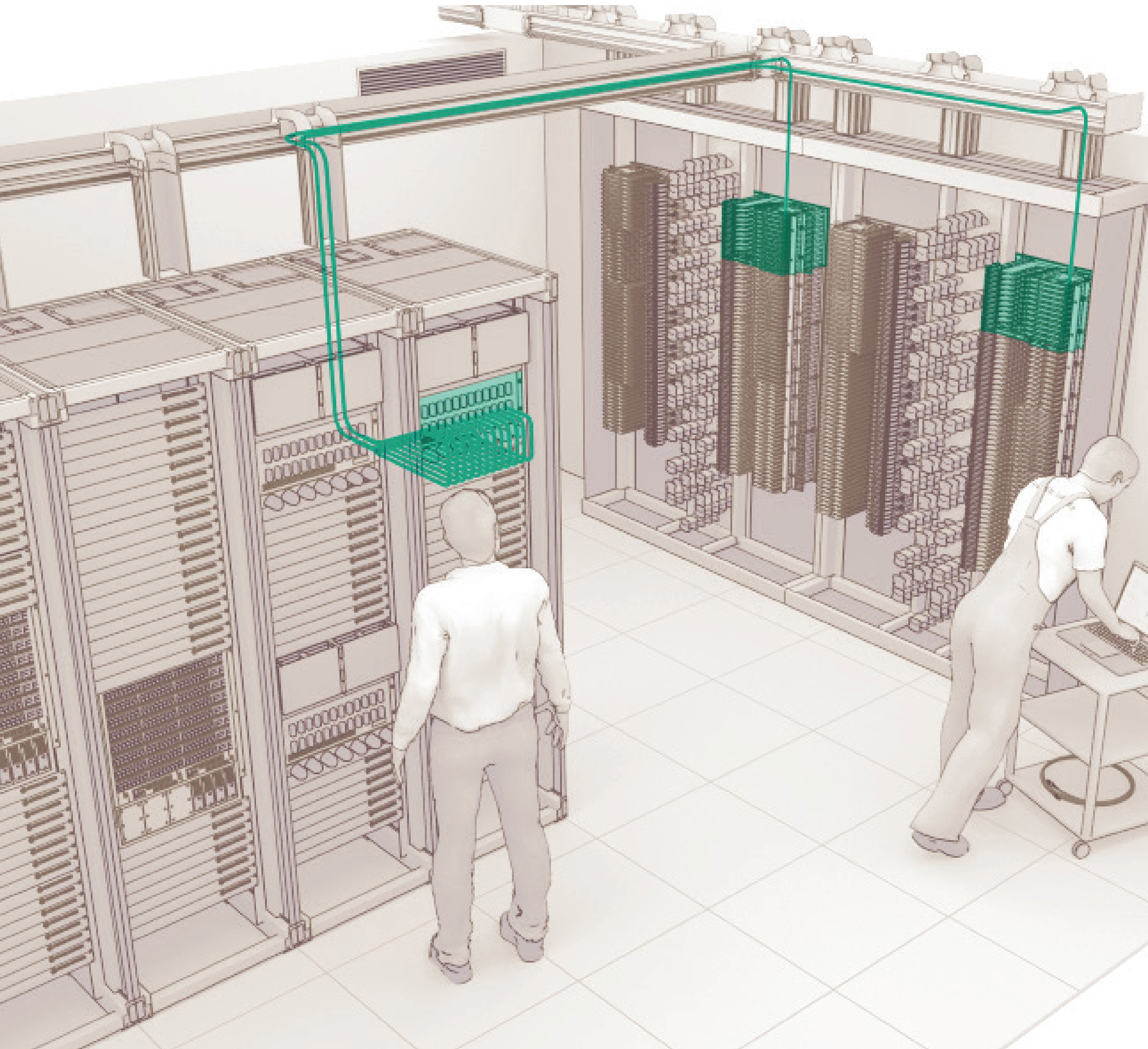
- **Automate complex connections efficiently with software-defined networking (SDN)**
- **Reroute traffic remotely to maintain service levels**
- **Provide rapid service provisioning**
- **Enable network traffic surveillance and monitoring capability**
- **Ensure service quality and reliability with minimal signal loss**
- **Eliminate human error in manual moves, adds and changes (MACs)**
- **Monitor degradation or loss of signal**
- **Provide fast service expansion with scalable solutions**

Content

Introduction

The “new normal” for data centers

Data centers are experiencing explosive traffic growth driven by the rise in mobile, video, cloud computing, and other cloud-based virtual services.



Over recent years data centers have been experiencing explosive traffic growth, driven by cloud computing, big data applications, entertainment streaming and interactive gaming. A new generation of data-intensive applications such as autonomous vehicles, many enabled by 5G and emerging 6G mobile technologies, are expected to be significant drivers for further traffic growth.

A leading equipment supplier estimates that overall mobile traffic will grow at an annual rate of around 55% over the period from 2020 to 2030 to reach over 600 exabytes in 2025 and over 5000 exabytes by 2030.

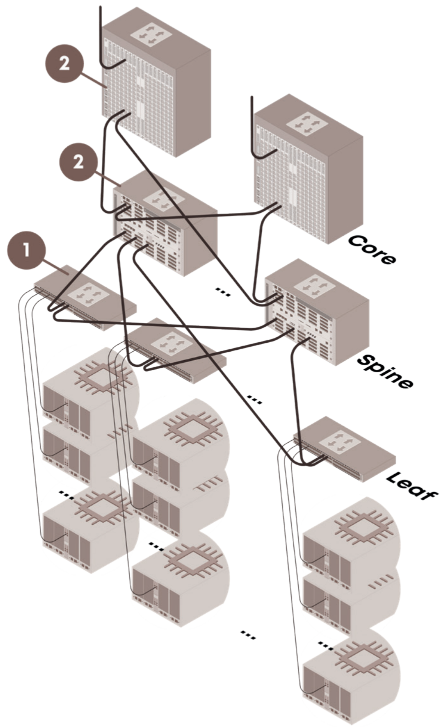
The COVID-19 pandemic has served to accelerate these growth trends simply because of people working from home and remote schooling. Network providers were able to handle the initial bandwidth increase demands after lockdowns went into effect by quickly provisioning excess capacity and in some cases decreasing streaming bandwidth for popular services. They then immediately started work to further ramp up capacity and have invested in automating and enabling remote operation of data centers, in part to protect the working conditions of their existing staff during the pandemic and in part to enable scaling up of provisioning without adding headcount. Far from being a temporary effect, increased demand for bandwidth is expected to persist even after the pandemic subsides as working from home becomes part of the "new normal".

OEO and OOO switching

Data center network architecture

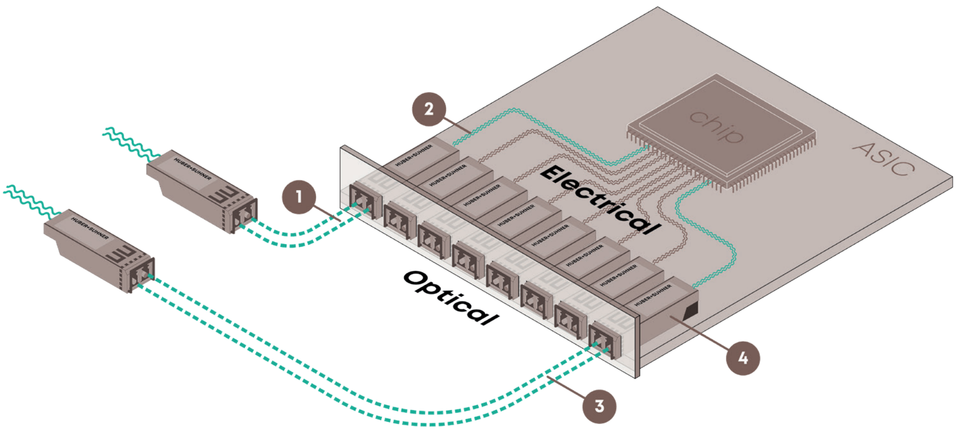
Current data center architectures have difficulties scaling to meet the expected increased traffic demands required by the proliferation of bandwidth-hungry cloud virtual applications. Operators need both more capacity and more network flexibility to allocate resources dynamically when and where they are needed most.

In data centers today, signals are typically transported optically but switched electrically, requiring numerous "optical to electrical to optical" (OEO) conversions. Transport is done with static point-to-point optical links, while switching is done electronically using OEO **switches** (1) and **routers** (2).



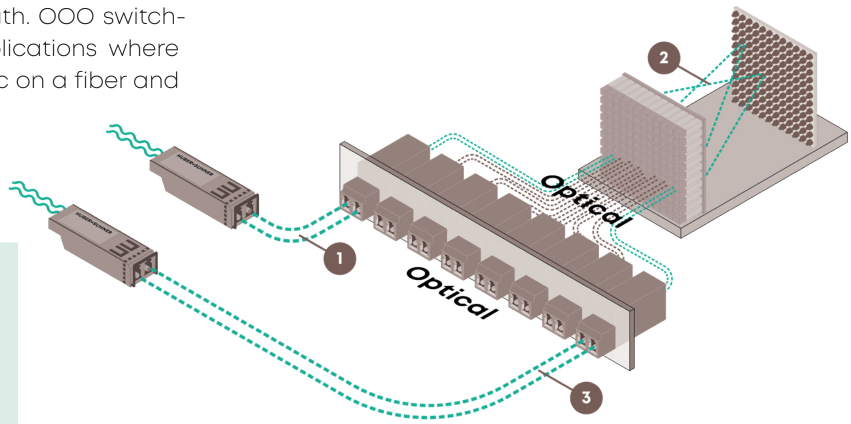
Optical to electrical to optical (OEO) packet circuit switches

OEO packet switches route individual data packets from input ports to output ports and OEO circuit switches route connection-oriented data streams from input to output connections. Both require conversion of the **optical signal** (1) to an **electrical signal** (2). The electrical signal is then regenerated and switched electrically before being converted back to an **optical signal** (3) for onward transmission. The electrical regeneration and retiming process refreshes the optical signal removing most of the optical transmission impairments of the input optical link, but adds significant amounts of signal latency. OEO switching is ideal for switching groomed packet or circuit traffic or when optical signals need to be regenerated. OEO technology is not considered future proof as the **transponders** (4) are tied to specific traffic formats and data rates and need to be replaced when the line transmission rates increase or change over time.



