NT0H65AM 323-1701-110

Nortel

Optical Metro 5100/5200

Network Planning and Link Engineering, Part 2 of 3

Standard Release 8.0 Issue 1 April 2005

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NORTEL

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About this document

> **ATTENTION**
> This document is presented in three parts: Part 1, Part 2, and Part 3. Each part has its own table of contents. The table of contents in Part 1 contains topics found in Part 1 only. The table of contents in Part 2 contains topics found in Part 2 only. The table of contents in Part 3 contains topics found in Part 3 only.

You are reading Part 2 of *Network Planning and Link Engineering,* 323-1701-110.

This document provides the information needed to understand and plan a Nortel Optical Metro 5100/5200 network (identified prior to Release 7 as Nortel Networks OPTera Metro 5000-series Multiservice Platform).

Part 1 of *Network Planning and Link Engineering* includes:

- system description
- building blocks
- supported configurations
- network interoperability

Part 2 of *Network Planning and Link Engineering* includes:

- link engineering prerequisites
- link engineering components
- link engineering rules
- basic fixed value link engineering
- remodeling a network plan for optimal link budgets
- data communications in the Optical Metro 5100/5200 network
- network security planning

Part 3 of *Network Planning and Link Engineering* includes:

- site requirements and equipping rules
- ordering information
- fiber characterization
- custom link engineering design output

Audience for this document

This document is intended for the following audience:

- strategic and current planners
- provisioners
- installers
- transmission standards engineers
- field maintenance engineers
- system lineup and testing (SLAT) personnel
- maintenance technicians
- network administrators

Documentation library for the Optical Metro 5100/5200

The documentation library consists of the *Nortel Optical Metro 5100/5200 Technical Publications*, NT0H65AM.

Technical Publications

The *Optical Metro 5100/5200 Technical Publications* (NTP) consist of descriptive information and procedures.

Descriptive information

These documents provide detailed descriptive information about the Optical Metro 5100/5200, including:

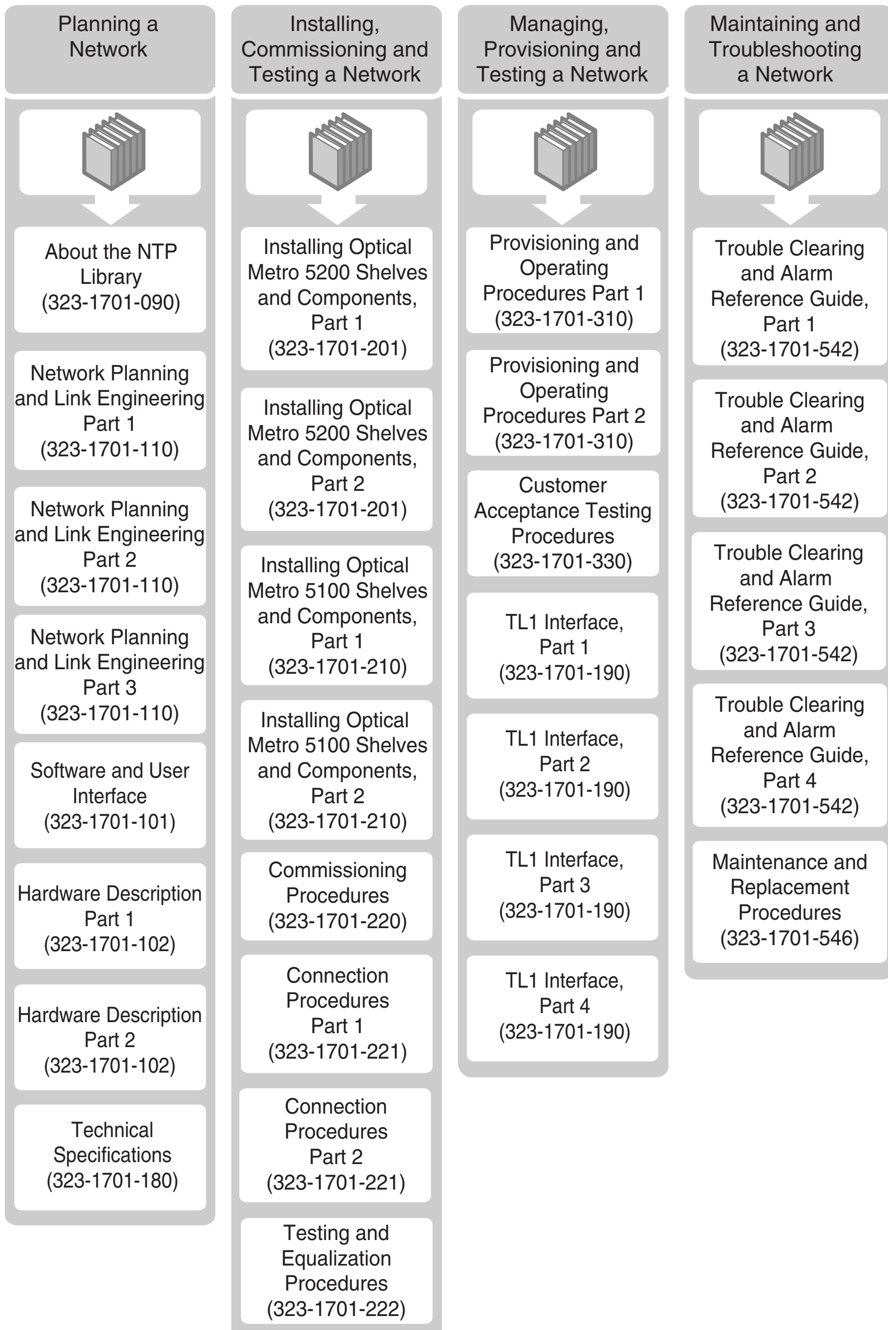
- system description
- software descriptions
- hardware descriptions
- technical specifications
- ordering information
- TL1 user information

Procedures

These documents contain all procedures required to install, provision, and maintain the Optical Metro 5100/5200 system.

The following roadmap lists the documents in the Optical Metro 5100/5200 library.

OM2805p



Technical assistance service telephone numbers

For technical support and information from Nortel Networks, refer to the following table.

Technical Assistance Service	
For service-affecting problems: For 24-hour emergency recovery or software upgrade support, that is, for: • restoration of service for equipment that has been carrying traffic and is out of service • issues that prevent traffic protection switching • issues that prevent completion of software upgrades	**North America:** 1-800-4NORTEL (1-800-466-7835) **International:** 001-919-992-8300
For non-service-affecting problems: For 24-hour support on issues requiring immediate support or for 14-hour support (8 a.m. to 10 p.m. EST) on upgrade notification and non-urgent issues.	**North America:** 1-800-4NORTEL (1-800-466-7835) ***Note:*** You require an express routing code (ERC). To determine the ERC, see our corporate Web site at www.nortel.com. Click on the Express Routing Codes link. **International:** Varies according to country. For a list of telephone numbers, see our corporate Web site at www.nortel.com. Click on the Contact Us link.
Global software upgrade support:	**North America:** 1-800-4NORTEL (1-800-466-7835) **International:** Varies according to country. For a list of telephone numbers, see our corporate Web site at www.nortel.com. Click on the Contact Us link.

Link engineering prerequisites

In this chapter

Link engineering primer

Optical link engineering consists of balancing all of the factors that impact the optical signal as the signal flows from its source to its destination. The objective is to ensure that the optical signal transmitted on each individual wavelength is received with sufficient power and with minimal distortion, so that the signal can be forwarded on to its final destination with integrity. In an Optical Metro 5100/5200 network, integrity is measured by ensuring a bit error ratio (BER) of no worse than 10^{-12}.

There are many factors that impact the quality of the signal as it flows from the transmitter to the receiver. The following section describes the key factors that you must take into account when engineering an optical network.

Each of these factors may result in some form of penalty that must be applied to the optical link budget, or the maximum difference, measured in dB, between the transmit power level and the receive power level. Optical link engineering consists of taking all of these penalties into account simultaneously and ensuring that the total combined impact does not exceed the allowable link budget.

Optical power losses

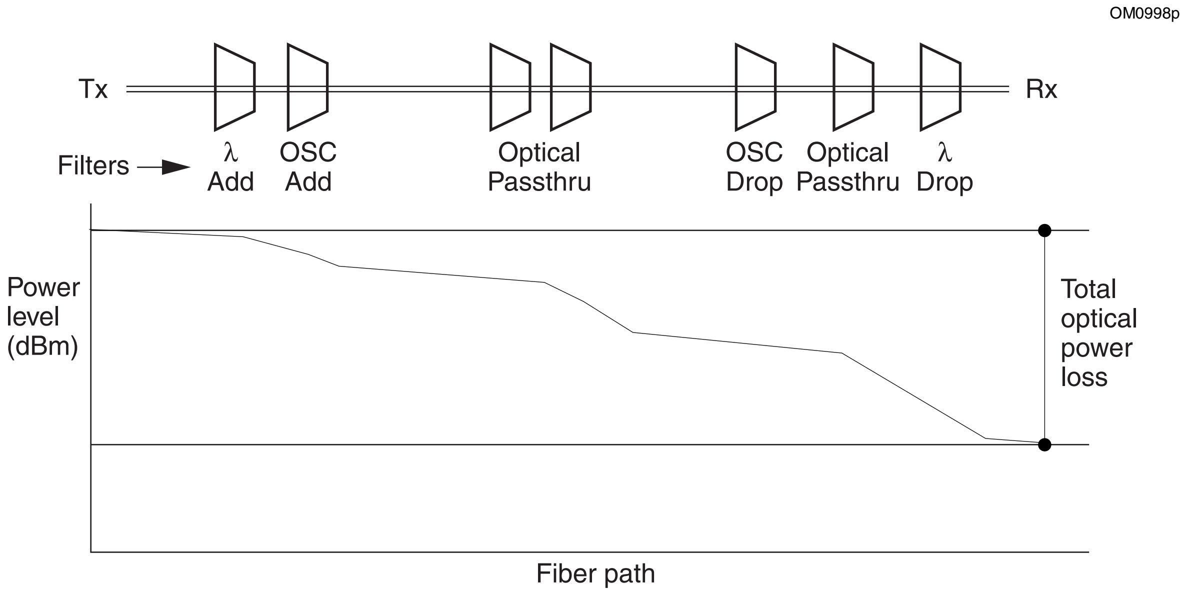
The most obvious impact to the integrity of an optical signal is caused by power losses. Power loss occurs as the power of the signal decreases in intensity because of minor obstacles or impediments on its path.

Sources of optical power loss include the following:

- optical fiber loss, which is the overall attenuation caused by the type of optical fiber used, including the number of splices, bends, and other imperfections in the fiber
- the filters through which a wavelength passes along its path.
- any connectors or patch panels through which the signal flows. These must be taken into account when you determine the overall optical power loss along an optical path.

Figure 5-1 shows an example of optical power loss.

Figure 5-1
Example of optical power loss



Chromatic dispersion

Chromatic dispersion results in the distortion of light signals traveling down an optical fiber. The light within a single channel is made up of different wavelengths that travel at different speeds. This results in changes in signal shape, which make it increasingly difficult to accurately interpret the signal at the destination.

The penalty associated with dispersion increases with distance and is dependent on the fiber type, as well as the performance of the transmitter and receiver at the two ends of the path. This means that there is an absolute maximum distance that a signal can travel in its optical form, before it must be received and converted to an electrical signal. The electrical signal can then be converted back to an optical signal for further optical transmission.

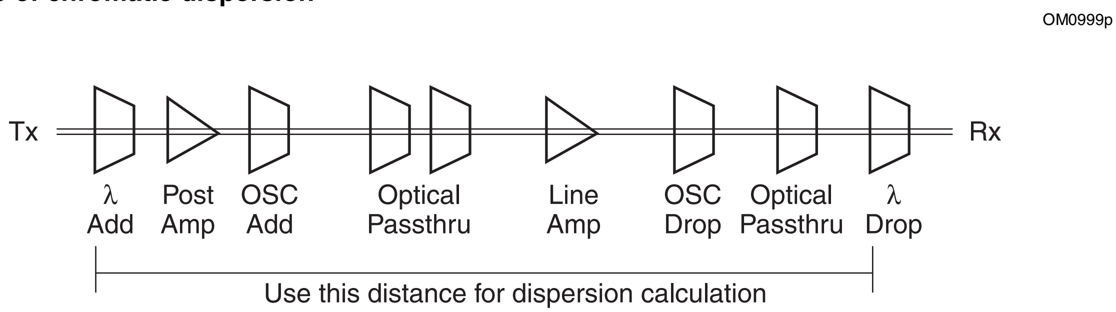
The conversion from an optical signal to an electrical signal and back to an optical signal is referred to as optical-electrical-optical (OEO) conversion. OEO conversion regenerates a signal and resets the dispersion limit.

For example, the dispersion limit for the standard OCLD circuit pack transmitting over non-dispersion shifted fiber (NDSF) is 110 km. This means that a signal generated by a standard OCLD circuit pack cannot travel more than 110 km before an OEO conversion must be applied.

Chromatic dispersion can also be compensated for with the use of DSCMs (Dispersion Slope Compensating Module). Networks that use these components are called Extended Metro networks.

Figure 5-2 shows a simplified span for dispersion calculations.

Figure 5-2
Example of chromatic dispersion



Jitter

Jitter occurs on an optical signal as a result of OEO conversions. The retiming of the signal that occurs during this process causes jitter.

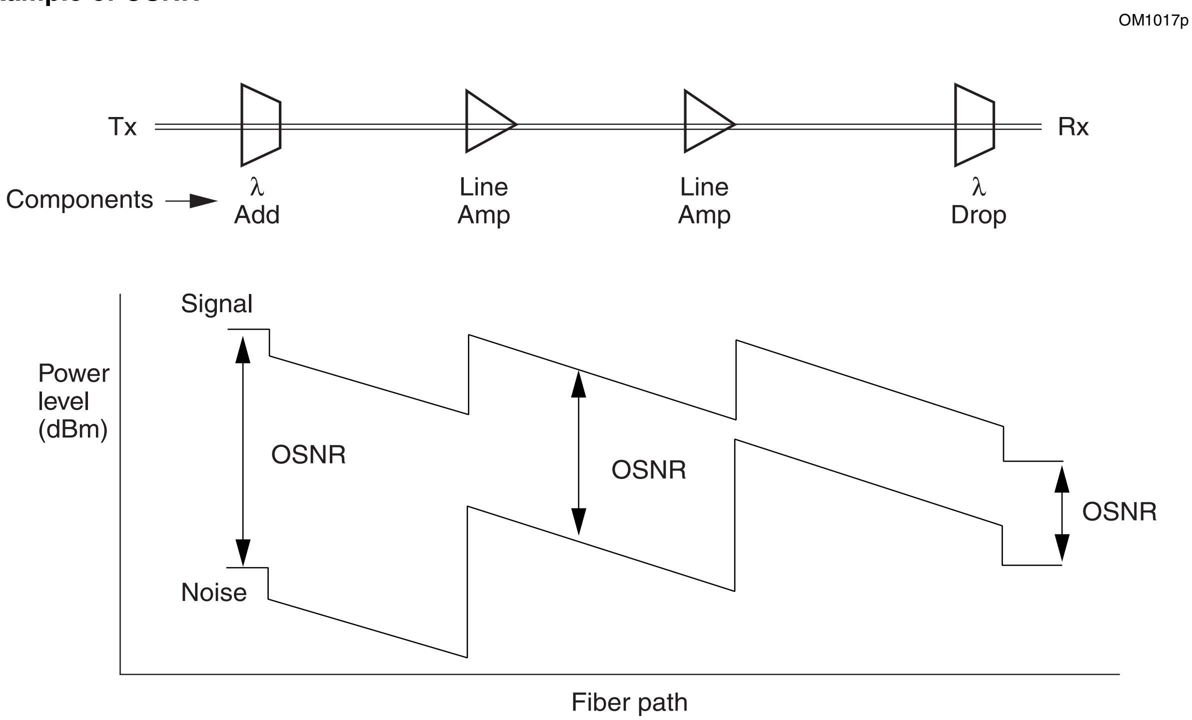
The jitter penalty increases with the number of OEO conversions that the signal undergoes as it travels from its source to its destination.

Optical signal to noise ratio (OSNR)

Optical signal-to-noise ratio (OSNR) is the ratio of the power level of the signal to the power level of the optical noise on the fiber. In order to maintain signal integrity, the level of noise on the fiber must not increase to the point of impacting the interpretation of the signal.

OSNR needs to be considered in amplified networks only. As a signal passes through an amplifier, its power level is increased by a fixed amount to compensate for optical power losses. Any noise that is being transmitted on the fiber is also amplified, and is being forwarded on with increased power along with the signal (see Figure 5-3 on page 5-4). In addition, the amplifier generates extra noise, referred to as amplified spontaneous emission (ASE). As the signal passes through more amplifiers, the noise level increases relative to the signal. Eventually, the receiver may not be able to interpret the signal because of the amplified noise.

Figure 5-3
Example of OSNR



To ensure signal integrity, the OSNR must never be allowed to drop below the level that is specified for the transmitting and receiving equipment.

To achieve this, the power level at which the signal enters an amplifier must never fall below a certain level. The total power or aggregate power that enters an amplifier is dependent on the number of wavelengths that are present. Also, there is a maximum power level at which the aggregate signal can enter an amplifier. Therefore, the more wavelengths you have, the lower each wavelength's maximum power must be before entering the amplifier. Lower power levels on a channel results in a lower OSNR. As networks are engineered for higher numbers of channels, OSNR becomes more of a concern.

Optical seams

In any ring based optical network with amplification, an optical seam is required. An optical seam is a point in the network through which there is guaranteed to be no optical pass-through of the accumulation of noise on the fiber.

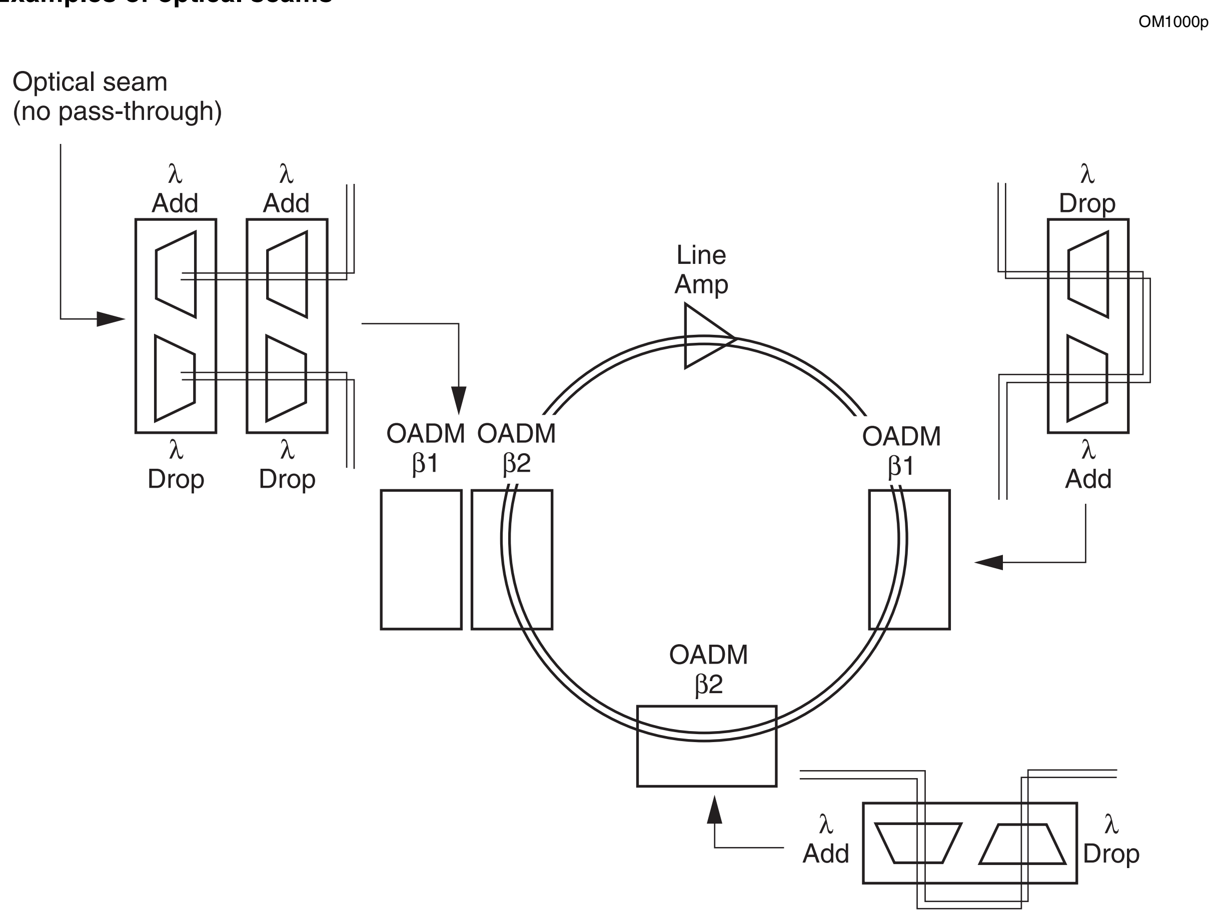
Amplifiers in a network produce broadband noise called ASE. Unlike regular traffic, which is added and dropped along the ring, the optical noise continues to travel along the ring, gaining power as it is repeatedly amplified. Not only does the amplified noise disrupt the OSNR, but the excessive power levels could cause serious overload problems.

One way to address this issue in a network design is to ensure that there is a true optical seam. This is a point or a site in the network where all wavelengths are dropped for full electrical termination or regeneration and there is a physical break in the continuity.

Another way is to ensure that there is at least one point where there is a filter with sufficient loss to compensate for the overall gain in the system.

