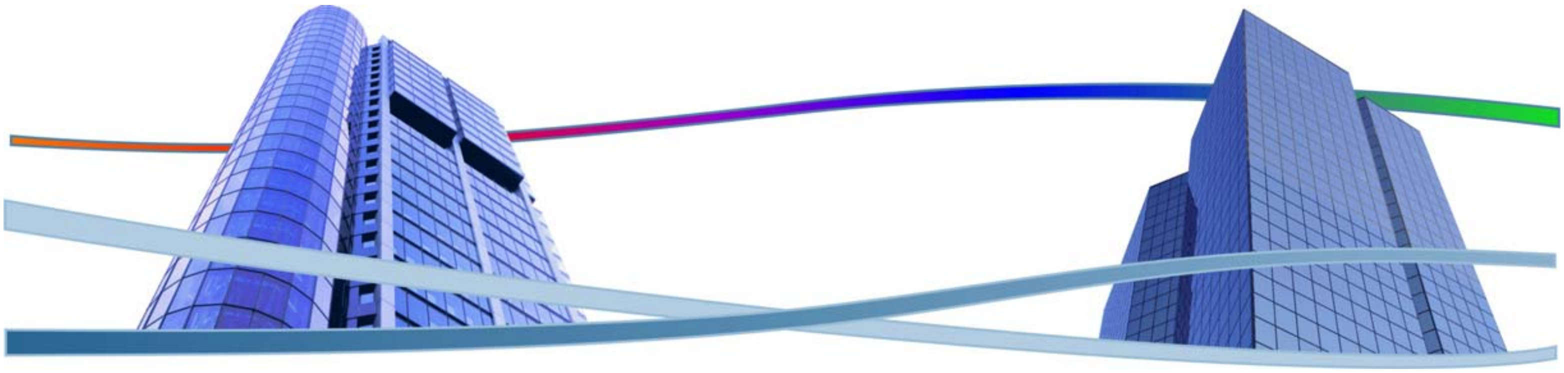
iConverter CWDM DESIGN GUIDE



Coarse Wavelength Division Multiplexing White Paper

This white paper provides an overview of *iConverter* fiber connectivity products with a series of applications illustrating how *iConverter* CWDM Multiplexers and media converters can be used to increase the capacity of fiber network infrastructure.

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Purpose and Scope

The purpose of this document is to provide a series of applications which illustrate common ways that the *iConverter* CWDM products can be used in typical communication networks.

Introduction

iConverter Products

Omnitron's CWDM modules are part of the *iConverter* product family. As such, the CWDM modules can be seamlessly integrated with other *iConverter* products – including media converters, transponders and small form pluggable (SFP) transceivers – to build a flexible, multi-service platform capable of delivering Ethernet, TDM, SONET and other services across a fiber pair or single-fiber connection.

Definitions

Following are definitions of commonly used terms within this document.

Attenuation: the rate at which an optical signal decreases in intensity.

Band-Splitter: a Band-Splitter module combines and separates the lower CWDM channels (1270nm to 1450nm) and the upper CWDM channels (1470nm to 1610nm).

Common link: a fiber optic connection that carries the aggregated CWDM wavelengths through the network. The common link can be a fiber pair or a single fiber, depending on application.

Common port: a port on a CWDM/X or CWDM/AD device that connects to the common link. A CWDM/X has one common port. A CWDM/AD has two common ports (left and right).

Channel: a route or path through a CWDM network for a communications device. In a fiber pair CWDM network, each channel uses a single CWDM wavelength. In a single-fiber network, each channel uses two CWDM wavelengths.

Channel port: a port on an *iConverter* CWDM/X or an *iConverter* CWDM/AD that connects to a communications device using a specific CWDM wavelength.

CWDM/AD: *iConverter* CWDM optical add/drop multiplexer, also known as OADM.

CWDM/X: *iConverter* CWDM multiplexer/demultiplexer, also known as MUX/DEMUX.

Dispersion: the spreading of light pulses as they travel through fiber optic cable. Dispersion results in distortion of the signal, which limits the bandwidth and distance of the fiber.

Fiber patch cable: typically a short, connectorized piece of fiber optic cable, single-mode or multimode, used to connect one optical device to another.

Fixed Fiber Interface: a fiber optic interface on a communications device that is fixed in place and cannot be removed or changed by the user. Fixed fiber interfaces typically utilize connectors such as ST, SC, LC or MT-RJ style, and operate over legacy wavelengths (i.e. 850nm, 1310nm, 1550nm).

Legacy 1310 wavelength: traditional 1310nm fiber optic communications that use a center wavelength of 1310nm. The tolerance of this wavelength is wide and not suitable for CWDM filters.

Legacy 1550 wavelength: traditional 1550nm fiber optic communications that use a center wavelength of 1550nm. The tolerance of this wavelength is wide and not suitable for CWDM filters.

MUX/DEMUX: multiplexer/demultiplexer.

OADM: optical add/drop multiplexer.

Optical Power Budget: the difference between the minimum transmit power and the minimum receiver sensitivity of the optical devices connected across a fiber optic link.

Pass Band Port: a dedicated channel port through which a wide spectrum of light may pass. The *iConverter* CWDM/X 1310 Pass Band (1310PB) port and Expansion (EXP) port are examples of pass band ports.

SFP: Small Form Pluggable. An SFP is a removable transceiver, typically fiber media, available in a wide range of modes, wavelengths and power ratings.

Transponder: a device that automatically receives, amplifies, and then retransmits a signal on a different wavelength without altering the data/signal content.

Water Region: also called "Water Peak". Water molecules are absorbed into the glass during the manufacturing process of traditional single-mode fiber, resulting in higher attenuation properties in the 1400nm wavelength region.

CWDM Overview

CWDM Wavelengths

The wavelengths used by the *iConverter* CWDM products are defined by ITU-T G.694.2. This standard lists eighteen wavelengths, ranging from 1271nm to 1611nm, with 20nm wavelength spacing between each center wavelength.

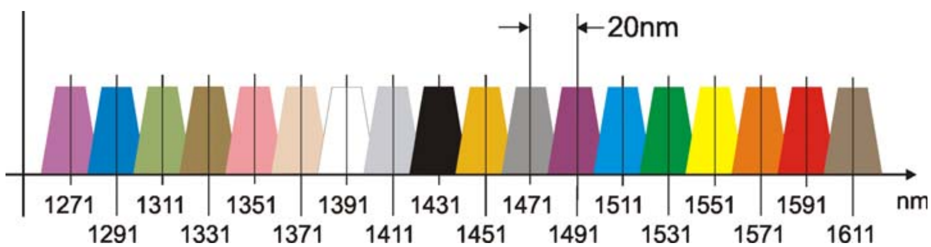

Figure 1: CWDM Wavelengths as Specified by ITU-T G.694.2

CWDM wavelengths can be used for a wide variety of functions and applications. Wavelengths can be dedicated to different customers' traffic, different speeds and services, or used for non-intrusive testing, monitoring and management.

Depending on the type of optical fiber used, some wavelengths will have better performance than others. Please refer to the next section for more detail.

Optical Fiber

iConverter CWDM products are typically intended for use with single-mode fiber. Use with multimode fiber is feasible, but involves considerations beyond the scope of this paper. (Please consult with Omnitron for more information.)

ITU-T has specified three principle types of single-mode fiber:

- Non-dispersion-shifted fiber (NDSF), G.652, G.652.C & G.652.D
- Dispersion-shifted fiber (DSF), G.653
- Non-zero dispersion-shifted fiber (NZ-DSF), G.655

The ITU-T G.652 non-dispersion-shifted fiber is known as conventional single-mode fiber. It is optimized for operation in the 1310nm band (its zero-dispersion wavelength) but can operate in the 1550nm band with increased dispersion characteristics. As indicated in *Figure 2*, ITU-T G.652 is not optimized for CWDM applications due to the high attenuation around the water peak region centered at 1383nm (wavelengths between 1340nm and 1420nm). For this reason, certain *iConverter* CWDM products – such as the 8862 8-channel CWDM/X – omit the 1390 and 1410 wavelengths.

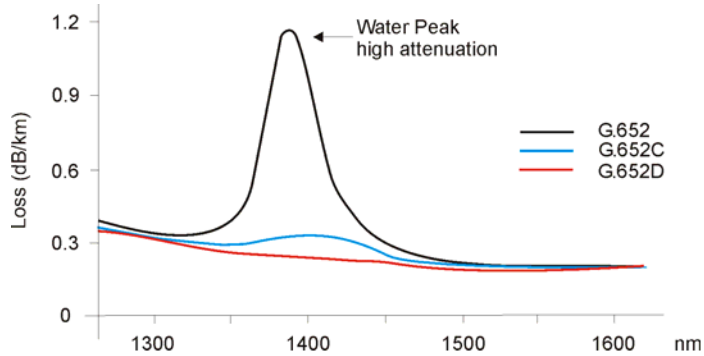

Figure 2: Loss vs. Wavelength Characteristics

CWDM systems can be designed with G.652 single-mode fiber. However, the distance will be limited by higher attenuation at wavelengths near the water peak.

ITU-T G.652.C and ITU-T G.652.D fiber cables are considered the standard single-mode cables available today. ITU-T G.652.C non-dispersion-shifted fiber is optimized for transmission for the range of wavelengths from 1285nm to 1625nm. However, the dispersion characteristics around the 1550nm wavelength have not been improved. ITU-T G.652.C compliant fiber offers good CWDM capabilities for metro and access networks.

ITU-T G.652.D single-mode optical fiber is designed to provide full optical transmission over the entire wavelength range from 1270 nm to 1610 nm. It has low attenuation and has no water peak impairments. It also has improved dispersion characteristic around the 1550nm wavelength, for improved performance at longer distances and higher data rates. ITU-T G.652.D is commonly referred to as the "full spectrum" fiber.

ITU-T G.653 dispersion-shifted fiber (not shown in Figure 2) is optimized for operating in the region between 1500 to 1600nm by moving the zero-dispersion wavelength from 1310nm to the vicinity of 1550nm. ITU-T G.653 can be used for CWDM applications, but is not recommended for CWDM applications outside of this 1500 to 1600nm range.

ITU-T G.655 nonzero dispersion-shifted fiber (not shown in Figure 2) moves the zero-dispersion wavelength outside the 1550nm operating window. The intention is to cause a small but finite amount of chromatic dispersion at 1550nm, which minimizes other "nonlinear effects" (other obstacles beyond the scope of this document) that are encountered in DWDM systems. ITU-T G.655 is not recommended for CWDM applications.

In summary, ITU-T G.652C/D non-dispersion-shifted fiber is the recommended single-mode optical fiber for CWDM applications.

Wavelength Conversion

Data from virtually any type of communications equipment can be carried over a CWDM network. This includes servers, switches, routers, ATM, TDM, SONET and SDH devices, management devices, serial communications equipment, and more.