All-optical (OOO) switches

An all-optical, or "optical to optical to optical" (OOO), fiber optic switch maintains the signal as light from input to output. It takes a signal via an **optical input (1)**, passes it through an optical **switching core (2)**, and out via an **optical output (3)**, switching all the data on the fiber with no intermediate conversion into an electrical signal. Since OOO switches do not buffer or regenerate the optical signals, they have extremely low data latency compared to OEO switches. OOO switches are virtually transparent except for a small amount of optical loss* and can switch signals regardless of the signal format, bit rate or wavelength. OOO switches are ideal for circuit switching applications where operators want to redirect all the traffic on a fiber and for any application requiring low latency. OOO technology is future proof as it does not need to be upgraded or replaced as signal formats change and bit rates increase over time. A distinct advantage of OOO switching, unique to HUBER+SUHNER, is the patented POLATIS® DirectLight™ beam-steering technology*. Unlike other OOO switches, the POLATIS® switching occurs completely independent of power level, color or direction of light on the path. That enables pre-provisioning of dark fibers and bidirectional transmission.

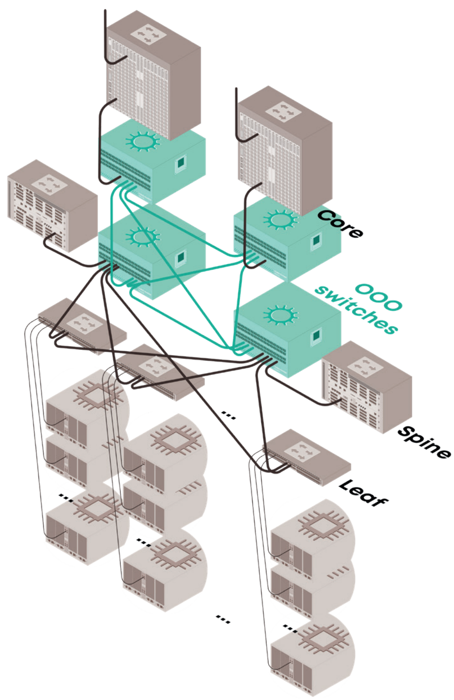


Please note

* POLATIS® DirectLight™ OOO switch technology has from 0.5 to 1.5dB typical optical loss depending on the switch matrix size.

Hybrid OOO and OEO networks

OOO switching will not replace OEO switching. Data center operators need to combine the strengths of each technology to build more flexible, dynamic, low-loss data center networks that can cost-effectively scale to meet future traffic growth requirements.

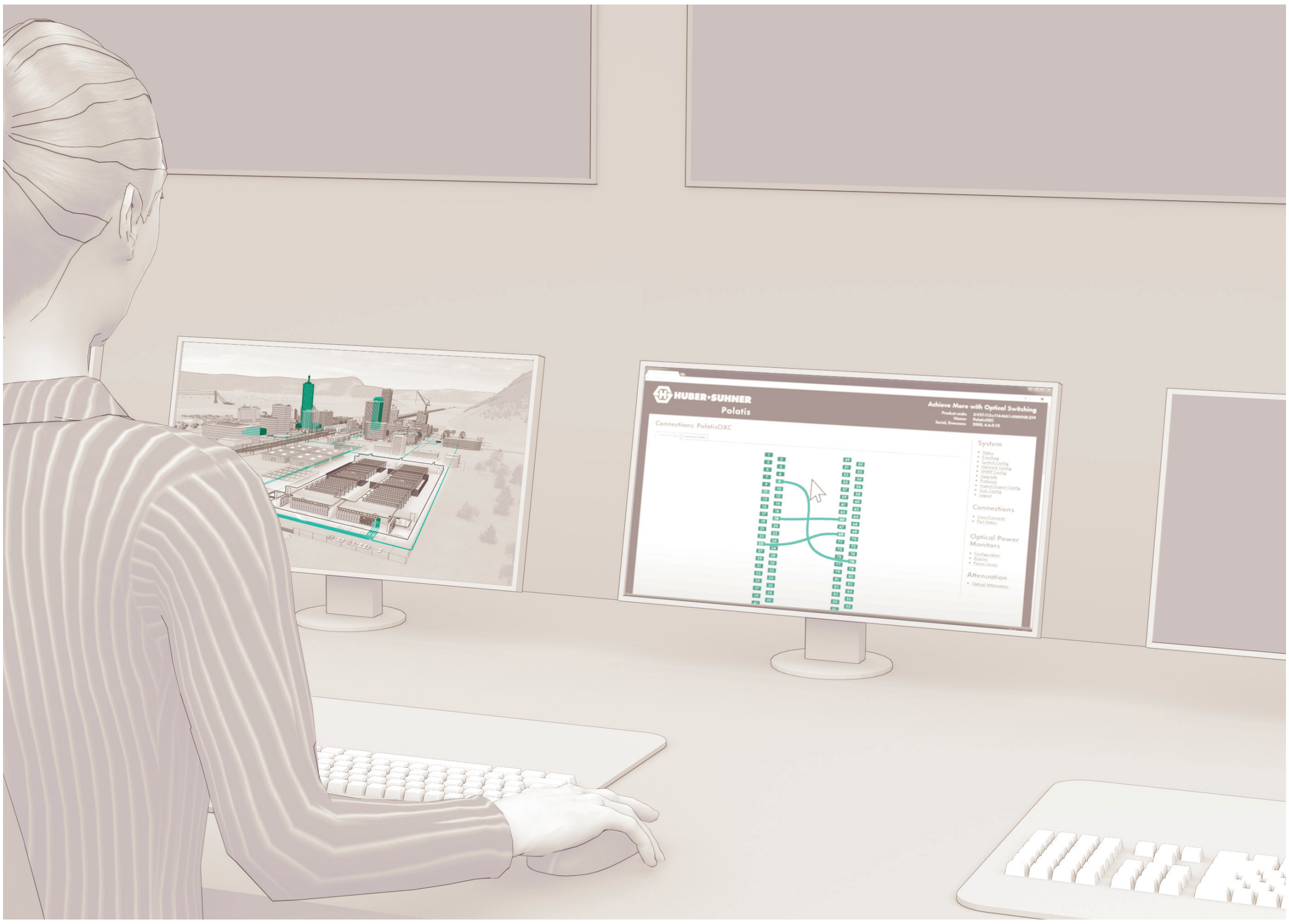


Maximising investment and efficiency

Reducing total cost of ownership (TCO)

An OEO switch can use many transceivers and other electronic components that take up additional space, consume more power and generate more heat that must be dissipated. With the environmental impact of data centers under increasing scrutiny, there are significant benefits to adopting a lower power switching technology such as OOO switching wherever possible.

OEO switches also have a higher cost per port than OOO switches so they are not the most efficient or cost-effective way to switch large amounts of traffic from one fiber to another. OEO switches are best used for packet switching and traffic grooming while OOO switches are the most cost effective for switching large amounts of high bit-rate traffic between fibers and for low latency applications.



Software Defined Networking (SDN)

With the explosion of cloud computing to support internet services and mobile computing, a modern data center network needs to cope with the demands of a multitude of applications with multiple clients or devices requiring access to many databases and servers. To accommodate this shift, network management and control has been dissociated from the physical hardware layer giving rise to the growth of Software Defined Networking (SDN).

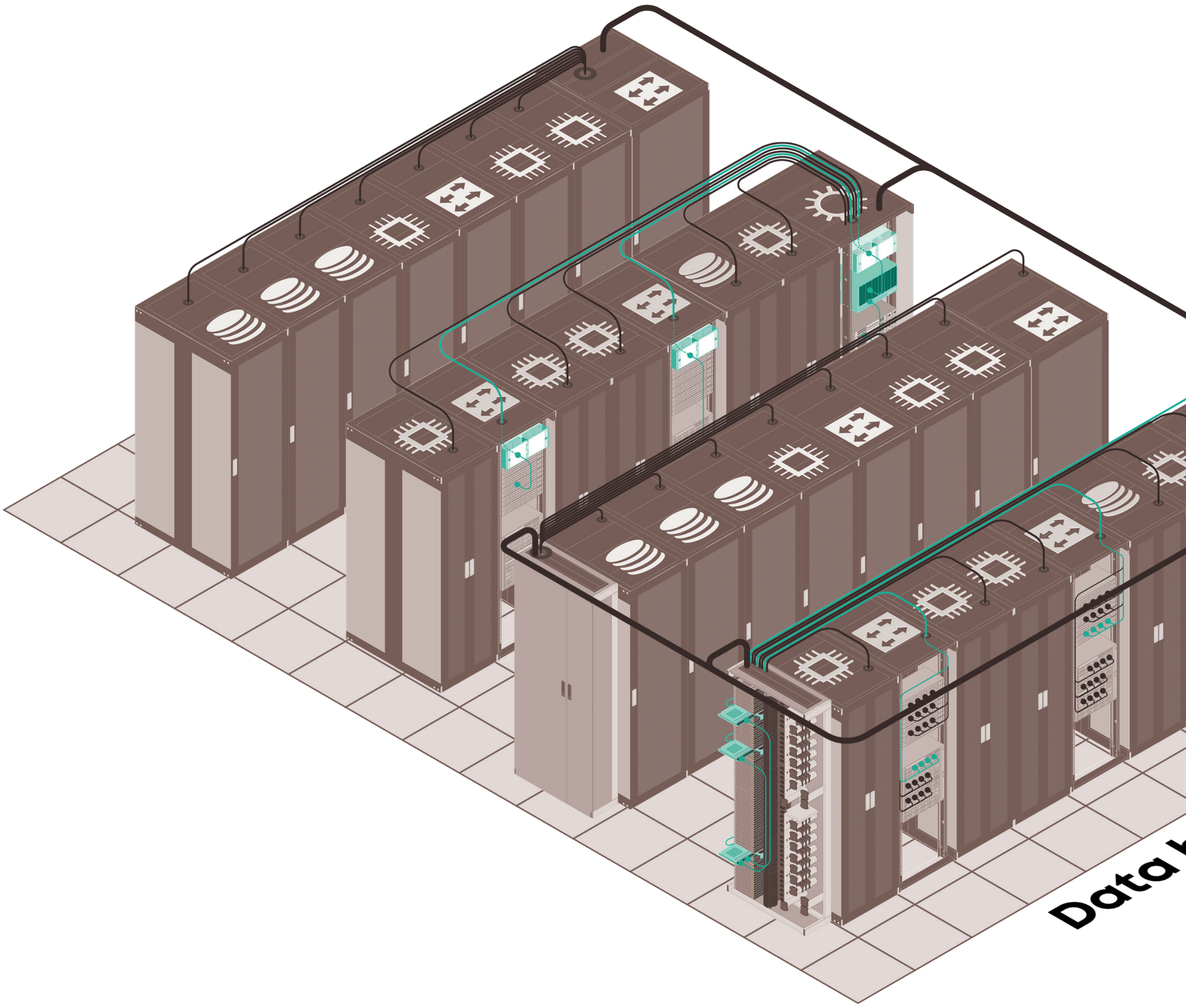
SDN is an approach to network management that enables dynamic, efficient network configuration to improve network performance and monitoring, making it more like cloud computing than traditional network management. With SDN, control of the network is centralized, giving operators the flexibility to manage network performance, adjust traffic flow across the network to bypass failure points, accommodate increased demand, optimize resources and maintain network security.

