Bandwidth expansion for data centers

Basics, fundamentals and scenarios

White Paper

HUBER+SUHNER

Provide bandwidth expansion solutions for data centers

When additional fiber capacity is needed outside a data center and deploying more fiber is not an option, it's time for bandwidth expansion. Maximise the capacity and transmission reach that increases data flow with wavelength-division multiplexing (WDM) technology.

And this is why:

- **Expand bandwidth efficiently with existing fiber**
- **Utilise rapid deployment and plug-and-play setup**
- **Future-ready WDM is data rate and protocol agnostic**
- **Reach longer distances without "repeater" location**
- **Provide cost-effective protection and remote monitoring**
- **Leverage powerful cost-effective demarcation**
- **Experience ultra low latency scalable solutions**
- **Ensure reliable redundancy**

Content

Bandwidth expansion challenges

Expanding the bandwidth within a data center

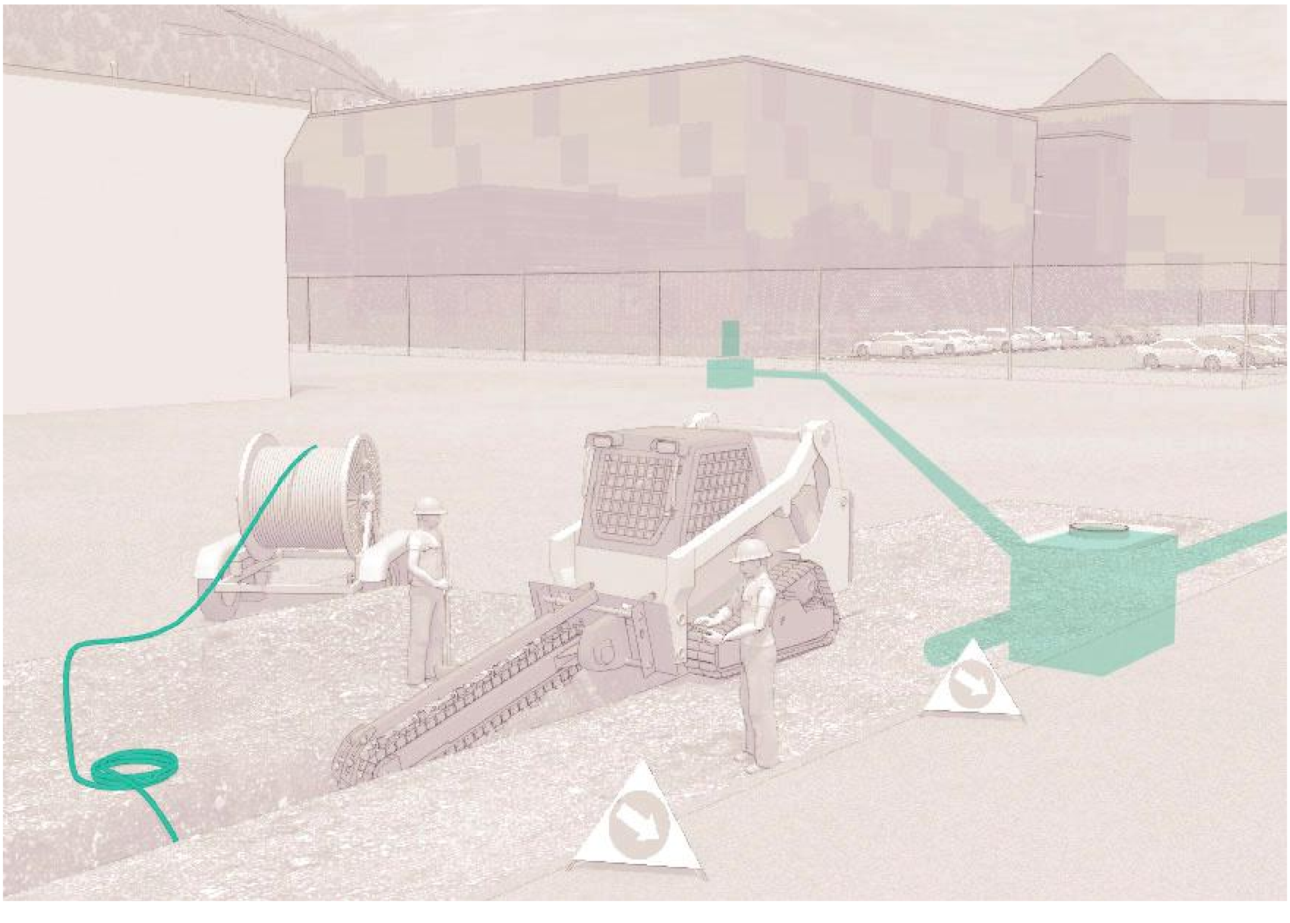
The ever-growing requirement for more bandwidth is a constant challenge. Within a data center it normally is no problem to add more fibers to existing ones to support the additional bandwidth requirements between equipment.

By means of structured cabling more cables can be easily installed between racks and cost-effective grey transceivers are used to establish the data connections between the equipment.

Expanding the bandwidth outside a data center

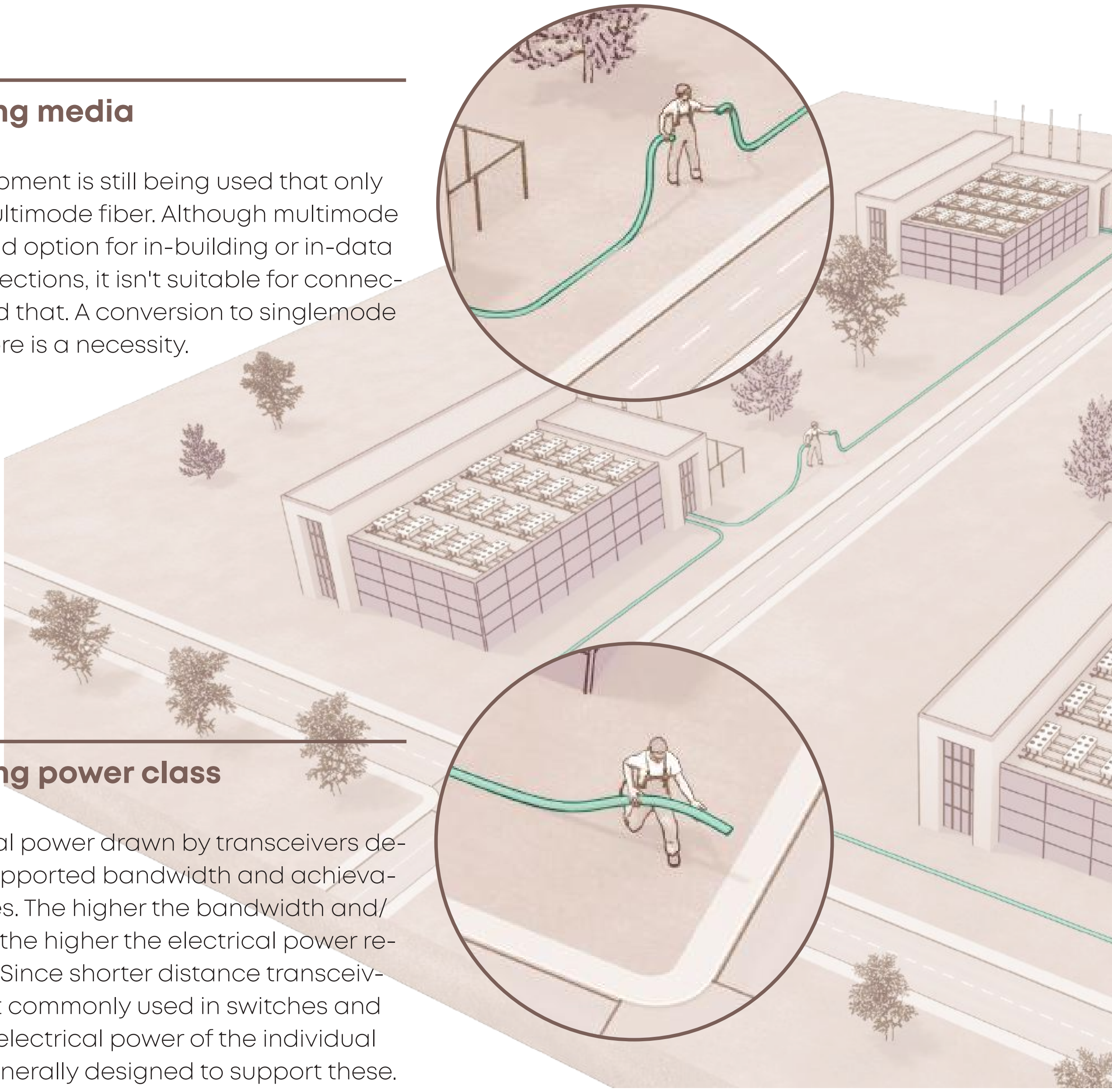
When it comes to deploying fiber outside the data center, things become much more challenging. It not only can be extremely expensive and take a long time but in some cases even not be possible at all. Therefore more often than not, expanding the capacity of the existing fiber is the better solution.