Figure 5-4 shows examples of optical seams.

Figure 5-4
Examples of optical seams



Coherent cross-talk

Coherent cross-talk can occur when a signal passes through an add/drop filter that drops a wavelength and subsequently passes through another add/drop filter that adds the same wavelength. Cross-talk is caused by some of the light from the dropped channel leaking through the pass-through of the add/drop filters onto the path of the added channel. That is, the light is not completely dropped; some residual light remains on the fiber at that wavelength. Ideally, this residual light would never exist but in practical applications, a small amount of leak-through is unavoidable. To correct any potential problems caused by residual light leaking through, filters are designed so that a signal experiences a large loss in this path. This is called filter isolation.

Polarization mode dispersion

Polarization mode dispersion (PMD) occurs in single-mode fiber because of the lack of perfect symmetry in the fiber and from external pressures on the cable.

For networks carrying traffic with bit rates of 1.25 Gbit/s or less, PMD can be ignored because its impact is negligible.

Fiber non-linearities

Fiber non-linearities can impact the quality of the signal if the power level of an individual wavelength launched directly into a fiber span is too high. For NDSF fiber, it is recommended that the per channel power level be less than 3 dBm.

In Extended Metro networks, fiber non-linearities can impact the quality of the signal if the power level of an individual wavelength launched directly into a DSCM is too high. The launch power into the DSCM must be limited.

Additional design considerations apply to Optical Metro 5100/5200 networks on fiber types other than NDSF. Due to non-linear effects, the performance of a given channel depends on the characteristics of all the other channels. Four-wave mixing (FWM), stimulated Raman scattering (SRS), and cross-phase modulation (XPM) can impact the performance of Optical Metro 5100/5200 on fiber types other than NDSF.

Span margins

A prudently designed system has a span margin to account for future power losses from factors such as cable repairs and bends. You must know the span margin (in dB) that you want to allocate.

Relating link engineering to an Optical Metro 5100/5200 network

This section relates the concepts introduced in the section “Link engineering primer” to the specific components of an Optical Metro 5100/5200 network.

Optical link budget

An optical link budget is determined by the transmit power at the source of a signal and the receiver sensitivity at the destination. The OCLD, OTR and Muxponder circuit packs define the source and destination of a signal in an Optical Metro 5100/5200 network.

The optical link budget defines the power level at which the signal must arrive at the receiving OCLD, OTR or Muxponder. Starting with launch power at the originating OCLD, OTR or Muxponder, all penalties, including margins, as defined by the link engineering rules, must be applied. In addition, any gains caused by amplification must be taken into account. If the final power level calculated at the destination OCLD, OTR or Muxponder is greater than the minimum receive sensitivity and less than the receiver overload, the link is within budget.

> ***Note:*** The different OCLD (1.25 Gbit/s and 2.5 Gbit/s), OTR and Muxponder circuit packs available with Optical Metro 5100/5200 have different transmit power and receiver sensitivity specifications. See the "Link engineering components" chapter in this book for the transmit power and receiver sensitivity specifications.

Add/drop filters

The add/drop filters are contained within the OMX. All OMXs that exist in the optical path between the transmitting OCLD, OTR or Muxponder circuit pack and the receiving OCLD, OTR or Muxponder circuit pack must be considered when determining the optical loss penalties. This includes not only the OMX where the specific wavelength is being added or dropped, but also any other OMX through which the wavelength passes.

In addition, for any wavelength being dropped and added through an OMX at a site with an optical pass-through, there is a possibility of cross-talk. The rule defining the cross-talk limit and penalty must be applied.

C&L splitter/coupler

The splitter is used to split the C-band and L-band channels onto two separate fibers. The coupler is used to recombine the C-band and L-band channels onto a single fiber. Both the splitting and the recombining processes introduce loss.

OSC

If the functionality of the optical supervisory channel (OSC) is required, the OSC splitter/coupler must be used to add and drop the OSC wavelength. All of the signal wavelengths experience loss when they pass through the OSC splitter/coupler.

To ensure correct operation of the OSC, this signal must be link engineered separately. In particular, the add port of the OSC splitter/coupler may need attenuation to prevent overload at the OSC receiver and excessive OSC bleed-through, which causes faulty alarm conditions. For more information, see “Rule 16: OSC link engineering” in the “Link engineering rules” chapter in this book.

1310 nm splitter/coupler

If an ITU CWDM network is overlaid onto a network that uses 1310 nm signals, the 1310 nm splitter/coupler must be used to add and drop the 1310 nm wavelength. All of the signal wavelengths experience loss when they pass through the 1310 nm splitter/coupler.

DSCM

Dispersion Slope Compensating Module (DSCM) are used to compensate the chromatic dispersion slope and dispersion accumulated after an optical fiber span of a given length. All of the signal wavelengths experience loss when they pass through the DSCM. Fiber non-linearities can impact the quality of the signal if the power level of an individual wavelength launched directly into a DSCM is too high. The launch power into the DSCM must be limited.

Equalization

Another factor that contributes to the optical power losses within an amplified network is equalization, either centralized or distributed.

In each case, to equalize the bands for amplification, the bands with higher power must be brought down to the level of the band with the lowest power. This causes power loss on each of the channels within those bands. Whether this is done by applying fixed pads at the OMXs where the bands are being added, or by using the variable optical attenuators of one of the ECT, PBE, APBE, or VOA variants, the power loss must be taken into account.

Also, any signal going through an ECT that is not part of the bands being equalized experiences optical power loss. The amount of loss is specified by the technical specifications in the “Link engineering components” chapter in this book.

Amplification

Amplification is provided by the OFA circuit pack in an Optical Metro 5200 network. The OFA circuit pack provides a fixed amount of gain to the optical signal. This is applied to either the full C-band (bands 1 through 4), or the full L-band (bands 5 through 8).

When designing networks with OFA circuit packs, you must take into account the optical characteristics of the OFA circuit pack. These specify the maximum and minimum power that is allowed on a per channel basis as well as on the aggregate signal.

For amplified networks, OSNR degradation may become an issue. It is very important that the OSNR penalties be understood and incorporated into the link engineering calculations. This is particularly important if the optical signal passes through multiple amplifiers on its path.

Because OFA circuit packs can boost channel powers, there is a greater likelihood of exceeding cross-talk levels than at OADM sites. To avoid exceeding cross-talk levels, you may need to attenuate the output of the amplifier.

> ***Note:*** A characteristic of OFAs is that they produce wide-band spurious power, called Amplified Spontaneous Emission (ASE). Operators should be aware that any APBE downstream of an OFA will detect the ASE power and will falsely indicate traffic signal power present (by extinguishing the APBE "LOS" LED) on all APBE ports within the operating band of the OFA.

Because the OFA circuit pack is optical and does not involve any OEO conversion, disregard any OFA circuit packs when calculating chromatic dispersion and jitter penalties.

Regeneration

There are two types of regeneration:

- regeneration within a network: the optical channel does not terminate or "leave" the network
- regeneration between cascaded networks: the optical channel terminates and leaves the network

Regeneration within a network

Regeneration occurs when a wavelength is dropped and received by an OCLD or OTR circuit pack and is routed directly to another OCLD or OTR circuit pack in the same shelf where it is added by way of the OMX. This is also referred to as electrical pass-through.

Electrical pass-through for signals which are generated at OCLD or OTR 2.5 Gbit/s circuit packs is done with the use of OCLD circuit packs, regeneration for signals which are generated at OTR 10 Gbit/s circuit packs is done with the use of OTR 10 Gbit/s circuit packs and regeneration for signals which are generated at OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit packs is done with the use of OTR 10 Gbit/s Enhanced circuit packs.

> ***Note:*** When signals that are carried by OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit packs undergo electrical pass-through, the signal flows out of the client interface on one OTR 10 Gbit/s or OTR 10 Gbit/s Enhanced circuit pack and back into the client interface on another OTR

10 Gbit/s or OTR 10 Gbit/s Enhanced circuit pack in the same shelf. Although client interfaces are involved in this process, the optical channel does not terminate or “leave” the network.

Regeneration between cascaded networks

When a signal is received by the OCLD, OTR or Muxponder, it is converted from an optical signal to an electrical signal. The signal is then forwarded to either an OCI circuit pack or another OCLD, OTR or Muxponder circuit pack and converted back to an optical signal, so that it can be routed to the next segment of its path. This OEO conversion regenerates the signal and resets the link budget, including dispersion limits and most penalties incurred on the path. The only exception is jitter, which must be taken into account as a penalty on the next segment of the path.

Optical seams

In an Optical Metro 5200 ring network with amplification, optical seams are implemented by generating a true optical seam using the OMXs, or by introducing the high-isolation filters available in the per band equalizers.

For a true optical seam, you must ensure that you have at least one terminal site in the network. A terminal site is one that does not have any optical pass-through. All wavelengths are dropped through an optical/electrical conversion. Then they are either terminated to the client equipment though the OCI, OTR or Muxponder circuit pack, or they are passed-through by way of another OCLD or OTR circuit pack where a subsequent electrical/optical conversion occurs.

All bands that are used on the ring must drop and be added with no bands passing through optically. This can only be achieved using the standard OMX fibering or the stacked OMX fibering, with no optical cross-over between the THRU OUT and the THRU IN.

An ECT, PBE, APBE or APBE Enhanced can be used in place of a true optical seam to filter out unused bands or noise present between each band.

Trunk Switch

Optical Metro 5100/5200 supports two types of trunk switch to provide line-side fiber protection.

The Optical Trunk Switch (OTS) can be deployed at each Optical Metro 5100/5200 terminal site in an unamplified point-to-point network. The Enhanced Trunk Switch (ETS) can be deployed at each Optical Metro 5100/5200 terminal site in unamplified point-to-point networks like the OTS, or in amplified point-to-point networks that contain a single pre-amplifier in the link.

Note: The OTS and the ETS are not compatible, and you cannot deploy an OTS and an ETS in the same point-to-point link.

In the event of physical damage to the primary optical fiber cable, traffic is switched to the redundant path by the trunk switch. Both the OTS and the ETS introduce additional loss to the signal path.

Additionally, it is important to remember to engineer both optical paths separately since they are independent fiber routes that are likely to be different lengths and introduce different loss.

Network modeling

In the next chapters, you are provided with the technical specifications of the components that are required to do link engineering, as well as a list of rules that must be applied.

There are a number rules that may appear to be disjointed. However, to design a proper network, you must ensure that all rules are applied simultaneously. That is, no rule is violated in order to satisfy another rule.

For the technical specifications, there are variants in the values provided. For any component, there can be a range of values provided either through min/max/typical set of values, or through a “+/-” specification. For instance, the gain on the OFA circuit pack is 23 dB (± 1 dB). The transmit power on the OCLD 1.25 Gbit/s circuit pack is minimum 0.3 dBm, maximum 0.8 dBm, and typical 0.5 dBm.

For simple unamplified networks, you may choose to validate all the rules manually. You can compensate for the variation in the component values by choosing to always use the worst case, or always use the typical case and build in some extra margin. In order to more accurately predict the behavior of the optical components, it is recommended that the Network Modeling Tool be used to validate networks.

Note: The Network Modeling Tool must be used for amplified networks and for networks that contain OCLD 2.5 Gbit/s Flex circuit packs, OTR or Muxponder circuit packs. The Network Modeling Tool cannot be used for ITU CWDM networks, amplified Enhanced Trunk Switch networks, Extended Metro networks, networks with fiber types other than NDSF, or networks that use the OMX 16CH.

The Network Modeling Tool builds in the concept of statistical modeling, where the technical specifications of each component are predicted based on the known mean value of the particular performance value and the standard deviation (the distribution around this mean value) of a large set of components. With this information, the tool is able to apply probability theory which more accurately represents complex networks.

For more information about statistical modeling and the Network Modeling Tool, refer to the Optical Metro 5100/5200, *Network Modeling Tool User Guide*.

Gathering information

Before you start calculating and adjusting signal power levels, you must understand some basic information about your network layout. This information is typically established during the network planning phase.

The following is a list of some of the basic information to consider:

- site location, including distance between sites
- traffic types
- bands per site
- equalization method selected
- optical fiber type
- span margin
- intersite losses
- OMX fibering method used

As a result of link engineering, the following information about the network is calculated:

- location of amplifiers
- equalization scheme
- location of shelves with electrical pass-through connections for signal regeneration
- total equipment needed for required traffic
- margins

Site locations

You must know the number of sites in you network, and their location. You must know the distance, between all sites.

To allow for potential amplifier placement and regeneration shelf placement, you must know of any other locations in the fiber path where you can place new sites. The initial network plan may not have identified any equipment at these sites since no signals are to be dropped there. However, for network design integrity, it may be necessary to place equipment there to amplify or regenerate the signal. These unpopulated site are referred to as glass-through sites.

Traffic types

The traffic types being transmitted on each wavelength must be known. This is required in order to determine which OCLD, OTR or Muxponder circuit packs are used for transmitting, receiving, and possibly regenerating the signal. Since the technical specifications vary depending on the OCLD, OTR or Muxponder circuit pack used, this must be known before engineering the network.

Bands per site

You must know the distribution of bands at each site in the network. Figure 5-5 shows an example of the allocation of bands in a ring configuration. For more information about supported configurations, see the "Supported configurations" chapter in this book.

Figure 5-5
Allocation of bands in a ring configuration

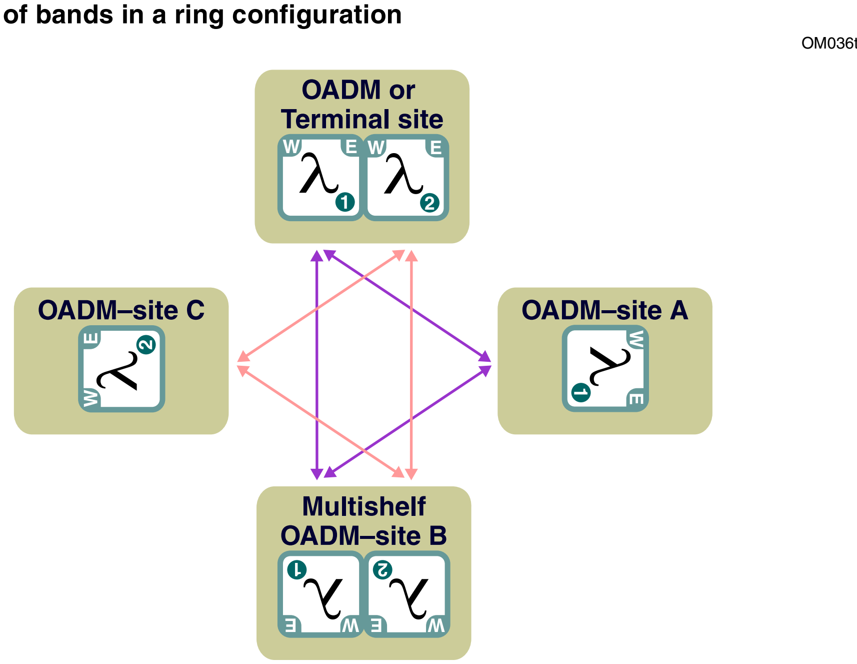
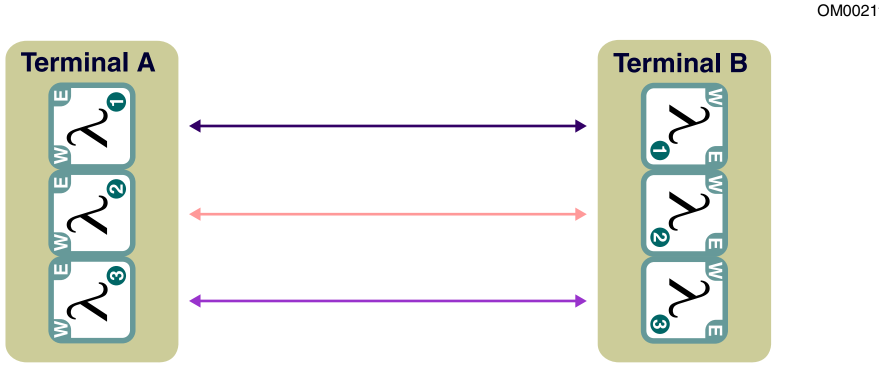


Figure 5-6 shows an example of the allocation of bands in a linear configuration.

Figure 5-6
Allocation of bands in a linear configuration



Equalization method selected

The method of equalization chosen for amplified networks may depend on cost, maintenance procedures, link engineering solutions, and network configuration. You can use either centralized or distributed equalization techniques. For more information about equalization, see the "Supported configurations" chapter in this book.

Optical fiber type

Link engineering of Optical Metro 5100/5200 systems on fiber types other than NDSF is not supported in NMT, nor is it supported through manual calculation. Contact Nortel Networks if your Optical Metro 5100/5200 application is on a fiber type other than NDSF or if it is on a mix of fiber types. For details on alternate fiber types, see "Alternate Fiber Types" on page 7-7.

Span margin

You must know the span margin (in dB) that you want to allocate.

Intersite losses

The losses for the fiber spans between sites include attenuation, connectors, patch panels, and splices. Although it is preferable to measure losses with an optical time domain reflectometer (OTDR), you can estimate these losses. All losses, from the OTS OUT of the last optical component to the OTS IN of the first optical component at the next site must be considered.

OMX fibering methods used

The way in which OMXs are connected affects the way a signal flows through the filters in each OMX at the originating and terminating sites for the signal. This in turn determines the losses a signal experiences. For information about OMX fibering methods, see the "Supported configurations" chapter in this book.

Link engineering components

In this chapter

Note: This chapter contains only the Optical Metro 5100/5200 components that directly affect line-side link engineering. Only the parts of the specification that are relevant to link engineering are described. For more information about all Optical Metro 5100/5200 components, see *Hardware Description,* 323-1701-102, and *Technical Specifications*, 323-1701-180.

Transmit and receive power specifications

OCLD circuit packs

OCLD circuit packs originate (Tx) and terminate (Rx) optical spans.

The transmit power level determines the output power of an originating OCLD circuit pack in an optical span. This is the starting point for all link engineering.

The receive power alarm level determines the minimum acceptable input power to a terminating OCLD circuit pack in an optical span. This value is derated (increased) by any penalties incurred in that optical span (chromatic dispersion, OSNR, and jitter). Any customer allocated span margin is added at this point to give the final target received power.

The receiver overload level determines the maximum acceptable input power to a terminating OCLD circuit pack in an optical span.

Table 6-1 lists the specifications for OCLD circuit packs.

Table 6-1
OCLD circuit pack specifications

Characteristic	**Value or range**			
Tx power	**Typical**	**Minimum**	**Maximum**	
OCLD 1.25 Gbit/s OCLD 1.25 Gbit/s Extended Reach OCLD 1.25 Gbit/s CWDM	0.5 dBm	0.0 dBm	1.0 dBm	
OCLD 2.5 Gbit/s OCLD 2.5 Gbit/s Extended Reach OCLD 2.5 Gbit/s CWDM	3.5 dBm	3.0 dBm	4.0 dBm	
OCLD 2.5 Gbit/s Flex OCLD 2.5 Gbit/s Flex Extended Reach OCLD 2.5 Gbit/s Flex Extended Metro OCLD 2.5 Gbit/s Flex 100 GHz OCLD 2.5 Gbit/s Flex CWDM OCLD 2.5 Gbit/s Flex ITU CWDM OCLD 2.5 Gbit/s Universal	3.5 dBm	2.8 dBm	4.2 dBm	
Rx power (see Note 1 and Note 3)	**Minimum Sensitivity at BER = 10^{-12}**		**Minimum Overload at BER = 10^{-12}**	**Damage Level**
OCLD 1.25 Gbit/s OCLD 1.25 Gbit/s Extended Reach OCLD 1.25 Gbit/s CWDM	–29.7 dBm		–3.0 dBm	+3.5 dBm
OCLD 2.5 Gbit/s OCLD 2.5 Gbit/s Extended Reach OCLD 2.5 Gbit/s CWDM	–25.8 dBm		–3.0 dBm	+3.5 dBm
OCLD 2.5 Gbit/s Flex OCLD 2.5 Gbit/s Flex Extended Reach OCLD 2.5 Gbit/s Flex Extended Metro OCLD 2.5 Gbit/s Flex 100 GHz OCLD 2.5 Gbit/s Flex CWDM OCLD 2.5 Gbit/s Flex ITU CWDM OCLD 2.5 Gbit/s Universal	–27.5 dBm		–5.0 dBm (see Note 2)	–2.0 dBm

Table 6-1 (continued)
OCLD circuit pack specifications

Characteristic	Value or range
Dispersion reach limit (NDSF)	
OCLD 1.25 Gbit/s OCLD 2.5 Gbit/s OCLD 2.5 Gbit/s Flex OCLD 2.5 Gbit/s Flex 100 GHz	110 km
OCLD 1.25 Gbit/s Extended Reach OCLD 2.5 Gbit/s Extended Reach OCLD 2.5 Gbit/s Flex Extended Reach	175 km
OCLD 2.5 Gbit/s Flex Extended Metro OCLD 2.5 Gbit/s Universal	350 km for C-band and 200 km for L-band
OCLD 1.25 Gbit/s CWDM OCLD 2.5 Gbit/s CWDM OCLD 2.5 Gbit/s Flex CWDM OCLD 2.5 Gbit/s Flex ITU CWDM	80 km

Note 1: Rx overload and Rx sensitivity specifications are back-to-back and include no path penalties. Use the Network Modeling Tool (NMT) to account for path penalties. If NMT is not used to design the network:

- For Rx sensitivity path penalties, see “Link engineering rules” in *Network Planning and Link Engineering,* 323-1701-110.
- For OCLD 2.5 Gbit/s Flex 100 GHz circuit packs, use the Common Photonic Layer Optical Modeler tool.