Operators are searching for bandwidth-on-demand capabilities that allow them to direct network capacity where and when it is needed. With SDN, operators can simply add physical capacity in the form of new switches and servers and bring them under the same centralized control. The ability to scale their network architecture enables operators to respond rapidly to increased demand for service provisioning. The advent of SDN enables data center operators to take advantage of the enormous benefits of OOO switching to provision or level-load traffic flows in real-time and react quickly to fiber and equipment outages.

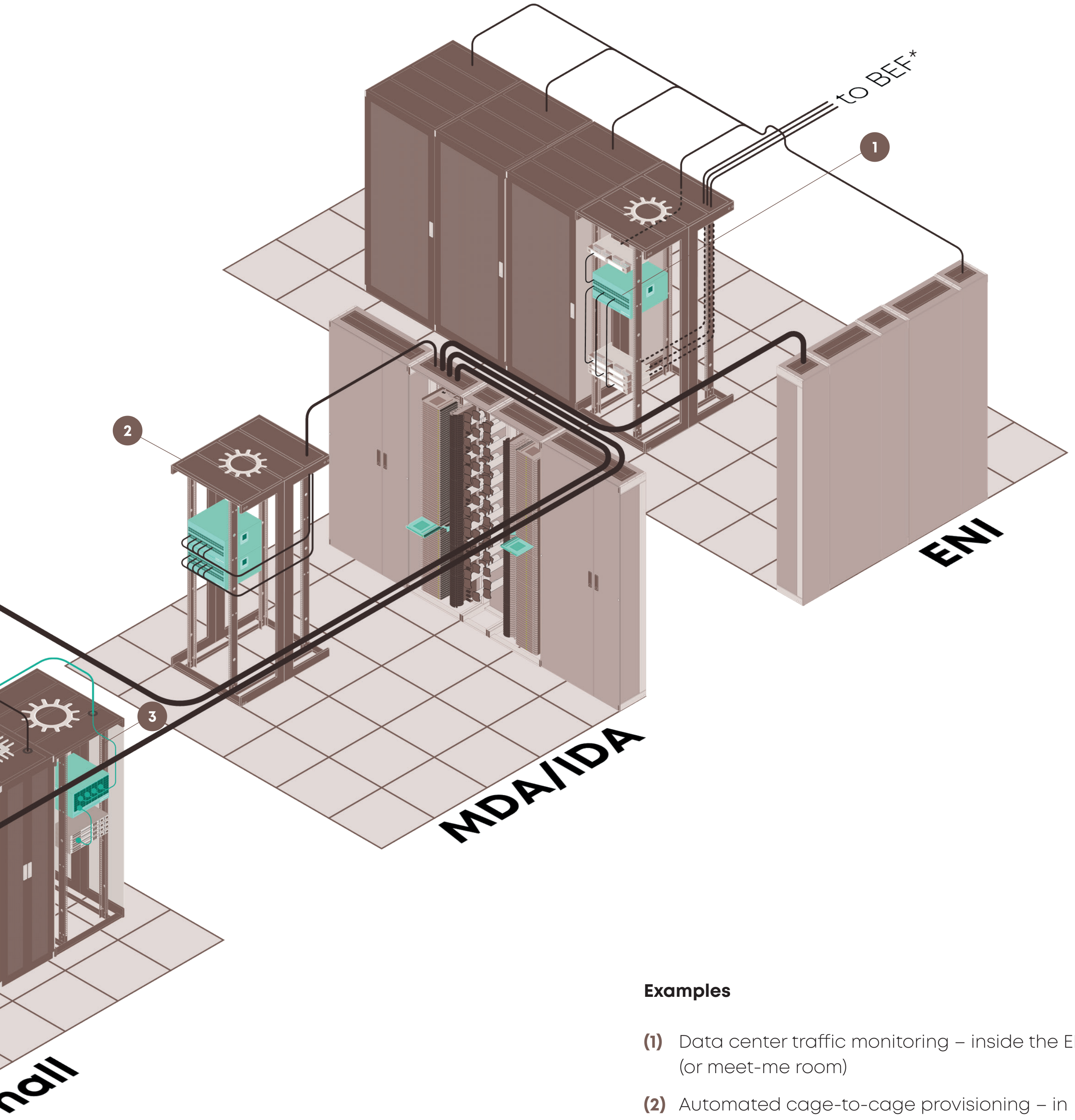
Example
OOO switch: HUBER+SUHNER POLATIS® Series 7000 384×384

Use cases

OOO switches can be used in all areas of the data center – starting from the data halls for automated provisioning and then in the main or intermediate distribution areas (MDA/IDA) where cables from customer cages are coming for data center interconnection (DCI) and protection switching. Also in the external network interfaces (ENI) room (or meet-me room) where switches play an important role in various data center interconnect scenarios.



* BEF – building entrance facility



Examples

(1) Data center traffic monitoring – inside the ENI (or meet-me room)

(2) Automated cage-to-cage provisioning – in the MDA/IDA and inside the customer cages in the data hall

(3) Automated fiber testing and protection switching – in the MDA/IDA and inside the customer cages in the data hall

With the continued growth of data centers we will see more applications for OOO switching.

Data center traffic monitoring

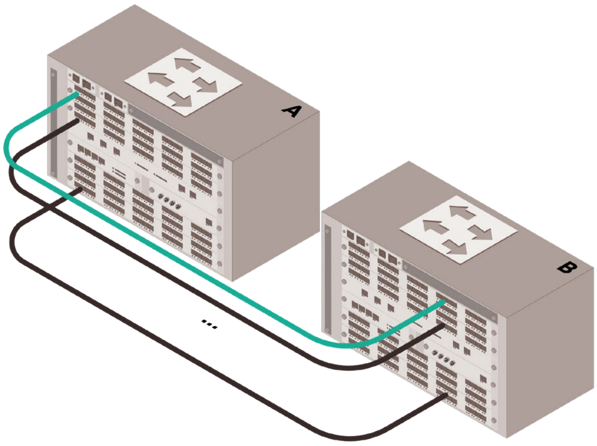
Network monitoring and cybersecurity

Maintaining high-performing digital services across distributed hybrid cloud environments is a significant challenge for data center operators. Traffic monitoring has become even more critical for data centers globally in response to the twin challenges of increased traffic flows, triggered by the COVID-19 pandemic, and widening cybersecurity breaches. Today's operators need more visibility into what is happening across the data center infrastructure to support new types of access as well as find and eliminate threats. Monitoring is also an integral part of network operators' performance and availability strategies.

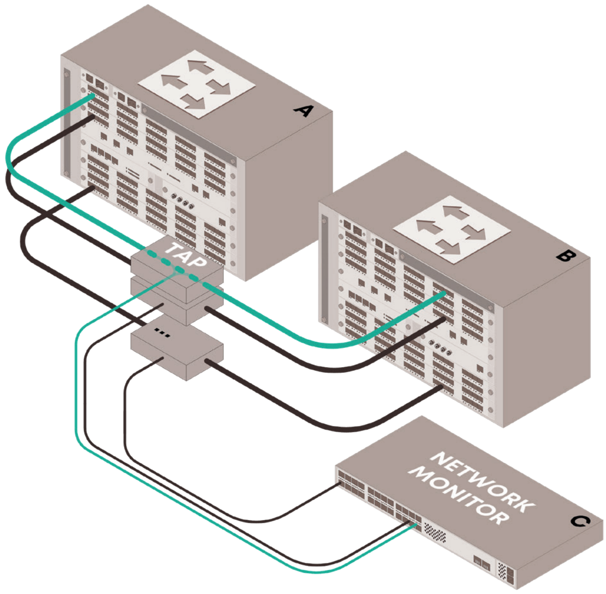
Commercially available network monitoring and cybersecurity products and services are available from a wide range of vendors. Combining OOO switching with these tools enables operators to remotely deploy and share these expensive monitoring tools across hundreds or thousands of traffic lines. Monitoring access to the fibers is provided by inline optical taps installed on the traffic fibers.

Combining OOO switching with commercially available network monitoring and cybersecurity products enables operators to remotely deploy these tools wherever and whenever they are needed without manual intervention. OOO switching can be used to interconnect hundreds or thousands of traffic lines to a small amount of expensive monitoring equipment and the system can be programmed to automatically cycle through those lines. The combination of OOO switching and cybersecurity tools creates an automated, mass cybersurveillance solution that provides unprecedented network visibility in the battle against cyber threats of all kinds.