In order to connect a communication device into a CWDM network, the device must transmit an optical signal using one of the eighteen specific CWDM wavelengths discussed above. Any two devices that are meant to communicate across the common link must use the same specific CWDM wavelength. Devices whose signals are to be kept isolated from each other must use different CWDM wavelengths.

Note that legacy 1310nm and legacy 1550nm wavelengths (both widely used in SONET/SDH networks today) are NOT the same as CWDM 1311nm and CWDM 1551nm wavelengths. The center wavelength tolerances for legacy 1310nm and 1550nm are much wider than the CWDM equivalents, and therefore not precise enough to run through CWDM filters. For this reason, legacy wavelengths must always be converted to CWDM wavelengths when used in CWDM networks.

The one exception to this rule is when a pass band port is utilized. A pass band port is a special channel port which allows a much wider spectrum of light to pass through. Pass band ports on *iConverter* CWDM products are discussed in more detail in the next section.

Small Form Pluggable Transceivers – SFPs

The most cost effective way to create CWDM wavelengths is by using a Small Form Pluggable (SFP) optical transceiver, either installed directly in the communications equipment, or as part of a serially attached media converter. An SFP transceiver generates an optical signal at a specific CWDM wavelength (i.e. 1471 nm, 1491 nm, etc.) according to ITU standards.

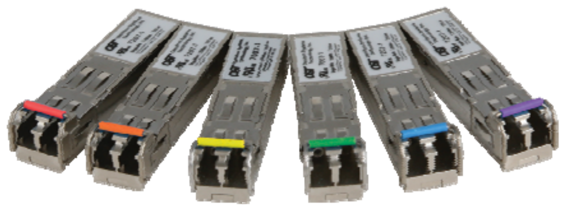

Figure 3: CWDM Small Form Pluggable (SFP) Transceivers

Many modern communications devices are available with SFP ports. To connect one of these communication devices to a CWDM network, simply select an SFP transceiver with the appropriate CWDM wavelength, and insert it into SFP receptacle port of the device. Then connect the SFP transceiver to the wavelength matching channel port on the CWDM device using a single-mode fiber patch cable. Ensure that the Tx of the SFP transceiver is connected to the Rx of the channel port, and the Rx of the SFP transceiver is connected to the Tx of the channel port.

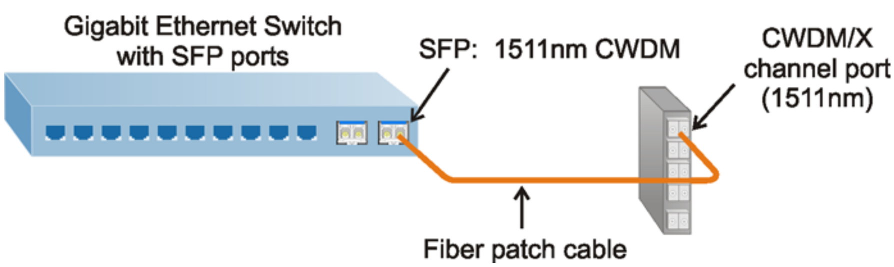

Figure 4: Communications Device with CWDM SFP Installed

Omnitron’s CWDM SFP transceivers have color coded handles to indicate the specific CWDM wavelength. For the eight wavelengths between 1471nm and 1611nm, the following industry-adopted color codes apply:

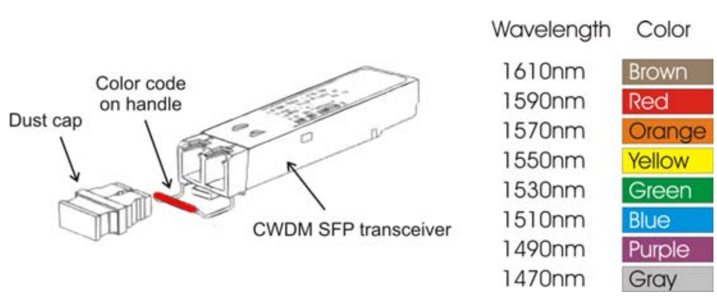

Figure 5: SFP Color Codes

For the ten wavelengths between 1270nm and 1450nm range, there are no commonly adopted standard color codes.

iConverter Media Converters

Transponders

Fiber optic communications equipment with fixed fiber interfaces – such as ST, SC, LC or MT-RJ connectors – operating over legacy wavelengths (i.e. 850nm, 1310nm, 1550nm) must be converted to CWDM wavelengths using a media converter configured as a transponder. A transponder is a device that automatically receives, amplifies, and then retransmits a signal on a different wavelength without altering the data/signal content.

The *iConverter* xFF transponder is the ideal product for this application. The xFF is an SFP to SFP protocol-transparent fiber converter, designed to provide conversion between different wavelengths, multimode and single-mode, fiber pair and single-fiber.

The following example shows an OC-12 circuit from an ATM router, which is connected to a CWDM/X channel port. The fiber interface on the router uses fixed fiber SC connectors and legacy 1310nm wavelength. The channel port on the CWDM/X requires a CWDM 1530nm wavelength, so a transponder is utilized.

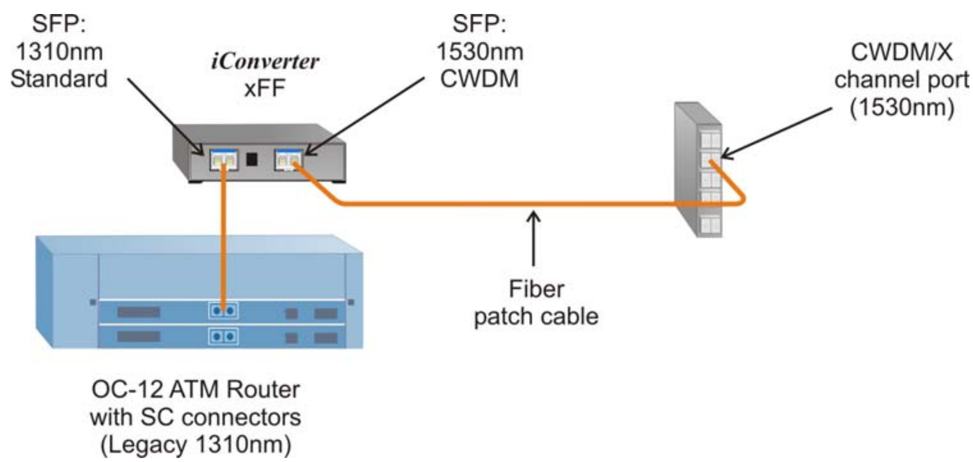

Figure 6: Communications Device with Transponder

The *iConverter* xFF converts the wavelength from legacy 1310nm to CWDM specific 1530nm. Two SFP transceivers are required in this example. The left side of the media converter uses a standard 1310nm SFP transceiver, while the right side of the media converter uses a CWDM 1530nm SFP transceiver (color code green).

Metallic Interfaces

Communications devices with metallic interfaces – such as RJ45, RJ48, BNC Coax – can also be connected to CWDM networks. This is done using a copper to fiber media converter that supports CWDM SFP transceivers.

The following example shows a DS3 (T3) service from a DS3 MUX, connected to a CWDM/X channel port. The DS3 interface uses two BNC coax connectors. The channel port on the CWDM/X requires a CWDM 1550nm wavelength, so a media converter is required.

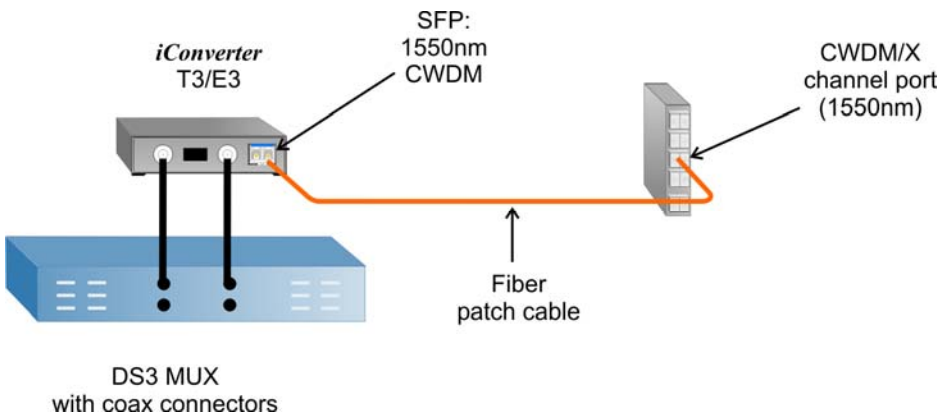

Figure 7: Communications Device with Media Converter and CWDM SFP

The *iConverter* T3/E3 with a CWDM SFP transceiver (color code yellow) converts the electrical signal (coax) to optical CWDM-specific 1550nm.

In the next example, a Fast Ethernet switch is connected to a CWDM/X channel port. The data interface on the Fast Ethernet switch is a metallic RJ45 connector. The channel port on the CWDM/X requires a CWDM 1570nm wavelength, so a media converter is required.

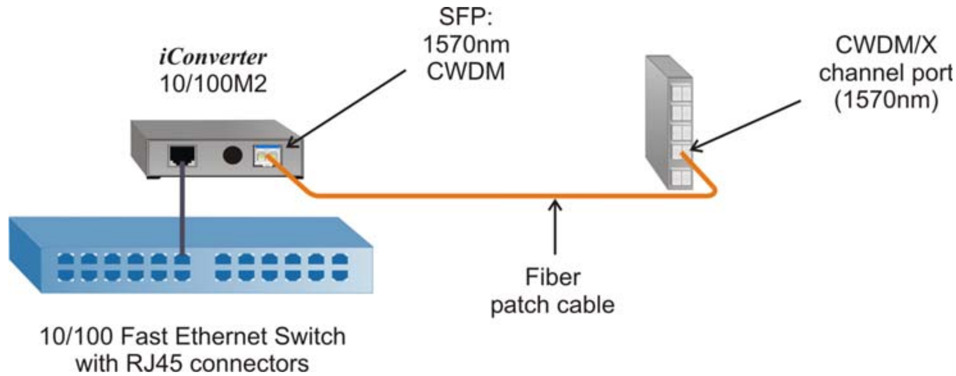

Figure 8: Communications Device with Media Converter and CWDM SFP

The *iConverter* 10/100M2 with a CWDM SFP transceiver (color code orange) converts the electrical signal (RJ45) to optical CWDM specific 1570nm.

iConverter CWDM Product Family

The *iConverter* CWDM product family consists of CWDM/X models and CWDM/AD models.

CWDM/X Modules

The CWDM/X (MUX/DEMUX) is the aggregation device within a CWDM network. The CWDM/X combines (multiplexes) and separates (demultiplexes) the unique wavelengths from the individual communications devices using a series of wavelength (color) filters. All communications devices "feed" their signals into the channel ports of the CWDM/X using unique CWDM wavelengths.