Note 2: A 3 dB path penalty needs to be added to the Rx minimum overload, resulting in a value of –8 dBm.

Note 3: In most cases, traffic continuity at high and low input power is determined by the Receive Power High Fail Threshold and Receive Power Low Fail Threshold rather than by the minimum overload and minimum sensitivity. For threshold values, see Table 6-2 on page 6-4.

Table 6-2 lists the optical power threshold levels for OCLD circuit packs.

Table 6-2
OCLD optical power threshold values for performance monitoring

OCLD Type	Threshold	Degrade Threshold (dBm)	Fail Threshold (dBm)	Clear Threshold (dBm)	Default User Threshold (dBm)
1.25 Gbit/s	Rx Power High	–3.50	–2.50	–4.00	–4.00
	Rx Power Low	–29.00	–29.50	–28.00	–28.50
	Tx Power High	1.00	1.10	0.90	0.90
	Tx Power Low	0.00	-0.10	0.10	0.10
2.5 Gbit/s	Rx Power High	–3.50	–2.50	–4.00	–4.00
	Rx Power Low	–25.40	–25.90	–24.40	–24.90
	Tx Power High	4.00	4.10	3.90	3.90
	Tx Power Low	3.00	2.90	3.10	3.10
2.5 Gbit/s Flex 2.5 Gbit/s Universal	Rx Power High	–5.50	–4.50	–6.50	–6.00
	Rx Power Low	–27.50	–28.50	–26.50	–27.00
	Tx Power High	3.90	4.10	3.70	3.80
	Tx Power Low	3.00	2.90	3.10	3.10
Note: There is no Fail alarm for Tx power low.					

OTR circuit packs

OTR circuit packs originate (Tx) and terminate (Rx) optical spans.

The transmit power level determines the output power of an originating OTR circuit pack in an optical span. This is the starting point for all link engineering.

The receive power alarm level determines the minimum acceptable input power to a terminating OTR circuit pack in an optical span. This value is derated (increased) by any penalties incurred in that optical span (chromatic dispersion, OSNR, and jitter). Any customer allocated span margin is added at this point to give the final target received power.

The receiver overload level determines the maximum acceptable input power to a terminating OTR circuit pack in an optical span.

Table 6-3 lists the line-side specifications for OTR circuit packs.

Table 6-3
Specifications for OTR circuit packs—line side

Characteristic	**Value or range**		
Tx power	**Typical**	**Minimum**	**Maximum**
OTR 2.5 Gbit/s Flex 1310 nm OTR 2.5 Gbit/s Flex 1310 nm Extended Reach OTR 2.5 Gbit/s Flex 1310 nm Extended Metro OTR 2.5 Gbit/s Flex 1310 nm 100 GHz OTR 2.5 Gbit/s Flex 1310 nm CWDM OTR 2.5 Gbit/s Flex 1310 nm ITU CWDM OTR 2.5 Gbit/s Universal 1310 nm OTR 2.5 Gbit/s Flex 850 nm OTR 2.5 Gbit/s Flex 850 nm Extended Reach OTR 2.5 Gbit/s Flex 850 nm Extended Metro OTR 2.5 Gbit/s Flex 850 nm 100 GHz OTR 2.5 Gbit/s Flex 850 nm CWDM OTR 2.5 Gbit/s Flex 850 nm ITU CWDM OTR 2.5 Gbit/s Universal 850 nm	3.5 dBm	2.8 dBm	4.2 dBm
OTR 10 Gbit/s	–1.0 dBm	–3.0 dBm	0.0 dBm
OTR 10 Gbit/s Enhanced OTR 10 Gbit/s Enhanced 100 GHz	3.3 dBm	2.6 dBm	4.0 dBm

Table 6-3 (continued)
Specifications for OTR circuit packs—line side

Characteristic	**Value or range**		
Rx power (see Note 1 and Note 3)	**Minimum Sensitivity**	**Minimum Overload**	**Damage Level**
OTR 2.5 Gbit/s Flex 1310 nm OTR 2.5 Gbit/s Flex 1310 nm Extended Reach OTR 2.5 Gbit/s Flex 1310 nm Extended Metro OTR 2.5 Gbit/s Flex 1310 nm 100 GHz OTR 2.5 Gbit/s Flex 1310 nm CWDM OTR 2.5 Gbit/s Flex 1310 nm ITU CWDM OTR 2.5 Gbit/s Universal 1310 nm OTR 2.5 Gbit/s Flex 850 nm OTR 2.5 Gbit/s Flex 850 nm Extended Reach OTR 2.5 Gbit/s Flex 850 nm Extended Metro OTR 2.5 Gbit/s Flex 850 nm 100 GHz OTR 2.5 Gbit/s Flex 850 nm CWDM OTR 2.5 Gbit/s Flex 850 nm ITU CWDM OTR 2.5 Gbit/s Universal 850 nm	–27.5 dBm BER=10^{-12}	–5.0 dBm BER=10^{-12} (see Note 2)	–2.0 dBm
OTR 10 Gbit/s	–24.0 dBm BER=10^{-15}	–5.0 dBm BER=10^{-15}	0 dBm
OTR 10 Gbit/s Enhanced OTR 10 Gbit/s Enhanced 100 GHz	–25.0 dBm BER=10^{-12}	–5.0 dBm BER=10^{-12}	–2.0 dBm

Table 6-3 (continued)
Specifications for OTR circuit packs—line side

Characteristic	Value or range
Dispersion reach limit (NDSF)	
OTR 2.5 Gbit/s Flex 1310 nm OTR 2.5 Gbit/s Flex 1310 nm 100 GHz OTR 2.5 Gbit/s Flex 850 nm OTR 2.5 Gbit/s Flex 850 nm 100 GHz	110 km
OTR 2.5 Gbit/s Flex 1310 nm Extended Reach OTR 2.5 Gbit/s Flex 850 nm Extended Reach	175 km
OTR 2.5 Gbit/s Flex 1310 nm Extended Metro OTR 2.5 Gbit/s Flex 850 nm Extended Metro OTR 2.5 Gbit/s Universal 1310 nm OTR 2.5 Gbit/s Universal 850 nm	350 km for C-band and 200 km for L-band
OTR 2.5 Gbit/s Flex 1310 nm CWDM OTR 2.5 Gbit/s Flex 850 nm CWDM OTR 2.5 Gbit/s Flex 1310 nm ITU CWDM OTR 2.5 Gbit/s Flex 850 nm ITU CWDM	80 km
OTR 10 Gbit/s	60 km

Table 6-3 (continued)
Specifications for OTR circuit packs—line side

Characteristic	Value or range
OTR 10 Gbit/s Enhanced	typically 110 km for C-band and 95 km for L-band (2000 ps/nm—see Note 4)
OTR 10 Gbit/s Enhanced 100 GHz	typically 110 km (2000 ps/nm—see Note 4)

Note 1: Rx overload and Rx sensitivity specifications are back-to-back and include no path penalties. The Network Modeling Tool (NMT) should be used to account for path penalties. If NMT is not used to design the network:

- For Rx sensitivity path penalties, see "Link engineering rules" in *Network Planning and Link Engineering,* 323-1701-110.
- For OTR 2.5 Gbit/s Flex 1310 nm 100 GHz, OTR 2.5 Gbit/s Flex 850 nm 100 GHz, and OTR 10 Gbit/s Enhanced 100 GHz circuit packs, use the Common Photonic Layer Optical Modeler tool.

Note 2: A 3 dB path penalty needs to be added to the Rx minimum overload, resulting in a value of –8 dBm.

Note 3: In most cases, traffic continuity at high and low input power is determined by the Receive Power High Fail Threshold and Receive Power Low Fail Threshold rather than by the minimum overload and minimum sensitivity. For threshold values, see Table 6-4 on page 6-9.

Note 4: In some applications, it may be possible to exceed the dispersion limits specified on NDSF fiber. To ensure that the dispersion limit of the circuit pack is not exceeded, it is necessary to check that either:

- The total measured dispersion of the fiber, from the TX (add) through all spans to the RX (drop), is less than 2000 ps/nm
- If the characteristic dispersion per unit length (ps/nm/km) of the fiber is known, then the maximum reach can be calculated using the 2000 ps/nm dispersion limit (for example, the maximum reach over 17 ps/nm/km dispersion fiber is 2000/17 = 117 km)

It is important to perform this check at the longest wavelength to be deployed, as dispersion is wavelength dependent.

Table 6-4 lists the line-side optical power threshold values for OTR circuit packs.

Table 6-4
OTR line-side optical power threshold values for performance monitoring

OTR Type	Threshold	Degrade Threshold (dBm)	Fail Threshold (dBm)	Clear Threshold (dBm)	Default User Threshold (dBm)
10 Gbit/s Enhanced	Rx Power High	–5.00	–4.00	–6.00	–5.50
	Rx Power Low	–25.00	–26.00	–24.00	–24.50
	Tx Power High	3.70	3.80	3.60	3.60
	Tx Power Low	2.50	2.40	2.60	2.60
10 Gbit/s	Rx Power High	–5.00	–4.50	–5.60	–5.50
	Rx Power Low	–23.50	–24.00	–22.90	–23.00
	Tx Power High	0.60	1.20	0.00	0.50
	Tx Power Low	–3.60	–4.20	–3.00	–3.50
2.5 Gbit/s Flex	Rx Power High	–5.50	–4.50	–6.50	–6.00
	Rx Power Low	–27.50	–28.50	–26.50	–27.00
	Tx Power High	3.90	4.10	3.70	3.80
	Tx Power Low	3.00	2.90	3.10	3.10

Note 1: Power readings sampled from OTR 2.5 Gbit/s Flex and displayed by the System Manager (Facility and Equipment PM windows) and those measured externally with an optical power meter can vary by up to ±2.0 dB. The power sensing design in OTR 2.5 Gbit/s Flex is calibrated to ±1.8 dB for Tx and ±1.6 dB for Rx when the Rx input power is between –18 dBm and –5 dBm.The power sensing design in OTR 2.5 Gbit/s Universal is calibrated to ±1.2 dB for Tx and ±1.5 dB for Rx when the Rx input power is between –18 dBm and –5 dBm.

Muxponder circuit packs

Muxponder circuit packs originate (Tx) and terminate (Rx) optical spans.

The transmit power level determines the output power of an originating Muxponder circuit pack in an optical span. This is the starting point for all link engineering.

The receive power alarm level determines the minimum acceptable input power to a terminating Muxponder circuit pack in an optical span. This value is derated (increased) by any penalties incurred in that optical span (chromatic dispersion, OSNR, and jitter). Any customer allocated span margin is added at this point to give the final target received power.

The receiver overload level determines the maximum acceptable input power to a terminating Muxponder circuit pack in an optical span.

Table 6-5 lists the line-side specifications for Muxponder circuit packs.

Table 6-5
Specifications for Muxponder circuit packs—line side

Characteristic	**Value or range**			
Tx power	**Typical**	**Minimum**	**Maximum**	
Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT	3.3 dBm	2.6 dBm	4.0 dBm	
Muxponder 10 Gbit/s GbE/FC 100 GHz Muxponder 10 Gbit/s GbE/FC VCAT 100 GHz	3.4 dBm	2.6 dBm	4.0 dBm	
Rx power (see Note 1 and Note 2)	**Minimum Sensitivity**		**Minimum Overload**	**Damage Level**
Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT Muxponder 10 Gbit/s GbE/FC 100 GHz Muxponder 10 Gbit/s GbE/FC VCAT 100 GHz	–25.0 dBm BER=10^{-12}		–5.0 dBm BER=10^{-12}	–2.0 dBm

Table 6-5 (continued)
Specifications for Muxponder circuit packs—line side

Characteristic	Value or range
Dispersion reach limit (NDSF)	
Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT	typically 110 km for C-band and 95 km for L-band (2000 ps/nm—see Note 3)
Muxponder 10 Gbit/s GbE/FC 100 GHz Muxponder 10 Gbit/s GbE/FC VCAT 100 GHz	typically 110 km (2000 ps/nm—see Note 3)

Note 1: Rx overload and Rx sensitivity specifications are back-to-back and include no path penalties. The Network Modeling Tool (NMT) should be used to account for path penalties. If NMT is not used to design the network:

- For Rx sensitivity path penalties, see “Link engineering rules” in *Network Planning and Link Engineering,* 323-1701-110.

For Muxponder 10 Gbit/s GbE/FC 100 GHz and Muxponder 10 Gbit/s GbE/FC VCAT 100 GHz circuit packs, use the Common Photonic Layer Optical Modeler tool.

Note 2: In most cases, traffic continuity at high and low input power is determined by the Receive Power High Fail Threshold and Receive Power Low Fail Threshold rather than by the minimum overload and minimum sensitivity. For threshold values, see Table 6-5 on page 6-10.

Note 3: In some applications, it may be possible to exceed the dispersion limits specified on NDSF fiber. To ensure that the dispersion limit of the circuit pack is not exceeded, it is necessary to check that either:

- The total measured dispersion of the fiber, from the TX (add) through all spans to the RX (drop), is less than 2000 ps/nm
- If the characteristic dispersion per unit length (ps/nm/km) of the fiber is known, then the maximum reach can be calculated using the 2000 ps/nm dispersion limit (for example, the maximum reach over 17 ps/nm/km dispersion fiber is 2000/17 = 117 km)

It is important to perform this check at the longest wavelength to be deployed, as dispersion is wavelength dependent.

Table 6-6 lists the line-side optical power threshold values for Muxponder circuit packs.

Table 6-6
Muxponder line-side optical power threshold values for performance monitoring

Muxponder Type	Threshold	Degrade Threshold (dBm)	Fail Threshold (dBm)	Clear Threshold (dBm)	Default User Threshold (dBm)
Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT	Rx Power High	–5.00	–4.00	–6.00	–5.50
	Rx Power Low	–25.00	–26.00	–24.00	–24.50
	Tx Power High	3.70	3.80	3.60	3.60
	Tx Power Low	2.50	2.40	2.60	2.60

Amplification specifications

OFA circuit packs

Optical-fiber amplifier (OFA) circuit packs contain an Erbium doped fiber amplifier (EDFA) that amplifies the optical signal without converting it to the electrical domain. With careful link engineering, OFA circuit packs can be used at any site in an Optical Metro 5200 network to boost the level of the optical signal.

The Optical Metro 5200 network uses two generic types of OFA circuit packs: the C band which amplifies the C-band wavelengths (bands 1 to 4) and the L band which amplifies L band wavelengths (bands 5 to 8). Each OFA circuit pack can amplify all sixteen wavelengths (four bands each containing four channels) simultaneously. Both OFA circuit packs provide a flat per channel gain of nominally 23 dB. With the Variable Gain amplifier, an integrated eVOA along with enhanced software power control provide a superior operational simplicity, due to the ability to adjust the gain (from 7-17 dB).

When you link engineer networks with OFAs, you must consider several factors. Not only are the per channel powers required in determining the validity of a network design, but the aggregate power of the optical signal is also important. This is because the input and output power alarm values on an OFA circuit pack are set at total power levels that ensure that the correct amplifier operating conditions are maintained, avoiding saturation effects that would degrade amplifier performance.

A generic OFA can be one of the following:

- Standard OFA
- high input power (HIP) OFA
- variable gain (VGA) OFA

The high input power (HIP) OFA is capable of operating at higher aggregate input powers than Standard OFAs. By supporting higher average channel powers, the HIP OFA enhances the performance of an Optical Metro 5200 DWDM network by allowing more amplifiers to be cascaded, at full channel fill, without reaching the OSNR limit of receivers. It is recommended that the HIP OFA be used wherever possible to maximize current and future network performance.

The variable gain (VGA) OFA is capable of operating at higher aggregate input powers than the HIP and Standard OFAs. By supporting higher average channel powers, the VGA OFA enhances the performance of an Optical Metro 5200 DWDM network by allowing more amplifiers to be cascaded, at full channel fill, without reaching the OSNR limit of receivers. It also uses an eVOA (electrically controlled variable optical attenuator) to provide amplifier band power control.

OFAs degrade the OSNR of a signal. You must ensure that the channel powers of all of the wavelengths are maintained as high as possible into the amplifier (without exceeding the overload level). You must equalize the different bands using one of the equalization schemes described in the "Supported configurations" chapter in this book.

Variable gain OFA circuit packs

The variable gain amplifier/optical-fiber amplifier (VGA OFA) circuit pack is a three-slot circuit pack specific to the Optical Metro 5200 shelf. The OFA VGA uses an erbium doped fiber amplifier (EDFA) to amplify C-band or L-band signals. It uses an eVOA (electrically controlled variable optical attenuator) to provide amplifier band power control.

To prevent the introduction of new penalties due to non-linear effects and to remain within the same safety standard, the output power of the OFA VGA circuit pack is the same as that of the OFA HIP circuit pack.

Since the amplifier allows a higher input power and has the same output power, the gain has to be smaller (up to 17 dB) than the OFA HIP circuit pack or the OFA Standard circuit pack (23 dB). Where the spans are too long for the gain of the OFA VGA, it is possible to cascade two OFA VGA circuit packs at the same amplifier site allowing higher gain.

To improve operational functionality, an eVOA has been added to allow the gain to be adjusted to the right level to meet the required output power target (gain can be between 7 to 17 dB). This can be done from a remote location (APBE-like control scheme).

The OFA VGA circuit pack adds value in the following applications:

- post-amplifier configurations (since the input power to the amplifier is normally high in this configuration)
- in systems where many amplifiers need to be cascaded
- in systems where the operational functionality of the eVOA is required

Due to the smaller gain, a solution using OFA VGA circuit packs will generally require more amplifiers than a solution using OFA HIP circuit packs. The value of the OFA VGA circuit pack comes into play when not enough OFA HIP circuit packs can be cascaded to reach the receivers with acceptable OSNR.

It is important to mention that the OFA VGA circuit pack is an additional asset of the Optical Metro 5200 platform and is not an improvement over the OFA HIP circuit pack in all cases. It is important to use the correct amplifier type to optimize the network design and reduce overall equipment cost.

Since the VGA adjusts its gain to meet a target output power, and since the output power is made up of signal power and ASE noise generated by upstream OFAs, it is possible to observe an offset between the target power per channel and the real signal launch power measured with an Optical Spectrum Analyzer. This offset increases with the level of noise present at the input of the OFA VGA and will also increase with a smaller channel count. Since this offset can result in link budget degradation, it is important to validate a design for both end of life and day one channel loading conditions.

High input power OFA circuit packs

The high input power (HIP) OFA has been designed to handle higher channel powers than the standard OFA, even when fully filled with all 16 channels. For this reason, it is not recommended to drop the supported channel count in order to boost the powers on the remaining channels.

The HIP OFA is similar to the Standard OFA, as follows:

- it can be deployed as a pre-amplifier, post-amplifier or line amplifier within a site
- it works with any of the equalization components
- it can be intermixed with the Standard amplifier, but this is likely to cause the number of amplifiers that can be cascaded to reduce depending on the ratio of HIP to Standard amplifiers, the network topology, and choice of equalization components

- it is possible to operate the HIP OFA at the same power levels as the standard amplifier. In this case, however the number of HIP OFAs that can be cascaded will be the same as for the standard OFA.

The HIP OFA differs from the Standard OFA, as follows:

- the HIP OFA does not support equalization target powers beyond the recommended –20 dBm per channel.
- the maximum aggregate output power of the HIP OFA exceeds that of the Standard OFA, which means that networks using HIP OFAs now must be classified as Hazard Level kx3A. The HIP OFA should not be deployed in networks that have to meet Hazard Level 3A, unless the ALS is enforced.

Table 6-7 lists the specifications for OFA circuit packs.

Table 6-7
OFA circuit pack optical interface specifications

Characteristic		**Value or range**		
Power consumption (see Note 1)		**Typical**		**Maximum**
	Standard OFA: C-band	14 W		22 W
	Standard OFA: L-band	20 W		36 W
	High Input Power OFA: C-band	16 W		29 W
	High Input Power OFA: L-band	26 W		49 W
	OFA VGA: C-band	25 W		30 W
	OFA VGA: L-band	25 W		30 W
Optical gain per channel		**Average**	**Minimum**	**Maximum**
	Standard OFA	23.0 dB	22.0 dB	24.0 dB
	High Input Power OFA	23.0 dB	22.0 dB	24.0 dB
	OFA VGA (see Note 2)	7 dB (see Note 3)	—	17.0 dB
Gain stability	Standard OFA			± 0.5 dB
	High Input Power OFA			± 0.25 dB
	OFA VGA	—	—	± 0.3 dB
Total Tx power	Standard OFA		–6.0 dBm	13.0 dBm
	High Input Power OFA		–6.0 dBm	16.0 dBm
	OFA VGA	—	–11.0 dBm	15.1 dBm (see Note 4)

Table 6-7 (continued)
OFA circuit pack optical interface specifications

Characteristic			Value or range		
Tx level per channel	Standard OFA		—	—	—
	High Input Power OFA		—	—	4.0 dBm
	OFA VGA		—	—	3.0 dBm (see Note 4)
Total Rx power (see Note 5)			**Average**	**Minimum**	**Maximum**
	Standard OFA		—	–28.0 dBm	–11.0 dBm
	High Input Power OFA		—	–28.0 dBm	–7.0 dBm (see Note 9)
	OFA VGA			–28.0 dBm	9.0 dBm
		17 dB gain	—	–28.0 dBm	–2.0 dBm (see Note 7)
		7 dB gain	—	–18.0 dBm (see Note 8)	8.0 dBm
Rx optical power monitor accuracy	Standard OFA		± 0.5 dB down to –22 dBm ± 1.0 dB down to –31 dBm		
	High Input Power OFA		± 0.25 dB down to –20 dBm ± 0.5 dB down to –25 dBm ± 1.0 dB down to –32 dBm		
	OFA VGA		± 0.6 dB down to –12 dBm ± 0.7 dB down to –26 dBm ± 0.9 dB down to –32 dBm		
Tx optical power monitor accuracy	Standard OFA				
	High Input Power OFA				
	OFA VGA		± 0.6 dB up to 17 dBm ± 1.0 dB up to 5 dBm ± 1.5 dB up to –9 dBm		
Wavelength			**Minimum**		**Maximum**
	Standard OFA: C-band High Input Power OFA: C-band OFA VGA: C-band		1528.52 nm		1562.48 nm
	Standard OFA: L-band High Input Power OFA: L-band OFA VGA: L-band		1570.17 nm		1606.98 nm

Table 6-7 (continued)
OFA circuit pack optical interface specifications

Characteristic		**Value or range**	
Noise figure		**Minimum**	**Maximum**
	Standard OFA: C-band	—	5.5 dB
	High Input Power OFA: C-band	—	5.3 dB
	OFA VGA: C-band	—	6.3 dB
	Standard OFA: L-band	—	6.0 dB
	High Input Power OFA: L-band	—	5.3 dB
	OFA VGA: L-band	—	6.3 dB

Note 1: Maximum power consumption values are obtained during worst-case operating conditions.