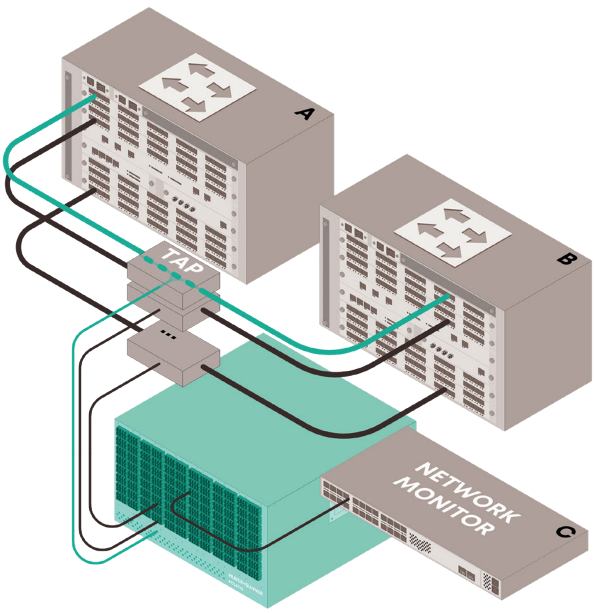
Monitoring deployment scenarios



Link with no monitoring
Traffic line A to B.



Link monitoring via TAP
TAP module added to each A to B link. Tapped signal connected to the monitor C. It serves only pre-selected A to B links and requires physical re-patching to monitor other links.



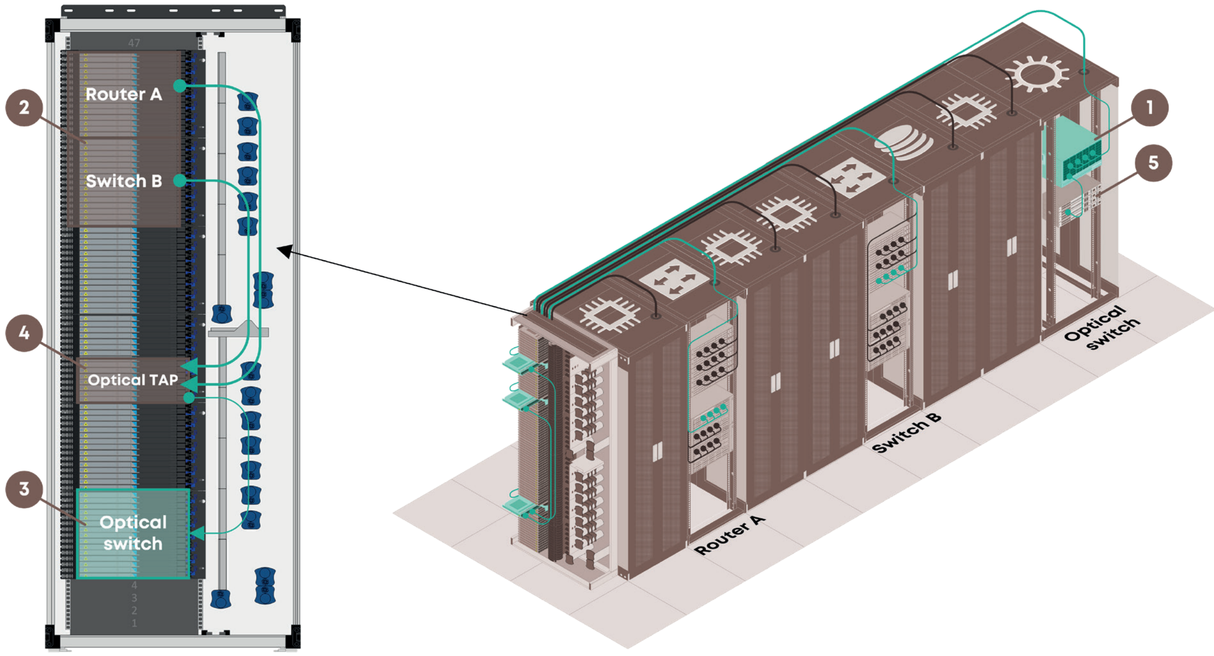
Monitoring via TAP and OOO switch
One monitor can serve multiple links. Operator can choose which link to connect to the monitor.

Data center traffic monitoring

Data center traffic monitoring via cross-connect cabling

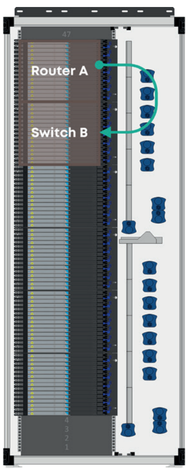
An OOO switch can easily be integrated into the fiber optic structured cabling. In the best case cross-connect deployment scenario, the **OOO switch (1)** is replicated onto the optical distribution frame (ODF). Desired **A to B links (2)** are cross-connected with the **replica (3)** of the switch via the **optical TAP (4)**.

The **monitor (5)** is mounted in the cabinet below the OOO switch and directly connected to the output ports of switch. The advantages of this approach are ODF capacity savings, clear cabling structure and flexibility in adding more links.

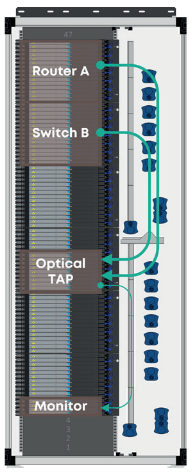


Example of ODF configuration

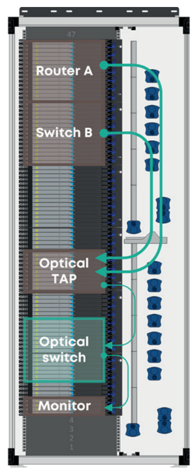
Other deployment scenarios via ODF



Initial setup without monitoring



Monitoring added, no OOO switch

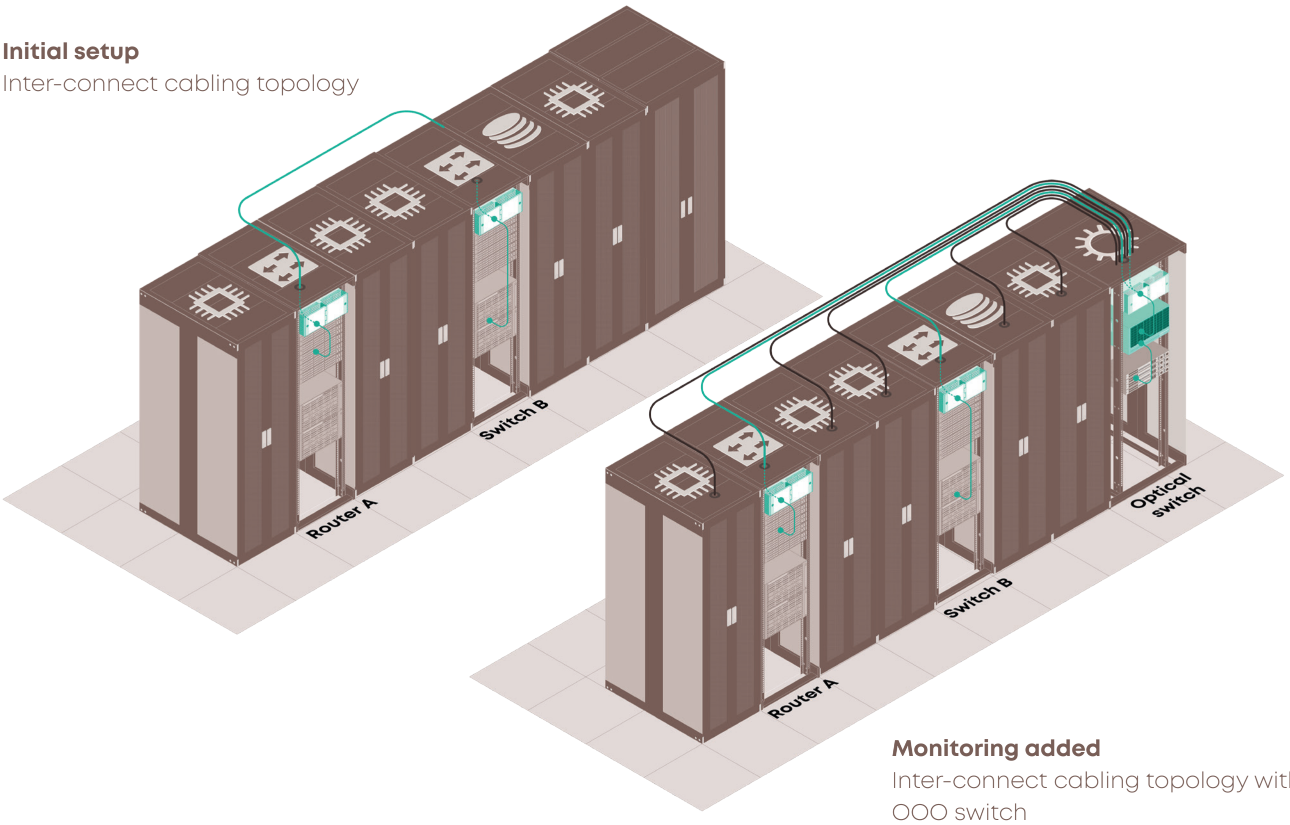


Monitoring via external TAP and OOO switch

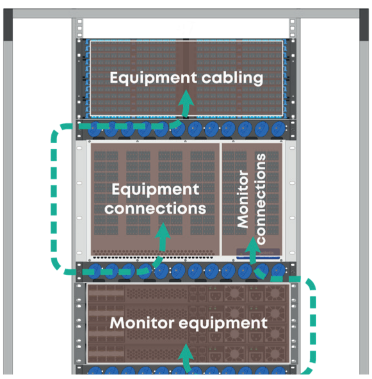
Data center traffic monitoring via inter-connect cabling

In the case of inter-connect cabling topology, the monitoring integration will require a dedicated separate cabinet where the OOO switch, monitors and fiber patch panels will be installed. The cabling will be re-organized in a way that the links will be connected with the new cabinet. All monitored ports will be connected via the OOO switch as shown on front view **drawings 1 and 2**. The advantage of this approach is that optical loss and CAPEX are lower (since there is no extra ODF), however the overall flexibility and simplicity of the deployment are lower.

