What is WDM?

Using Wavelength Division Multiplexing to expand network capacity

Many organizations have yet to discover the benefits of WDM networking and how it can be used to help maximize network investments and get the most out of fiber networks.

A whitepaper from Smartoptics

Wavelength division multiplexing, WDM, has long been the technology of choice for transporting large amounts of data between sites. It increases bandwidth by allowing different data streams to be sent simultaneously over a single optical fiber network. In this way WDM maximizes the usefulness of fiber and helps optimize network investments.

Traditionally WDM systems have been adopted by carriers and service providers. Large-scale systems, designed for “national infrastructures” made the systems prohibitively expensive and too complex for private network use. In recent years things have changed. And the technology is evolving rapidly. Today WDM networking solutions are available that meet the needs of corporate enterprises, governmental organizations and privately owned datacenters. Solutions that are simpler and more cost effective than the traditional carrier grade ones.

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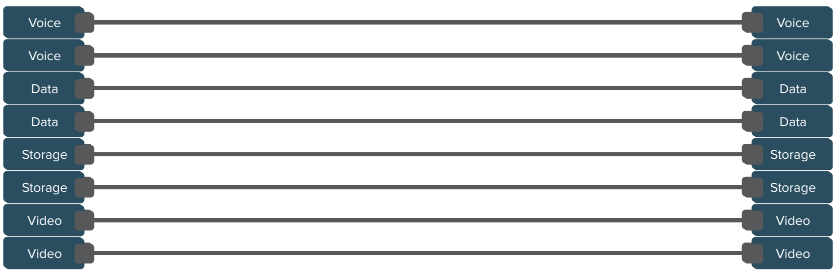
WDM – the basics

The foundation of WDM lies in the ability to send different data types over fiber networks in the form of light. By allowing different light channels, each with a unique wavelength, to be sent simultaneously over an optical fiber network a single virtual fiber network is created. Instead of using multiple fibers for each and every service, a single fiber can be shared for several services.



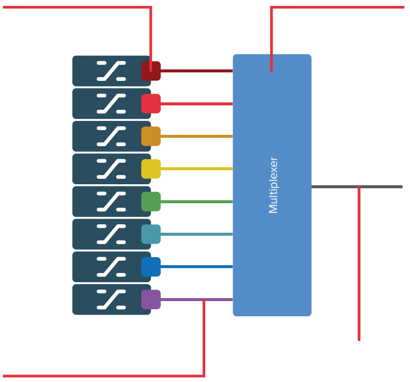
Individual fibers per channel

Multiplexing combines multiple channels on a single dark fiber

In this way WDM increases the bandwidth and maximizes the usefulness of fiber. Fiber rental or purchase represents a significant share of networking costs. So using an existing fiber to transport multiple traffic channels can generate substantial savings.

In its simplest form WDM systems consist of four elements:

1. **Transceivers** transmitting data as light
2. WDM **multiplexer** optimizes the use of fiber channels
3. **Patch cord** connecting the transceiver and the multiplexer
4. **Dark fiber -** prerequisite for a WDM solution



Transceivers – transmitting data as light

Transceivers are wavelength-specific lasers that convert data signals from SAN and IP switches to optical signals that can be transmitted into the fiber. Each data stream is converted into a signal with a light wavelength that is a unique color. Due to the physical properties of light, channels cannot interfere with each other. All WDM wavelengths are therefore independent. Creating virtual fiber channels in this way means that the number of fibers required are reduced by the factor of the wavelengths used. It also allows new channels to be connected as needed, without disrupting the existing traffic services. Since each channel is transparent to the speed and type of data, any mix of SAN, WAN, voice and video services can be transported simultaneously over a single fiber or fiber pair.

Multiplexers optimizing the use of fiber channels

The WDM multiplexer, sometimes referred to as the passive mux, is the key to optimizing, or maximizing, the use of the fiber. The multiplexer is at the heart of the operation, gathering all the data streams together to be transported simultaneously over a single fiber. At the other end of the fiber the streams are demultiplexed, i.e. separated into different channels again.

> *The WDM multiplexer is at the heart of the operation, gathering all data streams together to be transported simultaneously over a single fiber.*

Early WDM systems were able to transport two bi-directional channels over a pair of fibers. The technology has evolved rapidly and both the number of channels and the amount of data per channel transported has increased. Today up to 80 channels can be simultaneously transmitted down a fiber at any one time.

Since they're usually positioned at the end points in a network, multiplexers are often referred to as terminal muxes. When connecting two sites, a multiplexer is positioned at each site, creating a point-to-point connection. In many cases, networks have additional sites where connectivity is required of some form, but not for all types of traffic. Here optical add drop multiplexers (OADMs) are used to extract the desired wavelengths needed for the specific site while bypassing the traffic types not needed. In this way, more versatile ring, distribution and access networks can be built.