The wavelengths that are multiplexed/demultiplexed by the device are specific to each CWDM/X model number, and cannot be reconfigured by the user.

A typical point-to-point CWDM network uses two CWDM/X devices, one at each end of the network, as shown in *Figure 9*.

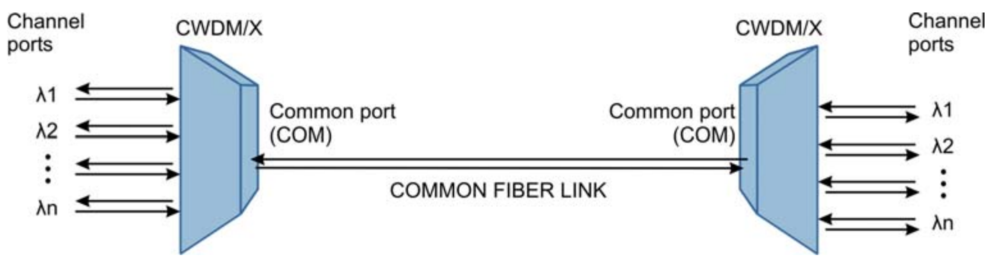

Figure 9: Point-to-point CWDM network

The common fiber link, which carries the aggregated wavelengths, can be either a fiber pair or a single-fiber connection. On *iConverter* CWDM/X products, the common link port is labeled **COM**.

For fiber pair CWDM/X products, this port is a duplex LC connector, with a separate Tx and Rx.

For single-fiber CWDM/X products, this port is a single LC connector.

iConverter CWDM/X devices are available with 2, 4 or 8 channel ports.

Each channel port on an *iConverter* CWDM/X is a duplex LC connector, with a separate Tx and Rx. Always connect the Tx of the SFP transceiver to the Rx of the channel port, and connect the Rx of the SFP transceiver to the Tx of the channel port.

The iConverter Multi-service Platform

The following diagram shows one end of a CWDM network incorporating all four of the previous examples: Gigabit Ethernet, OC-12, DS3 and Fast Ethernet multiplexed together on one fiber.

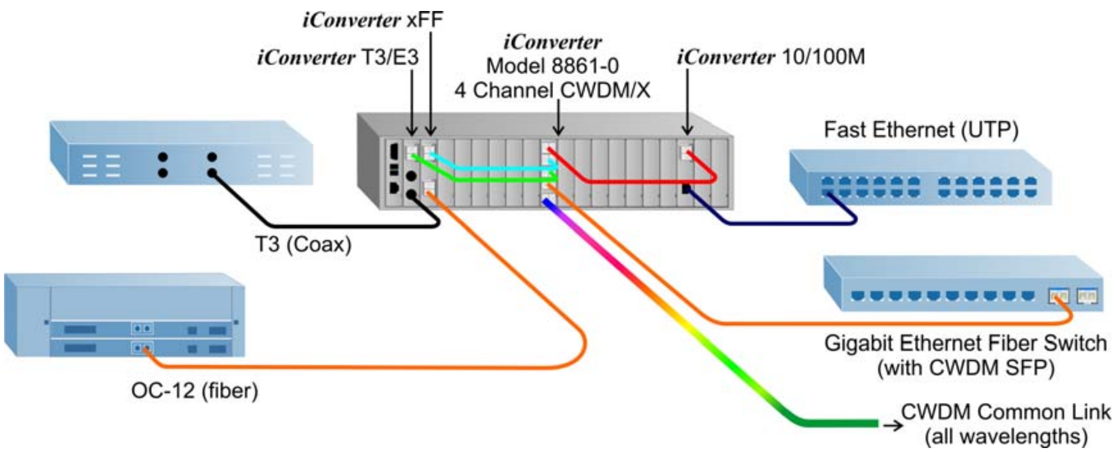

Figure 10: iConverter Multi-service Platform

Note that the Gigabit Ethernet switch does not require a media converter because it has an integrated SFP port. Its fiber patch cable connects directly to the 1510nm channel port of the CWDM/X.

The other three communications devices connect to three media converters installed in a 19-module *iConverter* multiservice chassis, where the CWDM wavelengths are produced (1530, 1550 and 1570nm). From there, the CWDM wavelengths are connected with fiber patch cables to the respective channel ports on the CWDM/X.

CWDM/X Options

A 1310 Pass Band (1310PB) port is an extra channel port on a CWDM/X module that allows a legacy 1310nm signal to pass through the network within a reserved band (1260nm to 1360nm). A 1310PB is useful when overlaying CWDM wavelengths on an existing SDH/SONET network, for example.

An Expansion (EXP) port enables the cascading of several CWDM MUX devices, allowing a network designer to expand the channel capacity of a CWDM network. Two 4-channel CWDM/X devices, for example, can be cascaded to create an eight channel CWDM network with this feature.

A Band-Splitter can be used to cascade two 8-channel CWDM/X devices to create a sixteen channel CWDM network. A Band-Splitter combines and separates the lower channels (1270nm to 1450nm) and the upper channels (1470nm to 1610nm). Band-Splitters are available as single or dual band-splitters. Dual Band-Splitters have two lower channel ports, two high channel ports and two common link ports.

1310PB ports and EXP ports are explained in more detail in the Applications section of this document.

The following tables summarize the *iConverter* CWDM/X product portfolio. (Note the exact center wavelengths per ITU-T G.694.2 are shown.).

Model Type: CWDM/X Single Band-Splitter

Model Number	Channel Port ITU Center Wavelength (nm)
8865-0	1270 – 1450 + 1470 - 1610

Table 1: Single Band-Splitters

Model Type: CWDM/X Dual Band-Splitter

Model Number	Channel Port ITU Center Wavelength (nm)
8865-2	1270 – 1450 + 1470 - 1610

Table 2: Dual Band-Splitters

Model Type: CWDM/X 4-Channel MUX/DEMUX – Fiber Pair

Model Number	Channel Port ITU Center Wavelength (nm)	1310PB Port	EXP Port
8860-0	1471, 1491, 1591, 1611	No	No
8860-1	1471, 1491, 1591, 1611	Yes	No
8860-2	1471, 1491, 1591, 1611	Yes	Yes
8860-3	1471, 1491, 1591, 1611	No	Yes
8861-0	1511, 1531, 1551, 1571	No	No
8861-1	1511, 1531, 1551, 1571	Yes	No

Table 3: 4-Channel CWDM/X over Fiber Pair

Model Type: CWDM / X 8-Channel MUX / DEMUX – Fiber Pair

Model Number	Channel Port ITU Center Wavelength (nm)	1310 PB Port	EXP Port
8862-0	1271, 1291, 1311, 1331, 1351, 1371, 1431, 1451	No	No
8863-0	1471, 1491, 1511, 1531, 1551, 1571, 1591, 1611	No	No
8863-1	1471, 1491, 1511, 1531, 1551, 1571, 1591, 1611	Yes	No

Table 4: 8-Channel CWDM/X over Fiber Pair

Model Type: CWDM / X 2-Channel MUX / DEMUX – Single-Fiber

Model Number	Channel Port ITU Center Wavelength (nm)	EXP Port
8870-0	1471/1491, 1511/1531	No
8871-0	1491/1471, 1531/1511	No
8872-0	1551/1571, 1591/1611	No
8873-0	1571/1551, 1611/1591	No

Table 5: 2-Channel CWDM/X over Single-Fiber

Model Type: CWDM / X 4-Channel MUX / DEMUX – Single-Fiber

Model Number	Channel Port ITU Center Wavelength (nm)	EXP Port
8874-0	1271/1291, 1311/1331, 1351/1371, 1431/1451	No
8875-0	1291/1271, 1331/1311, 1371/1351, 1451/1431	No
8876-0	1471/1491, 1511/1531, 1551/1571, 1591/1611	No
8877-0	1491/1471, 1531/1511, 1571/1551, 1611/1591	No

Table 6: 4-Channel CWDM/X over Single-Fiber

Please consult the *iConverter* CWDM/X datasheets for additional specifications and ordering information.

CWDM / AD Modules

A CWDM Add/Drop Multiplexer (CWDM/AD) is used to add (insert) and/or drop (extract) one or more specific wavelengths to/from a CWDM network. Typically, CWDM/AD devices are placed at intermediate locations between two CWDM/X devices. However, there are also applications where CWDM/AD devices can be used without CWDM/X devices. See the Applications section of this document for additional details.

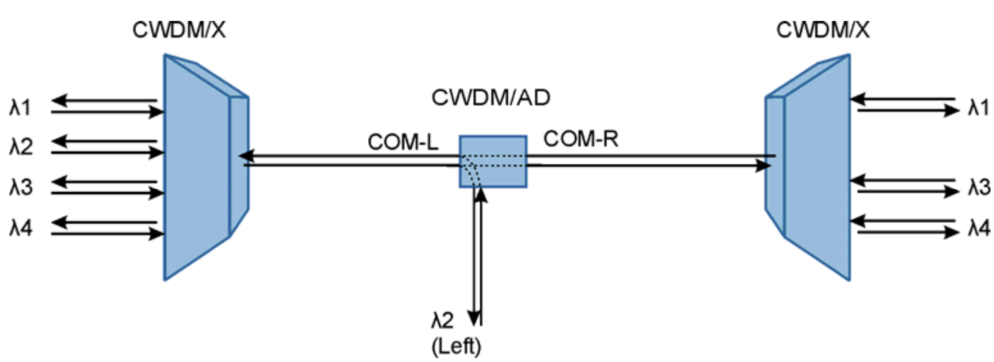

Figure 11: One Channel Uni-directional CWDM/AD Application

In the above diagram, the CWDM/X devices at each end of the network multiplex multiple CWDM wavelengths onto a common fiber link. The CWDM/AD device in the middle of the network terminates (extracts) one specific channel (wavelength) which originates from the CWDM/X on the left side of the network. All other channels pass through the CWDM/AD device to the CWDM/X on the right. Note that the extracted wavelength, λ2, does not continue to the right side of the network. The λ2 channel port on the right side CWDM/X is therefore unused.

On all *iConverter* CWDM/AD products, the common link port for the left side of the network is labeled **COM-L**. The common link port for the right side of the network is labeled **COM-R**. This common link can be either a fiber pair or a single-fiber.

For fiber pair CWDM/AD products, the COM-L port is a duplex LC connector with a separate Tx and Rx, and the COM-R port is a duplex LC connector with a separate Tx and Rx.

For single-fiber CWDM/AD products, the COM-L and COM-R ports share a duplex LC connector.