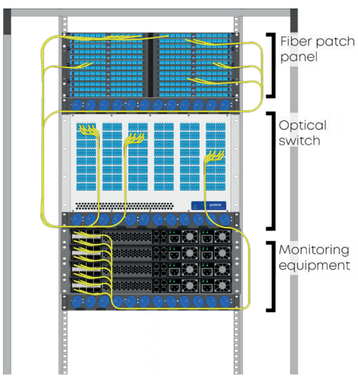
Initial setup
Inter-connect cabling topology



Monitoring added
Inter-connect cabling topology with OOO switch



Drawing 1
Inter-connect zone cabling architecture – installation example



Drawing 2
Inter-connect zone cabling architecture – logical connections

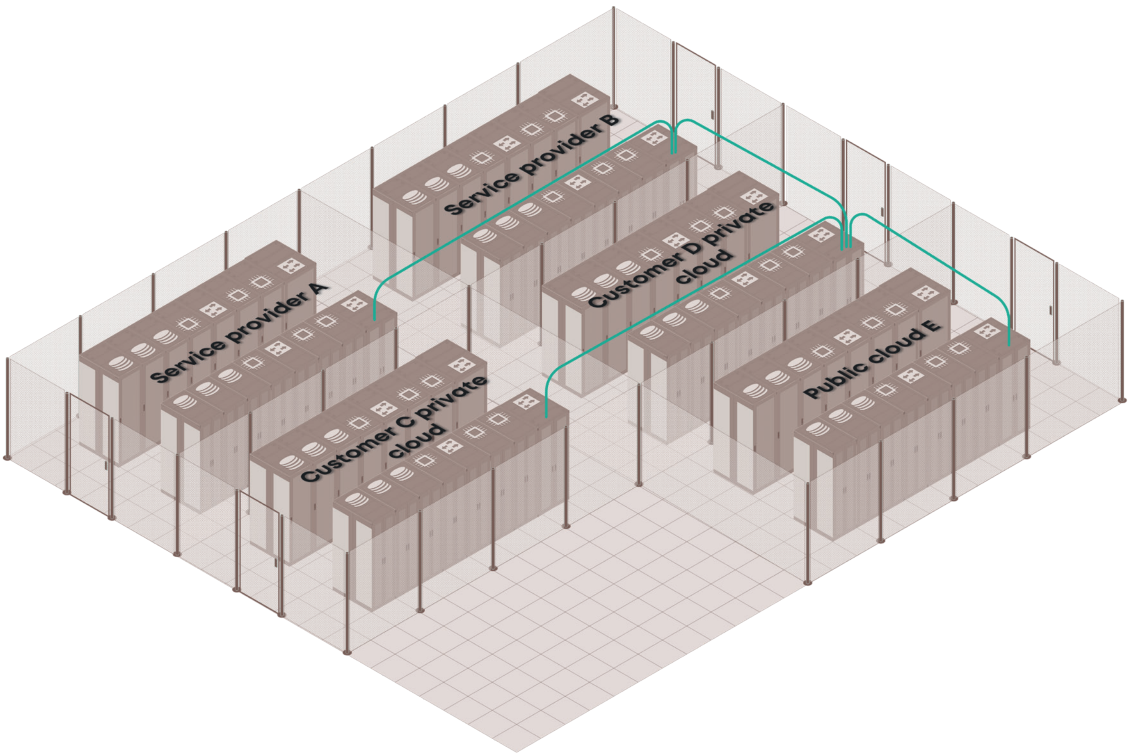
Cage-to-cage provisioning

Cage-to-cage point-to-point links

With the growth in internet traffic and services, colocation data center operators need to provide dynamic on-demand interconnection between their clients.

Operators typically deploy point-to-point fibers manually between the cages to provide these interconnections and increased bandwidth between customer server cages. These can take days or even weeks to engineer and deploy and are often abandoned and left in the trays after the connectivity is no longer needed.

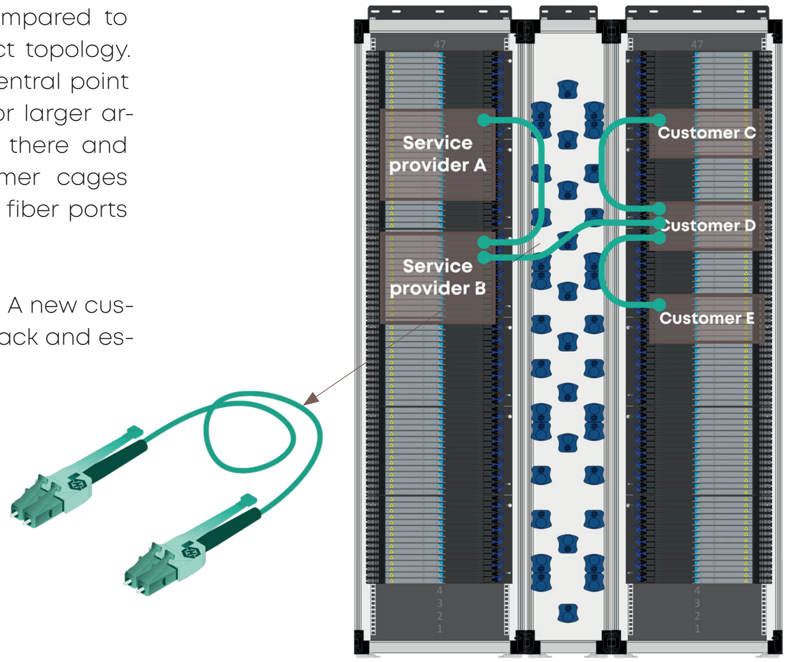
Repeating the cycle over and over soon leads to fiber tray exhaustion when there is no more room to add new fibers. Fiber tray exhaustion greatly complicates the cage-to-cage interconnection and can make it difficult or impossible to interconnect some areas of the data center.



Cage-to-cage through cross-connect structured cabling

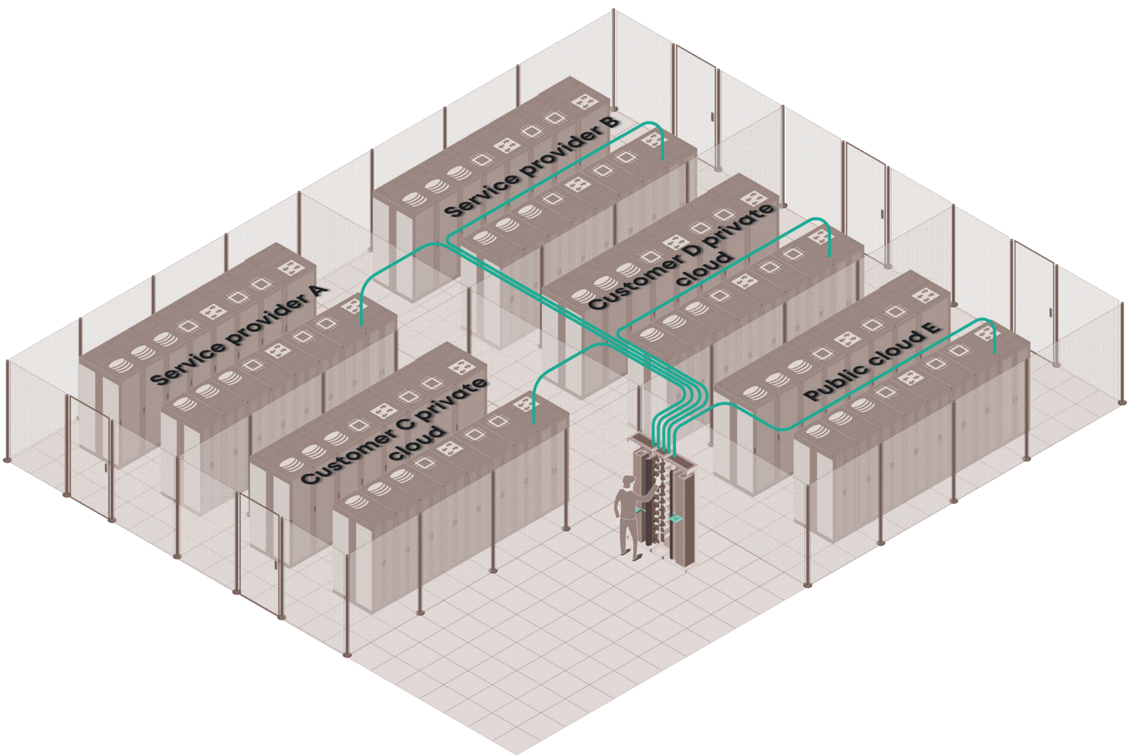
One way to achieve greater flexibility compared to point-to-point cabling is the cross-connect topology. In the cross-connect topology there is a central point which consolidates cabling from smaller or larger areas. Every customer's cage is connected there and desired interconnections between customer cages are achieved by cross-connecting various fiber ports inside the central distributor.

Fibers can be re-used if a customer leaves. A new customer can re-use the cable to the central rack and establish new connections to other tenants.



Please note

Required connections are achieved by cross-connecting different ports with patch cords inside the ODF.