The best and most cost-effective technology to expand the fiber capacity is wavelength-division multiplexing (WDM).



Bandwidth expansion – Considerations

Bandwidth expansion is an ever-present topic in these times of constant and drastic increasing of capacity requirements. While there is no 'one-size-fits-all' solution, there are important considerations concerning media conversion, power class support, distance and link redundancy that can help solidify your overall approach.

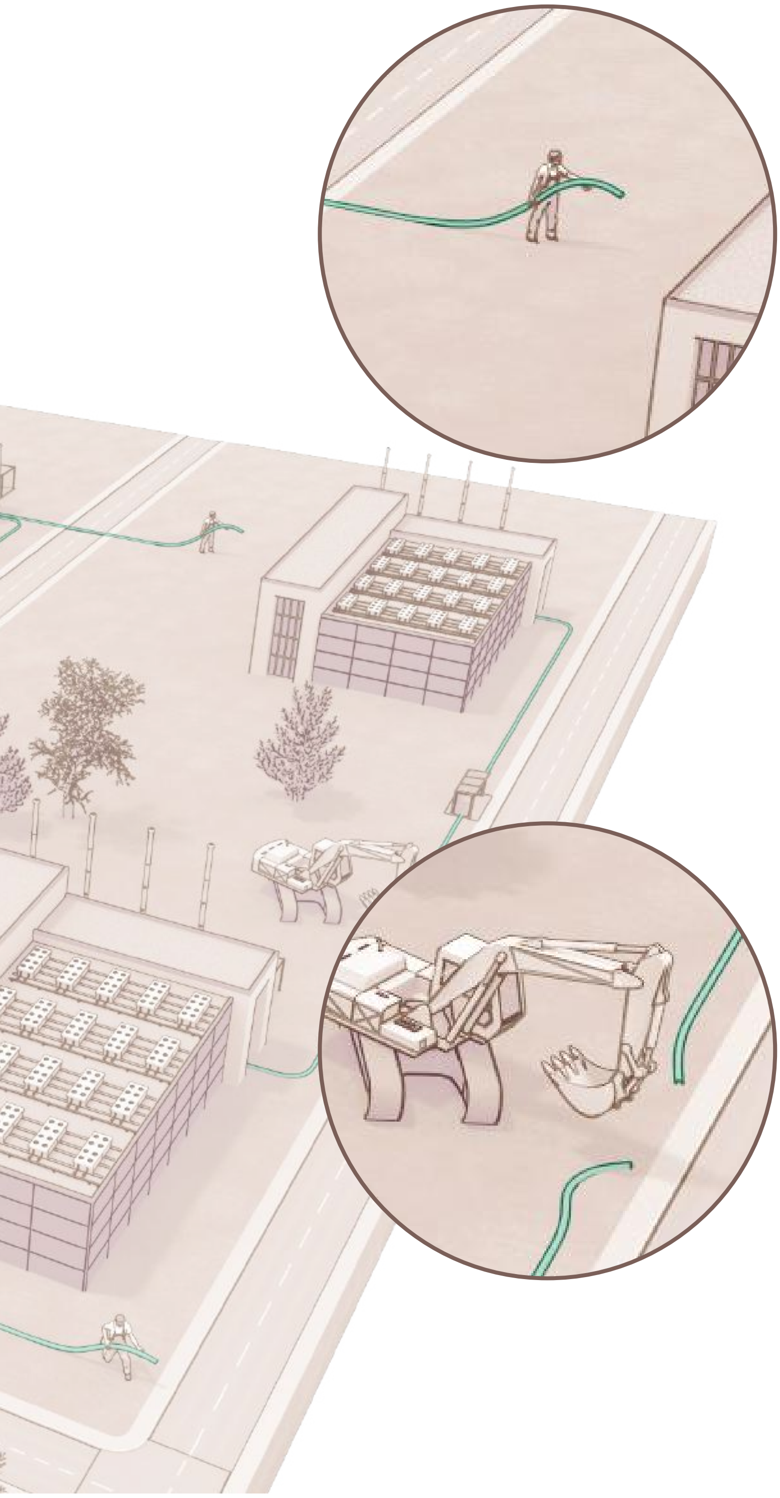


Converting media

A lot of equipment is still being used that only supports multimode fiber. Although multimode fiber is a valid option for in-building or in-data center connections, it isn't suitable for connections beyond that. A conversion to singlemode fiber therefore is a necessity.

Supporting power class

The electrical power drawn by transceivers depends on supported bandwidth and achievable distances. The higher the bandwidth and/or distance, the higher the electrical power requirements. Since shorter distance transceivers are most commonly used in switches and routers, the electrical power of the individual ports are generally designed to support these. However, there are quite some applications where transceivers are required that draw more electrical power than supported by the switches and routers.



Achieving longer distances

When it comes to bandwidth expansion the cost to achievable distance ratio comes with its challenges. Especially long distance transceivers with data rates 100Gb/s and higher are extremely expensive. However, a more cost-effective transceiver might not have the required reach.