Note 2: Gain is automatically adjusted by software to the value required to achieve the target output power given by the user. Once the target power is achieved, the circuit pack switches into constant gain mode.

Note 3: Although the minimum gain quoted is 7 dB, in order to have some margin, the circuit pack gain can go down to 5 dB.

Note 4: Tx power levels are independent of the gain setting of the module. Even though the amplifier can support a total output power of +17 dBm, in order to have margin, System Manager will enforce a maximum aggregate target output power of +15.1 dBm, (that is, +3 dBm/channel) if 16 channels are present.

Note 5: In most cases, traffic continuity at maximum and minimum input power is determined by the Receive Power High Fail Threshold and Receive Power Low Fail Threshold. For threshold values, see *Technical Specifications*, 323-1701-180.

Note 6: Although –1.0 dBm is acceptable, to allow room for input power variations, a –2.0 dBm value is recommended by link engineering and will be considered as the default target by NMT.

Note 7: At high input power, the gain has to be reduced in order to prevent saturation. For each dB of input power greater than –2 dBm, the gain will decrease by one dB to prevent saturation.

Note 8: At lower gain setting, the minimum Rx input power has to increase in order to prevent Loss Of Signal. For each dB of gain reduction, the maximum input power has to be increased by one dB.

Note 9: Although the HIP amplifier can accept a maximum input power of –7.0 dBm, it is recommended that you engineer to a maximum input power of –8 dBm, as implemented in the Network Modeling Tool. The –8.0 dBm value includes a 1.0 dB buffer for increased network reliability.

Loss specifications

Any passive component that the optical signal passes through reduces the power level. This includes optical connectors, splices, the fiber plant as well as the components in the Optical Metro 5100/5200 system. Link engineering has to take into account all of these losses when calculating the power budget. This section details the components in the Optical Metro 5100/5200 system that introduce loss. All loss figures quoted include connector losses.

OMXs

The OMX performs the add/drop functions for a shelf. For point-to-point unprotected configurations there is one OMX for each band present. In most other configurations there are two OMXs present, one for each direction (east and west).

In DWDM networks:

- the OMX (Standard), OMX 4CH + Fiber Manager, and OMX 4CH DWDM Enhanced add and drop the four channels in a band and pass through other bands
- the OMX 16CH adds and drops all sixteen C-band channels or all sixteen L-band channels. This OMX has no passthrough ports. The C-band OMX 16CH includes an L-band upgrade port that allows connection with the L-band OMX 16CH for 32 channel support

In CWDM networks:

- the OMX 1CH CWDM adds and drops a single channel and passes through other channels
- the OMX 4CH CWDM adds and drops all four C-band or L-band channels and passes through other bands
- the OMX 4CH CWDM with dual taps adds and drops all four C-band or L-band channels and passes through other bands

In ITU CWDM networks:

- the OMX 4CH ITU CWDM adds and drops wavelengths 1511, 1531, 1551 and 1571 nm. This OMX has no passthrough ports.
- the OMX 8CH ITU CWDM adds and drops wavelengths 1471, 1491, 1511, 1531, 1551, 1571, 1591 and 1611 nm. This OMX has no passthrough ports.
- the OMX 4CH OADM ITU CWDM adds and drops wavelengths 1471, 1491, 1511, and 1531 nm and passes through other wavelengths or adds and drops wavelengths 1551, 1571, 1591 and 1611 nm and passes through other wavelengths
- the OMX 1CH OADM ITU CWDM adds and drops a single wavelength (1471, 1491, 1511, 1531, 1551, 1571, 1591 or 1611 nm) and passes through other wavelengths

  Note: Some Optical Metro 5100/5200 ITU CWDM hardware introduced before the ITU CWDM standard (G.695) was finalized will have labels with a center wavelength that differs by 1 nm with respect to the finalized ITU CWDM standard (G.695). For example, for the 1471 nm wavelength, the label will show 1470 nm. However, there is no wavelength incompatibility since the passbands are the same. For example, the pre-finalized ITU CWDM standard 1470 nm channel specified a range of

–5.5 to +7.5 nm, that is, a passband of 1464.5 to 1477.5 nm. The finalized ITU CWDM standard 1471 nm channel specifies a range of ±6.5 nm, that is, the passband is still 1464.5 to 1477.5 nm. The only difference is one of labeling.

The losses associated with OMXs are:

- add or drop loss
- pass-through loss (four-channel DWDM OMXs, CWDM OMXs and OADM ITU CWDM OMXs only)
- L-band upgrade port loss (sixteen-channel DWDM OMX only)

Add or drop losses are the losses associated with channels that are being added or dropped by an OMX. Pass-through losses are the losses experienced by channels that are not adding or dropping, but are passing through the OMX. The number of losses experienced by any wavelength depends on the number of other bands present at all sites in a span and on the fibering method used to connect the OMXs. For information about OMX fibering methods, see the chapter “Supported configurations” in this book.

The following tables list the specifications for OMXs:

- OMX DWDM (see Table 6-8 on page 6-20)
- OMX 16CH DWDM (see Table 6-9 on page 6-21)
- OMX 1CH CWDM (see Table 6-10 on page 6-21)
- OMX 4CH CWDM (see Table 6-11 on page 6-22)
- OMX ITU CWDM (see Table 6-12 on page 6-23)
- OMX OADM ITU CWDM (see Table 6-13 on page 6-24)

Table 6-8
OMX DWDM specifications

<table>
<tr><th colspan="2" rowspan="2">Characteristic</th><th colspan="6">Value or range</th></tr>
<tr><th colspan="2">Standard</th><th colspan="2">4 CH + FM</th><th colspan="2">4 CH Enhanced</th></tr>
<tr><td colspan="2">Maximum total input power</td><td colspan="2">17 dBm</td><td colspan="2">17 dBm</td><td colspan="2">17 dBm</td></tr>
<tr><td colspan="2">Minimum return loss</td><td colspan="2">40 dB</td><td colspan="2">40 dB</td><td colspan="2">45 dB</td></tr>
<tr><td colspan="2">Passband</td><td colspan="6">Center wavelength ± 0.25 nm</td></tr>
<tr><td colspan="8">Minimum band isolation</td></tr>
<tr><td rowspan="2"></td><td>Drop</td><td colspan="2">20 dB</td><td colspan="2">20 dB</td><td colspan="2">35 dB</td></tr>
<tr><td>Thru Out</td><td colspan="2">12 dB</td><td colspan="2">12 dB</td><td colspan="2">20 dB</td></tr>
<tr><td colspan="2">Insertion loss</td><td>Maximum</td><td>Typical</td><td>Maximum</td><td>Typical</td><td>Maximum</td><td>Typical</td></tr>
<tr><td rowspan="3"></td><td>Add path</td><td>4.2 dB</td><td>3.0 dB</td><td>4.5 dB</td><td>3.2 dB</td><td>2.8 dB</td><td>2.1 dB</td></tr>
<tr><td>Drop path</td><td>4.6 dB</td><td>3.3 dB</td><td>4.9 dB</td><td>3.5 dB</td><td>3.1 dB</td><td>2.4 dB</td></tr>
<tr><td>Pass-through</td><td>1.2 dB</td><td>0.7 dB</td><td>1.2 dB</td><td>0.7 dB</td><td>1.0 dB</td><td>0.7 dB</td></tr>
<tr><td colspan="8">Note: For single-shelf OADM sites with a standard OMX (where the THRU OUT is wired to the THRU IN of the same OMX), one connector is saved between the two band filters. Because the values in this this table include the most common connector losses (typical is 0.2 dB, worst case is 0.3 dB), you must subtract the value of one connector from the table values. For example, the typical OMX pass-through losses for a single-shelf OADM site are:
0.7 dB × 2 (standard pass-through losses, including connectors) – 0.2 dB (one less connector) = 1.2 dB (total OMX pass-through losses).
This rule does not apply to single-shelf sites with the OMX + Fiber Manager 4CH or OMX 4CH Enhanced.</td></tr>
</table>

Table 6-9
OMX 16CH DWDM specifications

Characteristic		Value or range			
Maximum total input power		21 dBm			
Minimum return loss		40 dB			
Passband		Center wavelength ± 0.25 nm			
Minimum isolation	Channel Add and Drop	30 dB			
	L-band THRU In and Out	18 dB			
Insertion loss		**OMX 16CH DWDM C-band**		**OMX 16CH DWDM L-band**	
		Maximum	**Typical**	**Maximum**	**Typical**
	Add path	4.5 dB	3.9 dB	4.1 dB	3.5 dB
	Drop path	4.5 dB	3.9 dB	4.1 dB	3.5 dB
	L-band upgrade: OTS IN to L OUT L IN to OTS OUT	1.1 dB	0.8 dB	Not applicable	Not applicable
	Add and Drop (16 channel C- or L-band only, end-to-end)	6.9 dB	5.7 dB	6.0 dB	5.0 dB
	Add and Drop (32 channel C- and L-band, end-to-end)	6.9 dB	5.7 dB	8.2 dB	6.6 dB

Table 6-10
OMX 1CH CWDM specifications

Characteristic		Value or range
Maximum total input power		21 dBm
Minimum return loss		40 dB
Passband		Center wavelength ± 2.68 nm
Minimum isolation	Drop	25 dB
	Thru Out	25 dB

Table 6-10 (continued)
OMX 1CH CWDM specifications

Characteristic		Value or range	
Insertion loss		**Maximum**	**Typical**
	Add path	1.5 dB	1.0 dB
	Drop path	1.5 dB	1.0 dB
	Thru In - OTS Out	1.2 dB	0.8 dB
	OTS In - Thru Out	1.6 dB	1.2 dB

Table 6-11
OMX 4CH CWDM specifications

Characteristic		Value or range			
		OMX 4CH CWDM		**OMX 4CH CWDM with dual taps**	
Maximum total input power		21 dBm		21 dBm	
Minimum return loss		45 dB		40 dB	
Passband		Center wavelength ± 2.68 nm		Center wavelength ± 2.68 nm	
Minimum isolation	Drop	25 dB			
	Thru Out	20 dB		30 dB	
Insertion loss		**Maximum**	**Typical**	**Maximum**	**Typical**
	Add/Drop	2.7 dB	2.0 dB	2.6 dB	dB
	Thru in - OTS Out	2.2 dB	1.5 dB	2.1 dB	dB
	OTS In - Thru out	2.5 dB	1.8 dB	2.4 dB	dB

Table 6-12
OMX 4CH or 8CH ITU CWDM specifications

Characteristic		**Value or range**			
Maximum total input power		21 dBm			
Minimum return loss		45 dB			
Center wavelengths (see Note)		1471, 1491, 1511, 1531, 1551, 1571, 1591, 1611 nm			
Passband		Center wavelength ± 6.5 nm			
Minimum isolation	Drop	30 dB			
Insertion loss		**OMX 4CH ITU CWDM**		**OMX 8CH ITU CWDM**	
		Maximum	Typical	Maximum	Typical
	Add	2.1 dB	1.1 dB	3.7 dB	1.9 dB
	Drop	2.4 dB	1.2 dB	3.9 dB	2.2 dB
	Add and Drop (end-to-end)	3.7 dB	2.0 dB	5.3 dB	2.9 dB

Note: Some Optical Metro 5100/5200 ITU CWDM hardware introduced before the ITU CWDM standard (G.695) was finalized will have labels with a center wavelength that differs by 1 nm with respect to the finalized ITU CWDM standard (G.695). For example, for the 1471 nm wavelength, the label will show 1470 nm. However, there is no wavelength incompatibility since the passbands are the same. For example, the pre-finalized ITU CWDM standard 1470 nm channel specified a range of –5.5 to +7.5 nm, that is, a passband of 1464.5 to 1477.5 nm. The finalized ITU CWDM standard 1471 nm channel specifies a range of ±6.5 nm, that is, the passband is still 1464.5 to 1477.5 nm. The only difference is one of labeling.

Table 6-13
OMX 1CH or 4CH OADM ITU CWDM specifications

<table>
<tr><th colspan="2">Characteristic</th><th colspan="4">Value or range</th></tr>
<tr><td colspan="2">Maximum total input power</td><td colspan="4">21 dBm</td></tr>
<tr><td colspan="2">Minimum return loss</td><td colspan="4">40 dB</td></tr>
<tr><td colspan="2">Center wavelengths (see Note 1)</td><td colspan="4">1471, 1491, 1511, 1531, 1551, 1571, 1591, 1611 nm</td></tr>
<tr><td colspan="2">Passband</td><td colspan="4">Center wavelength +/–6.5 nm</td></tr>
<tr><td rowspan="2">Minimum isolation</td><td>Drop</td><td colspan="4">35 dB</td></tr>
<tr><td>Thru Out</td><td colspan="4">30 dB</td></tr>
<tr><td rowspan="7">Insertion loss</td><td rowspan="2"></td><td colspan="2">OMX 1CH OADM ITU CWDM</td><td colspan="2">OMX 4CH OADM ITU CWDM</td></tr>
<tr><td>Maximum</td><td>Typical</td><td>Maximum</td><td>Typical</td></tr>
<tr><td>Add</td><td>1.2 dB</td><td>0.8 dB</td><td>2.0 dB</td><td>1.4 dB</td></tr>
<tr><td>Drop</td><td>1.2 dB</td><td>0.8 dB</td><td>2.3 dB</td><td>1.7 dB</td></tr>
<tr><td>Add and Drop (end-to-end)</td><td>2.4 dB</td><td>1.6 dB</td><td>3.6 dB</td><td>2.5 dB</td></tr>
<tr><td>Thru in - OTS Out</td><td>1.0 dB</td><td>0.5 dB</td><td>1.8 dB</td><td>1.1 dB</td></tr>
<tr><td>OTS In - Thru out</td><td>1.2 dB</td><td>0.8 dB</td><td>1.3 dB</td><td>0.8 dB</td></tr>
<tr><td rowspan="3">Physical Dimension</td><td>Height</td><td colspan="2">43 mm (1.70 in.) (1 U rack space)</td><td colspan="2">43 mm (1.70 in.) (1 U rack space)</td></tr>
<tr><td>Width (see Note 2)</td><td colspan="2">443 mm (17.44 in.)</td><td colspan="2">443 mm (17.44 in.)</td></tr>
<tr><td>Depth</td><td colspan="2">279 mm (11 in.)</td><td colspan="2">279 mm (11 in.)</td></tr>
<tr><td colspan="6">Note 1: Some Optical Metro 5100/5200 ITU CWDM hardware introduced before the ITU CWDM standard (G.695) was finalized will have labels with a center wavelength that differs by 1 nm with respect to the finalized ITU CWDM standard (G.695). For example, for the 1471 nm wavelength, the label will show 1470 nm. However, there is no wavelength incompatibility since the passbands are the same. For example, the pre-finalized ITU CWDM standard 1470 nm channel specified a range of –5.5 to +7.5 nm, that is, a passband of 1464.5 to 1477.5 nm. The finalized ITU CWDM standard 1471 nm channel specifies a range of ±6.5 nm, that is, the passband is still 1464.5 to 1477.5 nm. The only difference is one of labeling.
Note 2: The width specified is with the mounting brackets installed.</td></tr>
</table>

C&L splitter/coupler tray

C&L splitter/coupler trays split and combine C-band and L-band signals. These components are most often used for parallel site configurations, with OSC trays for intersite fault sectionalization, or in amplified networks without ECTs.

The main factors to consider about C&L splitter/coupler trays for link engineering are the losses associated with the filters.

Table 6-14 lists the typical and maximum losses for the C&L splitter/coupler tray.

Table 6-14
C&L splitter/coupler specifications

Characteristic		Value or range	
Maximum total input power		21 dBm	
Wavelength	C-band	1528.52 nm to 1562.48 nm	
	L-band	1570.17 nm to 1605.99 nm	
Minimum return loss		40 dB	
Minimum isolation	C&L Drop	38 dB	
Insertion loss		**Maximum**	**Typical**
	Splitter: C-band	1.4 dB	1.0 dB
	Splitter: L-band	1.8 dB	1.2 dB
	Coupler: C-band	1.9 dB	1.4 dB
	Coupler: L-band	1.6 dB	1.1 dB
Tap loss		approx. 1.8% of the signal power or 17.4 dB less than the signal power	

1310 nm splitter/coupler tray

1310 nm splitter/coupler trays split and combine 1310 nm signals and ITU CWDM wavelength signals. These components are used when an ITU CWDM network is overlaid onto an existing network using the 1310 nm wavelength.

The main factors to consider about 1310 nm splitter/coupler trays for link engineering are the losses associated with the filters.

Table 6-15 lists the maximum losses for the 1310 nm splitter/coupler tray.

Table 6-15
1310 nm splitter/coupler specifications

Characteristic		Value or range
Maximum total input power		21 dBm
Wavelength (1310 nm)		1260 nm to 1360 nm
Wavelength (Thru)		1460 nm to 1620 nm
Minimum return loss		40 dB
Minimum isolation	1310 nm Drop	30 dB
	Thru Out	30 dB
Maximum insertion loss	1310 nm Add	1.1 dB
	1310 nm Drop	1.1 dB
	Thru Out	1.3 dB
	Thru In	0.9 dB

DSCM specifications

Dispersion Slope Compensating Module (DSCM) are used to compensate the chromatic dispersion slope and dispersion accumulated after an optical fiber span of a given length.

The main factors to consider about DSCMs for link engineering are its losses and fiber non-linearities.

Table 6-16 lists the maximum losses for the DSCM trays.

Table 6-16
DSCM specifications

Characteristic	Value or range	
	C-band	L-band
Maximum total input power	24 dBm	24 dBm
Minimum return loss	45 dB	45 dB
Wavelength range	1528 nm to 1565 nm	1570 nm to 1605 nm
Maximum insertion loss	see Table 6-17	see Table 6-18

Table 6-17
C-band DSCM loss specifications

DSCM Description	Maximum Insertion Loss (dB)
Type 1 DSCM-10	2.6
Type 1 DSCM-20	3.2
Type 1 DSCM-30	3.8
Type 1 DSCM-40	4.4
Type 1 DSCM-50	5.0
Type 1 DSCM-60	5.7
Type 1 DSCM-70	6.3
Type 1 DSCM-80	6.9
Type 1 DSCM-90	7.5
Type 1 DSCM-100	8.1
Type 1 DSCM-110	9.8
Type 1 DSCM-120	10.4
Type 1 DSCM-130	11.2
Type 1 DSCM-140	11.8

Table 6-18
L-band DSCM loss specifications

DSCM Description	Maximum Insertion Loss (dB)
Type 1 DSCM-10	2.9
Type 1 DSCM-20	3.7
Type 1 DSCM-30	4.5
Type 1 DSCM-40	5.3
Type 1 DSCM-50	6.1
Type 1 DSCM-60	6.9
Type 1 DSCM-70	7.3
Type 1 DSCM-80	7.8
Type 1 DSCM-90	8.3
Type 1 DSCM-100	8.8
Type 1 DSCM-110	10.3

Table 6-18 (continued)
L-band DSCM loss specifications

DSCM Description	Maximum Insertion Loss (dB)
Type 1 DSCM-120	10.4
Type 1 DSCM-130	11.2
Type 1 DSCM-140	11.6

Equalization and attenuation specifications

PBEs

Per band equalizers (PBE) are used in amplified networks to equalize the power levels of bands entering an amplifier. PBEs contain filters for muliplexing and demulitiplexing aggregate signals, and variable optical attenuators (VOA) to equalize the individual bands.

If you have both C-band and L-band signals on one fiber, you must use a C/L splitter/coupler tray to separate the C-band signals from the L-band signals upstream from the PBE and to re-combine the two signals downstream from the PBE.

The main factors to consider about PBEs for link engineering are the losses associated with the multiplexers and demultiplexers.

Table 6-19 lists the typical and maximum losses for the different types of PBEs.

Table 6-19
PBE specifications

Characteristic		Value or range					
Maximum total input power		21 dBm					
Minimum return loss		40 dB					
Attenuation for each band		Up to 30 dB					
Insertion loss		C-band PBE		L-band PBE		C-band and L-band PBE	
		Max.	**Typ.**	**Max.**	**Typ.**	**Max.**	**Typ.**
	C-band	4.6 dB	3.4 dB	—	—	4.6 dB	3.4 dB
	L-band	—	—	4.6 dB	3.4 dB	4.6 dB	3.4 dB

Note: For C/L splitter/coupler losses, refer to Table 6-14 on page 6-25.

APBE circuit packs

Active Per Band Equalizer (APBE) and Active Per Band Equalizer Enhanced (eAPBE) circuit packs are used in amplified Optical Metro 5200 networks in conjunction with OFA circuit packs to provide centralized equalization that can be managed remotely using the System Manager or a TL1 interface.