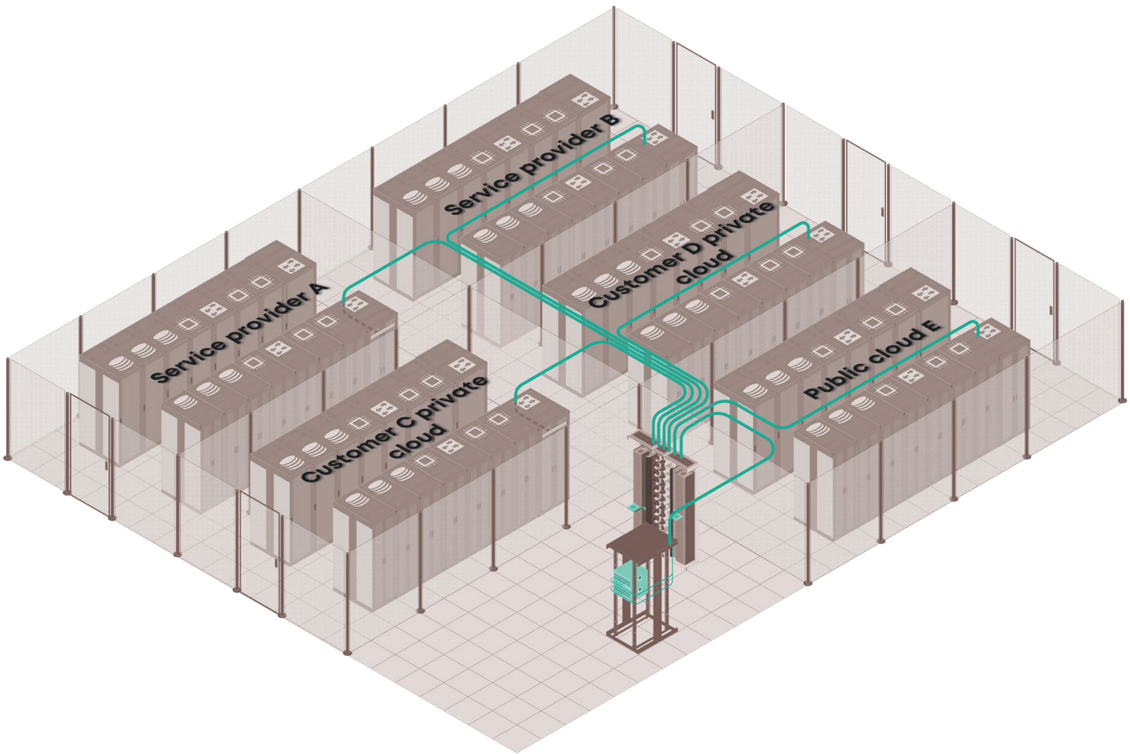
Cage-to-cage provisioning

Automated cage-to-cage provisioning

Cross-connects and cage-to-cage provisioning can be automated by using OOO switching. It enables operators to rapidly deploy bandwidth between customer server cages that are physically spread out within a large data center or across a group of closely located data centers.

Automated cage interconnection can be made with a distributed OOO switch architecture that places **small OOO switches (1)** in the customer cages and remote **center-stage switches (2)** colocated in a central location.

The overall switching matrix can be partitioned to provide a fixed bandwidth between cages or locations to simplify the interconnection and lower overall costs. Furthermore, using fiber trunks to interconnect center and edge switches can reduce the fiber tray space use by up to 90% compared to running individual fibers.

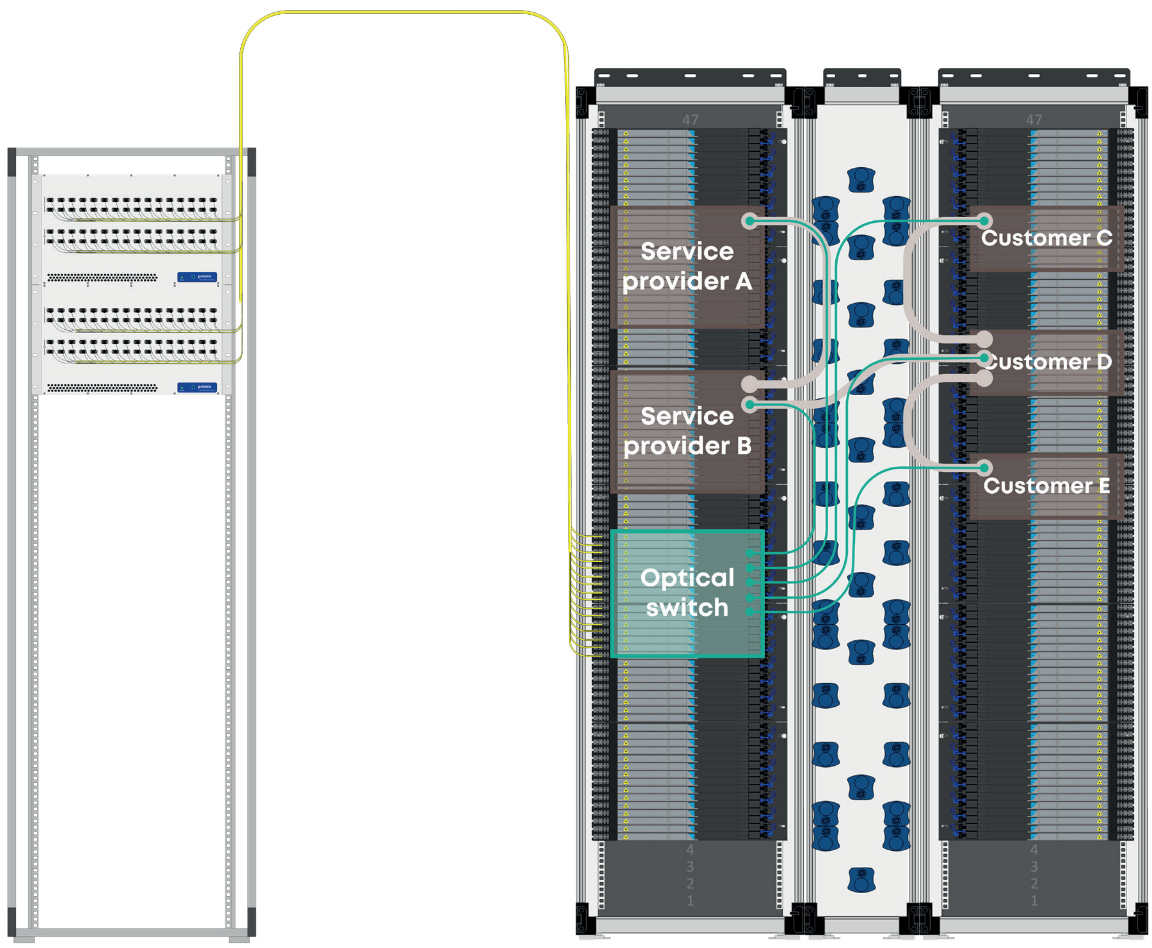


Cabling up the switch

The central optical switch can be located in any free space in the data center. Since the cabling is done via a distributor and all changes in the physical cabling are done with patch cords in the distributor, it can be beneficial to deploy OOO switches with MTP/MPO connectors. The reduced switch size leaves rack space for an additional switch or other equipment to be installed.

After replicating the OOO switch ports on the ODF, some ports from cables coming from customer cages are cross-connected to the OOO switch, thereby access to automated cage-to-cage provisioning is established.

Example
Space-saving solution for cross-connect cabling topologies: HUBER+SUHNER POLATIS® Series 7000 384×384.



Applications

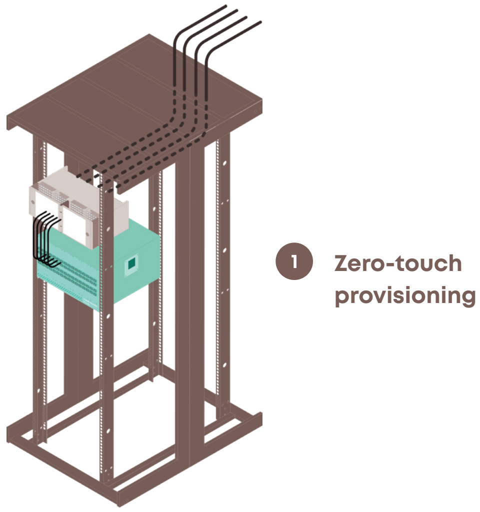
Data center interconnect (DCI)

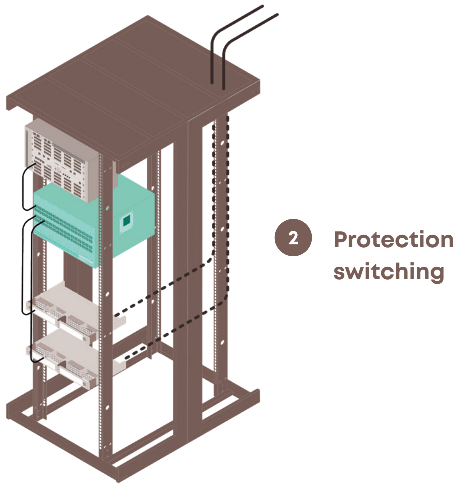
DCI scenarios

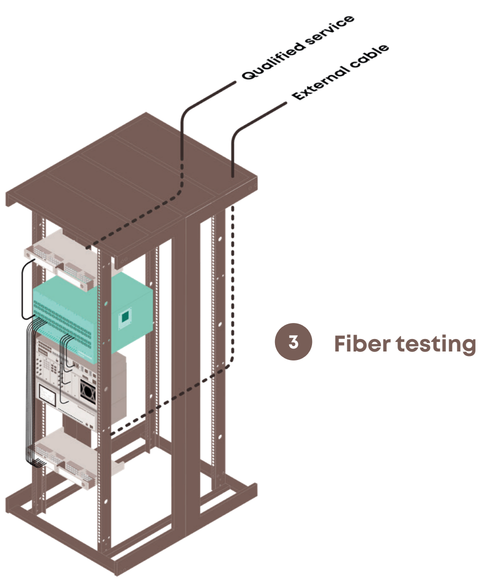
The connections between data centers, whether on the same campus, in the same town, or distributed globally, are essential for providing cloud-based services. It is a broad concept that comprises connecting solutions across different layers of the network. To meet the insatiable demand for bandwidth, video data and cloud-based services, Data Center Interconnect (DCI) has evolved to enable ultra-high capacity and massive scalability.