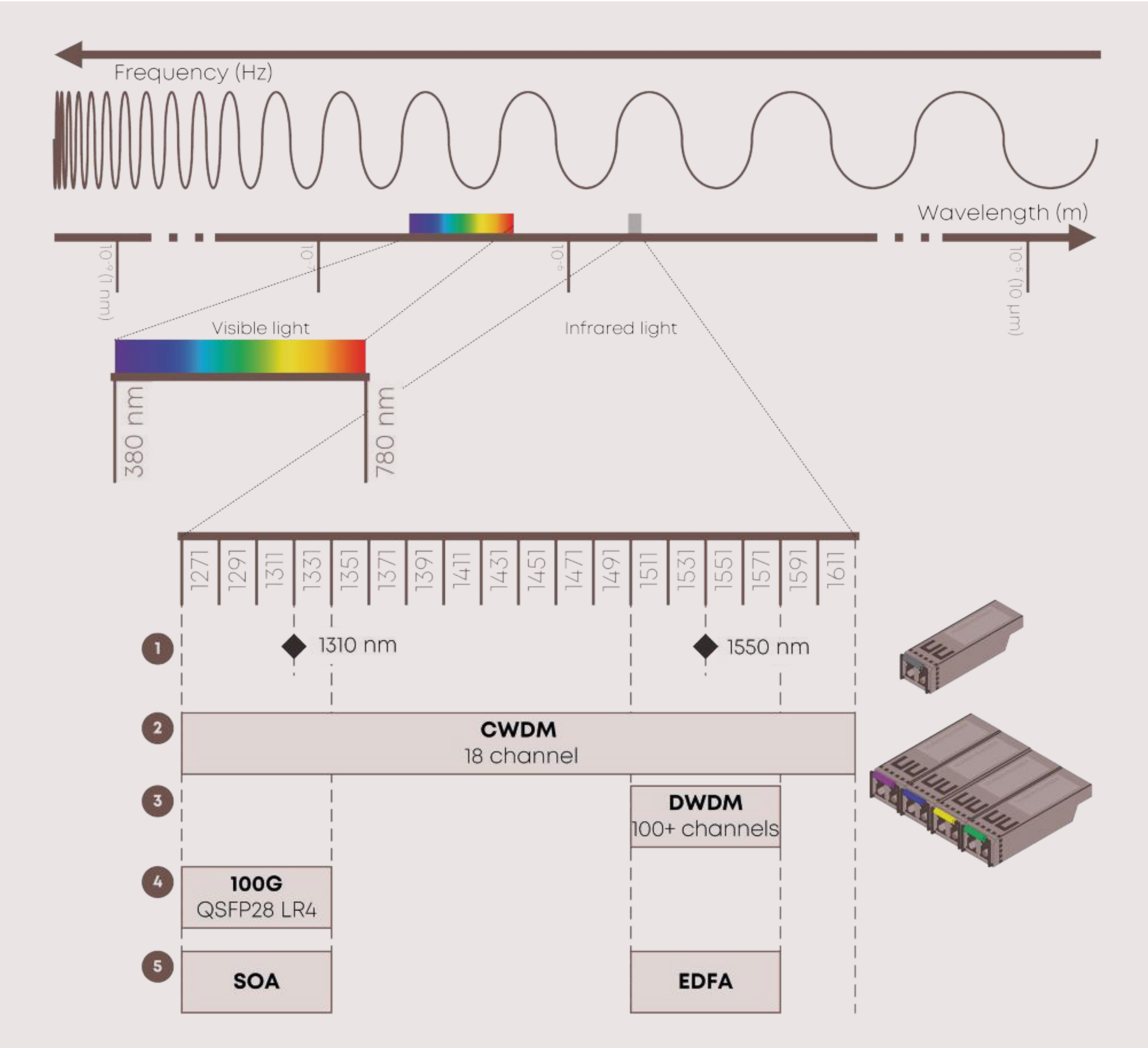
Adding link redundancy

The more signals that are combined on a fiber link, the greater the necessity for link redundancy. For example, a damaged fiber link would lead to the loss of all these signals.

Technology

Optical multiplexing

Optical multiplexing works on the principal that optical signals with different wavelengths (i.e. frequencies) do not interfere with each other. Therefore it is possible to combine and separate these different signals. In the visible light spectrum this principle can be seen when a white light passes through a prism and is separated into the individual spectral colours (i.e. rainbow colours). The spectrum for optical transport and multiplexing on singlemode cables is in the non-visable infrared area within a wavelength range of approximately 1260nm to 1625nm.



The first optical multiplexing in this spectrum was done by only using two wavelengths, 1310 and 1550nm. This basic form of optical multiplexing is still used today and is considered as wide wavelength-division multiplexing (WWDM - **(1)**). Since then two main grids have been defined for optical multiplexing. The coarse wavelength-division multiplexing (CWDM - **(2)**) grid is made up of 18 different channels with a channel spacing of 20nm and spans across the complete WDM spectral range. Dense wavelength-division multiplexing (DWDM - **(3)**) on the other hand is located in the 1550nm range. This range was specifically chosen for DWDM to solve a problem that CWDM always had, which is missing the possibility of amplification.

There are two main amplification technologies used for optical transport. The semiconductor optical amplifier (SOA - **(5)**) which amplifies at the 1310nm spectral range and the erbium doped fiber amplifier (EDFA - **(5)**) that amplifies the 1550nm spectral range. The SOA can be used to amplify 100G (LR4 - 4) signals whereas the EDFA is used to amplify DWDM signals. In other words the DWDM spectrum was chosen based on the amplification characteristics of the EDFA.

HUBER+SUHNER components and technology

For the passive products, HUBER+SUHNER makes use of various WDM technologies and components depending on available space, required optical performance and price. HUBER+SUHNER designs the active products and selects the relevant components that meet the highest quality and reliability standards. One of the WDM components used, especially when space is an issue, is the HUBER+SUHNER CUBE. This miniaturized optical multiplexer/demultiplexer is designed and manufactured by HUBER+SUHNER.

HUBER+SUHNER CUBE: Miniature WDM optical component.

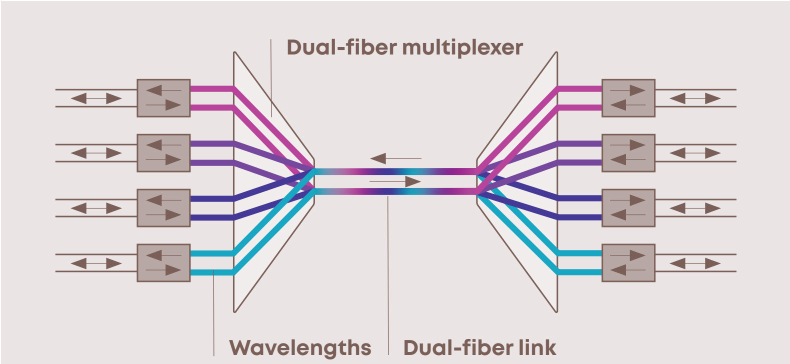
Building blocks – passive solutions

A trusted technology with vast potential

Bandwidth expansion or wavelength-division multiplexing (WDM) is a reliable, cost-effective, and future-proof way to expand capacity to transfer more data over each fiber. This is done by combining different wavelengths in a single fiber and separating them again. Data can therefore travel at different wavelengths through one single fiber.

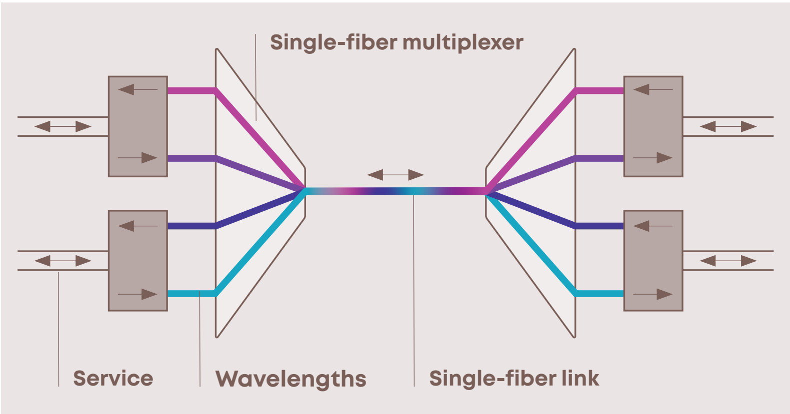
Principle of a dual-fiber multiplexer

Different wavelengths are combined in a single fiber and separated again. For each service two fibers are needed to allow data flow in both directions but only one wavelength.