Use the Optical Metro 5100/5200 Network Modeling Tool to perform link engineering for any networks that contain APBE circuit packs.

Table 6-20 lists the specifications for the APBE and eAPBE.

Table 6-20
APBE circuit packs specifications

Characteristic		Value or Range			
		APBE		**APBE Enhanced**	
Maximum total input power		17 dBm		18 dBm	
Minimum return loss		35 dB		35 dB	
Attenuation for each band		0.0 dB to 28.0 dB		0.0 dB to 30.0 dB	
Insertion loss		**Maximum**	**Typical**	**Maximum**	**Typical**
	C-band	6.9 dB	5.7 dB	4.6 dB	dB
	L-band	6.9 dB	5.9 dB	4.6 dB	dB

Discrete VOAs

Discrete VOAs attenuate aggregate C-band or L-band signals, and offer flexible attenuation options for amplified networks. Table 6-21 lists the technical specifications for the discrete VOA.

Table 6-21
Discrete VOA specifications

Characteristic	Value or Range	
Attenuation	0 dB to 35 dB	
Insertion loss (with VOA set to minimum attenuation)	**Maximum**	**Typical**
	2.0 dB	1.6 dB

ECTs

Equalizer coupler trays provide an alternative packaging arrangement from the PBEs. ECTs are used in conjunction with OFA circuit packs. They perform the following functions:

- split the incoming optical signal into the C-band and the L-band

- control the power level going into the OFA. The ECT types containing per-band equalizers (PBEs) can independently control the power of each individual band, whereas the C-band and L-band splitter/coupler with variable optical attenuators (VOAs) can only adjust the aggregate power in the C-band and L-band.
- recombine the C-band and L-band signals into one optical output. There is an optical tap monitor on this combined signal. The optical tap monitor can be used to measure either the total power (by connecting an optical power meter) or the power level of each channel (by connecting an optical spectrum analyzer). The optical tap is approximately 1.8%, for example, if the power out of the ECT is 10mW, the monitored power would be 0.18mW.

There are four types of ECTs. Table 6-22 lists the features of each type of ECT.

Table 6-22
Types of ECT

Description	Number of VOAs	Number of PBEs	Equalized wavelength range (nm)	Use
C-band equalizer with coupler/splitter (NT0H31AA)	4	1	1528.77 to 1562.23	• splits/couples C-band and L-band signals • attenuates and equalizes individual bands in C-band spectrum
L-band equalizer with coupler/splitter (NT0H31AB)	4	1	1570.42 to 1605.73	• splits/couples C-band and L-band signals • attenuates and equalizes individual bands in L-band spectrum
C-band and L-band equalizer with coupler/splitter (NT0H31AC)	8	2	1528.77 to 1562.23 1570.42 to 1605.73	• splits/couples C-band and L-band signals • attenuates and equalizes individual bands in C-band and L-band spectrum
C-band and L-band coupler/splitter with VOAs (NT0H31AD)	2	0	none	• splits/couples C-band and L-band signals • attenuates aggregate signal for all bands in C-band and L-band spectrum • no equalization

When considering ECTs for link engineering, you must consider both the loss and function. Table 6-23 lists the ECT losses by type.

Table 6-23
ECT specifications

Characteristic		Value or range							
Maximum total input power		21 dBm							
Attenuation		Up to 35 dB							
Minimum Return Loss		40 dB							
Optical Tap		Approximately 1.8% of the signal power or 17.4 dB less than the signal power							
Insertion loss		C-band equalizer with splitter/coupler		L-band equalizer with splitter/coupler		C-band and L-band equalizer with splitter/coupler		C-band and L-band splitter/coupler with VOA	
		Max.	**Typ.**	**Max.**	**Typ.**	**Max.**	**Typ.**	**Max.**	**Typ.**
	Splitter and demultiplexer: C-band	4.6 dB	3.4 dB	2.2 dB	1.7 dB	6.5 dB	4.9 dB	3.5 dB	2.2 dB
	Splitter and demultiplexer: L-band	2.2 dB	1.7 dB	4.6 dB	3.4 dB	4.6 dB	3.4 dB	3.9 dB	2.4 dB
	Coupler and multiplexer: C-band	1.9 dB	1.4 dB	1.9 dB	1.4 dB	1.9 dB	1.4 dB	1.9 dB	1.4 dB
	Coupler and multiplexer: L-band	1.6 dB	1.1 dB	1.6 dB	1.1 dB	1.6 dB	1.1 dB	1.6 dB	1.1 dB

Optical supervisory channel specifications

The optical supervisory channel (OSC) is outside of the Optical Metro 5100/5200 traffic-carrying wavelength spectrum and is used for network monitoring and communication. The OSC tray uses drop filters to split the OSC from the rest of the network traffic and add filters to recombine the OSC with the rest of the traffic after being monitored by the OSC circuit packs.

Because the OSC (1510 nm) is outside of the traffic-carrying spectrum and cannot pass through OFAs, ECTs or OMXs, the OSC signal must be added last before leaving a site and must be dropped first when entering the next site. For a four-fiber system, two OSC trays are required, one for east traffic and one for west traffic. OSC trays can be installed in OADM, terminal, and OFA sites.

For traffic-carrying signals, link engineering must account for the loss experienced as the signals pass through the OSC add and drop filters. You must ensure that the OSC has sufficient power to span a link. If the OSC does not have sufficient power to span a link, you cannot use the OSC in that link. For more information, see “Rule 16: OSC link engineering” in the chapter “Link engineering rules” in this book.

Both the OSC add section and the OSC drop section contain an add/drop filter (ADF). The ADF drops the OSC-specific wavelength (1510 nm) while allowing other traffic-carrying wavelengths to pass through the filter. For fixed value link engineering, you must account for the pass-through losses from the ADFs.

For the OSC tray with tap, each tray has a tap. The tap monitors the incoming channels for power level and wavelengths. For the OSC tray with dual tap, each tray has two taps. One tap monitors the incoming channels for power level and wavelengths and the other tap monitors the outgoing channels for power level and wavelengths.

Table 6-24 lists the pass-through losses for 1528 nm to 1620 nm signals associated with the OSC.

> ***Note:*** The OSC cannot be used in ITU CWDM networks since the OSC 1510 nm wavelength aligns with one of the ITU CWDM wavelengths.

Table 6-24
OSC tray specifications

Characteristic		**Value or range**					
Maximum total input power		21 dBm					
Wavelength (Thru)		1528 nm to 1615 nm					
Wavelength (OSC)		1500 nm to 1520 nm					
		OSC tray without tap		**OSC tray with tap**		**OSC tray with dual taps**	
Minimum isolation	OSC Drop	25 dB		25 dB		30 dB	
	Thru In	12 dB		12 dB		15 dB	
	Thru Out	12 dB		12 dB		30 dB	
		Maximum	**Typical**	**Maximum**	**Typical**	**Maximum**	**Typical**
Insertion loss	OSC Drop	1.6 dB	1.4 dB	1.6 dB	1.4 dB	1.7 dB	1.4 dB
	OSC Add	1.6 dB	1.4 dB	1.6 dB	1.4 dB	1.7 dB	1.3 dB
	Thru Out	1.2 dB	1.0 dB	1.8 dB	1.6 dB	1.9 dB	1.5 dB
	Thru In	1.2 dB	1.0 dB	1.2 dB	1.0 dB	1.5 dB	1.1 dB
						Minimum	**Maximum**
Tap loss	OTS IN port	Not applicable		Not applicable		13.6 dB	15.6 dB
	OTS OUT port	Not applicable		Not applicable		16.2 dB	19.0 dB
	THRU OUT port	Not applicable		approx. 4% of the signal power or 14.0 dB less than the signal power of the THRU OUT port		Not applicable	

Optical trunk switch specifications

The Optical Trunk Switch (OTS) is a standalone component that provides optical path protection for point-to-point unamplified configurations.

When the switch is installed at each site in a point-to-point system, it protects traffic or data from physical damage to fiber-optic cables by switching bidirectionally to a redundant optical fiber path.

The main factors to consider about the OTS for link engineering are the power losses associated with the OTS. Both the working and the protection paths must be considered when performing link engineering calculations since the distances and losses are likely to be different for both paths.

Table 6-25 lists the specifications for the OTS.

Table 6-25
Optical Trunk Switch specifications

Characteristic		**Value or range**		
		Minimum	**Maximum**	**Typical**
Pilot tone laser launch power (at 1550 nm)		–3.5 dBm	–0.5 dBm	—
Operating optical power range (all optical ports)		–30 dBm	24 dBm	—
		Value or range		
Wavelength		1260 nm to 1360 nm and 1460 nm to 1620 nm		
Minimum return loss		40 dB		
Maximum Insertion loss	End-to-End 1528 nm to 1607 nm	4.0 dB		
	End to End 1260 nm to 1360 nm and 1460 nm to 1620 nm	5.0 dB		

Enhanced trunk switch specifications

The Enhanced Trunk Switch (ETS) is a standalone component that provides line-side fiber protection for multi-channel links on single-mode fiber. The ETS is supported in unamplified point-to-point configurations like the Optical Trunk Switch (OTS), and in amplified point-to-point configurations that contain a single pre-amplifier in the link. Table 6-26 lists the specifications for the ETS.

Table 6-26
Enhanced Trunk Switch specifications

Characteristic		**Value or range**		
Fiber type		Single mode fiber		
Wavelength		1260 nm to 1360 nm and 1460 nm to 1630 nm		
Minimum return loss	Switch section	40 dB		
	Coupler section	40 dB		
Maximum Insertion loss	Switch section	2.1 dB		
	Coupler section	4.3 dB		
	End-to-End	6.4 dB		
		Minimum	**Maximum**	**Typical**
Absolute Switching Mode (see Note 1 and Note 2)	Absolute switching limit threshold (ASLTH) (see Note 3)	–35.0 dBm	–35.0 dBm	—
	Absolute switching limit threshold (ASLTH) accuracy	—	± 2.0 dB	—
	Received power level (operating)	—	19 dBm	—
	Received power level (without damage)	—	19 dBm	—

Table 6-26 (continued)
Enhanced Trunk Switch specifications

Characteristic		Value or range		
Window Switching Mode (see Note 1 and Note 2)	Reference power level (RPL) Default: –29.0 dBm	–29.0 dBm	–6.0 dBm	—
	RPL accuracy	—	±2.0 dB	—
	Upper window switching range (UWSR) (see Note 4) Default: 6.0 dBm	6.0 dB	29.0 dB	—
	Lower window switching range (LWSR) (see Note 4) Default: 6.0 dBm	6.0 dB	29.0 dB	—
	Upper window switching limit threshold (UWSLTH) UWSLTH = RPL + UWSR	—	0.0 dBm	—
	Lower window switching limit threshold (LWSLTH) LWSLTH = RPL – LWSR	–35.0 dBm	—	—
	Received power level (operating) (see Note 5)	—	–6.0 dBm	—
	Received power level (without damage)	—	19 dBm	—
Received power monitor accuracy		± 2.0 dB (Received power range –35.0 dBm to 0.0 dBm)		

Note 1: See *Hardware Description,* 323-1701-102 for detailed information about this mode of operation.

Note 2: All dBm power levels referenced are aggregate power levels.

Note 3: This value cannot be provisioned.

Note 4: This range can be provisioned in 1 dB increments.

Note 5: The value of the captured RPL at the moment the link is setup should not exceed –6 dBm.

Link engineering rules

In this chapter

Fixed value and statistical link engineering methods

There are two methods of performing link engineering:

- fixed value
- statistical (using the Optical Metro 5100/5200 Network Modeling Tool)

Fixed value method

The fixed value method uses fixed values for component specifications and does not require specialized tools. It is considered less accurate than the statistical method. Chapter "Basic fixed value link engineering" in this book describes how to perform fixed value link engineering. The rules in this chapter and the component values in the chapter "Link engineering components" in this book are used when performing basic fixed value link engineering.

This method can be used for the following network types:

- unamplified DWDM or CWDM networks using OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs
- all ITU CWDM networks
- amplified Enhanced Trunk Switch networks
- networks that use the OMX 16CH DWDM

Statistical method

The statistical method can be performed using the Optical Metro 5100/5200 Network Modeling Tool. The advantage of the statistical method is that it takes into account potential variations in channel power within bands, and more accurately represents component parameters.

The statistical method uses the mean and standard deviation values for the component parameters. The power per channel is tracked through the link using the mean transmit power and the mean component losses and using the "root sum of squares" approach to combine the standard deviations. The NMT uses the worst case receive power, which is calculated (mean – 3 x standard deviation).

Penalties such as OSNR and crosstalk are calculated based on the appropriate derated powers according to the link engineering rules described in this chapter. The required received power is compared to the actual worst case received power to validate the link design for each channel and band.

The Network Modeling Tool uses the statistical distribution of all component parameters. This information is proprietary and therefore cannot be published. Although it is possible to perform fixed value link engineering for unamplified networks using OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs, it is recommended that you use the Network Modeling Tool to validate all network designs. You must use the Network Modeling Tool to perform link engineering for all amplified networks, and for CWDM and DWDM networks using OCLD 2.5 Gbit/s Flex, OCLD 2.5 Gbit/s Universal, OTR 2.5 Gbit/s Flex, OTR 2.5 Gbit/s Universal, OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT circuit packs. NMT cannot be used for the following network types:

- ITU CWDM networks, amplified Enhanced Trunk Switch networks and networks that use the OMX 16CH DWDM. For these network types, use the fixed value method. See Chapter 8, "Basic fixed value link engineering".
- Extended Metro networks. For these network types, contact Nortel Networks for custom link engineering.
- Alternate fiber type networks (that is, networks that do not use NDSF). For these network types, contact Nortel Networks for custom link engineering.
- Common Photonic Layer networks. For these network types, use the Common Photonic Layer Optical Modeler tool.

The Network Modeling Tool has undergone rigorous product verification which demonstrates that the link engineering algorithms have been correctly implemented. The algorithms have also been successfully tested on physical links built in a laboratory environment. Nortel Networks expects that 99% of links that are successfully modeled using the tool will have sufficiently high Rx powers to ensure functional links when deployed in the field.

Link engineering Release 7.0 networks

Table 7-1 lists the link engineering methods to use if the system is using a Release 7.0 introduced hardware.

Table 7-1
Link engineering method for Release 7.0 introduced hardware

Release 7.0 Hardware	Link engineering method
100 GHz DWDM circuit packs	Use Common Photonic Layer Optical Modeler.
OMX 16CH DWDM	Either: Use fixed value link engineering, refer to "Performing fixed value link engineering for DWDM networks using OMX 16CH" on page 8-16. or: Use the NMT, refer to "Modeling the 16CH OMX DWDM in the NMT" on page 7-3.
OMX OADM ITU CWDM	Use fixed value link engineering, refer to "Performing fixed value link engineering for ITU CWDM networks" on page 8-26.
Enhanced Trunk Switch	**Unamplified networks:** Either: • Use the NMT, refer to "Modeling the Enhanced Trunk Switch in the NMT" on page 7-4. or: • Use fixed value link engineering, refer to "Performing fixed value link engineering for DWDM networks using OMX 16CH" on page 8-16 for DWDM networks without amplification, using OMX 16CH or • Use fixed value link engineering, refer to "Performing fixed value link engineering for ITU CWDM networks" on page 8-26 for ITU CWDM networks **Amplified networks:** Use fixed value link engineering, refer to "Performing fixed value link engineering for Enhanced Trunk Switch amplified networks" on page 8-33.
DSCM	Contact Nortel Networks for custom link engineering and to obtain a Nortel Networks Custom Equalization Report for your Extended Metro system

Modeling the 16CH OMX DWDM in the NMT

- Use NMT Release 8.0.
- In NMT, use the OMX 4CH DWDM Enhanced + Fiber Manager instead of the 16CH OMX DWDM.
- Supported circuit packs:

- — 2.5 Gbit/s Flex OCLD/OTR
- — 2.5 Gbit/s Universal OCLD/OTR
- — OTR 10 Gbit/s Enhanced
- — Muxponder

- Unsupported circuit packs:
  - — 1.25 Gbit/s OCLD
  - — 2.5 Gbit/s Fixed OCLD
  - — OTR 10 Gbit/s
- Operational considerations:
  - — Optical pass-through is not supported.
  - — Amplification is not supported
  - — Only the OMX 4CH + Fiber Manager DWDM and the OMX 4CH DWDM Enhanced + Fiber Manager are supported at remote OADM sites.
  - — OMX Standard DWDM is not supported.
  - — SLEC and Extended Metro are not supported.
  - — The resulting NMT design may be more conservative.
  - — NMT wiring diagrams and equipment list outputs must be adjusted because they reflect the OMX 4CH DWDM Enhanced + Fiber Manager instead of the OMX 16CH DWDM.

Modeling the Enhanced Trunk Switch in the NMT

- Use NMT Release 8.0.
- In NMT, use the Optical Trunk Switch instead of the Enhanced Trunk Switch.
- Increase the Inter-site Span Margin by 2.4 dB, for both the primary and standby paths, to account for the increased insertion loss of the ETS.
- Manually adjust the NMT-produced equipment list by replacing the Optical Trunk Switch by the Enhanced Trunk Switch.
- Supported circuit packs:
  - — 2.5 Gbit/s Flex OCLD/OTR
  - — 2.5 Gbit/s Universal OCLD/OTR
  - — OTR 10 Gbit/s Enhanced
  - — Muxponder
- Unsupported circuit packs:
  - — 1.25 Gbit/s OCLD
  - — 2.5 Gbit/s Fixed OCLD

- — OTR 10 Gbit/s
- Operational considerations:
  - — Only NDSF fiber is supported.
  - — Regeneration of bridging not allowed for bands using ETS for line-side protection.
  - — Only the OMX 4CH + Fiber Manager DWDM and the OMX 4CH DWDM Enhanced + Fiber Manager are supported at remote OADM sites.
  - — OMX Standard DWDM is not supported.
  - — Channel meshing is not supported.
  - — Band switching is supported on ETS only.
  - — SLEC and Automatic Link Engineering are not supported.

Extended Metro DWDM

Extended Metro DWDM is an Optical Metro 5200 system solution that enables system reach up to 600 km without the need for regeneration. Eliminating the need for regeneration can result in significant network cost savings. By applying a new set of engineering rules, it is possible to extend the reach of Optical Metro 5200 systems beyond typical metro distances.

New link engineering rules are required to manage non-linear effects. For example, the launch power into the fiber is reduced, all traffic carrying wavelengths must be a minimum of 1 Gbit/s, and per-band power control is required at specific points along the link to manage tilt in the channel powers caused by Stimulated Raman Scattering (SRS).

In release 8.0, the ability to use DSCMs enables system reaches of up to 600 km without the need for regeneration. Note that DSCMs are only supported on NDSF. Only the following line-side circuit packs can be used in these extended metro links:

- OCLD 2.5 Gbit/s Universal
- OTR 2.5 Gbit/s Universal 1310 nm
- OTR 2.5 Gbit/s Universal 850 nm
- OTR 10 Gbit/s Enhanced
- Muxponder 10 Gbit/s GbE/FC
- Muxponder 10 Gbit/s GbE/FC VCAT

Link engineering for specific applications is a custom exercise performed by Nortel Networks. All Extended Metro DWDM system deployments require a Nortel Networks Custom Equalization Report. A sample Nortel Networks Custom Equalization Report is included in “Appendix B—Custom link engineering design output”.

Link engineering of Extended Metro DWDM systems is not supported in NMT nor is it supported using manual calculations. Contact Nortel Networks for custom link engineering and to obtain a Nortel Networks Custom Equalization Report for your Extended Metro system.

ATTENTION

To avoid potential service interruption, indicate your initial capacity and the targeted fulfill capacity when you contact Nortel Networks for custom link engineering. The design must take into account total losses from all OMXs (those currently installed and those you plan to install) in order to derive the correct padding for your initial channels.

The Nortel Networks link engineering team provides:

- an outline schematic of the design indicating the position of amplifiers and regenerators
- the location and size of the DSCMs required
- an equipment list for each site (line equipment only)
- site fibering diagrams showing the connections for each site
- equalization report showing all necessary optical power information for provisioning

Function of Equalizers in Extended Metro DWDM solutions

Extended Metro DWDM solutions require power equalization preceding every amplifier following add/drop. This is different from a standard system (that is, a non-Extended Metro DWDM system). In a non-Extended Metro DWDM system, you can be free to use equalization only when required provided that you can absorb the OSNR hit. You can also use a fixed pad approach in the add path of the OMX (distributed equalization) to accomplish the equalization function. This approach is not supported in Extended Metro applications.

Extended Metro DWDM applications also make use of equalizers on the line to manage SRS tilt. The placement of an equalizer to manage SRS tilt is application specific. An equalizer is required approximately every third amplifier on the line (whether traffic is added and dropped or not).

Alternate Fiber Types

ATTENTION
Link engineering of Optical Metro 5100/5200 systems on fiber types other than NDSF is not supported in NMT, nor is it supported through manual calculation. Contact Nortel Networks if your Optical Metro 5100/5200 application is on a fiber type other than NDSF or if it is on a mix of fiber types.

Optical Metro 5100/5200 has been characterized to date with the commercially available fiber types listed in Table 7-2.

Table 7-2
Commercially available fiber types characterized with Optical Metro 5100/5200

Type	Trademark	Manufacturer
NDSF (see Note 1)	SMF-28	Corning
	AllWave	Lucent/Optical Fiber Solutions (OFS)
DSF (see Note 2)	λ_0 1535 nm to 1565 nm	
	SMF-DS	Corning
NZ-DSF (see Note 3)	Truewave RS	Lucent/Optical Fiber Solutions (OFS)
	LEAF	Corning
	E-LEAF	Corning

Note 1: Optical Metro 5100/5200 is supported on any G.652 compliant fiber.