The wavelength that is extracted by the device is specific to each CWDM/AD model number, and cannot be reconfigured by the user. For a complete list of *iConverter* CWDM/AD models, see *Table* .

iConverter CWDM/AD devices are available in one-channel and two-channel versions. They can be used in uni-directional applications, as shown in *Figure 11*, or dual-directional applications, as shown in *Figure 12.*

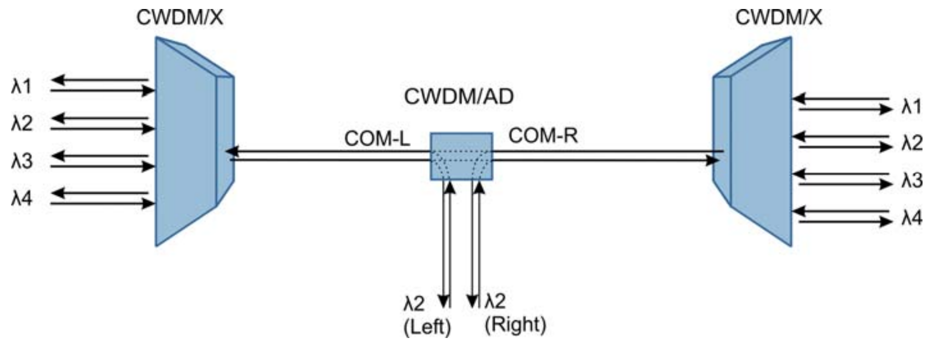

Figure 12: One Channel Dual-directional CWDM/AD Application

Note that the λ2 wavelength in *Figure 12* coming from the left is terminated by the CWDM/AD. It is then re-inserted into the network and re-used on the right side of the span as a separate and independent connection.

Uni-directional and dual-directional modes are explained in more detail in the Applications section of this document.

The following table summarizes the *iConverter* CWDM/AD product portfolio. (Note the exact center wavelengths per ITU-T G.694.2 are shown.)

Model Type: CWDM/AD 1 and 2-Channel OADM

Model Number	Channel Port ITU Center Wavelength (nm)	Common Link
8867-XX	Add/Drop any one channel (one CWDM wavelength between 1271 and 1611)	Fiber Pair
8868-XX	Add/Drop any two channels (two CWDM wavelengths between 1271 and 1451)	Fiber Pair
8869-XX	Add/Drop any two channels (two CWDM wavelengths between 1471 and 1611)	Fiber Pair
8878-XX	Add/Drop any one channel (two consecutive CWDM wavelengths between 1271 and 1611)	Single-Fiber

Table 7: CWDM/AD over Single-Fiber or Fiber Pair

All interfaces on *iConverter* CWDM/X and CWDM/AD products use LC/UPC connectors. Please consult *iConverter* CWDM/AD datasheets for additional specifications and ordering information.

iConverter CWDM Design Considerations

The *iConverter* CWDM/X and CWDM/AD products are passive devices that require no external power. However, if management is required, then they must be installed in, and powered from, an *iConverter* chassis with an appropriate management module.

As with all passive optical devices, a certain amount of optical signal loss will occur with each device. Detailed calculations should be performed for each fiber optic network link to ensure the optical devices are specified with sufficient optical power budget.

When calculating optical loss, the total loss plus safety factor (typically 3dB) must not exceed the optical power budget. The optical power budget is calculated by subtracting the minimum receive sensitivity from the minimum transmit power.

There are many factors that can result in optical signal loss in a CWDM network:

-Fiber loss (depends on length and type of the fiber used)

-Passive device insertion loss (CWDM/X and CWDM/AD)

-Connectors (couplings)

-Patch panels and splices

The transmitter optical output power and receiver optical sensitivity values may be obtained from the manufacturers of the respective equipment. For Omnitron's SFP transceiver values, consult Omnitron's SFP transceiver datasheets.

Please consult the *iConverter* CWDM datasheets to find the CWDM/X and CWDM/AD insertion loss specifications. Note that the insertion loss for *iConverter* CWDM/X and CWDM/AD modules is uniform and consistent across all channel ports, which facilitates and simplifies network design.

Sample calculations are shown in the following example. In *Figure 13*, two channels are multiplexed through an 8860-0 four channel CWDM/X, transporting two Ethernet services across 8 Km of single-mode fiber. An 8867-59 CWDM/AD located mid-span drops one of the Ethernet services to a switch as shown (Network A). The other Ethernet service continues another 10 Km to a second CWDM/X and switch (Network B).

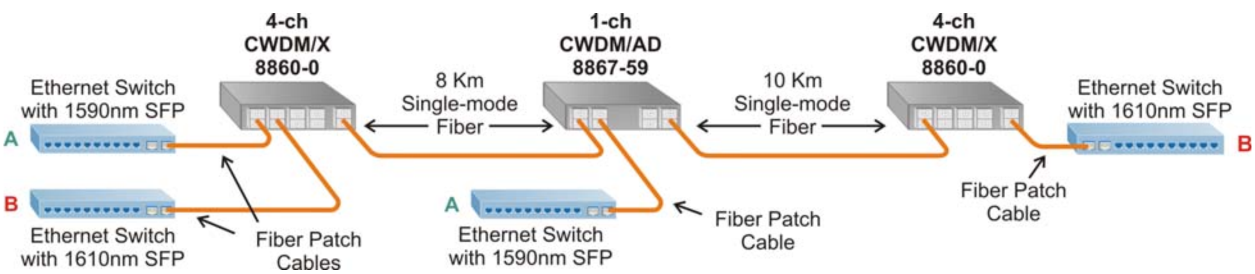

Figure 13: Example Network for Calculating Optical Loss

Network A utilizes two (2) 7359-3 CWDM SFP transceivers (1590nm), each with Min Tx power at -5 dBm, and Min Rx Sense at -24 dBm.

Network A connects through one (1) 8860-0 CWDM/X with insertion loss (channel port to COM port) at 1.9 dB, and one 8867-59 CWDM/AD with insertion loss (COM-L to drop port) at 1.7 dB.

The following table shows the optical budget calculations for Network A.

Network A Optical Budget Calculations

	Minimum Transmit Power		-5 dBm
	Minimum Receive Sensitivity	-	-24 dBm
	Available Power	=	19 dB
Optical Coupling loss	SFP to fiber patch cable		0.5 dB
Optical Coupling loss	Fiber patch cable to CWDM/X channel port	+	0.5 dB
CWDM/X Insertion loss	CWDM/X channel port to COM port	+	1.9 dB
Optical Coupling loss	CWDM/X COM port to long haul fiber	+	0.5 dB
Fiber Cable loss	8 Km single-mode cable @ .5 dB/Km	+	4.0 dB
Optical Coupling loss	Long haul fiber to CWDM/AD	+	0.5 dB
CWDM/AD insertion loss	CWDM/AD COM-L port to channel port	+	1.7 dB
Optical Coupling loss	CWDM/AD channel port to fiber patch cable	+	0.5 dB
Optical Coupling loss	Fiber patch cable to SFP	+	0.5 dB
Other losses	Patch panels, splices, etc. (not shown)	+	1.5 dB
	Total Optical Loss	=	12.1 dB

Table 8: Optical Budget Calculations for Network A

In this example, the total loss (12.1 dB) plus the 3 dB safety factor is less than the total power available (19 dB), so there is indeed sufficient power for Network A.

Network B follows a separate fiber path and requires its own optical budget calculation.

Network B utilizes two (2) 7361-3 CWDM SFP transceivers (1610nm), each with Min Tx power at -5 dBm, and Min Rx Sense at -24 dBm.

Network B connects through two (2) 8860-0 CWDM/X with insertion loss (channel port to COM port) at 1.9 dB, and one 8867-59 CWDM/AD with insertion loss (COM-L to drop port) at 1.7 dB.

The following table shows the optical budget calculations for Network B.

Network B Optical Budget Calculations

	Minimum Transmit Power		-5 dBm
	Minimum Receive Sensitivity	-	-24 dBm
	Available Power	=	19 dB
Optical Coupling loss	SFP to fiber patch cable		0.5 dB
Optical Coupling loss	Fiber patch cable to CWDM/X channel port	+	0.5 dB
CWDM/X insertion loss	CWDM/X channel port to COM port	+	1.9 dB
Optical Coupling loss	CWDM/X COM port to long haul fiber	+	0.5 dB
Fiber Cable loss	8 Km single-mode cable @ .5 dB/Km	+	4.0 dB
Optical Coupling loss	Long haul fiber to CWDM/AD	+	0.5 dB
CWDM/AD insertion loss	CWDM/AD COM-L port to COM-R port	+	1.7 dB
Optical Coupling loss	CWDM/AD COM-R to long haul fiber	+	0.5 dB
Fiber Cable loss	10 Km single-mode cable @ .5 dB/Km	+	5.0 dB
Optical Coupling loss	Long haul fiber to CWDM/X	+	0.5 dB
CWDM/X insertion loss	CWDM/X COM port to channel port	+	1.9 dB
Optical Coupling loss	CWDM/X channel port to fiber patch cable	+	0.5 dB
Optical Coupling loss	Fiber patch cable to SFP	+	0.5 dB
Other losses	Patch panels, splices, etc. (not shown)	+	2.0 dB
	Total Optical Loss	=	20.5 dB

Table 9: Optical Budget Calculations for Network B

In this example, the total loss (20.5 dB) plus the 3 dB safety factor is greater than the total power available (19 dB). So the network as designed will fail.

The solution is to increase the optical power budget by using a stronger SFP transceiver. Select the 7361-4 CWDM Transceiver (1610nm SFP) for both Network B Ethernet switches. The 7361-4 Min Tx power is 0 dBm, while the Min Rx Sense is -24 dBm. The available power is therefore 24 dB, which exceeds the total loss (20.5 dB) by more than the 3 dB safety factor.

Applications

In the following example application diagrams, only the communications devices (routers, switches, servers, etc.), the CWDM/X devices, and the CWDM/AD devices are shown. For clarity, these diagrams do not show media converters, transponders, and SFP transceivers that may also be needed. The reader should assume these converters, transponders, and SFP transceivers are there (if needed), and consult the previous sections of this document for more information on how to generate CWDM specific wavelengths.

Applications using Fiber Pair Common Link

The following applications show example networks which use a fiber pair as the common link. In all these examples, the aggregated Tx wavelengths travel in one direction on one fiber, while the aggregated Rx wavelengths travel in the opposite direction on the other fiber.