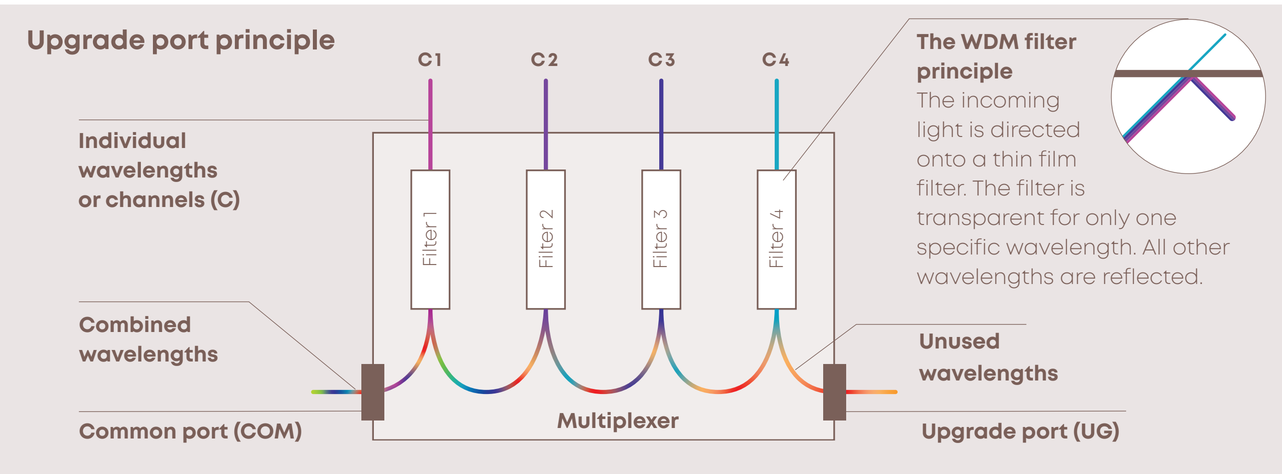


Principle of a single-fiber multiplexer

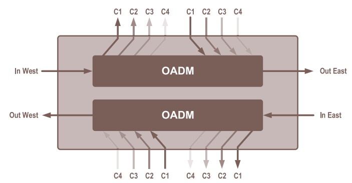
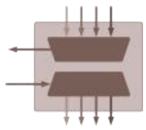
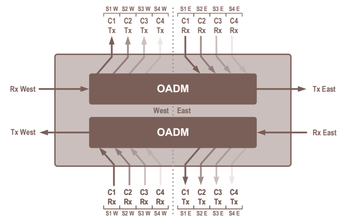
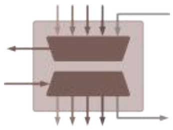
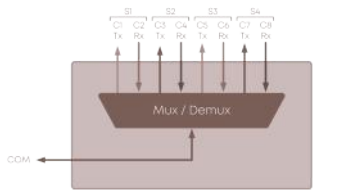
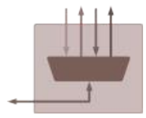
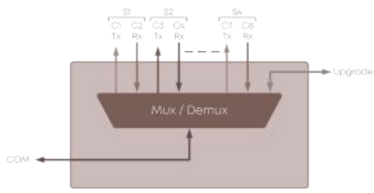
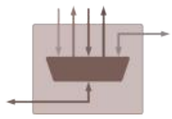
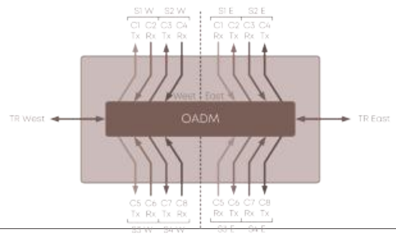
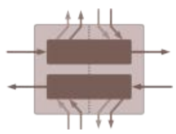
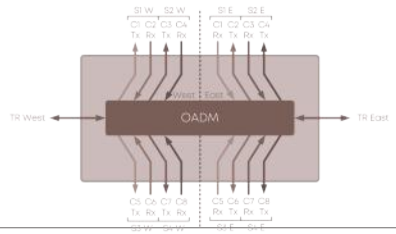
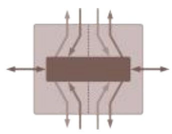
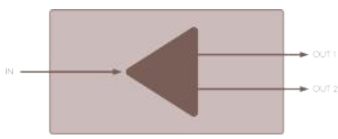
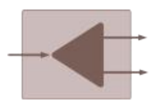
Here only one fiber is used for both directions. So two wavelengths are needed per service to allow data flow in both directions.



Passive optical mulitplexers are available with upgrade ports. An upgrade port passes the wavelengths that are not used by the multiplexer. This makes it possible to add further multiplexers for these remaining wavelengths to either have specific topology designs or to add further channels at a later point in time.



Passive blocks

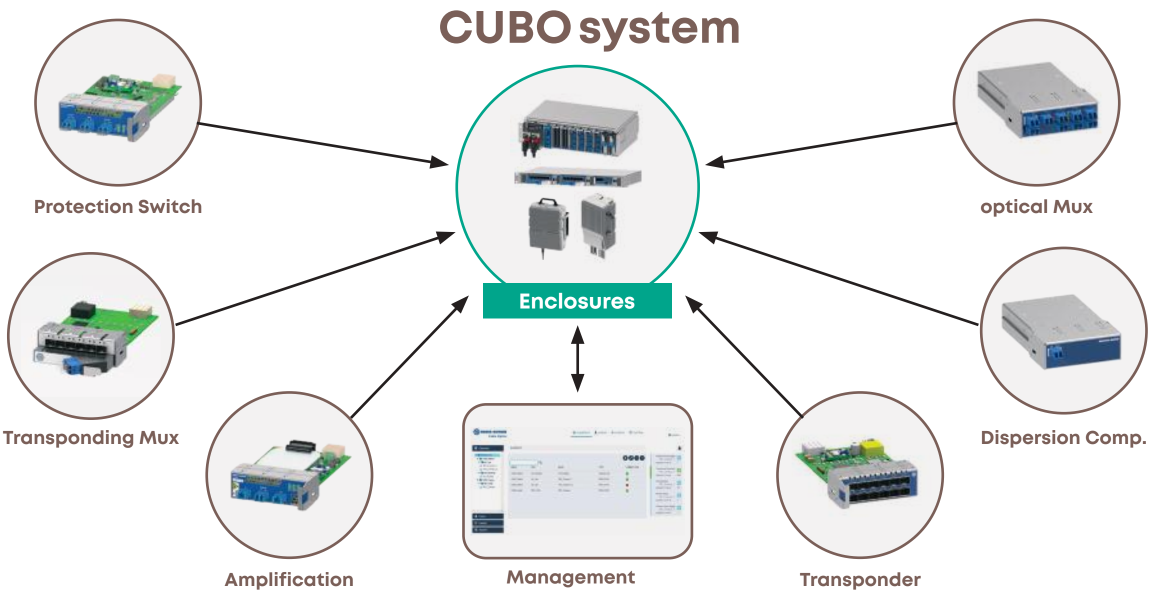
Description	Functional diagram	Icon used in this document
Dual Fiber – Mux/DeMux Uses two separate fiber connections for transmission (Tx) and reception (Rx). The number of wavelengths is identical to the number of services (Tx+Rx).		
Dual Fiber – Mux/DeMux + Upgrade Uses two separate fiber connections for transmission (Tx) and reception (Rx). The number of wavelengths is identical to the number of services (Tx+Rx). It includes a dual fiber upgrade port to add further multiplexers.		
Single Fiber – Mux/DeMux Uses a single fiber for both transmission (Tx) and reception (Rx). The number of wavelengths is twice the number of services (Tx+Rx).		
Single Fiber Mux/DeMux + Upgrade Uses a single fiber for both transmission (Tx) and reception (Rx). The number of wavelengths is twice the number of services (Tx+Rx). It includes a single fiber upgrade port to add further multiplexers.		
Dual Fiber Optical Add Drop Mux West and East connections each use a separate fiber for transmission (Tx) and reception (Rx). The number of wavelengths is identical to the number of add/drop services (Tx+Rx).		
Single Fiber Optical Add Drop Mux West and East connections each use a single fiber for both transmission (Tx) and reception (Rx). The number of wavelengths is twice the number of add/drop services (Tx+Rx).		
Passive Optical Splitter An optical signal is passively split into two or more signals. The power budget is split between the outputs. The split ratio can be even or asymmetrical.		

Building blocks – active solutions

A system designed to adapt to the requirements

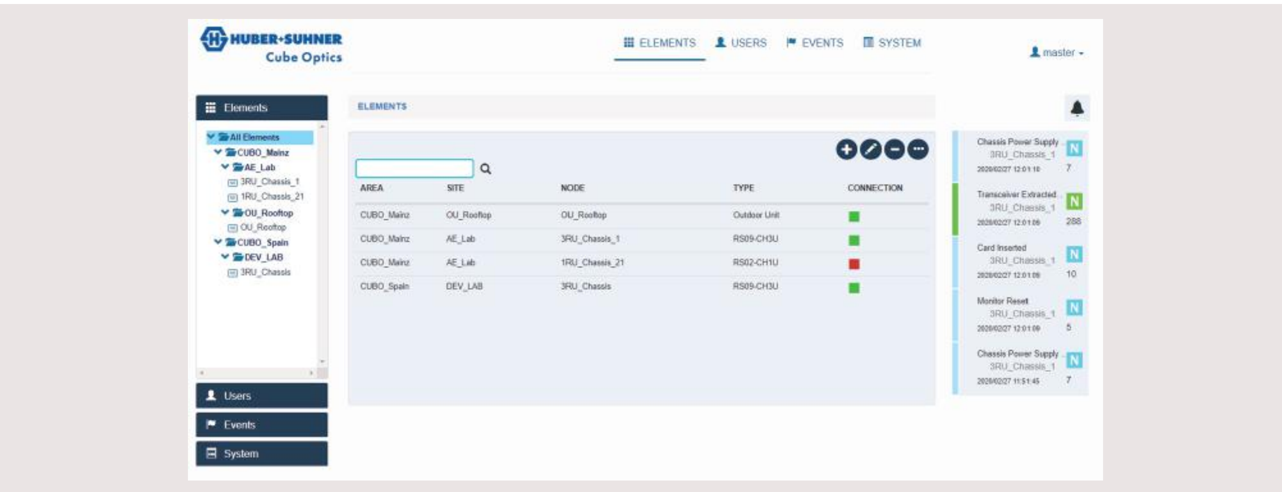
Wavelength-division multiplexing (WDM) is an ideal solution for bandwidth expansion. Combined with a selection of active products, WDM is even more versatile and covers even more applications. The CUBO system is the HUBER+SUHNER active transport solution. The foundation of this flexible system are the line card modules.