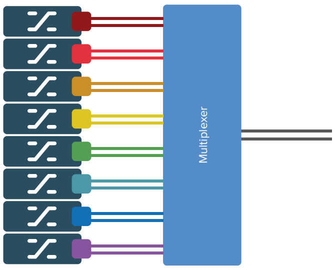
Patch cord connecting the transceiver and the mux

The transceiver transmits the high-speed data protocols on narrow band wavelengths while the multiplexer is at the heart of the operation. The patch cable is the glue that joins these two key elements together. LC connector cords are popular, and connect the output of the transceiver to the input on the multiplexer.

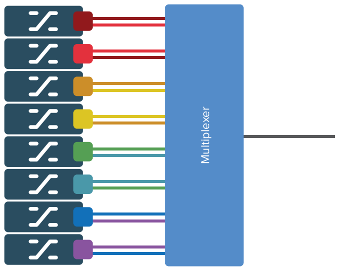
Dark fiber: Fiber pair or single fiber strand

A re-requisite for any wdm solution is access to a dark fiber network. The most common way of transporting optical traffic over an architecture is by using a fiber pair. One of the fibers is used for transmitting the data and the other is used for receiving the data. This allows the maximum amount of traffic to be transported.

At times only a single fiber is available. Because different light colors travel on different wavelengths, a WDM system can be built regardless. One wavelength is used to send data and a second one to receive it.



Fiber pair used for transmitting and receiving data on different fibers.



Bi-directional transceivers used to transmit and receive data over single fiber.

Choosing between CWDM and DWDM

The two key WDM technologies are coarse wavelength division multiplexing, CWDM and dense wavelength division multiplexing, DWDM. Which solution is best suited to a given environment depends on the network and user requirements.

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CWDM supports up to 18 wavelength channels transmitted through a fiber at the same time. To achieve this, the different wavelengths of each channel are 20nm apart. DWDM, supports up to 80 simultaneous wavelength channels, with each of the channels only 0.8nm apart.

CWDM technology offers a convenient and cost-efficient solution for shorter distances of up to 70 kilometers. For distances between 40 and 70 kilometers, CWDM tends to be limited to supporting eight channels. Unlike CWDM, DWDM connections can be amplified and can therefore be used for transmitting data much longer distances.

The sweet spot for CWDM is up to 10 Gigabit Ethernet and 16G Fibre Channel. And it is quite unlikely capacities with increase beyond this in the future. DWDM however, is able to handle higher speed protocols up to 100Gbps per channel making it a more suitable technology for higher speed protocols.

Traditionally CWDM components have been lower in cost making it more popular than DWDM. Now the price for both solutions is comparable. With higher speeds, more channel capacity, longer distances and passive networking, DWDM is the technology of choice for green field installations.

Active or passive systems – what's the difference?

Both CWDM and DWDM solution**s** are available as active or passive systems.

In a passive, unpowered solution the XWDM transceiver resides directly in the data switch. The output from the XWDM transceiver connects to an unpowered multiplexer that combines and redistributes, multiplexes and demultiplexes, the various signals. As the XWDM transceiver resides in the data switch, it means that all XWDM functionality is embedded in the data switch.

Active XWDM solutions are stand-alone AC or DC powered systems separated from the switch. The task of the stand-alone system is to take the short-range optical output signal of the fiber or IP switch and convert it to a long-range XWDM signal. This OEO, (optical to electrical to optical), conversion is handled by a transponder. The converted XWDM signal is then transmitted with the help of transceivers and multiplexers. Due to the separation of the XWDM transport solution from the actual switch, active systems also tend to be more complex than passive, embedded solutions.

A transceiver for every need

To meet the needs of transporting multiple protocols of different speeds and types, transceivers are available in a range of categories.

CWDM/DWDM. XWDM transceivers are available for two different applications. The first is used in an embedded XWDM system directly in a data switch to transport an XWDM wavelength channel from the switch on to a dark fiber with the help of a passive multiplexer. The second application is used to take the output signal from a transponder-based XWDM system.

Grey (uncolored). An XWDM signal is a colored wavelength channel. So any signal that is not XWDM is typically referred to as uncolored, or a grey signal. Grey transceivers are available in four categories: short range (SR) transceivers for 850nm signal, long range (LR) for 1310nm, extended range (ER) for 1550nm and further extended reach (ZR) for 1550nm signals. Grey transceivers are typically used for single channel connectivity. The shorter ranges, 850 and 1310nm, are also commonly used as the interface to a transponder-based XWDM platform.

Data speed and protocol type. Data exists in various speeds and applications. The output of a Fibre Channel switch running at 16Gbps is different to that of an Ethernet switch running at 100G requiring different types of transceivers supporting the different protocols. Fibre Channel transceivers run at 4/8/10/16/32G FC while Ethernet transceivers run at 1/10/40/100 Gigabit Ethernet.