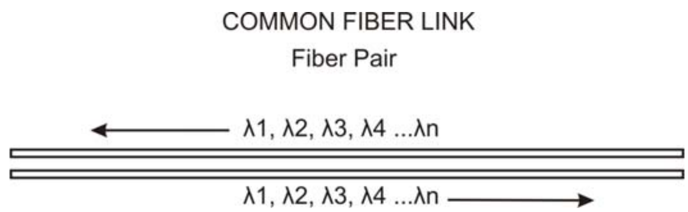

Figure 14: Fiber Pair Common Fiber Link

Point-to-point 4 Channel

In this example application, the common link is a fiber pair. There are four separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

CWDM products used:

iConverter 8860-0 CWDM/X (qty 2)

SFP transceivers:

1470nm (qty 2) 1490nm (qty 2) 1590nm (qty 2) 1610nm (qty 2)

Application Diagram:

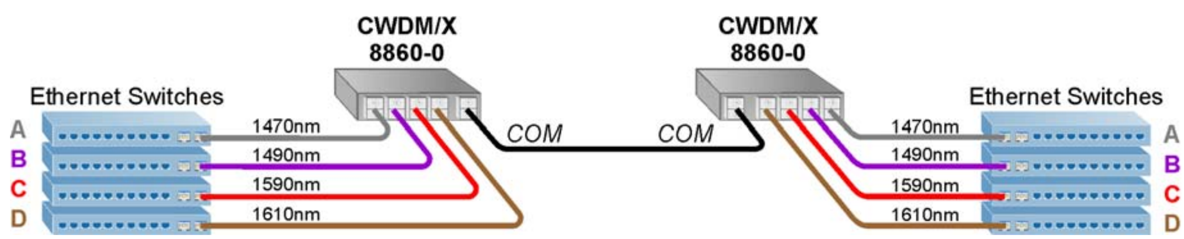

Figure 15: 4 Channel CWDM over Fiber Pair

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate with each other across the common fiber using 1470nm wavelength. The two switches labeled Network B will communicate with each other using 1490nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the left CWDM/X COM port to the Rx on the right CWDM/X COM port.
- Connect the Rx from the left CWDM/X COM port to the Tx on the right CWDM/X COM port.

Notes:
This application can also be implemented with the 8861-0 CWDM/X device using 1510, 1530, 1550 and 1570nm wavelengths.

Point-to-point 4 Channel (with EXP)

In this example application, the common link is a fiber pair. The initial network is the same as the previous application, except now the CWDM/X also has an Expansion Port (EXP). There are four separate communication networks before the expansion, and there are eight separate communication networks after the expansion. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

CWDM products used:
iConverter 8860-2 CWDM/X w/EXP port (qty 2)
iConverter 8861-0 CWDM/X (qty 2)

SFP transceivers:

1470nm (qty 2)	1490nm (qty 2)	1510nm (qty 2)	1530nm (qty 2)
1550nm (qty 2)	1570nm (qty 2)	1590nm (qty 2)	1610nm (qty 2)

Application Diagram (before expansion):

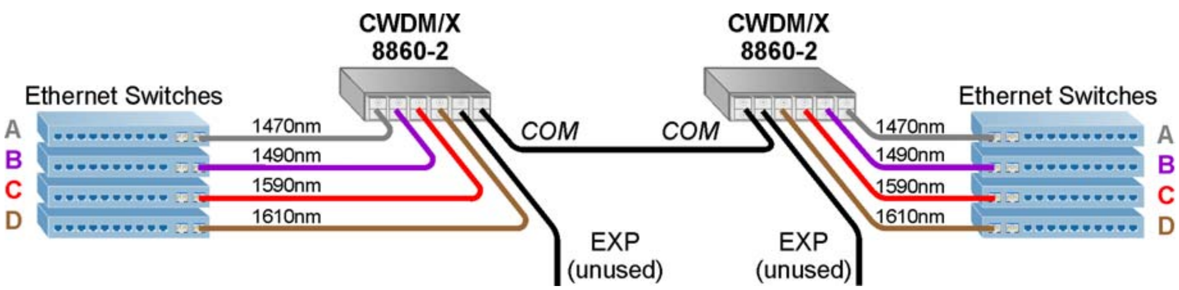

Figure 16: 4 Channel CWDM over Fiber Pair before expansion

Application Diagram (after expansion):

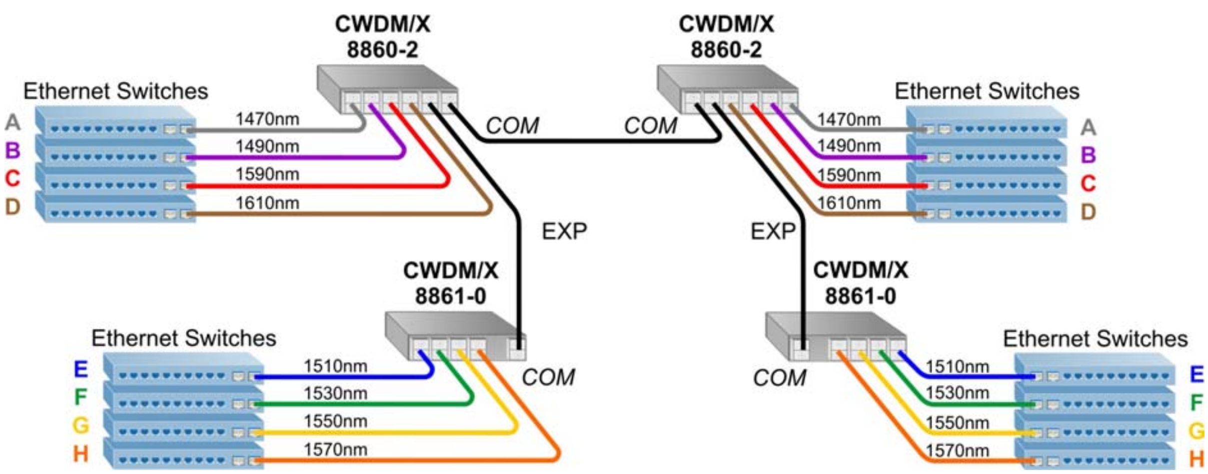

Figure 17: 4 Channel CWDM over Fiber Pair after expansion

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate with each other across the common fiber using 1470nm wavelength. The two switches labeled Network B will communicate with each other using 1490nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the left CWDM/X COM port to the Rx on the right CWDM/X COM port.
- Connect the Rx from the left CWDM/X COM port to the Tx on the right CWDM/X COM port.

EXP port: note that the 4 channel CWDM/X device in the top section of the network has a fifth channel port labeled as "EXP" (Expansion Port.) This port may initially be left unused. At such time that the user intends to upgrade the network (add more channels) the EXP port is connected to the COM port of a second CWDM/X device. The fiber patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the EXP port to the Rx on the second CWDM/X COM port.
- Connect the Rx from the EXP port to the Tx on the second CWDM/X COM port.

This example demonstrates one of several ways that CWDM networks can be upgraded using the Expansion Port feature. The following table lists the full set of upgrade applications that are supported within the *iConverter* CWDM product line:

Upgrade path	Base CWDM/X	Expansion CWDM/X
From 4 channels to 8 channels	8860-2 (1470, 1490, 1590, 1610)	8861-0 (1510, 1530, 1550, 1570)

Table 10: CWDM Upgrade Combinations

Point-to-point CWDM Overlay on Legacy 1310nm Network

In this example application, the common link is a fiber pair ring carrying SDH/SONET traffic using a legacy 1310nm wavelength. There are two separate communication networks to be added (overlaid) on various sections of the ring. These networks are represented by Ethernet switches, although other types of equipment can also be used.

CWDM products used:

iConverter 8861-0 CWDM/X with 1310PB port (qty 6)

SFP transceivers:

1510nm (qty 4)   1530nm (qty 2)

Application Diagram:

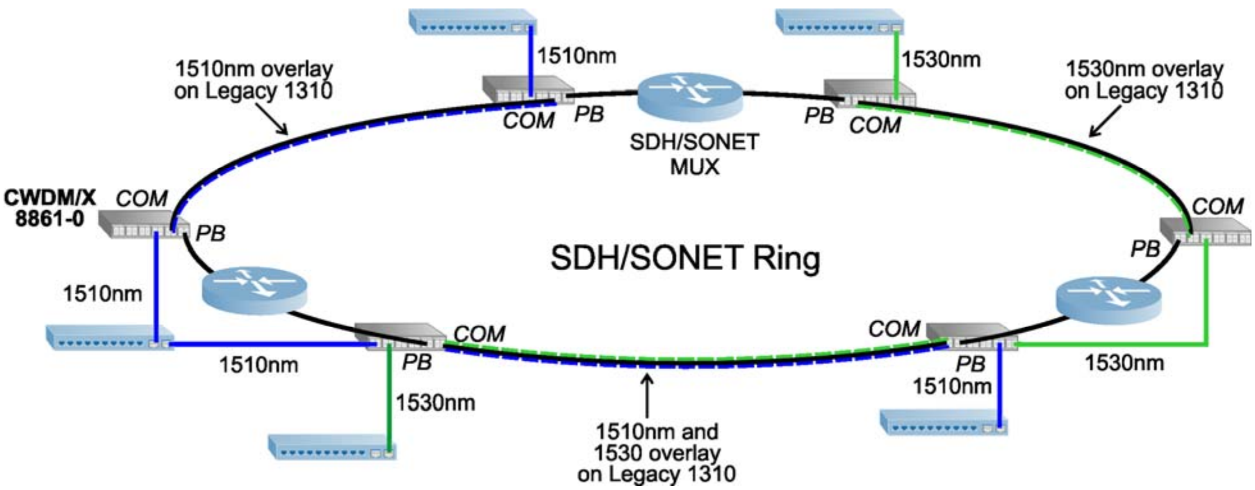

Figure 18: CWDM Overlay on Legacy 1310nm Fiber Pair

One or two CWDM SFP transceiver(s) are required for each switch, depending on how they are used in the network. All Ethernet switches using the 1510nm wavelength communicate together on an isolated network. All Ethernet switches using the 1530nm wavelength communicate together on an isolated network. The SDH/SONET traffic is unaffected by the overlay CWDM networks.

1310PB port: note how the CWDM/X devices are connected in the diagram above. Each 1310PB port is connected directly to the SDH/SONET MUX. These fiber patch cables carry ONLY legacy 1310nm traffic. The connections are single-mode fiber pairs with LC/UPC duplex connectors.

- Connect the Tx from the SDH/SONET MUX to the Rx on the CWDM/X 1310PB port.
- Connect the Rx from the SDH/SONET MUX to the Tx on the CWDM/X 1310PB port.

Common port: the fiber from one CWDM/X COM port must be connected to the COM port of the next CWDM/X. This connection is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from one CWDM/X COM port to the Rx on the other CWDM/X COM port.
- Connect the Rx from one CWDM/X COM port to the Tx on the other CWDM/X COM port.

Channel ports: the 1510 and 1530 channel ports on the CWDM/X devices are connected to the appropriate SFP transceivers installed in the Ethernet switches. Fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Notes:
Up to four overlay channels can be added in this example, but only two are shown for clarity.
This application can also be implemented with the 8860-0 CWDM/X device using alternate wavelengths. This application can also be implemented with the 8 channel 8863-1 CWDM/X using alternate wavelengths.