These modules can be mixed and matched in any combination in the 3RU and 1RU chassis enclosures. In addition to that they can also be integrated into the standard (2 line cards) or slim (1 line card) outdoor enclosures.

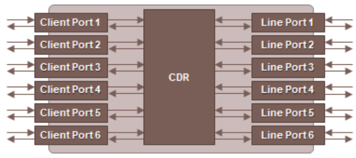
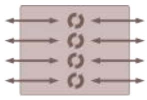
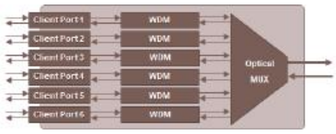
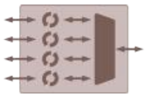
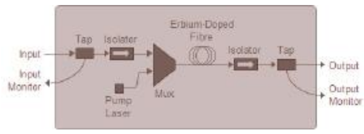
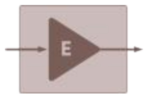
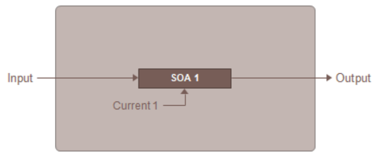
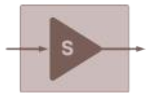
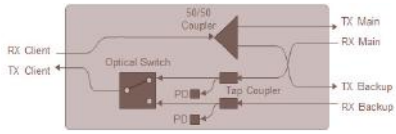
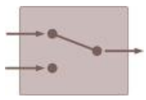


Managing the flexibility

Each CUBO system enclosure has a management module that comes with an intuitive WebGUI as well as SNMP for remote monitoring and control. In addition, the CUBO EMS is a powerfull tool to consolidate the management of all CUBO system elements in the network.



Active blocks

Description	Functional diagram	Icon used in this document
Universal Transponder A universal transponder is made up of one or more back-to-back transceiver ports. These ports can be equipped with different types of transceivers. The HUBER+SUHNER transponder range includes 10G, 25G and 100G modules.		
Transponding Multiplexer The transponding multiplexer is a transponder with an integrated WDM multiplexer. It is available as CWDM and DWDM versions. The HUBER+SUHNER transponding multiplexer range includes 10G and 25G modules.		
Erbium Doped Fiber Amplifier (EDFA) The EDFA module amplifies the incoming optical signal in the range of 1528nm to 1563nm and therefore is ideally suited for DWDM applications. The HUBER+SUHNER EDFA modules are available as Booster or Pre-Amp versions.		
Semiconductor Optical Amplifier (SOA) The SOA module amplifies the incoming optical signals in the range from 1290 to 1330nm and therefore is ideal for 100G and 40G LR4 (1310nm) applications. The HUBER+SUHNER SOA modules are available as single or dual versions.		
Optical Protection Switch (OPS) The OPS module anables a backup fiber link of a point-to-point link. It automatically switches from the main optical line to the backup optical line when the main input signal is disrupted. The HUBER+SUHNER OPS modules are available as single or dual versions.		

Universal Transponder – One product, multiple solutions

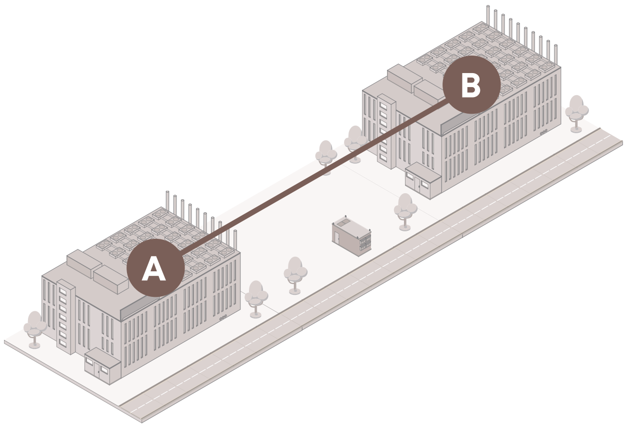
The universal transponder modules are true multitools as they can be used for a wide range of solutions. Here is a list of the most common use cases.

- **Media Converter** - As different types of transceivers can be combined, the universal transponder can be used as a media converter. From multimode to single fiber or copper-to-fiber just to name a few.
- **Repeater** - Since the transponders also electrically regenerate the signal, they can be used as a repeater.
- **Demarcation** - A common use case for a transponder is as a demarcation point at the customer premise.
- **Power class extender** - High data rate transceivers require a lot of electrical power. Sometimes the power requirements exceed what the switches/routers can provide. HUBER+SUHNER transponders, however, can support higher power classes and can be used to overcome the power limitations of switches/routers.

WDM Topologies – Point-to-point and beyond

Point-to-point

The most common and most basic topology is to connect two points. The same WDM multiplexer/demultiplexer (mux/demux = MUX) is used on both ends to virtually increase the given number of fibers by using several channels in parallel, which increases the bandwidth between both points.



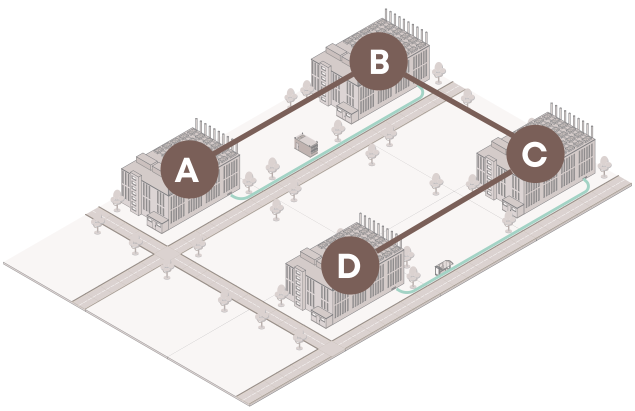
Physical layer structure versus logical network topology

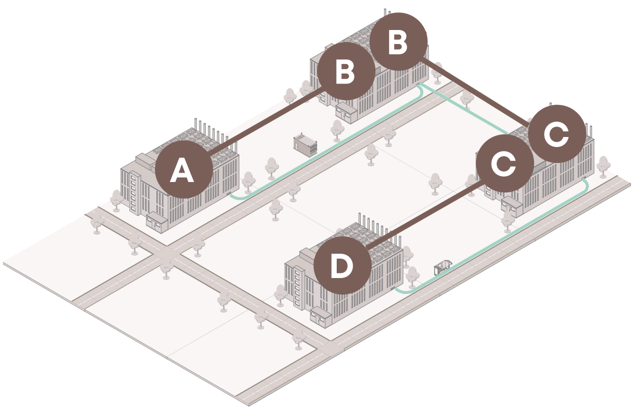
Of course, WDM is not limited to the interconnection of only two sites. When many sites are connected then two fundamentally different multiplexing functions come into play: the MUX, which launches/terminates all traffic. Versus optical add-drop multiplexers (OADM) and daisy-chain multiplexers which both only add/drop some of the channels and transparently pass through all remaining channels/traffic. The different multiplexing functions can be used to create a logical network topology independently and differing from the physical cable connection as shown in the following examples.