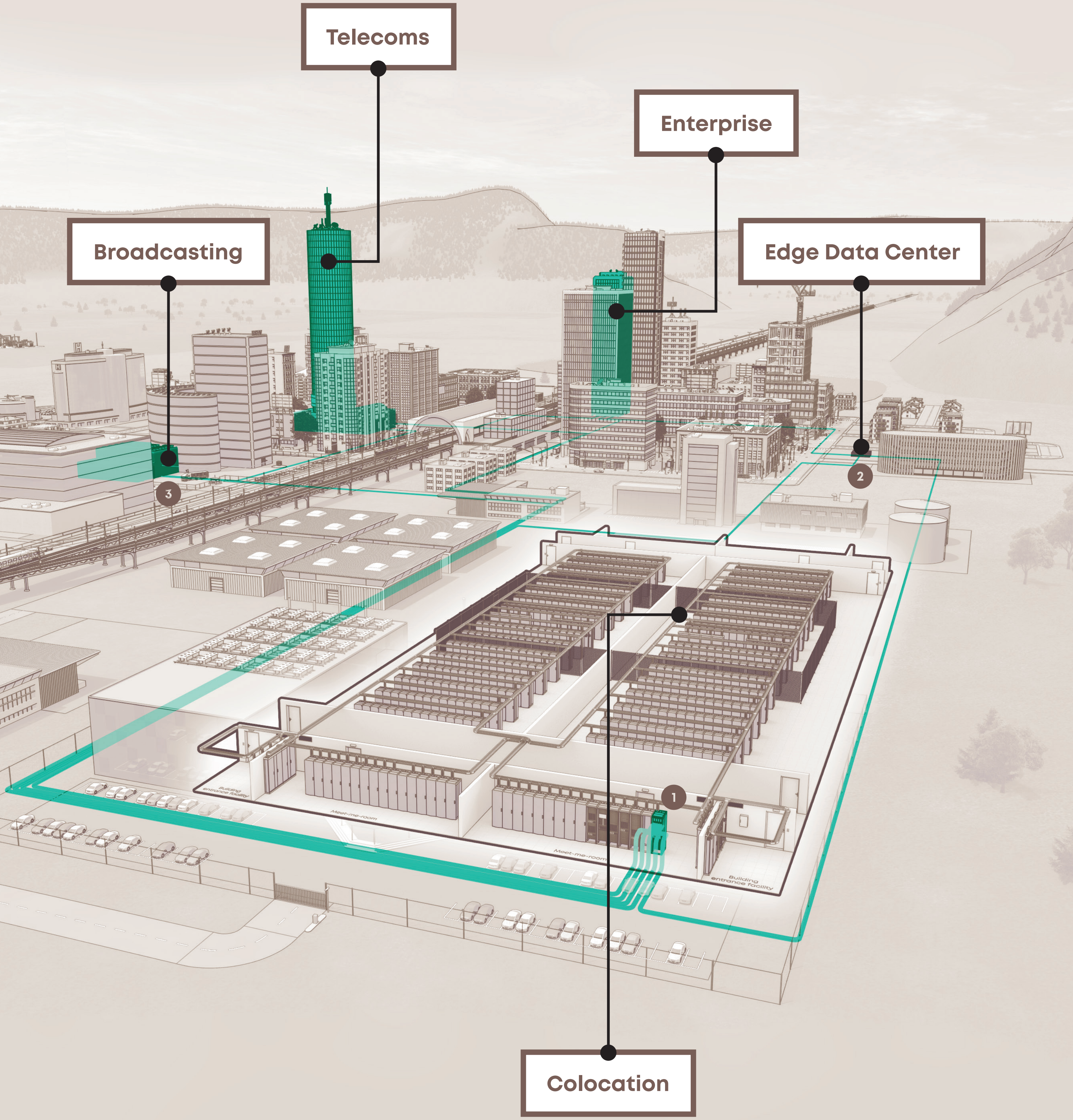
DCI technology essentially connects two or more data centers over short, medium, or long distances using high-speed optical connections. These connections may be between data centers belonging to one enterprise or connecting to other data centers, partners, and cloud service providers. Typically, these interconnects are providing access to cloud services and applications, carrying volumes of shared datasets, and connecting to backup and disaster recovery resources.

The interface between customer cages and the DCI transport equipment is often a bottleneck or the cause of delay when setting up new services. Deploying OOO switching in the DCI network provides more flexibility and enables rapid, remote and **zero-touch provisioning (ZTP)** **(1)** between data centers. With the addition of optical power monitors, an all-optical switch can be configured to provide fast automatic **protection switching** **(2)** against fiber faults and other degradation that affects the optical power on the fiber. Optical switching allows **automated fiber testing** **(3)** that operators can use to monitor the status of data center interconnections..








Telecoms
Enterprise
Broadcasting
Edge Data Center
3
2
Building entrance facility
Meet-me-room
1
Meet-me-room
Building entrance facility
Colocation

DCI scenarios

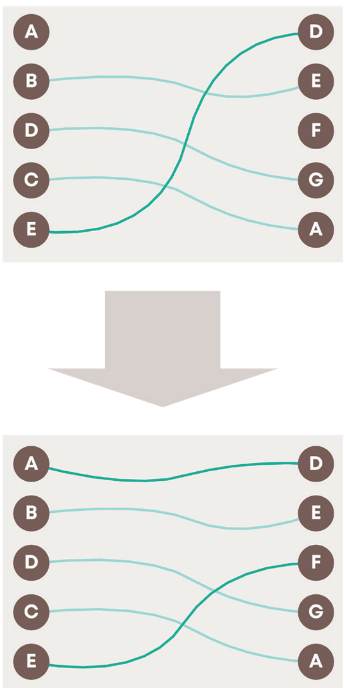
Zero-touch provisioning (ZTP)

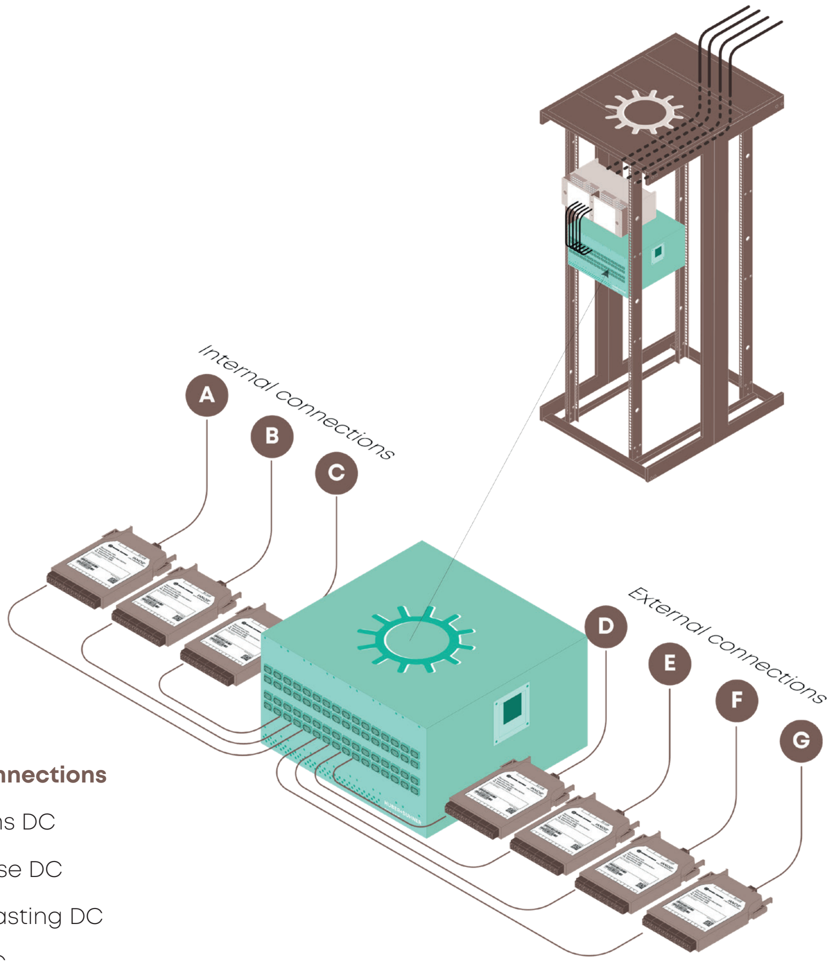
Zero-touch provisioning (ZTP) currently allows operators to set up and provision network elements automatically after they are installed in the data center. With OOO switching, ZTP concepts can be extended to installation testing and provisioning new data services within or across the data center network.

OOO switching enables automated fiber and transmission gear testing during the initial installation and before service provisioning. Automating testing minimizes time spent on-site manually connecting fibers and performing tests, reducing operational costs. Test equipment simply needs to be connected to the OOO switch interconnecting the fiber plant to automate testing. Further, uncommissioned fiber and equipment testing can be scripted and done periodically over time to ensure they are operational and ready when needed.

Automated testing can be done from a remote location, and the data automatically populated in the database eliminating human error entering test results.

Manual service configuration takes time and is prone to human error — especially if multiple devices must be configured across the network to provision a new service. Reducing human error results in faster service velocity, higher service availability, reduced customer churn, and minimised service-level agreement (SLA) penalties. OOO switching combined with ZTP speeds deployment of new services. Service activation times can be a key differentiator between winning and losing business in the competitive wholesale bandwidth market. Furthermore, faster service activation times mean the customer can be charged and start paying for services sooner, increasing revenues.