Point-to-point CWDM Overlay on Legacy 1310nm and Legacy 1550nm Networks

In this example application, the common link is a fiber pair. There are four separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

In addition, there are Legacy 1310nm and Legacy 1550nm networks multiplexed through the network, sharing the same common fiber. In this application, no wavelength conversion is required for these Legacy devices.

CWDM products used:

iConverter 8860-2 CWDM/X (qty 2)

SFP transceivers:

1470nm (qty 2)   1490nm (qty 2)   1590nm (qty 2)   1610nm (qty 2)

Application Diagram:

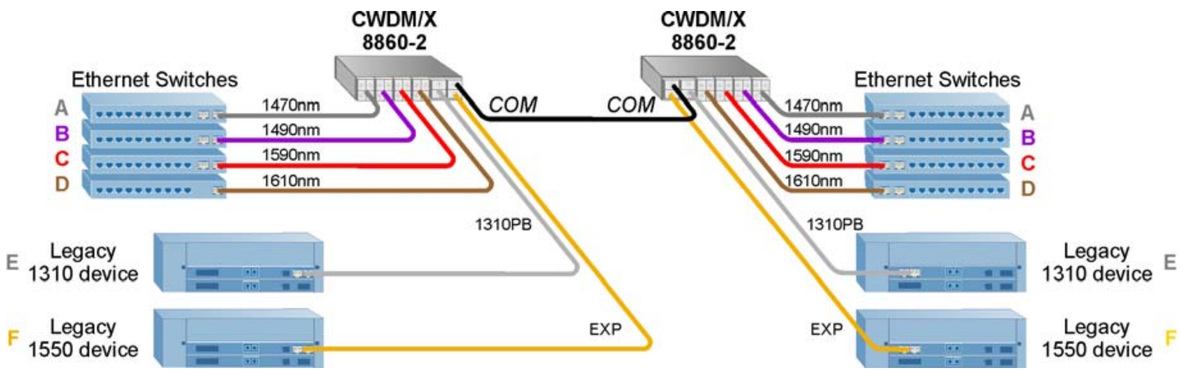

Figure 19: 4 Channel CWDM with Legacy 1310 and 1550 over Fiber Pair

One CWDM SFP transceiver is required for each Ethernet switch. The two switches labeled Network A will communicate with each other across the common fiber using 1470nm wavelength. The two switches labeled Network B will communicate with each other using 1490nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

1310PB port: fiber patch cables are used to connect each Legacy 1310 device to the 1310PB port on the CWDM/X. Each patch cable is a fiber pair.

- Connect the Tx from the Legacy 1310 device to the Rx on the CWDM/X 1310PB port.
- Connect the Rx from the Legacy 1310 device to the Tx on the CWDM/X 1310PB port.

EXP port: fiber patch cables are used to connect each Legacy 1550 device to the EXP port on the CWDM/X. Each patch cable is a fiber pair.

- Connect the Tx from the Legacy 1550 device to the Rx on the CWDM/X EXP port.
- Connect the Rx from the Legacy 1550 device to the Tx on the CWDM/X EXP port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the left CWDM/X COM port to the Rx on the right CWDM/X COM port.
- Connect the Rx from the left CWDM/X COM port to the Tx on the right CWDM/X COM port.

Point-to-point 8 Channel over Fiber Pair

In this example application, the common link is a fiber pair. There are eight separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

CWDM products used:

iConverter 8862-0 CWDM/X (qty 2)

SFP transceivers:

1270nm (qty 2)	1290nm (qty 2)	1310nm (qty 2)	1330nm (qty 2)
1350nm (qty 2)	1370nm (qty 2)	1430nm (qty 2)	1450nm (qty 2)

Application Diagram:

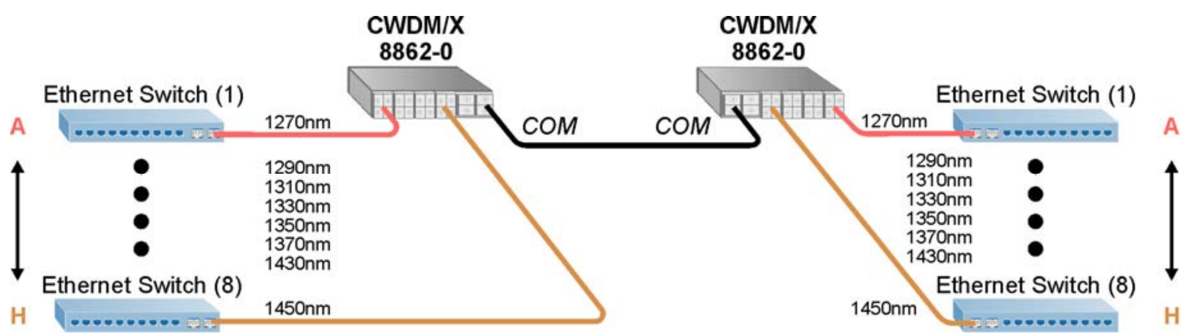

Figure 20: 8 Channel CWDM over Fiber Pair

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate with each other across the common fiber using 1270nm wavelength. The two switches labeled Network B will communicate with each other using 1290nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the left CWDM/X COM port to the Rx on the right CWDM/X COM port.
- Connect the Rx from the left CWDM/X COM port to the Tx on the right CWDM/X COM port.

Notes:
This application can also be implemented with the 8863-0 CWDM/X device using 1470, 1490, 1510, 1530, 1550, 1570, 1590 and 1610nm wavelengths.

Point-to-point 16 Channel over Fiber Pair

In this example application, the common link is a fiber pair. There are sixteen separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

CWDM products used:

iConverter 8862-0 CWDM/X (qty 2)
iConverter 8863-0 CWDM/X (qty 2)
iConverter 8865-0 CWDM/X Band-Splitter (qty 2)

SFP transceivers:

1270nm (qty 2)	1290nm (qty 2)	1310nm (qty 2)	1330nm (qty 2)
1350nm (qty 2)	1370nm (qty 2)	1430nm (qty 2)	1450nm (qty 2)
1470nm (qty 2)	1490nm (qty 2)	1510nm (qty 2)	1530nm (qty 2)
1550nm (qty 2)	1570nm (qty 2)	1590nm (qty 2)	1610nm (qty 2)

Application Diagram:

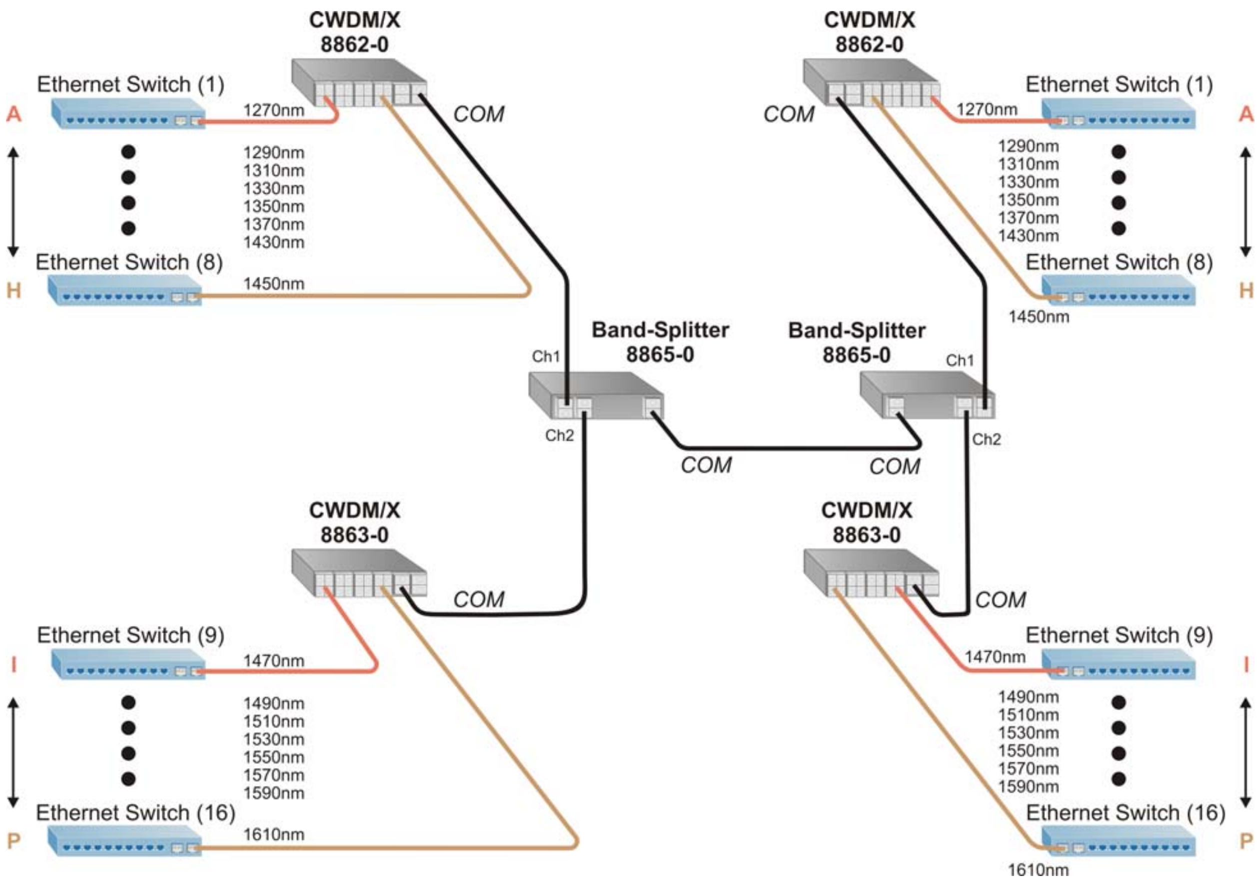

Figure 21: 16 Channel CWDM over Fiber Pair

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate with each other across the common fiber using 1270nm wavelength. The two switches labeled Network B will communicate with each other using 1290nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

CWDM/X Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the upper left CWDM/X COM port to the Rx on the left Band-Splitter channel port 1.
- Connect the Rx from the upper left CWDM/X COM port to the Tx on the left Band-Splitter channel port 1.
- Connect the Tx from the lower left CWDM/X COM port to the Rx on the left Band-Splitter channel port 1.
- Connect the Rx from the lower left CWDM/X COM port to the Tx on the left Band-Splitter channel port 1.
- Connect the Tx from the upper right CWDM/X COM port to the Rx on the right Band-Splitter channel port 1.
- Connect the Rx from the upper right CWDM/X COM port to the Tx on the right Band-Splitter channel port 1.
- Connect the Tx from the lower right CWDM/X COM port to the Rx on the right Band-Splitter channel port 1.
- Connect the Rx from the lower right CWDM/X COM port to the Tx on the right Band-Splitter channel port 1.