Chains as logical point-to-point

Several nodes can be connected with one cable to a long chain. For example, in the illustration below, connecting A to B to C to D.

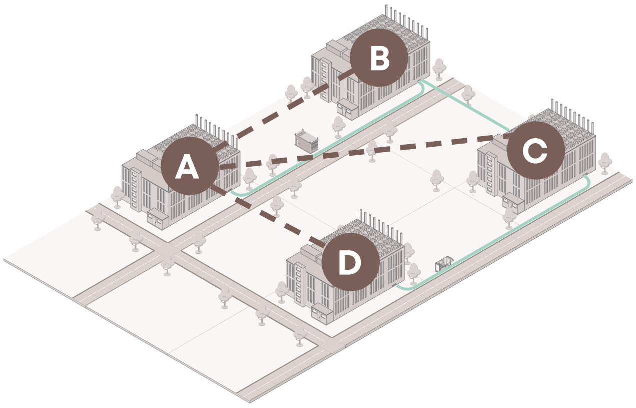
If all network node MUXes are used to terminate all traffic, then the logical network topology would consist of multiple and independent point-to-point connections: For example, connecting A to B, B to C and C to D.





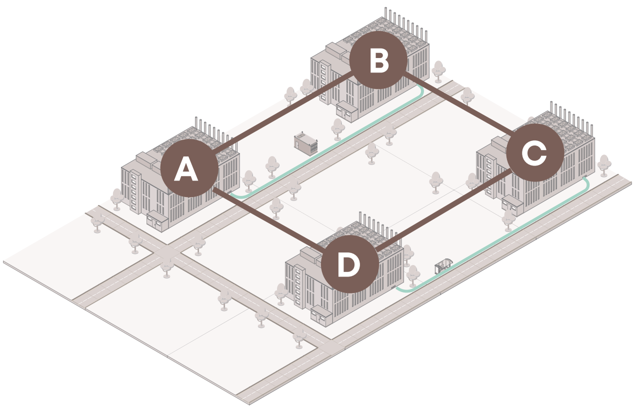
Chains as logical daisy chain (Hub-and-Spokes)

However, on the same physical cable chain, WDM allows to implement a logical daisy-chain network. In this case, the initial node (A) serves as a "hub" with a logical direct link to each "spoke" site (B, C, D), without processing traffic on the intermediate sites. Node A will host the main MUX while nodes B, C and D feature smaller daisy-chain multiplexers. Each will only add/drop a channel subset of the main multiplexer and forward pass through traffic via their UG port. This leads to a logical daisy-chain network like shown below.

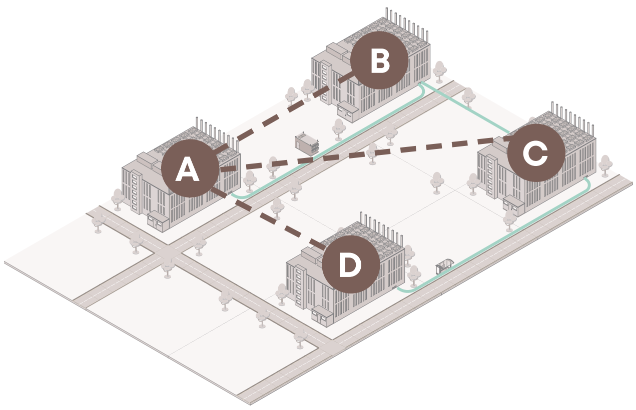


Ring with optional Hub-and-Spokes

The same principals may be used in physical ring structures. Again, each site may be equipped with only one MUX type to terminate all traffic and build a logical point-to-point structure. Or a logical Hub-and-Spoke topology is realized by using a MUX in the central site or "hub" (A) and OADMs in connected ring sites or "spokes" (B, C, D). Combinations of both logical architectures are also possible.



Physical ring with logical point-to-point network using MUXes



Logical Hub-and-Spokes architecture with OADMs used on physical ring network.

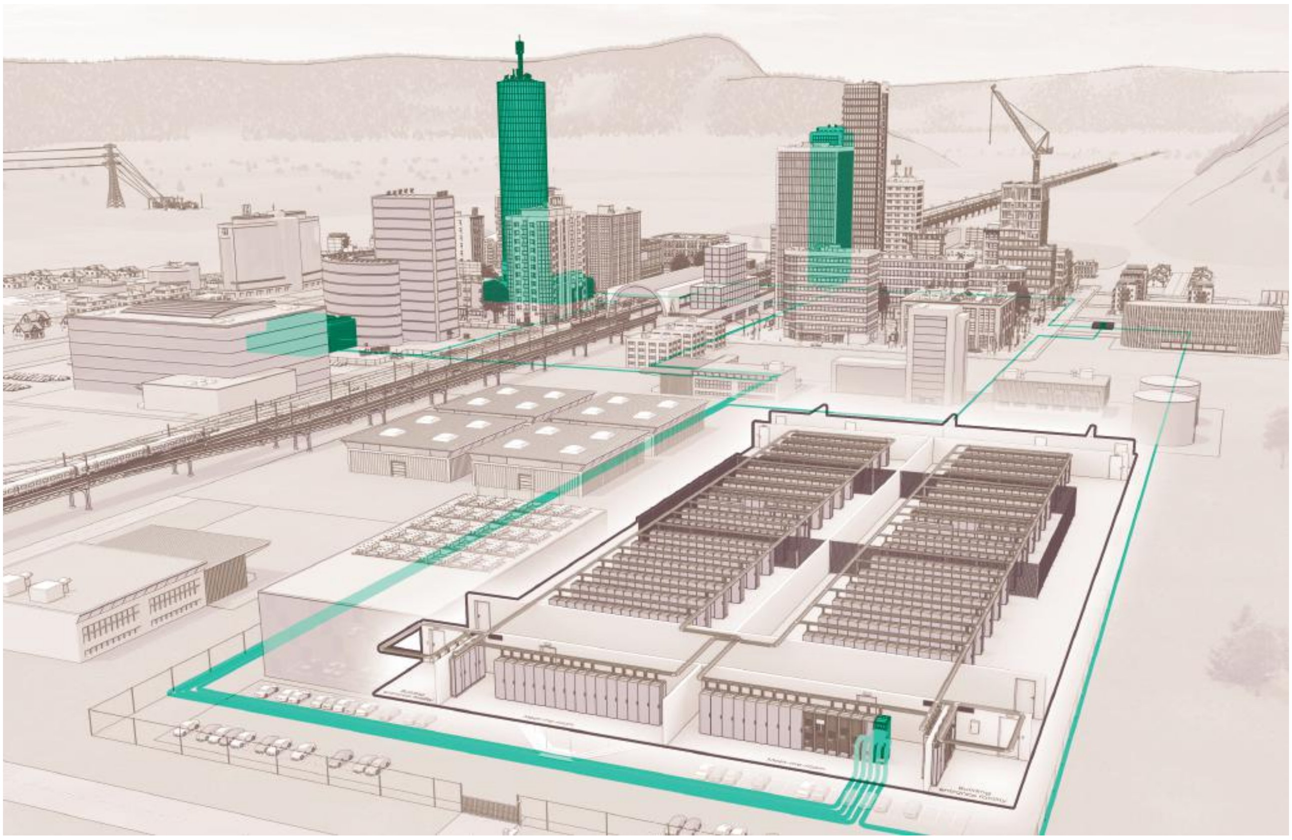
Application scenarios

Transport fundamentals

Regardless of the application, for example, data center interconnect, serving the financial industry or governmental entities, backhauling residential internet traffic or fronthauling mobile 4G/5G - or maybe even all at once - it all comes down to the same challenge: what is the lowest cost and effort approach to transport data from A to B (or more points)? If the amount of available fiber between those sites is not sufficient and getting additional new fibers/cables comes at a very high premium (for example, due to civil engineering work or high fiber taxes) then the virtual increase of fiber routes via optical WDM is usually the best choice.

Protocol and data rate transperency

Optical WDM is agnostic to protocol, application and data rate. It natively transports all existing protocols such as Ethernet, IP, FiberChannel, OTN, CPRI, eCPRI, PON and SDI in a transparent manner without any conversion or additional latency. Consequently, it is ideally suited for data center interconnects, edge data center backhauling, finacial technology applications and all types of metro core and access networking.