Note 2: Optical Metro 5100/5200 is supported on G.653 compliant fiber with λ_0 in the 1535 nm to 1565 nm range. This range is more restrictive than the G.653 standard range.

Note 3: E-LEAF is a Nortel Networks designation for reduced dispersion slope LEAF.

Additional design considerations apply to Optical Metro 5100/5200 networks on fiber types other than NDSF. Due to nonlinear effects, the performance of a given channel depends on the characteristics of all the other channels. Four-wave mixing (FWM), stimulated Raman scattering (SRS), and cross-phase modulation (XPM) can impact the performance of Optical Metro 5100/5200 on fiber types other than NDSF.

In FWM, the WDM signals interact to produce new signals called mixing products. The mixing products can interfere with a WDM channel, causing an Rx sensitivity penalty. FWM is enhanced when there is low chromatic dispersion.

In SRS, lower wavelength channels transfer power to higher wavelength channels. SRS causes crosstalk between channels, since the power gain by a bit in one channel depends on the bits that are transmitted in all the other channels. Like FWM, SRS crosstalk is enhanced on low dispersion fibers.

In XPM, the phase of one channel is modulated by power variations in all the other channels. Chromatic dispersion converts the phase modulation to amplitude modulation, resulting in an Rx sensitivity penalty. XPM can be enhanced on optical spans that have a mixture of different fiber types.

Depending on the application, “Extended Metro” distances may be supported on fiber types other than NDSF (with no DSCMs and non-Extended Metro circuit packs) due to the better dispersion characteristics of the other fiber types. However, these links are limited more by OSNR than by dispersion due to non-linearities.

There are wavelength restrictions when using alternate fiber types. Table 7-3 lists the wavelength restrictions for unamplified networks on fiber types other than NDSF.

> ***Note:*** Amplified networks have the same or greater restrictions, depending on the specific application. Contact Nortel Networks for more information.

Table 7-3
Alternate fiber type supported wavelengths, unamplified networks

System Type	Fiber type	Circuit pack type	Supported wavelengths
DWDM	TWRS LEAF (E-LEAF)	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex OTR 10 Gbit/s Enhanced Muxponder 10 Gbit/s GbE/FC	All 32 channels
	DSF	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex OTR 10 Gbit/s Enhanced Muxponder 10 Gbit/s GbE/FC	All 16 channels in the L-band
CWDM	TWRS LEAF (E-LEAF)	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex OTR 10 Gbit/s Enhanced Muxponder 10 Gbit/s GbE/FC	All 8 bands
	DSF	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex OTR 10 Gbit/s Enhanced Muxponder 10 Gbit/s GbE/FC	Bands 5 to 8
ITU CWDM (see Note)	TWRS LEAF (E-LEAF) DSF	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex OTR 10 Gbit/s Enhanced Muxponder 10 Gbit/s GbE/FC	1531 nm 1551 nm 1571 nm 1591 nm 1611 nm

Note: Some Optical Metro 5100/5200 ITU CWDM hardware introduced before the ITU CWDM standard (G.695) was finalized will have labels with a center wavelength that differs by 1 nm with respect to the finalized ITU CWDM standard (G.695). For example, for the 1471 nm wavelength, the label will show 1470 nm. However, there is no wavelength incompatibility since the passbands are the same. For example, the pre-finalized ITU CWDM standard 1470 nm channel specified a range of –5.5 to +7.5 nm, that is, a passband of 1464.5 to 1477.5 nm. The finalized ITU CWDM standard 1471 nm channel specifies a range of +/-6.5 nm, that is, the passband is still 1464.5 to 1477.5 nm. The only difference is one of labeling.

Link engineering rules

Following is a summary of the basic rules that govern link engineering for Optical Metro 5100/5200 networks.

These rules are not applicable for Extended Metro DWDM or Alternate Fiber Type solutions.

> **ATTENTION**
> You must use all of the following rules together to implement a successful network. No rule supersedes any other rule.

Rule 1: Adherence to network engineering rules

In addition to following all of the applicable link engineering rules in this chapter, you must adhere to all network engineering rules as described in the chapter "Supported configurations" in this book.

Rule 2: OCLD, OTR or Muxponder power level

Power levels presented at the receive port of an OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit pack must be greater than the Rx power low degrade, and less than the Rx power high clear, of the OCLD circuit pack power threshold values for performance monitoring (see Table 6-2 on page 6-4). The OCLD Rx power low degrade value should first be derated for all applicable penalties. Applicable penalties may include chromatic dispersion penalty, jitter penalty, OSNR penalty, and span margin.

Power levels presented at the receive port of an OCLD 2.5 Gbit/s Flex or OCLD 2.5 Gbit/s Universal or OTR 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Universal circuit pack must be greater than the minimum Rx sensitivity value (–27.5 dBm), and less than the Rx overload value (–8 dBm). The minimum Rx sensitivity value should first be derated for all applicable penalties. Applicable penalties may include chromatic dispersion penalty, jitter penalty, OSNR penalty, and span margin. For information about calculating the total combined penalties, see Rule 21: Combining penalties for OCLD 2.5 Gbit/s Flex, OCLD 2.5 Gbit/s Universal, OTR 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Universal on page 7-42.

Power levels presented at the receive port of an OTR 10 Gbit/s circuit pack must be greater than the Rx power low degrade, and less than the Rx power high clear, of the OTR 10 Gbit/s circuit pack power threshold values for performance monitoring (see Table 6-4 on page 6-9). The OTR Rx power low degrade value should first be derated for chromatic dispersion penalty, jitter penalty, polarization mode dispersion penalty (PMD), optical signal to noise ratio (OSNR) penalty, cross-talk penalty, and span margin. For information about calculating the total combined penalties, see Rule 19: Combining penalties for the OTR 10 Gbit/s on page 7-40.

Power levels presented at the receive port of an OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit pack must be greater than the minimum Rx sensitivity value (–25.0 dBm), and less than the Rx overload value (–5 dBm). The minimum Rx sensitivity value should first be derated for chromatic dispersion penalty, jitter penalty, OSNR penalty, PMD penalty, cross-talk penalty and span margin. For information about calculating the total combined penalties, see Rule 20: Combining penalties for the OTR 10 Gbit/s Enhanced, Muxponder circuit packs on page 7-41.

Rule 3: OMX pass-through losses

Rule 3 applies only to OMXs that have pass-through ports. That is, 4CH DWDM OMXs, CWDM OMXs and OADM ITU CWDM OMXs.

The pass-through losses of the optical multiplexers (OMX) depend on the OMX fibering method used. For DWDM OMXs at the source or destination sites or in multishelf sites, the loss is 1.2 dB (maximum) or 0.7 dB (typical) on each shelf through which a signal passes (where each shelf counted comprises a single add or drop filter).

At sites with single-shelf fibering with DWDM OMXs (Standard) that are not source or destination sites, the pass-through loss is 2.1 dB (maximum) or 1.2 dB (typical) for the entire shelf (where the shelf includes both a drop filter and an add filter).

For CWDM OMX pass-through loss specifications, refer to Table 6-10 and Table 6-11. For OADM ITU CWDM OMX pass-through loss specifications, refer to Table 6-13.

Rule 4: Amplifier band restrictions

C-band channels cannot be presented at the input of an L-band OFA.

L-band channels cannot be presented at the input of a C-band OFA.

Rule 5: Amplifier receive power

The total aggregate power into an OFA must be within the limits listed in Table 7-4.

Table 7-4
Aggregate powers into OFAs

Amplifier type	Input power must be not less than	Input power must be not more than
Standard	–28 dBm (aggregate)	–11 dBm (aggregate)
High input power	–28 dBm (aggregate)	–7 dBm (aggregate) (see Note1)
	–28 dBm (per channel)	–20 dBm (per channel)

Table 7-4
Aggregate powers into OFAs

Amplifier type		Input power must be not less than	Input power must be not more than
Variable gain (See Note2)	7 dB gain	–18 dBm (see Note4)	+8 dBm
	17 dB gain	–28 dBm	–2 dBm (see Note3)

Note 1: Although the HIP amplifier can accept a maximum input power of –7.0 dBm, it is recommended that you engineer to a maximum input power of –8 dBm, as implemented in the Network Modeling Tool. The –8.0 dBm value includes a 1.0 dB buffer for increased network reliability.

Note 2: In most cases, traffic continuity at maximum and minimum input power is determined by the Receive Power High Fail Threshold and Receive Power Low Fail Threshold.

Note 3: At High Input Power, the gain has to be reduced to prevent saturation. For each dB of input power past -2dBm, the gain will decrease by one dB to prevent saturation.

Note 4: At lower gain setting, the minimum Rx input power has to increase in order to prevent Loss Of Signal. For each dB of gain reduction, the maximum input power has to be increased by one dB.

The power per channel needs to be considered in conjunction with the OSNR rule.

Rule 6: Cascaded amplifiers

You must use the Network Modeling Tool to verify all amplified network designs.

A maximum of five OFAs or ten VGA OFAs can be cascaded providing that the OSNR requirements stated in Rule 7 are met and that the maximum input power limits are not exceeded. This rule applies to all bit rates.

Rule 7: Amplified spans

You must use the Network Modeling Tool to verify all amplified network designs.

The number of amplified spans is limited to:

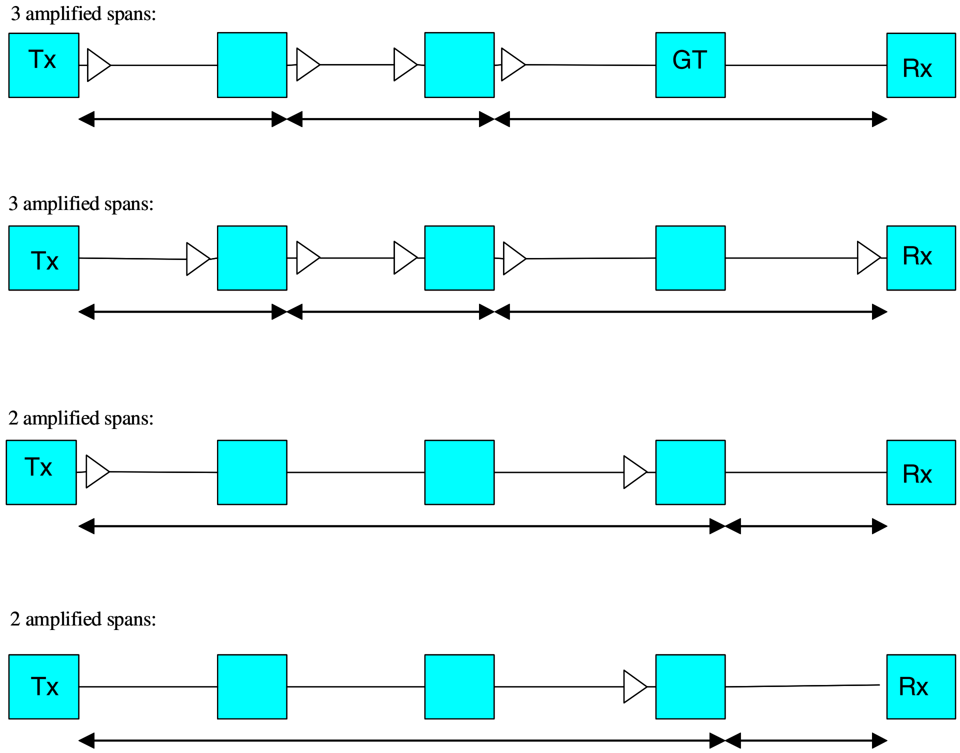
- 6 in the case where the launch power is limited to a maximum of +3 dBm per channel on each span of the network
- 8 if the launch power is limited to a maximum of +1 dBm per channel on all spans

You need to consider a Tx-to-Rx optical span in a specific band (C-band or L-band) for amplified fiber spans calculation. Figure 7-1 shows an example of cascaded amplified spans. In this example, to illustrate the calculation of amplifier fiber spans in the clockwise direction, we need to consider a Tx-to-Rx optical span in the C-band.

Count the number of C-band amplifiers, in the optical span and:

- Subtract 1 for every site that has two C-band amps
- subtract 1 if there is a pre-amp at the Rx site of the optical span
- add 1 if there is not a post-amp at the Tx site of the optical span.

Figure 7-1
Cascaded amplified spans



For all optical spans:

- Start from the Tx on the optical span
- count the total number of amplifiers in that amplifier band (C-band, L-band) on the optical span. Stop at the Rx on the optical span
- subtract 1 for every site that has two amplifiers in that amplifier band
- subtract 1 if there is a pre-amp at the Rx site of the optical span
- add 1 if there is not a post-amp at the Tx site of the optical span.

Rule 8: OSNR

Use the following equation to calculate OSNR.

$$OSNR\,(out) = -10\log(10^{\frac{-OSNR\,(in)}{10}} + \frac{10^{\frac{F}{10}} \times 1.58e-6}{10^{\frac{P_{in}}{10}}})$$

where:

- OSNR(in) is the input OSNR to the amplifier. In the case of the first amplifier in a series, use 60 dB as the input OSNR.
- F (noise figure) is 5.5 dB for Standard C-band amplifiers, 6 dB for Standard L-band amplifiers, 5.3 dB for HIP C-band and L-band amplifiers, and 6.3 dB for VGA C-band and L-band amplifiers
- Pin is the minimum channel input power into the amplifier

For OCLD 2.5 Gbit/s circuit packs, you must ensure that the OSNR at the receiver is greater than 24 dB to maintain signal integrity.

For OCLD 1.25 Gbit/s circuit packs, you must ensure that the OSNR is greater than 21.9 dB. If the OSNR is between 21.9 dB and 24 dB, you must account for OSNR by applying a penalty against the OCLD receiver sensitivity. See Table 7-5 on page 7-15 for the OSNR penalties for OCLD 1.25 Gbit/s circuit packs.

For OCLD 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Flex circuit packs, you must ensure that the OSNR is greater than 22 dB. If the OSNR is between 22 dB and 35 dB, you must account for OSNR by applying a penalty against the Rx sensitivity. See Table 7-6 on page 7-15 for the OSNR penalties for OCLD 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Flex circuit packs.

For OCLD 2.5 Gbit/s Universal or OTR 2.5 Gbit/s Universal circuit packs, you must ensure that the OSNR is greater than 21 dB. If the OSNR is between 21 dB and 35 dB, you must account for OSNR by applying a penalty against the Rx sensitivity. See Table 7-6 on page 7-15 for the OSNR penalties for OCLD 2.5 Gbit/s Universal or OTR 2.5 Gbit/s Universal circuit packs.

For OTR 10 Gbit/s circuit packs, you must ensure that the OSNR is greater than 20.5 dB. If the OSNR is between 20.5 dB and 35 dB, you must account for OSNR by applying a penalty against the OTR receiver sensitivity. See Table 7-7 on page 7-17 for the OSNR penalties for OTR 10 Gbit/s circuit packs.

For OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs, you must ensure that the OSNR is greater than 22 dB. If the OSNR is between 22 dB and 35 dB, you must account for OSNR by applying a penalty against the receiver sensitivity. See Table 7-7 on page 7-17 for the OSNR penalties for the OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs.

Table 7-5 lists the OSNR penalty to be applied against OCLD 1.25 Gbit/s circuit pack Rx sensitivity values, depending on the OSNR present. To maintain signal integrity, the OSNR at the OCLD receiver must be greater than 21.9 dB.

Table 7-5
OSNR penalties for 1.25 Gbit/s bit rate OCLDs

If the OSNR (measured in 0.1 nm) is	Penalty
greater than or equal to 24 dB	0.0 dB
greater than or equal to 21.9 dB, but less than 24 dB	2.0 dB

Table 7-6 lists the OSNR penalties to be applied against 2.5 Gbit/s flex bit rate OCLD and OTR, and 2.5 Gbit/s OCLD and OTR Universal circuit pack Rx sensitivity values, depending on the OSNR present. To maintain signal integrity, the OSNR at the OCLD or OTR receiver must be greater than 22 dB for flex circuit packs and 21 dB for Universal circuit packs.

Table 7-6
OSNR penalties for 2.5 Gbit/s OCLDs and OTRs

OSNR (dB) (measured in 0.1 nm)	Penalty (dB)	
	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex	OCLD 2.5 Gbit/s Universal OTR 2.5 Gbit/s Universal
35	0.00	0.00
32	0.20	0.20
30	0.60	0.60
28	0.95	0.95
27	1.10	1.10
26	1.40	1.40
25	1.70	1.70
24	2.00	2.00

Table 7-6 (continued)
OSNR penalties for 2.5 Gbit/s OCLDs and OTRs

OSNR (dB) (measured in 0.1 nm)	Penalty (dB)	
	OCLD 2.5 Gbit/s Flex OTR 2.5 Gbit/s Flex	OCLD 2.5 Gbit/s Universal OTR 2.5 Gbit/s Universal
23	2.60	2.60
22	3.20	3.20
21	not supported	3.20

Table 7-7 lists the OSNR penalties to be applied against OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced, or Muxponder 10 Gbit/s GbE/FC circuit pack Rx sensitivity values, depending on the OSNR present. To maintain signal integrity, the OSNR at the receiver must be greater than:

- 20.5 dB for an OTR 10 Gbit/s
- 22.0 dB for an OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s Gb/FC, or Muxponder 10 Gbit/s GbE/FC VCAT

Table 7-7
OSNR penalties for 10 Gbit/s OTRs and Muxponder

OSNR (dB) (measured in 0.1 nm)	Penalty (dB)	
	OTR 10 Gbit/s	OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT
35	0.00	0.00
30	0.20	0.18
29	0.26	0.21
28	0.33	0.25
27	0.42	0.28
26	0.53	0.32
25	0.68	0.35
24	0.88	0.53
23	1.17	0.72
22	1.56	0.90
21	2.12	not supported
20.5	2.50	not supported

To accurately assess the impact of OSNR on the integrity of a network, you must consider the variations of the power levels between the channels within a band. These variations are due to the accumulation of minor loss differences at each individual optical component along the path between the transmitter and the amplifier's input. In a typical amplified network, this accumulation becomes significant enough to affect the relative power levels of the individual channels, resulting in different OSNR values for each channel.

The Network Modeling Tool addresses this issue by incorporating statistical modeling to accurately predict the input power level of each channel. This provides an increased level of confidence that the network design can be deployed with a high degree of integrity for all channels.

Nortel Networks requires that the Network Modeling Tool be used to validate all amplified network designs.

To accommodate preliminary network design assessments using manual calculations, Table 7-8 and Table 7-9 on page 7-19 are provided as a guideline only for calculating the input power requirements into the Standard amplifiers. They detail the minimum per channel input power required in to each amplifier in a chain in order to maintain an OSNR of 24 dB and 21.9 dB respectively.

Table 7-8 provides the minimum input power for Standard OFAs for 24 dB OSNR (for OCLD 2.5 Gbit/s). Table 7-9 provides the minimum input power for Standard OFAs for 21.9 dB OSNR (for OCLD 1.25 Gbit/s). These numbers assume that all the channels in a band are the same OCLD type and that the bands have been equalized using a manual per band equalizer.

> ***Note:*** Table 7-8 and Table 7-9 are provided as a guide only and the channel counts are not guaranteed.

CAUTION
Table 7-8 and Table 7-9 must be used with caution, given the limitations identified. Any network designed using these tables must be validated using the Network Modeling Tool, or with the assistance of Nortel Networks experts, prior to deployment, to guarantee the right level of confidence in the network design integrity.

Table 7-8
Minimum input power for Standard OFAs for 24 dB OSNR

Number of amplifiers	C-band		L-band	
	Min. input power (dBm)	Max. number of channels	Min. input power (dBm)	Max. number of channels
1	–27.1	16	–26.6	16
2	–23.8	16	–23.3	16
3	–21.7	11	–21.2	10
4	–20.1	8	–19.6	7
5	–18.9	6	–18.4	5

Table 7-9
Minimum input power for Standard OFAs for 21.9 dB OSNR

Number of amplifiers	C-band		L-band	
	Min. input power (dBm)	Max. number of channels	Min. input power (dBm)	Max. number of channels
1	–29.2	16	–28.7	16
2	–25.9	16	–25.4	16
3	–23.8	16	–23.3	16
4	–22.2	12	–21.7	11
5	–21.0	9	–20.5	8

Rule 9: Maximizing OSNR

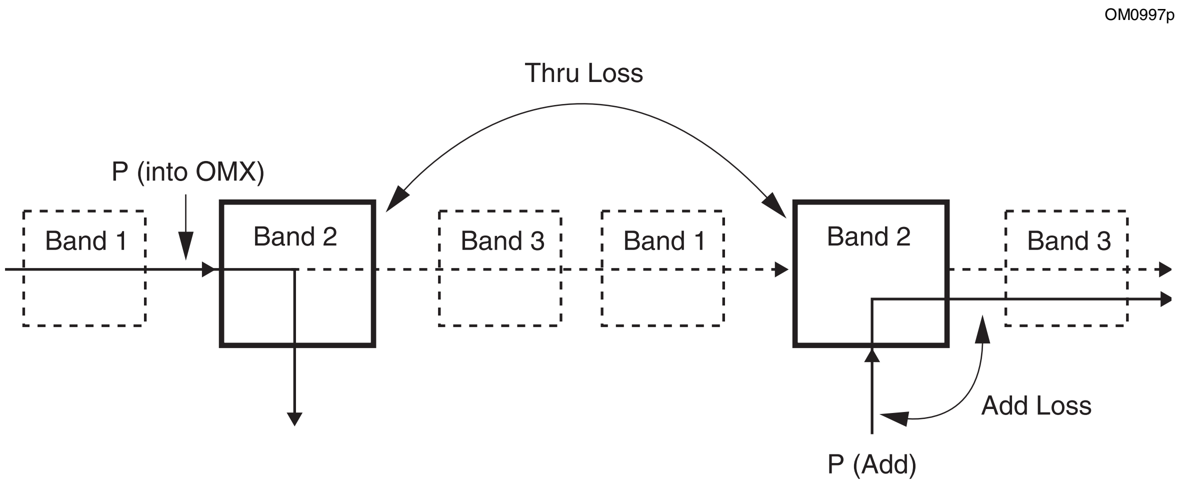
To maximize the OSNR on all channels, it is important that all channel powers are as equal as possible at the input of any amplifier. Nortel Networks recommends the use of a PBE (or distributed equalization) before the first amplifier in a span to equalize the average power levels. Because it is not possible to equalize, within a band, different launch powers of circuit packs with different bit rates, the maximum OSNR will be achieved only if bit rates are not mixed within a band.