Band-Splitter Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the Band-Splitter devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the Tx from the left Band-Splitter COM port to the Rx on the right Band-Splitter COM port.
- Connect the Rx from the left Band-Splitter COM port to the Tx on the right Band-Splitter COM port.

Bus Network with OADM Drops over Fiber Pair

In this example application, the common link is a fiber pair. There are four separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique CWDM wavelength.

CWDM products used:

iConverter 8860-0 CWDM/X (qty 1)
iConverter 8867-47 CWDM/AD (qty 1)
iConverter 8867-49 CWDM/AD (qty 1)
iConverter 8869-67 CWDM/AD (qty 1)

SFP transceivers:

1470nm (qty 2) 1490nm (qty 2) 1590nm (qty 2) 1610nm (qty 2)

Application Diagram:

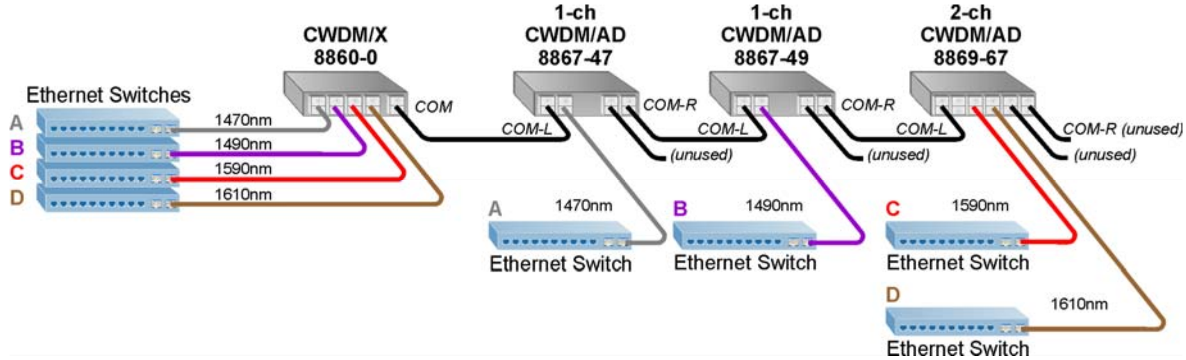

Figure 22: 4 Channel CWDM Bus Network with Drops over Fiber Pair

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate with each other across the common fiber using 1470nm wavelength. The two switches labeled Network B will communicate with each other using 1490nm wavelength, and so on.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel ports on the CWDM/X and CWDM/AD devices. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X or CWDM/AD channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X or CWDM/AD channel port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/X and CWDM/AD devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- Connect the CWDM/X COM port to the first CWDM/AD COM-L port. Connect the Tx of each device to the Rx of the other.
- When CWDM/AD devices are connected to each other, the COM-L of one device should always be connected to COM-R of the other. Connect the Tx of each device to the Rx of the other.

Notes:
The 1-channel and 2-channel CWDM/AD devices shown in this example are capable of adding/dropping channels in both directions (left and right.) However, in this application, only one direction (the left channel port) is used. The right channel port is unused. Additionally, in this example the COM-R port on the last CWDM/AD in the chain is also unused. This application can also be implemented with the 8861-0 CWDM/X device (and appropriate CWDM/AD devices) using alternate wavelengths.

Redundant Ring over Fiber Pair

In this example application, the common link is a fiber pair ring. There are three separate communication networks, A, B, and C. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch communicates with its peer(s) using a unique wavelength. Traffic can travel in both directions around the ring. Each Ethernet switch has two uplinks to the ring, and uses Spanning Tree Protocol to control which is the working link, and which is the protect link.

CWDM products used:

iConverter 8869-67 CWDM/AD (qty 1)
iConverter 8867-57 CWDM/AD (qty 2)
iConverter 8867-59 CWDM/AD (qty 2)
iConverter 8867-61 CWDM/AD (qty 1)

SFP transceivers:

1570nm (qty 4)   1590nm (qty 6)   1610nm (qty 4)

Application Diagram:

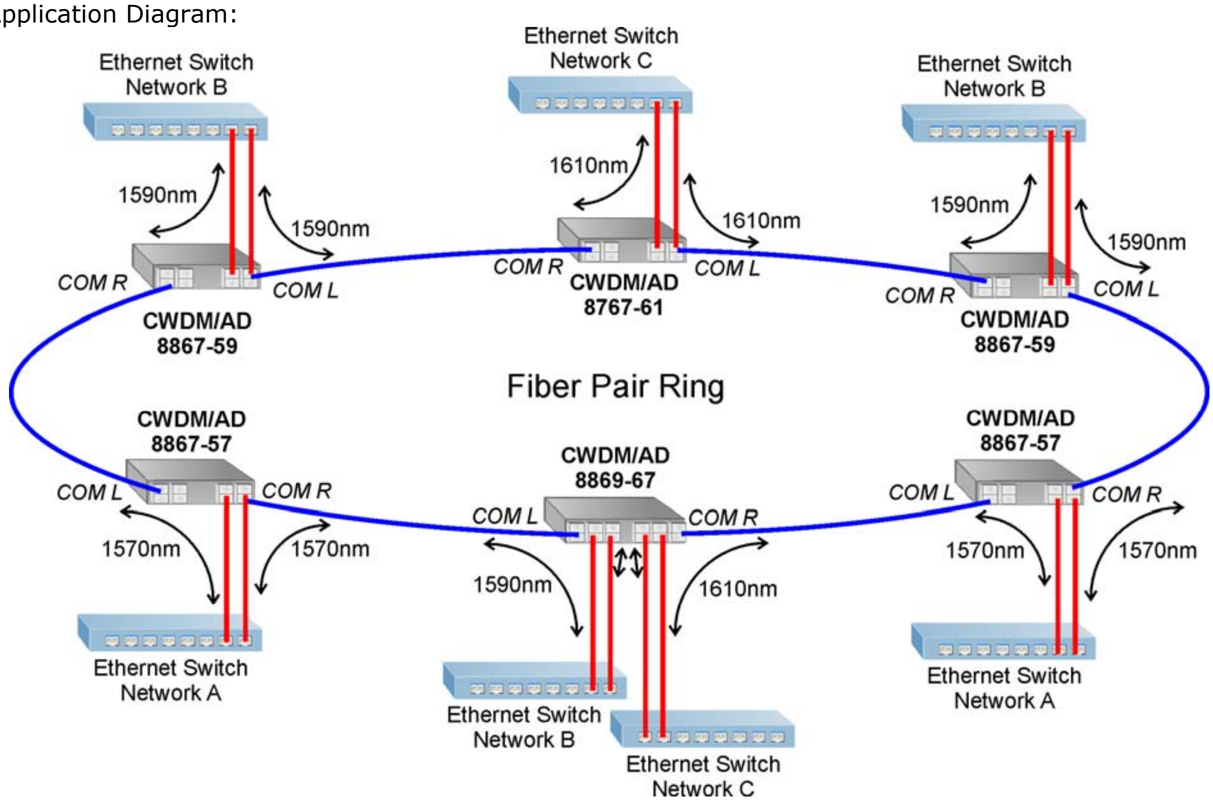

Figure 23: Redundant Ring over Fiber Pair

Two CWDM SFP transceivers are required for each switch. The two switches labeled Network A will communicate over the ring using the 1570nm wavelength. The three switches labeled Network B will communicate using the 1590nm wavelength. The two switches labeled Network C will communicate using the 1610 wavelength.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/AD. Each switch requires two patch cables. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/AD channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/AD channel port.

Common port: the common link is a single-mode fiber pair, with LC/UPC duplex connectors on the ends to plug into the common ports of the CWDM/AD devices. All traffic flows in one direction on one fiber, and in the opposite direction on the second fiber.

- When CWDM/AD devices are connected to each other, the COM-L of one device should always be connected to COM-R of the other. Connect the Tx of one device to the Rx of the other.

This example shows the use of both 1-channel and 2-channel CWDM/AD devices. Each device provides two connections to its switch. Each connection sends traffic in the opposite direction around the ring (left and right directions.) Spanning Tree Protocol must be running on each switch in order to change the traffic direction in the event of a fiber failure.

Notes:

This application can also be implemented with other wavelengths using the appropriate CWDM/AD devices.

Applications using Single-Fiber Common Link

The following applications show example networks which use a single-fiber as the common link. Note that single-fiber networks require two wavelengths for each channel (communications device). On the common link, half the wavelengths travel in one direction, while half the wavelengths travel in the opposite direction.

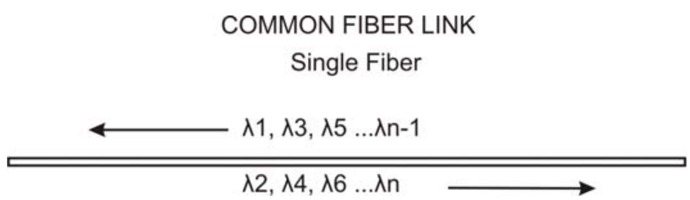

Figure 24: Single Fiber Common Fiber Link

Point-to-point 2 Channel over Single-Fiber

In this example application, the common link is a single-fiber with bi-directional traffic. There are two separate communication networks. The Gigabit Ethernet switch on the left communicates with its peer on the right using a unique pair of wavelengths. The ATM switch on the left communicates with its peer on the right using a unique pair of CWDM wavelengths.

CWDM products used:

iConverter 8872-0 CWDM/X (qty 1)
iConverter 8873-0 CWDM/X (qty 1)

SFP transceivers:

1550nm (qty 1)   1570nm (qty 1)   1590nm (qty 1)   1610nm (qty 1)

Application Diagram:

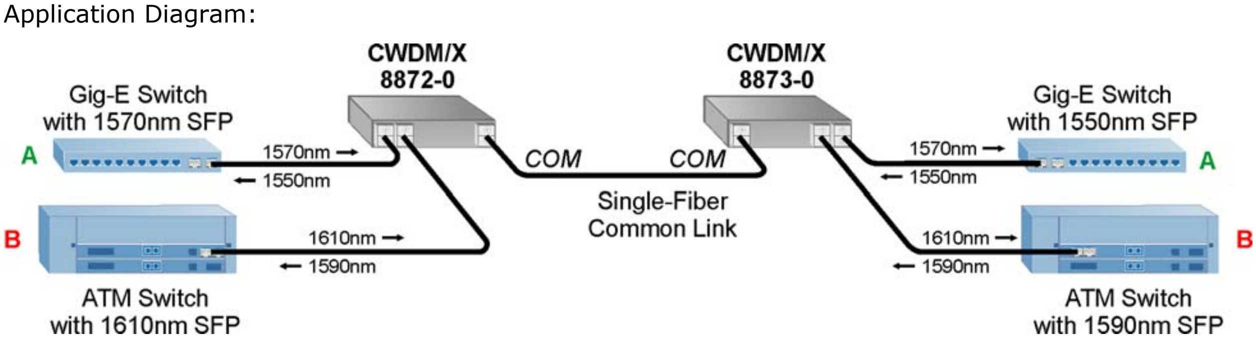

Figure 25: 2 Channel over Single-Fiber

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate across the common fiber using 1550 and 1570nm wavelengths. The 1570nm wavelength runs from left to right. The 1550nm wavelength runs from right to left.