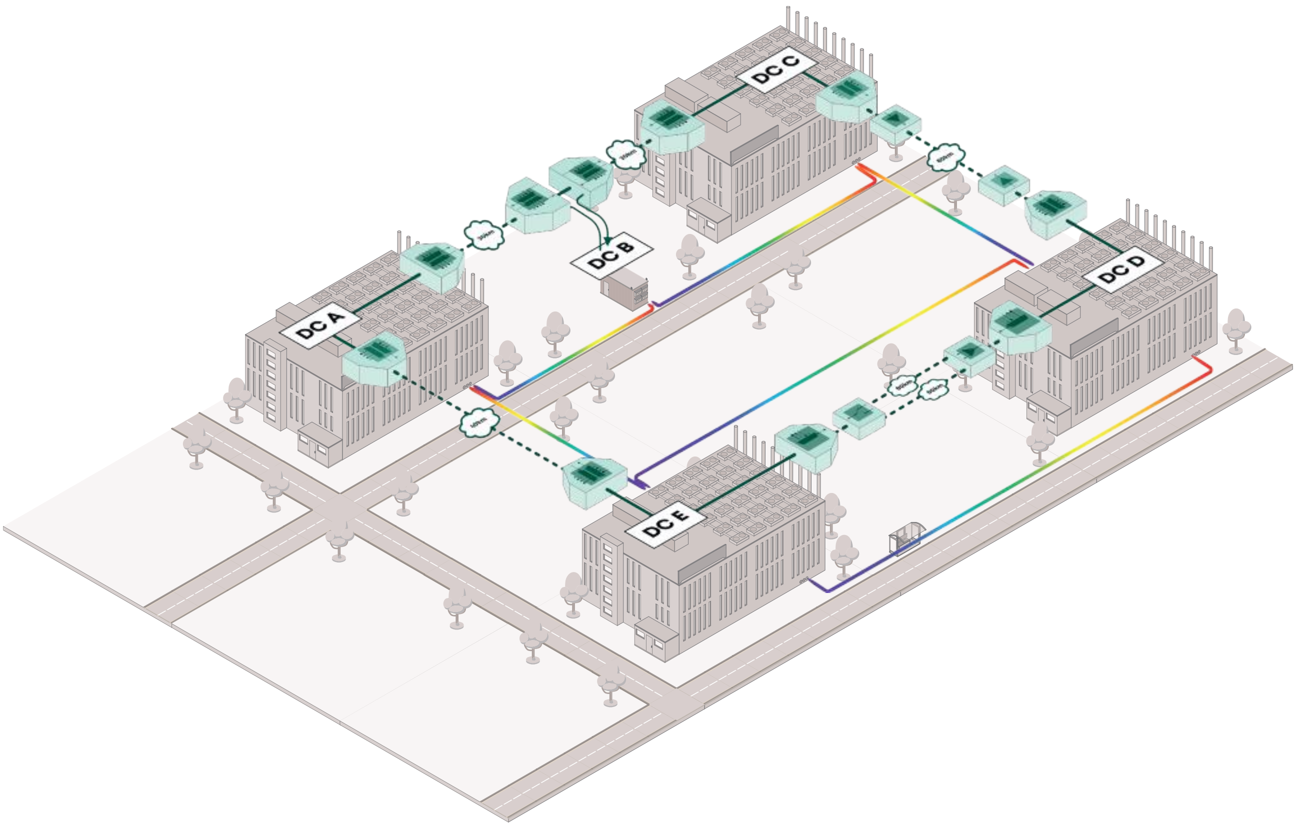


Active versus passive WDM

Passive WDM transport is the simplest bandwidth expansion method while offering the lowest latency, the highest reliability and by far the lowest cost. The "coloured" CWDM, DWDM, xWDM transceivers are directly used in terminal equipment like an ethernet switch, router, BBU or DSLAM which generate data that needs to be transported. The differntly "coloured" WDM channels of the transceiver Tx and Rx ports are then multiplexed via the matching passive WDM to the transmission fiber. If the equipment (switch, router, etc.) does not support coloured WDM transceivers, or if a demarcation between two networks is required or if a reach needs to be extended, then Active WDM transport comes into play. Here the so-called "grey" client transceivers with a short reach are placed in the terminal equipment and then first converted via active transponder cards into the desired coloured WDM line signal before being MUXed over the transmission fiber.

Available frequency grids

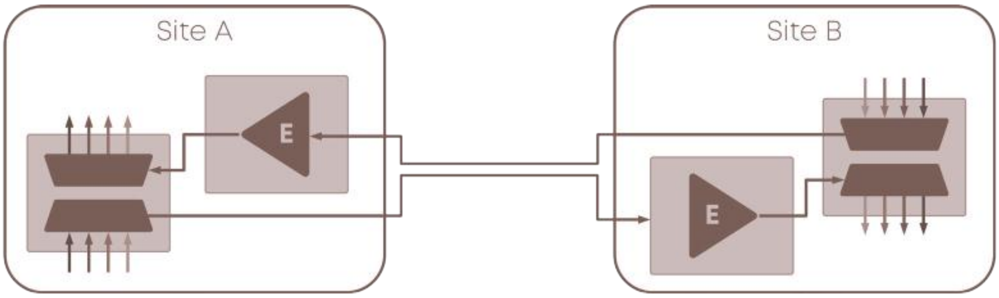
There are different frequency grids available, including DWDM, CWDM and LWDM. The grid chosen should be selected on the specifics of the application. For example, considerations like the number of required channels, reach (ability to amplify), transceiver cost and availability depending on protocol should be examined before choosing a specific grid.



Application scenarios

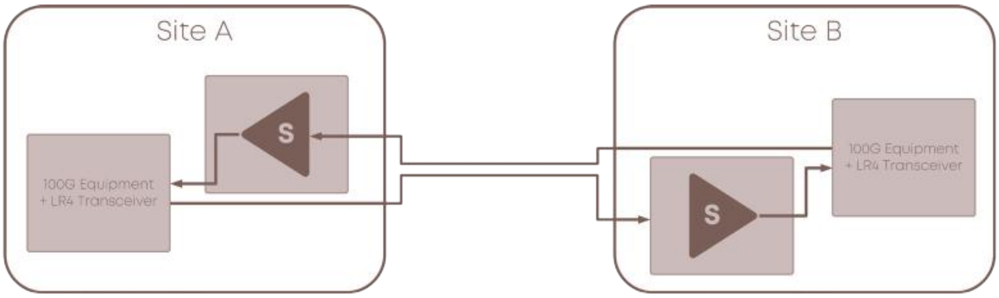
Optical amplification – DWDM

The DWDM grid was deliberately defined between the wavelengths 1510nm to 1570nm. The reason for this being that erbium doped fiber amplifier (EDFA) are able to amplify this range of wavelengths. In other words, EDFAs are ideally suited to amplify DWDM multiplexed signals, making it possible to extend the reach of these signals beyond the optical power budget provided by the individual transceivers.



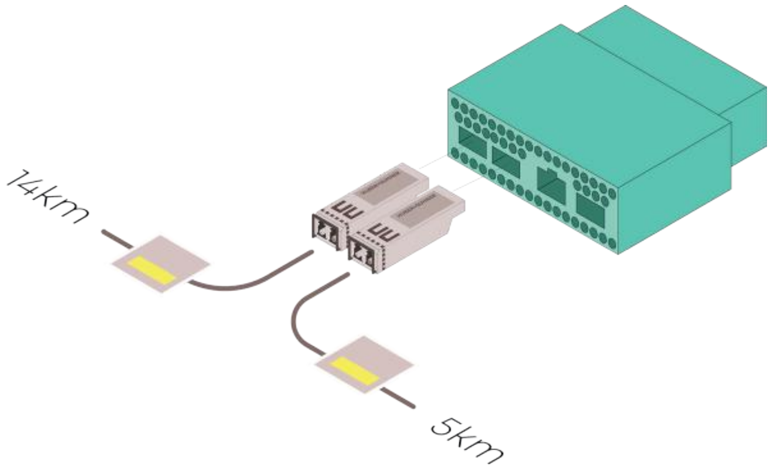
Optical amplification – 100G

A semiconductor optical amplifier has the characteristics to amplify wavelength between the range of 1290nm and 1330nm. This is ideal to extend the reach of 100G optical quad signals (e.g. QSFP28 LR4 or ER4lite transceivers) as these operate on the wavelengths 1295.56nm, 1300.05nm, 1304.58nm and 1309.14nm.