Rule 10: Coherent cross-talk

Coherent cross-talk is a result of light from the dropped channel leaking through the pass-through of the add/drop filters onto the path of the added channel, where the dropped and added channels are at the same wavelength.

Figure 7-2 shows an example of intrasite coherent cross-talk at an OADM site.

Figure 7-2
Cross-talk



To avoid exceeding the permitted cross-talk level for the OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s, or OTR 2.5 Gbit/s circuit packs, the following relationship must be satisfied:

P(into OMX) < P(add) – add loss + Thru loss

where the powers are for individual channels, and:

- P(into OMX) is the power of the channel immediately before the OMX at which it is dropped
- P(add) is the transmit power of the OCLD
- add loss is the OMX add loss
- Thru loss is the loss that the given channel would experience between the drop and the add OMX, not including the isolation of the filters, but including the pass-through losses of any other OMXs adding or dropping other bands.

In the calculation, you must consider the ordering and OMX connection methods of the shelves at the site. For example, if you have a three-shelf OADM site with standard OMX connections for bands 1, 2, and 3, the standard OMX connections dictate that the signal flow sequence is:

- drop (band 1) drop (band 2) drop (band 3)
- add (band 1) add (band 2) add (band 3)

For the cross-talk calculation for band 2, P(into OMX) is the power of the band 2 channels after they pass through the band 1 drop filter. The Thru loss is the sum of the pass-through losses of the band 3 drop filter and the band 1 add filter.

For 10 Gbit/s OTRs and 10 Gbit/s Muxponders, you must derate the Rx sensitivity for a cross-talk penalty where:

$$\text{cross-talk ratio} = [P_{(\text{add})} - \text{add loss}] - [P_{(\text{into OMX drop})} - (2 \times \text{isolation}) - \text{thru loss}]$$

Table 7-10 lists the cross-talk penalty to be applied against the circuit pack Rx sensitivity, depending on the cross-talk ratio present.

Table 7-10
Cross-talk penalty for 10 Gbit/s OTRs and 10 Gbit/s Muxponders

Cross-talk ratio (dB)	Penalty (dB)	
	OTR 10 Gbit/s	OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT
20	2.53	not supported
21	1.96	not supported
22	1.55	not supported
23	1.24	not supported
24	1.02	not supported
25	0.86	not supported
26	0.74	not supported
27	0.65	0.25
28	0.58	0.25
29	0.51	0.25
30	0.46	0.25
32	0.35	0.25
33	0.31	0.25
34	0.26	0.25

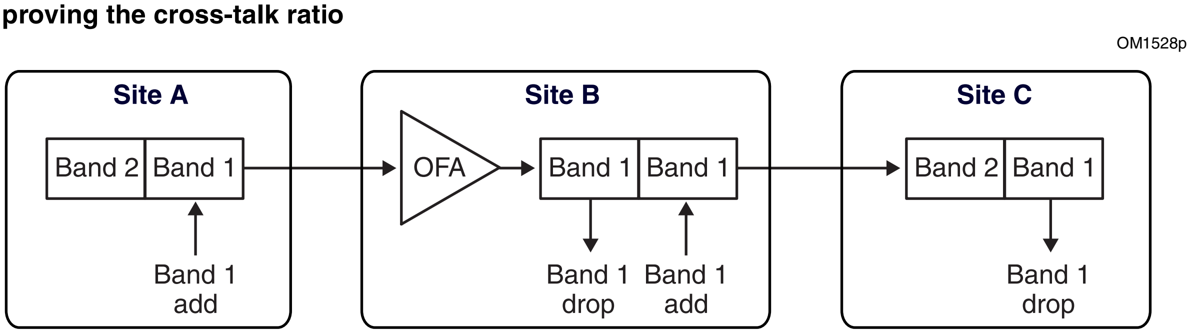
Table 7-10 (continued)
Cross-talk penalty for 10 Gbit/s OTRs and 10 Gbit/s Muxponders

Cross-talk ratio (dB)	Penalty (dB)	
	OTR 10 Gbit/s	OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT
36	0.19	0.25
38	0.14	0.00
40	0.10	0.00

In some network configurations, the cross-talk ratio can be lower than the minimum ratio that is supported. The cross-talk ratio can be increased to an acceptable level by deploying fixed pad attenuators. In the network shown in Figure 7-3, a fraction of the power from the Band 1 channel originating at site A leaks through the add/drop filter at site B and interferes with the Band 1 channel dropped at site C. The cross-talk ratio can be increased by placing a fixed pad attenuator at the output of the pre-amp OFA at site B. Each dB of attenuation at the output of the OFA increases the cross-talk ratio by 1 dB.

The cross-talk ratios in amplified networks depend on the location of the OFAs. Cross-talk ratios tend to be lower when pre-amp sites are used, since post-amp or line-amp sites tend to have higher loss between the OFA output and the drop OMX. In some cases the cross-talk ratio may be increased to an acceptable level by changing the location of the OFAs. In the example shown in Figure 7-3, the cross-talk ratio is increased by changing the pre-amp at site B to a post-amp at site A or a line-amp between sites A and B.

Figure 7-3
Improving the cross-talk ratio



Rule 11: Optical seams

Any ring-based Optical Metro 5200 network with OFAs must include an optical seam to prevent any excess build up of noise in the network.

The Optical Metro 5200 amplifiers produce broadband noise called amplified spontaneous emission (ASE). Unlike regular traffic that is added and dropped around the ring, the ASE continues to travel around the ring, gaining power as it is repeatedly amplified. This excess noise causes an additional degradation to the OSNR. A full optical seam is a physical break in the optical continuity of the ring. A terminal site is configured with an optical seam. Ensuring that your network has at least one terminal site is the simplest way of meeting this requirement.

In the absence of a true optical seam, an APBE, PBE, or ECT (with per band equalizers) can all be used to provide the required isolation in a ring. If a network fails the optical seam rule in the Network Modeling Tool due to insufficient isolation, increasing the number of APBEs, PBEs, or ECTs should clear the fault. In practice, if a band is not used in a network, you must set the corresponding VOA in the PBE or ECT to maximum; the eVOAs in APBEs are automatically set to maximum until a band is successfully provisioned.

Rule 12: Fiber non-linearities

The fiber non-linearities rule is linked to Rule 7.

When the launch power into the fiber is set to 3 dBm per channel, the number of amplified spans is limited to 6. If the non-linear limit is decreased to +1 dBm, the number of amplified spans allowed is increased to 8.

Rule 13: Jitter penalty

You must account for jitter by derating circuit pack Rx sensitivity values for a jitter penalty. For networks with OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs, add the jitter penalty to the OCLD Rx sensitivity. For networks with OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC, OTR 2.5 Gbit/s Flex or OCLD 2.5 Gbit/s Flex circuit packs, include the jitter penalty in the combined penalty sum (see Rule 19: Combining penalties for the OTR 10 Gbit/s, Rule 20: Combining penalties for the OTR 10 Gbit/s Enhanced, Muxponder circuit packs and Rule 21: Combining penalties for OCLD 2.5 Gbit/s Flex, OCLD 2.5 Gbit/s Universal, OTR 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Universal on page 7-42). Jitter is a function of the type of circuit pack and the network configuration.

The Optical Metro 5100/5200 system accumulates jitter as a result of signal retiming at optical termination and generation points in the network (that is, termination and generation of an optical signal at an OCLD, OCI, OTR or Muxponder circuit pack). Since signals enter and exit the Optical Metro 5100/5200 network through an OCI/OCLD combination, through an OTR, or through a Muxponder, the optical termination points required for the signal to enter or exit the network, to and from the client equipment are included in the minimal link budget and therefore, do not contribute to the jitter penalty.

A jitter contributing unit (JCU) represents the smallest amount of jitter that can be added to the signal path for a given pair of circuit packs. For all circuit packs supported on the Optical Metro 5100/5200 product, a JCU is counted for every pair of circuit packs used in any of the following configurations on the signal path:

- OCLD to OCLD pass-through for signal regeneration
- OCLD to OCLD pass-through for bridged systems
- OTR to OTR pass-through for signal regeneration
- OCLD/OCI (within one shelf) for cascaded Optical Metro 5100/5200 networks
- OTR to OTR (across two shelves) for cascaded Optical Metro 5100/5200 networks
- Muxponder to Muxponder (across two shelves) for cascaded Optical Metro 5100/5200 networks

In any of these configurations, for each pair of circuit packs that are inserted into the signal path, add 1 JCU to calculate the jitter penalty for the total signal path.

Using Table 7-11, add the total JCUs for all shelves where there has been an OEO conversion between the originating (where the client signal first entered the Optical Metro 5100/5200 network) and the terminating or pass-through/regenerator shelves in the optical span.

Table 7-11
Jitter contributing units

Bit rate	Shelf configuration	Signal flow	JCU
OCLD 1.25 or 2.5 Gbit/s	pass-through connections for regeneration or bridged systems (one shelf)	OCLD OCM OCLD	1
OCLD 1.25 or 2.5 Gbit/s	cascaded network connections (two shelves)	OCLD OCM OCI (network A) OCI (network B) OCM OCLD	2
OTR 10 Gbit/s or OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT	pass-through connections for regeneration	OTR OTR or Muxponder Muxponder	1
OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced, or 2.5 Gbit/s	cascaded network connections (two shelves)	OTR (network A) OTR (network B)	1
Muxponder 10 Gbit/s GbE/FC Muxponder 10 Gbit/s GbE/FC VCAT	cascaded network connections (two shelves)	Muxponder (network A) Muxponder (network B)	1

Table 7-12 lists the jitter penalties, according to the total number of jitter contributing units in an optical span.

Table 7-12
Jitter penalties

# of JCUs	Penalty (dB)				
	OCLD 1.25 Gbit/s	**OCLD 2.5 Gbit/s fixed**	**OCLD 2.5 Gbit/s Flex and OCLD 2.5 Gbit/s Universal and OTR 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Universal**	**OTR 10 Gbit/s**	**OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT**
1	0.5	0.75	0.75	0.2	0.2
2	0.7	0.95	0.95	0.2	0.2
3	0.7	0.95	0.95	0.2	0.2
4	0.7	0.95	0.95	0.2	0.2
5	not supported	0.95	0.95	0.2	0.2
6	not supported	0.95	0.95	0.2	0.2
7	not supported	0.95	0.95	0.2	0.2
8	not supported	0.95	0.95	not supported	0.2
9	not supported	0.95	0.95	not supported	0.2
10	not supported	0.95	0.95	not supported	0.2
11	not supported	0.95	0.95	not supported	0.2
12	not supported	0.95	0.95	not supported	0.2
13	not supported	0.95	0.95	not supported	0.2
14	not supported	not supported	not supported	not supported	not supported
15	not supported	not supported	not supported	not supported	not supported
16	not supported	not supported	not supported	not supported	not supported

Mixing OCLD 1.25 and 2.5 Gbit/s in Cascaded Networks (through OCI/OCI connections)

It is recommended that newly installed cascaded networks always use the OCLD 2.5 Gbit/s Flex circuit pack in each of the networks which are to be cascaded. However, if an existing functional network needs to be expanded and cascaded with another network through OCI/OCI connections then there may be a scenario where OCLD 1.25 Gbit/s circuit packs are used in the existing network and OCLD 2.5 Gbit/s Flex circuit packs are used in the new network. When the existing network is cascaded with the new network then the following Jitter penalty rules apply:

- the total number of JCUs must be 13 or less
- the total number of JCUs that include OCLD 1.25Gbit/s circuit packs must be 4 or less

If possible, it is preferred that OCLD 2.5 Gbit/s Flex circuit packs be used at the end points of the cascaded network as these circuit packs have better jitter performance when compared to the OCLD 1.25 Gbit/s circuit packs.

Rule 14: Dispersion penalty

Dispersion is a function of distance and the type of optical fiber. This rule is specific to the NDSF fiber type.

You must account for dispersion by derating circuit pack Rx sensitivity values for a chromatic dispersion penalty. For networks with OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs, add the dispersion penalty to the OCLD Rx sensitivity. For networks with OCLD 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Flex circuit packs, include the dispersion penalty in the combined penalty sum (see Rule 21: Combining penalties for OCLD 2.5 Gbit/s Flex, OCLD 2.5 Gbit/s Universal, OTR 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Universal on page 7-42). For 10 Gbit/s networks, include the dispersion penalty in the combined penalty sum (see Rule 19: Combining penalties for the OTR 10 Gbit/s and Rule 20: Combining penalties for the OTR 10 Gbit/s Enhanced, Muxponder circuit packs).

Table 7-13 lists the dispersion penalties for standard reach OCLD 1.25 Gbit/s and OCLD 2.5 Gbit/s circuit packs.

Table 7-13
Dispersion penalties for standard reach OCLDs for BER 10^{-12}—OCLD 1.25 Gbit/s and OCLD 2.5 Gbit/s

Fiber length (km)	Penalty (dB)	
	OCLD 1.25 Gbit/s	OCLD 2.5 Gbit/s
10	0.12	0.16
20	0.25	0.33
30	0.37	0.51
40	0.51	0.69
50	0.64	0.89
60	0.78	1.09
70	0.93	1.30
80	1.08	1.52
90	1.24	1.75
100	1.40	2.00
110	1.57	2.26

Table 7-14 lists the dispersion penalties for extended reach OCLD 1.25 Gbit/s and OCLD 2.5 Gbit/s circuit packs.

Table 7-14
Dispersion penalties for extended reach OCLDs for BER 10^{-12}—OCLD 1.25 Gbit/s and OCLD 2.5 Gbit/s

	Penalty (dB)	
Fiber length (km)	**OCLD 1.25 Gbit/s**	**OCLD 2.5 Gbit/s**
10	0.12	0.10
20	0.25	0.20
30	0.37	0.30
40	0.51	0.40
50	0.64	0.50
60	0.78	0.70
70	0.93	0.80
80	1.08	0.90
90	1.24	1.00
100	1.40	1.10
115	1.70	1.30
130	1.73	1.60
145	2.22	1.80
160	2.53	2.00
175	2.86	2.30

Table 7-15 lists the dispersion penalties for standard and extended reach OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex and Universal OCLD 2.5 Gbit/s and OTR 2.5 Gbit/s circuit packs used in DWDM and CWDM networks. For the dispersion penalties for standard reach OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex circuit packs used in ITU CWDM networks, see Table 7-16.

Table 7-15
Dispersion penalties for standard and extended reach flex OCLDs and OTRs and universal OCLDs and OTRs for BER 10^{-12}—OCLD 2.5 Gbit/s Flex, OTR 2.5 Gbit/s Flex

Fiber length (km)	Penalty (dB)	
	OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex standard reach	OCLD 2.5 Gbit/s Flex, OTR 2.5 Gbit/s extended reach and OCLD 2.5 Gbit/s and OTR Universal
0	0	0
10	0.32	0.32
25	0.80	0.80
35	0.95	0.95
50	1.20	1.20
60	1.45	1.45
75	1.85	1.85
90	1.90	1.90
110	2.00	2.00
125	Not supported	2.10
135	Not supported	2.15
150	Not supported	2.20
160	Not supported	2.20
175	Not supported	2.20

Table 7-16 lists the dispersion penalties for standard reach OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex circuit packs used in ITU CWDM networks.

Table 7-16
Dispersion penalties for standard reach OCLDs and OTRs for BER 10^{-12}— OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex

Fiber length (km)	Penalty (dB)
	OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex standard reach
0	0
20	0.7
40	1.1
60	1.6
80	2.0

Table 7-17 lists dispersion penalties for OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC.

Table 7-17
Dispersion penalties for OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs

Fiber length (km)	Penalty (dB)	
	OTR 10 Gbit/s for BER 10^{-6}	OTR 10 Gbit/s Enhanced and Muxponder for BER 10^{-12}
0	0.00	0.00
5	0.15	0.17
10	0.30	0.33
15	0.45	0.50
20	0.55	0.50
25	0.70	0.50
30	0.90	0.50
35	1.10	0.50
40	1.30	0.50
45	1.55	0.50

Table 7-17 (continued)
Dispersion penalties for OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs

Fiber length (km)	Penalty (dB)	
	OTR 10 Gbit/s for BER 10^{-6}	OTR 10 Gbit/s Enhanced and Muxponder for BER 10^{-12}
50	1.80	0.50
55	2.15	0.50
60	2.5	0.50
75	not supported	0.50
95	not supported	0.50
110	not supported	0.50

Note: The dispersion penalty for the 10 Gbit/s OTR is measured at BER 10^{-6} rather than 10^{-12}. In operation, the 10 Gbit/s OTR will have forward error correction (FEC) enabled, which guarantees a corrected BER better than 10^{-15}, provided the uncorrected BER does not exceed 10^{-6}.

Rule 15: Dispersion limit

The dispersion limit for standard reach OCLDs and for the OTR 2.5 Gbit/s on NDSF fiber in CWDM and DWDM networks is 110 km.

The dispersion limit for standard reach OCLD 2.5 Gbit/s and OTR 2.5 Gbit/s on NDSF fiber in ITU CWDM networks is 80 km.

The dispersion limit for extended reach OCLDs and for the OTR 2.5 Gbit/s on NDSF fiber is 175 km.

The dispersion limit for Universal OCLDs and for the OTR 2.5 Gbit/s on NDSF fiber in CWDM and DWDM networks is 175 km.

The dispersion limit for OTR 10 Gbit/s on NDSF fiber is 60 km. The dispersion limit for OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT on NDSF fiber is 110 km for C-band traffic and 95 km for L-band traffic.

Rule 16: OSC link engineering

The optical supervisory channel (OSC) is an overlay to an Optical Metro 5200 or Optical Metro 5100 network. An OSC link consists of the OSC signal from one site to another site. The OSC signal is always the first signal to be dropped when entering a site, and the last to be added exiting a site.

Link engineering rules for the OSC with dual taps

This OSC uses optical filters with improved isolation that eliminates the problems associated with OSC bleed-through. As a result, the link engineering for this OSC is greatly simplified, which is summarized as follows:

- The loss of the link must not exceed 28.3 dB, which includes fiber losses, patch-panel losses, ETS or OTS losses but exclude the OSC Add and Drop losses. It is important to validate the link loss at the OSC wavelength, since the loss of the fiber varies with wavelength and is typically slightly worse at 1510 nm compared to 1550 nm.
- If the total link loss is less than 3 dB, install a 6 dB attenuator at the Add port of the OSC tray of the originating OSC link to prevent overloading the receiver.

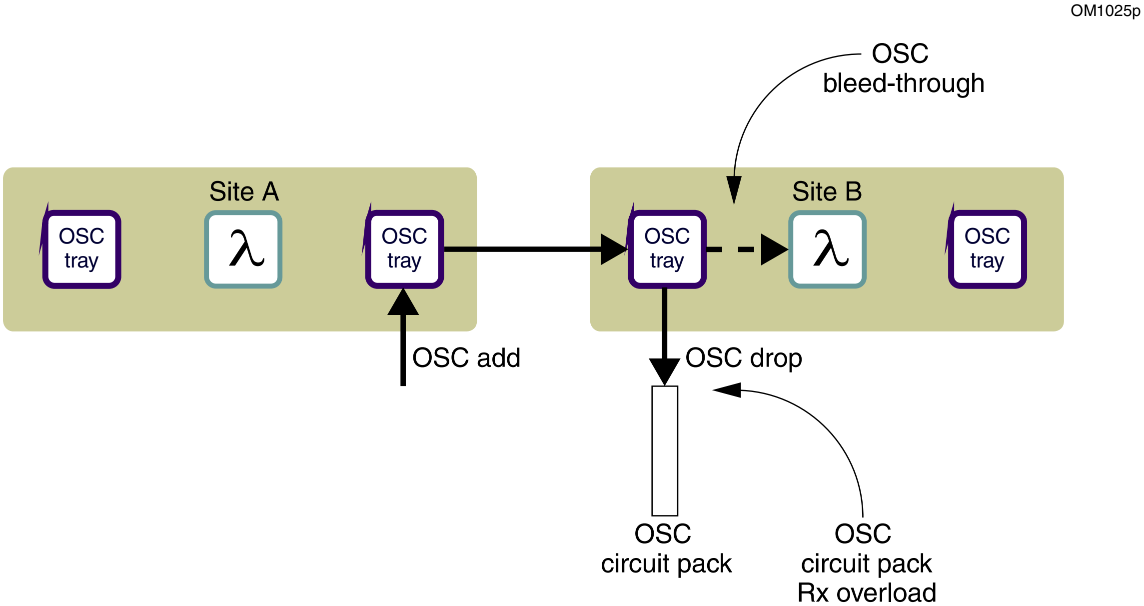
The reach of the OSC circuit pack is limited by the link losses, which means that distances up to 140 km can be achieved provided that the total span loss does not exceed 28.3 dB.

For information about installing an attenuator at the Add port of an OSC tray, see the procedure “Installing an attenuator at the add port in an OSC tray” in the chapter “Connecting components” in *Connection Procedures,* 323-1701-221.