The two switches labeled Network B will communicate using 1590nm and 1610nm wavelengths. The 1610nm wavelength runs from left to right. The 1590nm wavelength runs from right to left.

Please note the following:

Unlike dual fiber applications, in this single-fiber example, each switch uses a different and unique wavelength SFP transceiver.

A receiver in an SFP has a very wide wavelength tolerance. For example, the 1570nm SFP transceiver in this example (transmitting at 1570nm) can receive the 1550nm signal coming from its link partner. Because of this, both devices are able to communicate across a single-fiber, while each transmits with a different wavelength.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Since single-fiber networks use two wavelengths per channel, use caution to ensure that the appropriate wavelengths match correctly.

Common port: the common link is a single-mode single-fiber, with one LC/UPC connector on each end to plug into the common ports of the CWDM/X devices. All traffic flows in both directions on this fiber.

- Connect the COM port from the left CWDM/X to the COM port on the right CWDM/X. These are single connectors that do not have a Tx or Rx.

Notes:

This application can also be implemented with the 8870-0 and 8871-0 CWDM/X devices using 1470/1490, and 1510/1530 wavelength pairs.

Point-to-point 4 Channel over Single-Fiber

In this example application, the common link is a single-fiber with bi-directional traffic. There are four separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch on the left communicates with its peer on the right using a unique pair of CWDM wavelengths.

CWDM products used:

iConverter 8874-0 CWDM/X (qty 1)
iConverter 8875-0 CWDM/X (qty 1)

SFP transceivers:

1270nm (qty 1)	1290nm (qty 1)	1310nm (qty 1)	1330nm (qty 1)
1350nm (qty 1)	1370nm (qty 1)	1430nm (qty 1)	1450nm (qty 1)

Application Diagram:

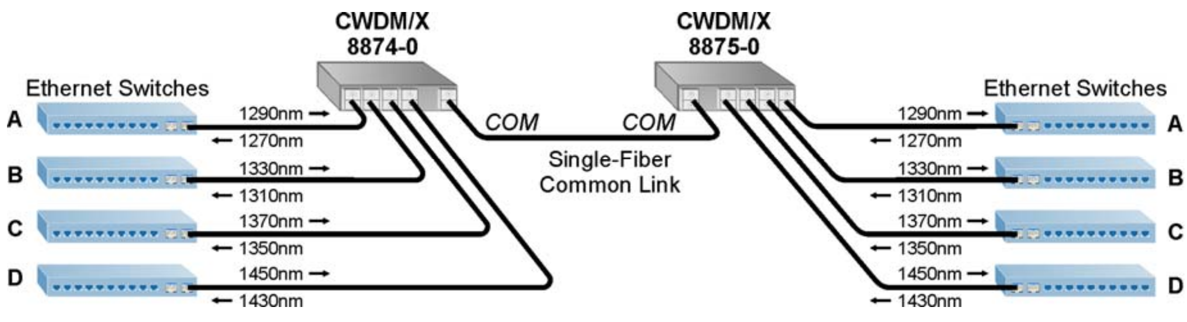

Figure 26: 4 Channel over Single-Fiber

One CWDM SFP transceiver is required for each switch. The two switches labeled Network A will communicate across the common fiber using 1270 and 1290nm wavelengths. The 1290nm wavelength runs from left to right. The 1270nm wavelength runs from right to left. The two switches labeled Network B will communicate using 1310nm and 1330nm wavelengths, and so on.

Note the following:

Unlike dual fiber applications, in this single-fiber example, each switch uses a different and unique wavelength SFP transceiver.

A receiver in an SFP has a very wide wavelength tolerance. For example, the 1290nm SFP transceiver in this example (transmitting at 1290nm) can receive the 1270nm signal coming from its link partner. Because of this, both devices are able to communicate across a single-fiber, while each transmits with a different wavelength.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/X. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Since single-fiber networks use two wavelengths per channel, use caution to ensure that the appropriate wavelengths match correctly.

Common port: the common link is a single-mode single-fiber, with one LC/UPC connector on each end to plug into the common ports of the CWDM/X devices. Traffic flows in both directions on this fiber.

- Connect the COM port from the left CWDM/X to the COM port on the right CWDM/X. These are single connectors that do not have a Tx or Rx.

Notes:

This application can also be implemented with the 8876-0 and 8877-0 CWDM/X devices using 1470/1490, 1510/1530, 1550/1570 and 1590/1610nm wavelength pairs.

Redundant Ring Application over Single-Fiber

In this example application, the common link is a single-fiber ring. There are two separate communication networks. These networks are represented by Ethernet switches, although other types of equipment can also be used. Each Ethernet switch communicates with its peer(s) using a unique pair of CWDM wavelengths. Traffic can travel in both directions around the ring. Each Ethernet switch has two uplinks to the ring, and uses Spanning Tree Protocol to control which is the working link, and which is the protect link.

CWDM products used:

iConverter 8878-55 CWDM/AD (qty 2)
iConverter 8878-59 CWDM/AD (qty 2)

SFP transceivers:

1550nm (qty 2)   1570nm (qty 2)   1590nm (qty 2)   1610nm (qty 2)

Application Diagram:

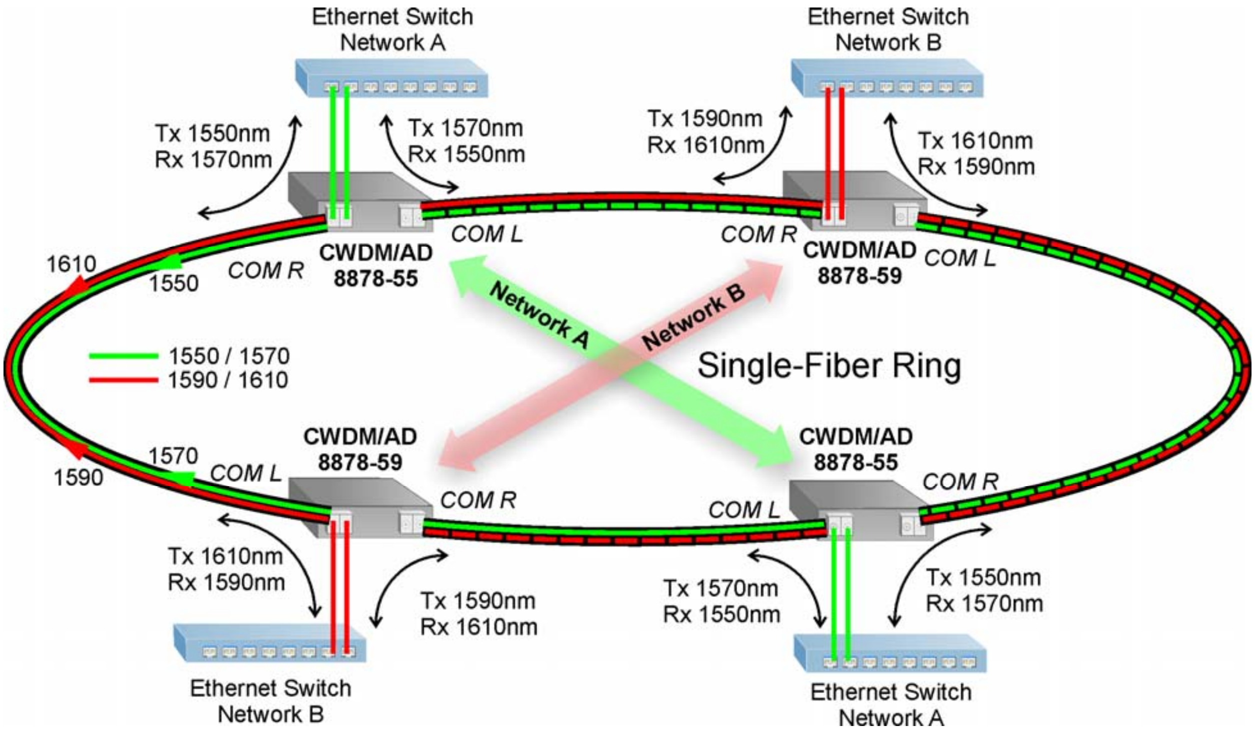

Figure 27: Redundant Ring over Single-Fiber

Two CWDM SFP transceivers are required for each switch. The two switches labeled Network A will communicate over the ring using the 1550nm and 1570nm wavelengths. The 1550nm wavelength runs counter-clockwise around the ring. The 1570nm wavelength runs clockwise around the ring.

The two switches labeled Network B will communicate using the 1590nm and 1610nm wavelengths. The 1590nm wavelength runs counter-clockwise around the ring. The 1610nm wavelength runs clockwise around the ring.

Note the following:

Each switch uses two different and unique wavelength SFP transceivers, because each switch has two uplinks to the ring. One uplink travels clockwise, and one uplink travels counter-clockwise. For example, both Network A switches will use a CWDM 1550nm SFP transceiver and also a CWDM 1570nm SFP transceiver.

A receiver in an SFP has a very wide wavelength tolerance. For example, the 1570nm SFP transceiver in this example (transmitting at 1570nm) can receive the 1550nm signal coming from its link partner.

Because of this, both devices are able to communicate across a single fiber, while each transmits with a different wavelength.

Channel ports: fiber patch cables are used to connect each SFP transceiver to the appropriate channel port on the CWDM/AD. Each patch cable is a single-mode fiber pair with LC/UPC duplex connectors.

- Connect the Tx from the SFP transceiver to the Rx on the CWDM/X channel port.
- Connect the Rx from the SFP transceiver to the Tx on the CWDM/X channel port.

Since single-fiber networks use two wavelengths per channel, use caution to ensure that the appropriate wavelengths match correctly.

Common port: the common link is a single-mode single-fiber, with one LC/UPC connector on each end to plug into the common ports of the CWDM/AD devices. Traffic flows in both directions on this fiber.

- When CWDM/AD devices are connected to each other, the COM-L of one device should always be connected to COM-R of the other. These are single connectors that do not have a Tx or Rx.

Each CWDM/AD device provides two connections to its switch. Each connection sends traffic in the opposite direction around the ring (left and right directions.) Spanning Tree Protocol must be running on each switch in order to change the traffic direction in the event of a fiber failure.

Notes:

This application can also be implemented with other wavelengths using the appropriate CWDM/AD devices.