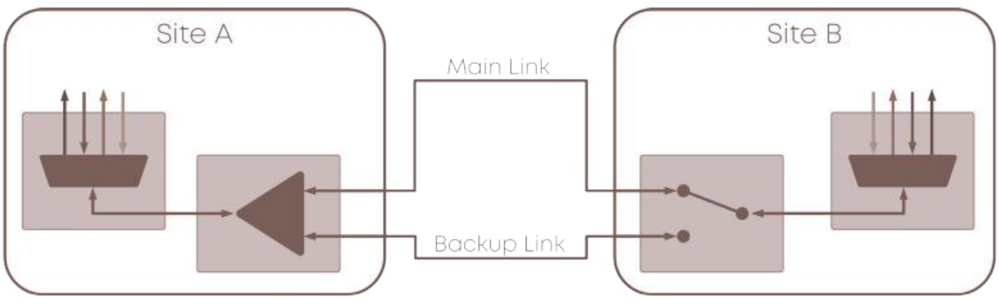
Repater reach extension

A cost-effective alternative to optical amplification to increase the reach is an interim repeater. This of course is only possible if a location is available to place the repeater. The choice of transceivers used in the repeater determine the additional reach.



Link redundancy

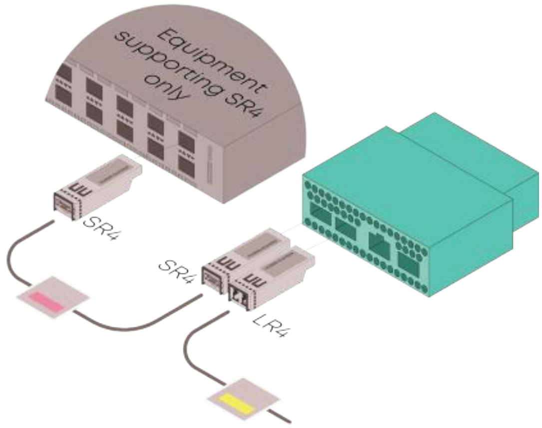
For critical links a certain level of backup is imperative. The most cost-effective solution for this is an optical protection switch which makes it possible to have two fiber links connecting the locations. The power input level of the optical protection switch is permanently monitored. As soon as the power level falls below a threshold level, the OPS will automatically switch to the backup link. An optical protection switch can also be used for multiplexed signals.



Application scenarios

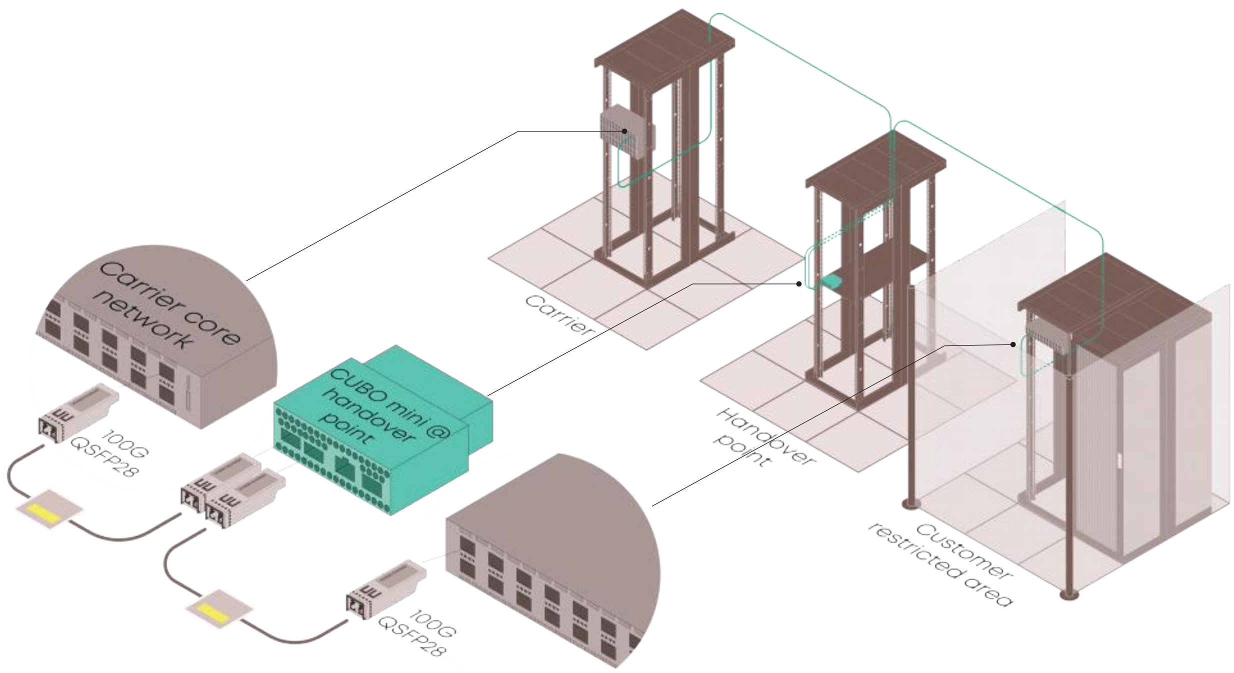
Media conversion

There are various scenarios in which a conversion between different types of transport media is required. Although it is pretty much standard that singlemode cable is used when distances of 1 km or more are required. However, there is still a lot of equipment in use that only provides multimode or RJ45 interfaces. In these cases a conversion between singlemode and the respective other transport medium is required. The same thing applies when connecting to a building that has multimode in-building cabling.



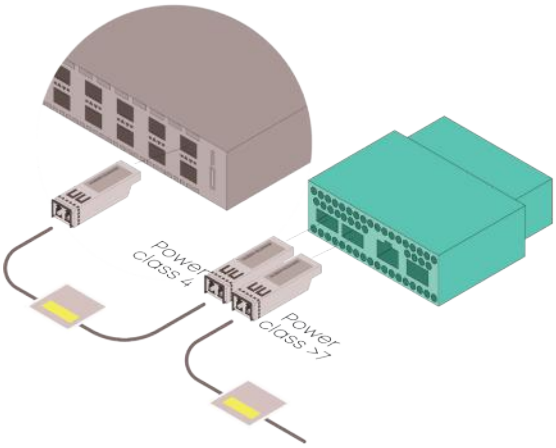
Demarcation

More often than not, a clear demarcation point at a facility is required. A transponder is an ideal and cost-effective solution for this.



Power class extension

MSA specifies the different power classes (PC) for QSFP28 transceivers, meaning how much electrical power the transceivers require. The majority of QSFP28 routers natively only support up to 3.5 W per port. However, nowadays there are the high power transceivers such as ZR4 (80km) that require ~6.5W.



QSFP28 MSA

Power class	Max power
1	1.5W
2	2.0W
3	2.5W
4	3.5W
5	4.0W
6	4.5W
7	5.0W
8	6.5W
	8.0W
	10.0W

Supported by all 100G switches

Power required by e.g. ZR4 (80km) transceiver

Power supported by CUBO mini 100G ODD

Summary

Data center interconnect transport systems

Bandwidth expansion based on WDM is an ideal alternative to deploying new fiber. Not only is it more cost effective but the time to deploy is a mere fraction compared to laying additional fiber.

The flexibility of working with different topologies makes WDM a versatile solution. It becomes even more advantageous when adding active modules such as optical amplification, transponders or optical protections switches.

HUBER+SUHNER AG
Degersheimerstrasse 14
9100 Herisau
Switzerland
Phone +41 71 353 41 11
hubersuhner.com

4014/4743/05.2022

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