Internal connections

(A) Client A

(B) Client B

(C) Client C

External connections

(D) Telecoms DC

(E) Enterprise DC

(F) Broadcasting DC

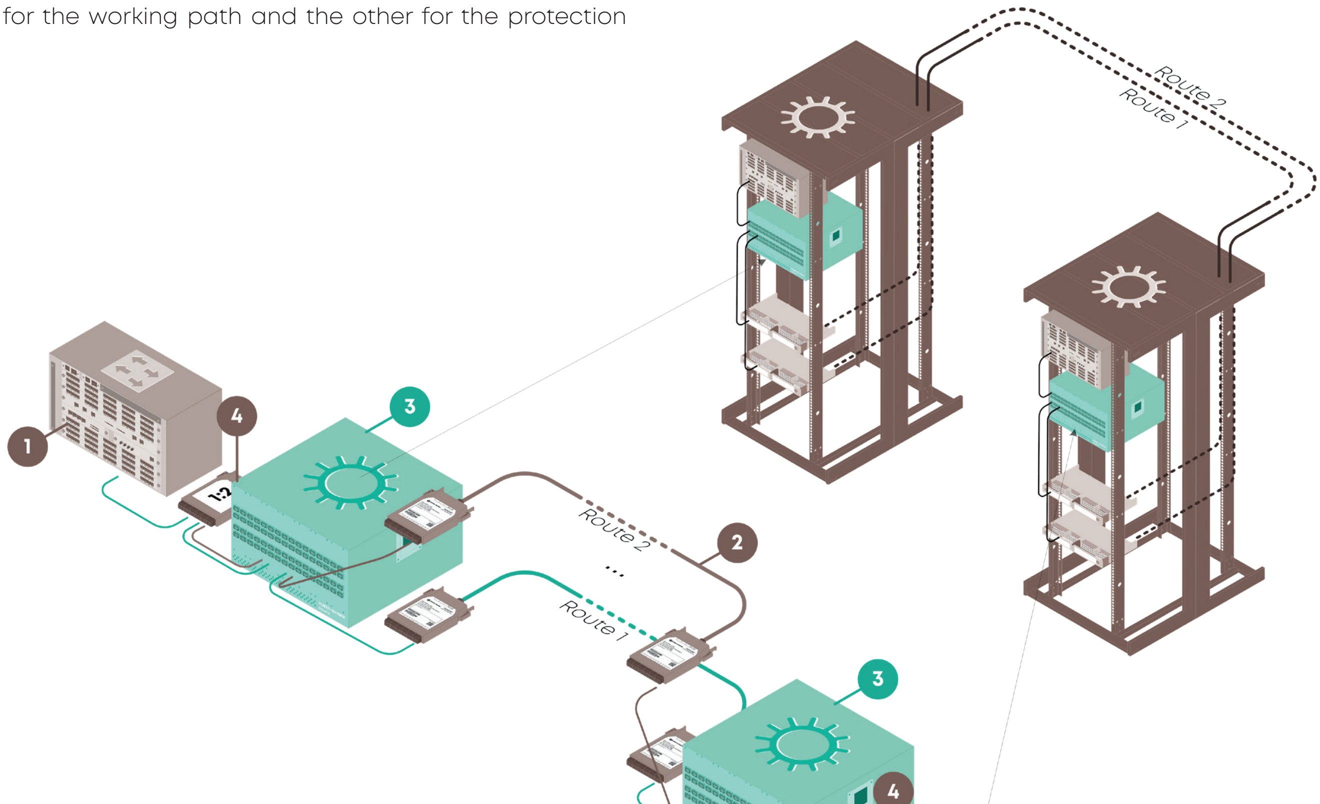
(G) Edge DC

Protection switching

OOO switching combined with integrated optical power monitoring offers a powerful combination for automated protection switching in the data center. In the event of an equipment or fiber failure, the OOO switch can restore service by automatically switching traffic around the fault. The optical power monitor locally detects a loss or degradation in the fiber optical power and automatically triggers switching between the working and protection lines. The protection switching can be done automatically by the switch or initiated by the data center network-control plane.

This example shows using an OOO switch to do automated 1+1 OOO switching in the data center. 1+1 implies that two fiber paths exist—the working and the protection. For 1+1 protection switching, a splitter is used at the transmitting end to create working and protection copies of the data traffic signal. Two optical fibers, one for the working path and the other for the protection path, are used to transmit signals. Both working and protection fibers are connected to the switch at the receiving end. An optical protection switch is triggered if the working line optical power monitor detects an optical power loss or reduction due to a fiber cut or other degradation. This type of protection switching can be deployed anywhere enhanced data reliability is needed within or between data centers.

Service uptime and continuity are critical parameters within data center SLAs so data center operators can avoid having to pay punitive fees for loss of service if they deploy protection switching.



(1) OEO switch

(2) External cabling

(3) OOO switch

(4) Optical splitter

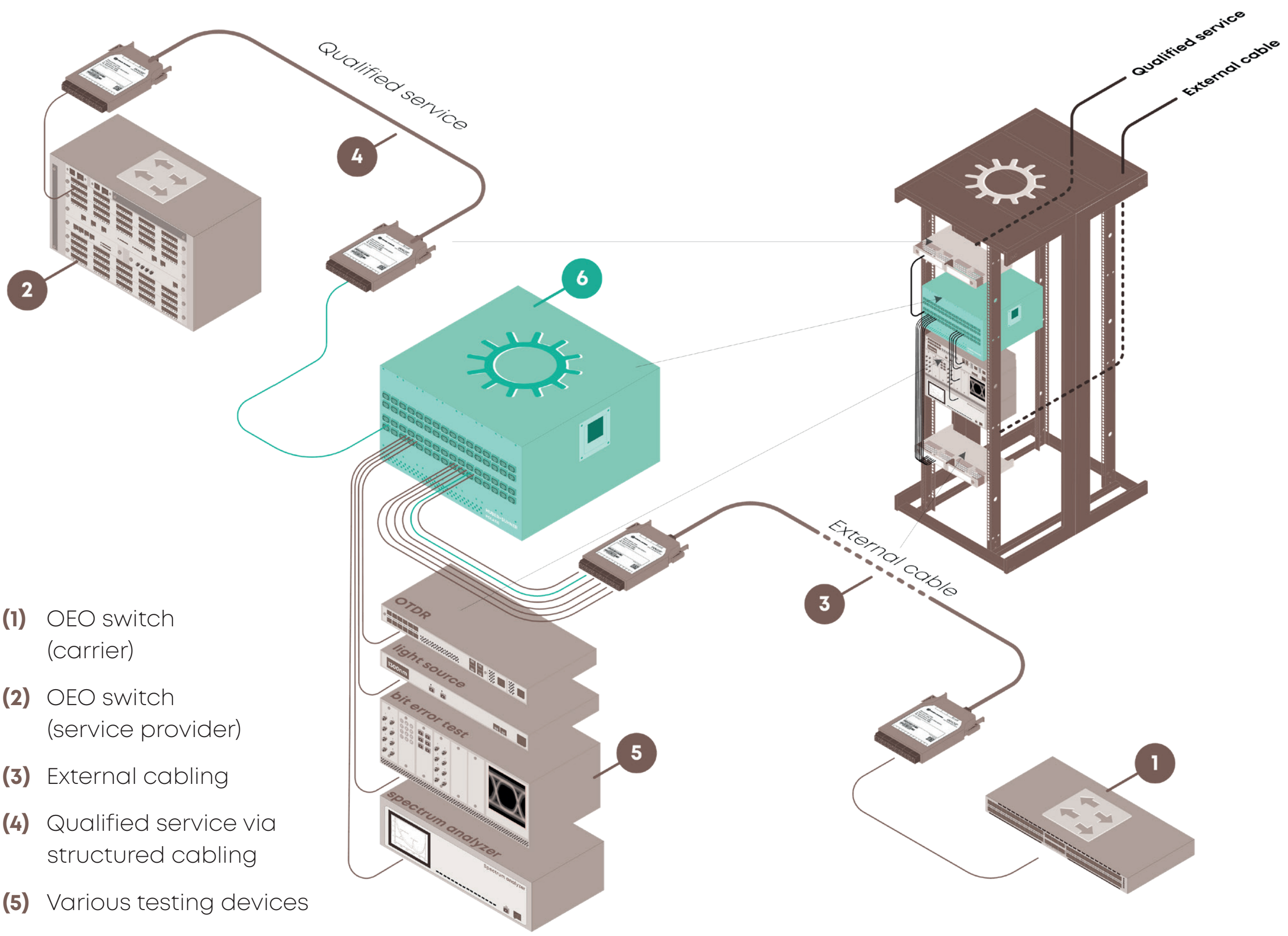
DCI scenarios

Automating optical fiber testing

OOO switching combined with existing test equipment in the data center lowers operational expenses by automating fiber routing testing for provisioning and maintenance activities. Manually testing dark fiber to verify performance during installation and service provisioning requires breaking connections to insert test equipment and then reconnecting the fibers which is problematic on many levels. In addition, fault location and other maintenance operations often require technicians at different locations to coordinate their test efforts to resolve problems. These manual processes are time consuming and human error can lead to unintended network outages.

Automating fiber testing and characterization using OOO switches reduces measurement times and costs along with human error by minimizing the need to break connections. Once the test equipment is connected to the data center network via an OOO switch, virtually all of the provisioning and maintenance activities that once required manual intervention, like breaking and remaking connections, can be automated and performed remotely. Automating routine fiber testing with OOO switching has many benefits:

- Limit network outages due to human errors
- Shorten traffic down time during repairs
- Reduce costs
- Reduce time needed to test and provision dark fiber
- Automate and improve the accuracy of fiber data records
- Enable remote fiber testing and fault location.



(1) OEO switch (carrier)

(2) OEO switch (service provider)

(3) External cabling

(4) Qualified service via structured cabling

(5) Various testing devices

(6) OOO switch

Summary

All-optical (OOO) switches clearly have an important role to play in enabling the automation and software control of the physical layer in the modern data center network. The ability to combine several applications over and above cross-connect automation on the same switch offers increasingly attractive return on investment (ROI). The ability to switch and hold dark fiber connections for service pre-provisioning and the transparency to bit rates and signal protocols allow data center operators to plan for the future, comfortable in the knowledge that their investment in the switch is protected.

Meanwhile, work continues on developing novel architectures using OOO switches for the next generation of data centers, such as the disaggregation of computing resources, in collaboration with both customers and industrial and academic partners.

Beyond the world of data centers, OOO switches are being used to create innovative solutions in telecoms networks and broadcasting applications, supercomputing, quantum networking and quantum key distribution, amongst many others.

HUBER+SUHNER has a team of technical experts that can help you to integrate OOO switches into your network and more detailed information is available on request.

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HUBER+SUHNER is certified according to ISO 9001, ISO 14001, OHSAS 18001, EN(AS) 9100, IATF 16949 and ISO/TS 22163 – IRIS.

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