Form factor. The form factor is the physical shape and size of the transceiver. They vary in size depending on protocols and tend to get larger as the speeds get faster because of the amount of circuitry and signal conditioning required.

CFP, CFP2, CFP4, CXP 40/100G pluggable transceivers	QSFP28, SFP28, QSFP+ 40/100G pluggable transceivers
XFP 10G optical transceivers	X2 & Xenpaks 10G optical transceivers with converter solutions for entire SFP+ family
SFP+ 16/10/8Gbps optical transceivers and cable assemblies	SFP Ethernet, 4/2/1G FC, Sonet/SDH, multirate and bidi transceivers

Common optical transceiver form factor types

To meet the needs of transporting multiple protocols of different speeds and types, transceivers are available in a range of categories.

Different ways of transporting data over an optical network

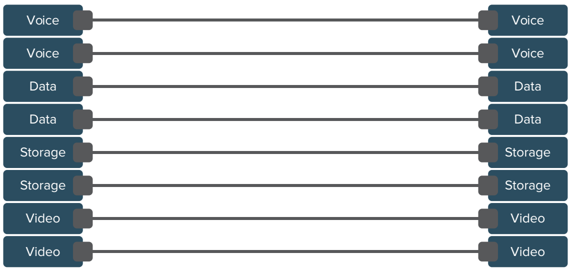
The most common approaches for transporting data over a fiber network is by using single channel connectivity, embedded XWDM solutions or active, transponder-based WDM platforms. Each alternative is based on an organization's access to dark fiber, either owned or leased.

Embedded XWDM allows multiple traffic signals to be transported over the same fiber and increases the utilization of that fiber.

Single channel connectivity

The most basic way of transporting data over a fiber network is through single channel connectivity, where individual traffic channels run over individual fibers. A single channel transceiver is connected directly between the data switches at each site with a line fiber connected between. The method is also referred to as ELWL, extended long wavelength laser, connectivity.

This non-WDM enabled approach requires access to a fiber for each and every service. And no other traffic can be transported through the fiber. This in turn means that the cost for adding additional channels increases linearly at the cost of renting additional fiber.



Singel channel connectivity requires an individual fiber for each channel

Embedded WDM solutions

Embedded XWDM represents an evolution from single channel connectivity. An XWDM transceiver is used instead of an ELWL single channel transceiver and connected directly to the data switch. Each signal is then connected to a multiplexer. With only these components, an embedded WDM solution is as simple as an ELWL approach to implement and manage.

What's more: The WDM solution allows multiple traffic signals to be transported over the same fiber, increasing the utilization of that fiber. New channels can be added to the embedded WDM system simply by connecting new transceivers. By deploying WDM technology, up to 80 channels of traffic can be connected together over the same fiber. ROI is realized when the second channel is added.

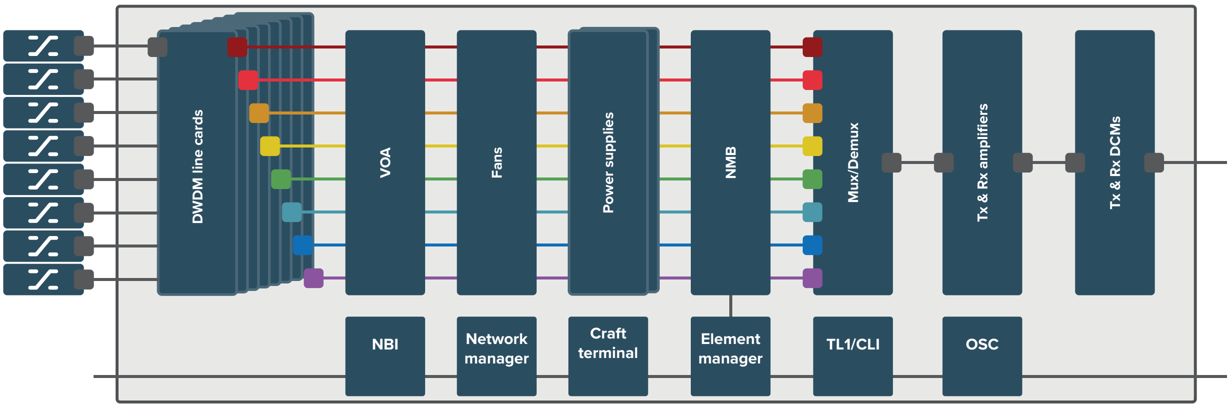
WDM allows multiple traffic signals to be transported over the same fiber

Although a basic ELWL transceiver usually beats the embedded WDM components on price per unit, a WDM based solution is far more cost effective as soon as a second channel is required.

Embedded WDM offers simple, easy to manage and cost efficient solutions for transporting large amounts of data over short to mid-range distances, typically up to 80 kilometers. Since no additional power is required for the embedded components the solutions are also preferred for creating green datacenters.

Active WDM networking solutions

Active XWDM solutions are stand-alone AC or DC powered systems, separated from the switch. In an active solution a transponder takes the output from the SAN or IP switch and converts it to a longer distance XWDM signal. After this OEO conversion, the long distance XWDM signal is transmitted through transceivers and multiplexers. To support management and control of the active, stand-alone, WDM solutions they usually come with a GUI-based management interface.



An active XWDM solution is a powered system, separated from the switch.

This makes an active, transponder based solution a powerful platform for transmitting huge amounts of data between different sites over short or long distances. A drawback of active systems: OEO conversions tend to incur unwanted latency.

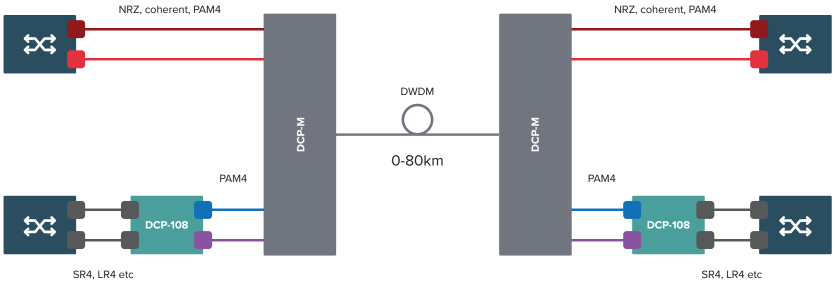
Traditionally active WDM systems were designed for dedicated carriers and service providers. In most cases neither the capacities nor the advanced feature-set of a traditional active WDM solution is required for corporate use. This makes an active system not only unnecessarily complicated to design, install and configure from an enterprise point of view, but also expensive to own and maintain.

> *Traditional active WDM systems are designed for carriers and service providers, making them unnecessarily complicated to design, install and configure from an enterprise point of view.*

Traditionally, enterprises and corporate datacenters have opted for the embedded approach to WDM solutions, offering similar capabilities to transmit a vast range of channels over a single fiber, at a fraction of the cost of an active system.

A new approach to embedded WDM networking

Having recognized that a full-scale traditional active WDM system in many cases is overkill for enterprise use, these systems do offer significant benefits over passive systems in terms of system management and signal amplification for longer distances. An ideal WDM networking solution for corporate datacenter connectivity should combine the simplicity of a passive, embedded solution with the value-adding features of an active WDM platform.



Smartoptics open line systems and the DCP-M offers embedded, advanced WDM functionality and is extremely simple to use.

> *Smartoptics' open line systems and embedded approach to WDM networking, enable advanced functionality, are simple to use and have a clear cost advantage compared to traditional solutions.*

Smartoptics DCP-M-Series marks a revolution in fiber optic networking solutions. DCP-M is a 1U multiplexer platform that combines the simplicity of a passive multiplexer with the features of a more traditional transponder-based DWDM platform. A multiplexer with integrated channel monitoring, amplification and signal conditioning. It easily handles all of today's data protocols up to 400Gbps per channel in a simple plug and forget approach. Corporate data centers, enterprises, and campus networks can now synchronously connect all their storage and data traffic between sites with minimal complexity and signal latency. Service Providers can also reap the benefits of the simplicity and the embedded approach in DCI and Metro applications.

The DCP-M can be used as a flexible DWDM multiplexer for any ITU standardized DWDM transponder or muxponder system. Inputs from such systems as well as embedded DWDM wavelengths can all be used together with the DCP-M for optimal networking flexibility. The DCP-M is truly plug and play and has built-in channel monitoring, amplification and signal conditioning. It is therefore easy to design into networks, install and maintain. The result is the most compact and cost-efficient solution available on the market.

Expand your network horizons

Technology is evolving. With new services and applications introduced on an ongoing basis. Organizational needs also change. To keep up, they need to expand their network horizons. Adopting approaches that are simple to install, re-configure and maintain. Through Smartoptics, enterprises can ensure their networks are more cost effective. Flexible. And "future proof"—responding to shifting marketplace demands today and tomorrow.

About Smartoptics

Smartoptics provides innovative optical networking solutions and devices for the new era of open networking. Our customer base includes thousands of enterprises, governments, cloud providers, Internet exchanges as well as cable and telecom operators.

We have an open networking approach in everything we do which allows our customers to break unwanted vendor lock-in, remain flexible and minimize costs. Our solutions are used in metro and regional network applications that increasingly rely on data center services and specifications.

Smartoptics is a Scandinavian company founded in 2006. We partner with leading technology and network solution providers such as Brocade, Cisco, HPE and Dell EMC and have a global reach through more than 100 business partners.

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