Link engineering rules for other OSC variants

You must ensure that each OSC link has sufficient loss to prevent alarm and cross-talk problems, and OSC circuit pack Rx overload. Alarm and cross-talk problems can occur as a result of OSC bleed-through. OSC circuit pack overload can occur when the power level of the OSC signal exceeds the OSC circuit pack input power range. Bleed-through can occur when a small amount of OSC signal leaks through when dropped at the beginning of each site. Figure 7-4 shows an example of OSC bleed-through.

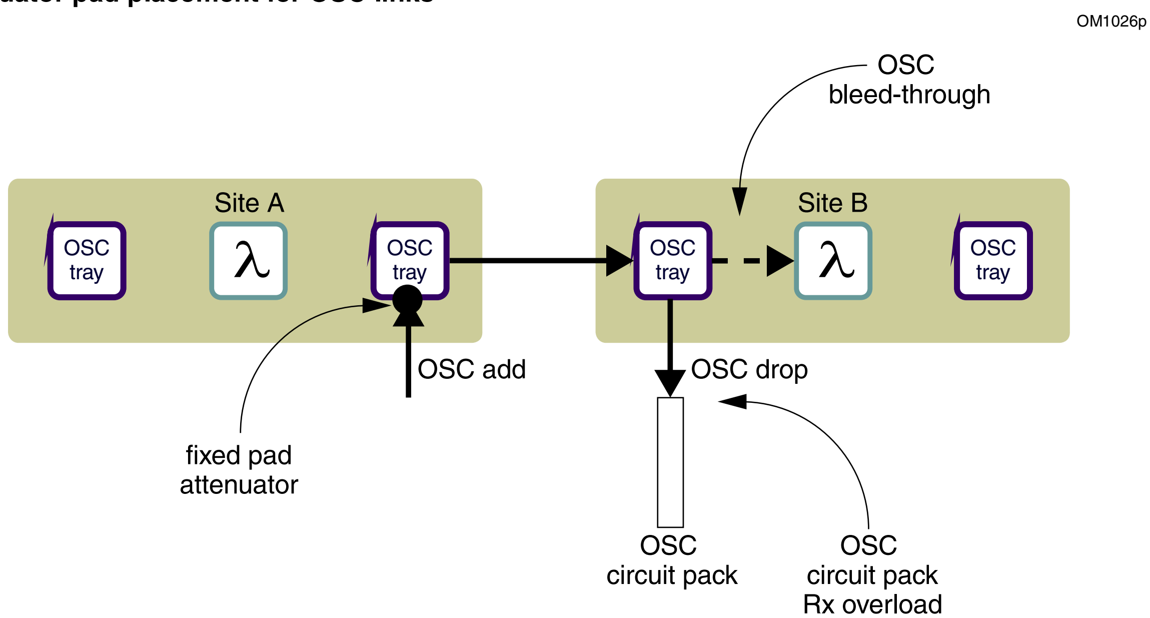
Figure 7-4
OSC bleed-through



Depending on the span losses associated with the link (which are known from the results of the network link engineering), attenuator pads may be required to ensure sufficient losses in each OSC link.

To avoid both of the potential problems with bleed-through and OSC circuit pack overload, the attenuator pads are placed at the input to the OSC Add port of the OSC tray at the previous site. Figure 7-5 shows the attenuator pad placement.

Figure 7-5
Attenuator pad placement for OSC links

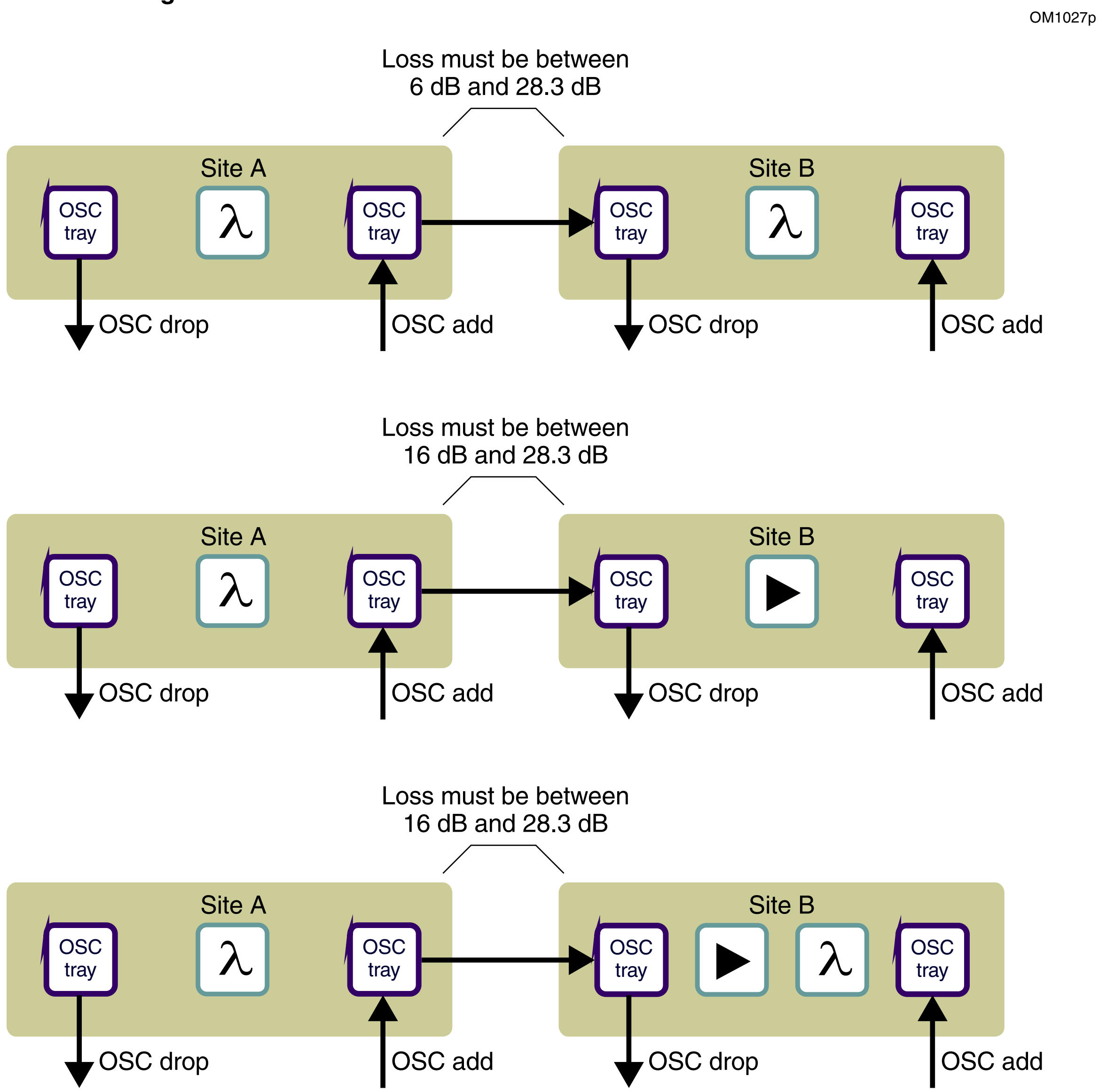


The required loss for each OSC link depends on the network configuration as follows:

- If an OSC link terminates with the OSC signal dropping before an amplifier, the loss for the link must be between 16 dB and 28.3 dB. This situation occurs at pre-amplified or OFA sites.
- For all other situations, the loss must be between 6 dB and 28.3 dB.

Figure 7-6 shows the required losses.

Figure 7-6
OSC link loss ranges



If the network link engineering indicates that the losses in an OSC link are insufficient to meet the required losses, you must install attenuator pads.

If you are using the attenuator kit available from Nortel Networks, use Table 7-18 or Table 7-19 to determine which attenuator to install. If you are not using a Nortel Networks attenuator kit and are using 5 dB or 15 dB attenuators, use Table 7-20 to determine which attenuator to install.

Table 7-18 lists the attenuator to use from the attenuator kit if no amplifier follows a terminating OSC signal.

Table 7-18
Attenuation requirements with no amplifiers

If the span loss is between	Then
0 dB and 6 dB	install a 6 dB attenuator at the Add port of the OSC tray of the originating OSC link.
6.1 dB and 28.3 dB	no attenuation is required.

Table 7-19 lists the attenuator to use from the attenuator kit if an amplifier follows a terminating OSC signal.

Table 7-19
Attenuation requirements with amplifiers

If the span loss is between	Then
0 dB and 12 dB	install a 16 dB attenuator at the Add port of the OSC tray of the originating OSC link.
12.1 dB and 16 dB	install a 4 dB attenuator at the Add port of the OSC tray of the originating OSC link.
16.1 dB and 28.3 dB	no attenuation is required.

If you are not using a Nortel Networks attenuator kit and are using 5 dB or 15 dB attenuators, use Table 7-20 to determine the required attenuator values.

Table 7-20
Attenuation requirements with amplifiers - Attenuation values for 5 dB and 15 dB attenuators

If the span loss is between	Then
1 dB and 11 dB	install a 15 dB attenuator at the Add port of the OSC tray of the originating OSC link.
11.1 dB and 16 dB	install a 5 dB attenuator at the Add port of the OSC tray of the originating OSC link.
16.1 dB and 28.3 dB	no attenuation is required.

The reach of the OSC circuit pack is limited by the link losses. This means that distances up to 140 km can be achieved provided that the total span loss, (which includes fiber and connector losses between a pair of facing OSC circuit packs), does not exceed 28.3 dB. It is important to validate the link loss at the OSC wavelength, since the loss of the fiber varies with wavelength and is typically slightly worse at 1510 nm compared to 1550 nm.

For information about installing an attenuator at the Add port of an OSC tray, see the procedure "Installing an attenuator at the add port in an OSC tray" in the chapter "Connecting components" in *Connection Procedures,* 323-1701-221.

Rule 17: Trunk Switches with OTR 10 Gbit/s Enhanced or Muxponder circuit packs

The OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit pack is supported on networks that use either the Optical Trunk Switch or the Enhanced Trunk Switch.

To ensure the protection switch times are kept below the specification for the OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT channels, it is necessary to balance the optical powers into the primary and standby ports of the trunk switch.

During installation of the OTS or ETS, optical attenuator pads may be required to balance the primary and standby powers if the link containing the trunk switch:

- is to support the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit pack at day 1
- will be later upgraded with the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit pack

Note 1: Optical attenuator pads are not required for those OTS or ETS links that will never support the OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT.

Note 2: Bypassing the installation of optical attenuator pads, if required, jeopardizes the means to support OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs once service is active.

For the reasons given above, it is highly recommended that Patch Panels (NT0H43CA) are installed on all 10 Gbit/s networks to accommodate the attenuators required for balancing the powers into the trunk switch.

Rule 18: Polarization mode dispersion

The OCLD 2.5 Gbit/s Flex, OTR 2.5 Gbit/s Flex, and the OCLD 2.5 Gbit/s are supported without a polarization mode dispersion (PMD) penalty on networks with a mean PMD value of less than or equal to 11 ps. If the mean PMD exceeds 11 ps, contact Nortel Networks.

For networks using 10 Gbit/s circuit packs, you must account for polarization mode dispersion (PMD) by derating the Rx sensitivity for a PMD penalty. PMD depends on the number of components in the span, and the length and quality of the fiber.

> ***Note:*** For networks with a blend of 2.5 Gbit/s Flex circuit packs and OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs, in order to best match the link budget of the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC to that of the OCLD/OTR 2.5 Gbit/s Flex, it is recommended that the mean PMD of the link be limited to a maximum of 5ps. For networks with a blend of 2.5 Gbit/s Universal circuit packs and OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs, in order to best match the link budget of the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC to that of the OCLD/OTR 2.5 Gbit/s Universal, it is recommended that the mean PMD of the link be limited to a maximum of 5ps. For information about blended bands, see the "Screen Tour" chapter in the *Network Modeling Tool User Guide*, NT0H7147.

To determine the PMD penalty, you must calculate the mean PMD for each span to find the corresponding PMD penalty to apply against the Rx sensitivity.

Table 7-21 lists the PMD values for each component.

Table 7-21
Component PMD values

Component	Value (ps)
OMX (pass-through)	0.15
OMX (add/drop)	0.2
OMX 16CH	0.15
Amplifier	0.5
OSC filter	0.1
OSC filter with dual tap	0.15
C&L band splitter/coupler	0.2
PBE (not including amplifier)	0.5
Trunk switch (OTS or ETS)	0.15 (end-to-end)
Note: In most cases, a value of 0.2 ps/√km can be used for the PMD value for fiber. However, if it is likely that the PMD value is greater than 0.2 ps/√km, then the values must be measured.	

Using the supplied component values, calculate the mean PMD for the span:

$$\text{MeanPMD} = \sqrt{\Sigma\,(\text{length} \times \text{PMD(fiber)}^2) + \Sigma\,\text{PMD(omx)}^2 + \Sigma\,\text{PMD(amp)}^2 + \Sigma\,\text{PMD(pbe)}^2 + \Sigma\,\text{PMD(osc)}^2 + \Sigma\,\text{PMD(c/l)}^2}$$

Using the calculated mean PMD for the span, find the corresponding PMD penalty in Table 7-22.

The values in Table 7-22 support a mean PMD of up to 11 ps. If the mean PMD exceeds 11 ps, contact Nortel Networks.

Table 7-22
PMD penalties

Mean PMD (ps)	Penalty	
	OTR 10 Gbit/s	OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT
0.0	0.00	0.00
1.0	0.00	0.00
2.0	0.10	0.00
2.5	0.10	0.00
3.0	0.10	0.02
4.0	0.30	0.06
5.0	0.40	0.10
6.0	0.60	0.38
7.0	0.80	0.66
7.5	0.90	0.80
8.0	1.00	0.97
9.0	1.30	1.31
10.0	1.60	1.66
11.0	1.90	2.00

Rule 19: Combining penalties for the OTR 10 Gbit/s

This rule applies only to the OTR 10 Gbit/s circuit pack. To combine the penalties for the OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit pack, refer to "Rule 20: Combining penalties for the OTR 10 Gbit/s Enhanced, Muxponder circuit packs" on page 7-41.

For networks using the OTR 10 Gbit/s circuit pack, you must derate the OTR Rx sensitivity by applying penalties for jitter, chromatic and polarization mode dispersion, OSNR, cross-talk. You must first convert the penalties (given in tables throughout the link engineering rules) into linear penalties, add the linear penalties, and then use the sum of the linear penalties to calculate the final penalty to apply against the Rx sensitivity. The Rx sensitivity is further derated by any customer-defined span margin.

To convert the penalties to linear penalties, use the following equation:

$$\text{penalty (linear)} = 1 - 10^{-\left[\frac{\text{penalty (dB)}}{10}\right]}$$

Use the sum of all linear penalties to calculate a total penalty:

$$\text{penalty (total)} = 10\log\frac{1}{(1-\sum \text{penalty (linear)})}$$

If the total penalty exceeds 5.0 dB, the network cannot be supported and the span must be re-engineered.

Add any span margin to the resulting total penalty to get the final penalty to apply against the Rx sensitivity.

Rule 20: Combining penalties for the OTR 10 Gbit/s Enhanced, Muxponder circuit packs

This rule applies only to the OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC and Muxponder 10 Gbit/s GbE/FC VCAT circuit pack. To combine the penalties for the OTR 10 Gbit/s circuit pack, refer to "Rule 19: Combining penalties for the OTR 10 Gbit/s" on page 7-40.

For networks using OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit packs, you must combine the penalties for jitter, chromatic and polarization mode dispersion, OSNR, and cross-talk using the formula:

$$\text{total penalty} = \text{jitter penalty} + \text{OSNR penalty} + \text{dispersion penalty} + \text{PMD penalty} + \text{cross-talk penalty}$$

> ***Note:*** There is no maximum total penalty for the OTR 10 Gbit/s Enhanced, Muxponder 10 Gbit/s GbE/FC or Muxponder 10 Gbit/s GbE/FC VCAT circuit pack.

Add the total penalty to the Rx sensitivity (–25 dBm) to obtain the required receive power value. If required, further derate this power value by any customer-defined span margin.

Rule 21: Combining penalties for OCLD 2.5 Gbit/s Flex, OCLD 2.5 Gbit/s Universal, OTR 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Universal

For networks using OCLD 2.5 Gbit/s Flex or OTR 2.5 Gbit/s Flex, you must combine the penalties for jitter, OSNR, and chromatic dispersion, using the formula:

total penalty = jitter penalty + OSNR penalty + dispersion penalty

Add the total penalty to the Rx sensitivity (–27.5 dBm) to obtain the required receive power value. If required, further derate this power value by any customer-defined span margin.

Rule 22: Interoperability of OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex with OCLD 2.5 Gbit/s

Both the OCLD 2.5 Gbit/s Flex and OTR 2.5 Gbit/s Flex can interoperate with the OCLD 2.5 Gbit/s. The following rules apply to interopability:

- use the Tx power of the transmitter type to calculate the receive power and OSNR
- use the rules specified for the receiver type to calculate the required receive power—with one exception; you must apply the dispersion penalty specified for the transmitter type

Basic fixed value link engineering

In this chapter

Overview

To perform fixed value link engineering, you must use the rules described in the "Link engineering rules" chapter in this book, and the components values listed in the "Link engineering components" chapter of this book. You can use the fixed value link engineering method for the following network types:

- DWDM networks without amplification, using OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs. Refer to "Performing fixed value link engineering for CWDM or DWDM networks" on page 8-8 for information about fixed value link engineering for these network types.
- DWDM networks without amplification, using OMX 16CH. Refer to "Performing fixed value link engineering for DWDM networks using OMX 16CH" on page 8-16 for information about fixed value link engineering for these network types.
- CWDM networks, using OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs. Refer to "Performing fixed value link engineering for CWDM or DWDM networks" on page 8-8 for information about fixed value link engineering for these network types.

- ITU CWDM networks. Refer to “Performing fixed value link engineering for ITU CWDM networks” on page 8-26 for information about fixed value link engineering for these network types.
- Amplified Enhanced Trunk Switch networks. Refer to “Performing fixed value link engineering for Enhanced Trunk Switch amplified networks” on page 8-33 for information about fixed value link engineering for these network types.

Gathering information

Before you start link engineering, you must know:

- the logical connectivity of the network with all required traffic channels
- the optical spans with protection requirements
- band placement
- site types, OMX types, and OMX connection methods
- span margins desired by the customer
- fiber spans with losses. Although it is preferable to measure losses with an optical time domain reflectometer (OTDR), you can estimate these losses. Additionally, if you have unusually high losses within the building that houses a site, you may need to consider losses between sites rather than losses between site buildings.
- amplifier placement, if applicable

Fixed value link engineering work flow

Figures 8-1, 8-2, 8-3, 8-4 and 8-5 describe the fixed value link engineering process.

Figure 8-1
Flow chart 1: Overall link engineering process

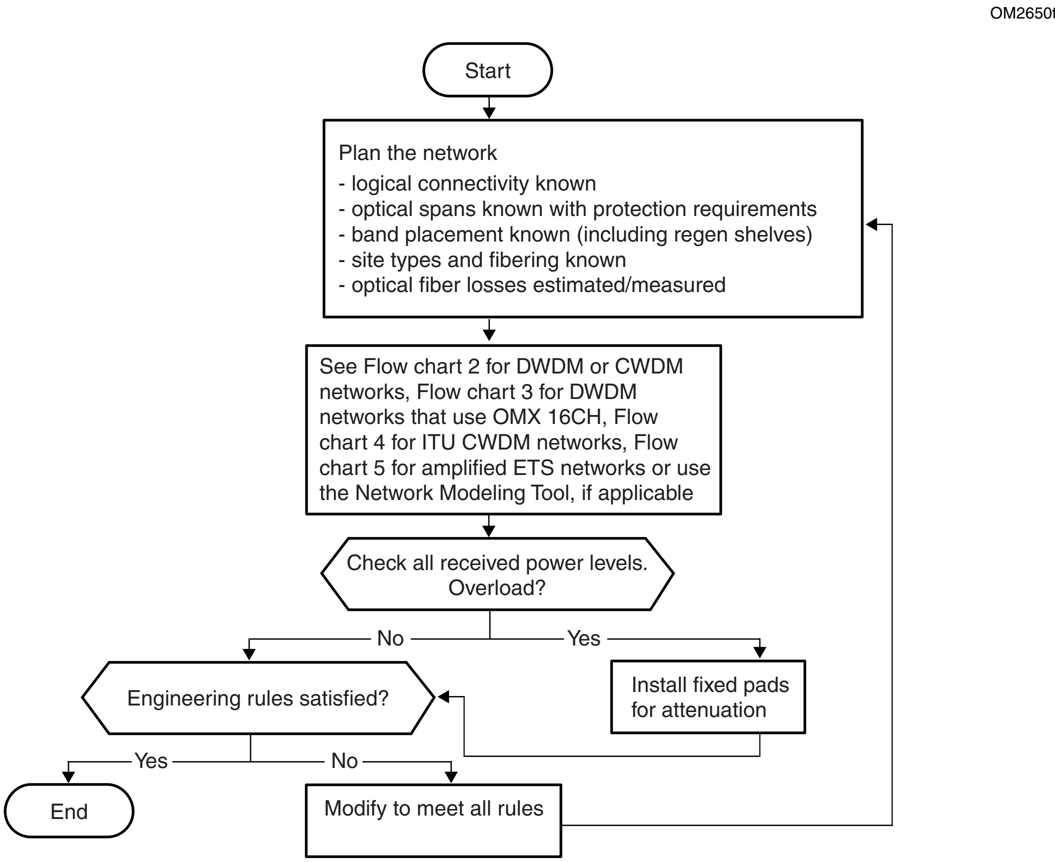


Figure 8-2 shows the process for computing margins for optical spans in unamplified DWDM or CWDM networks.

Figure 8-2
Flow chart 2: Computing margins for DWDM or CWDM networks

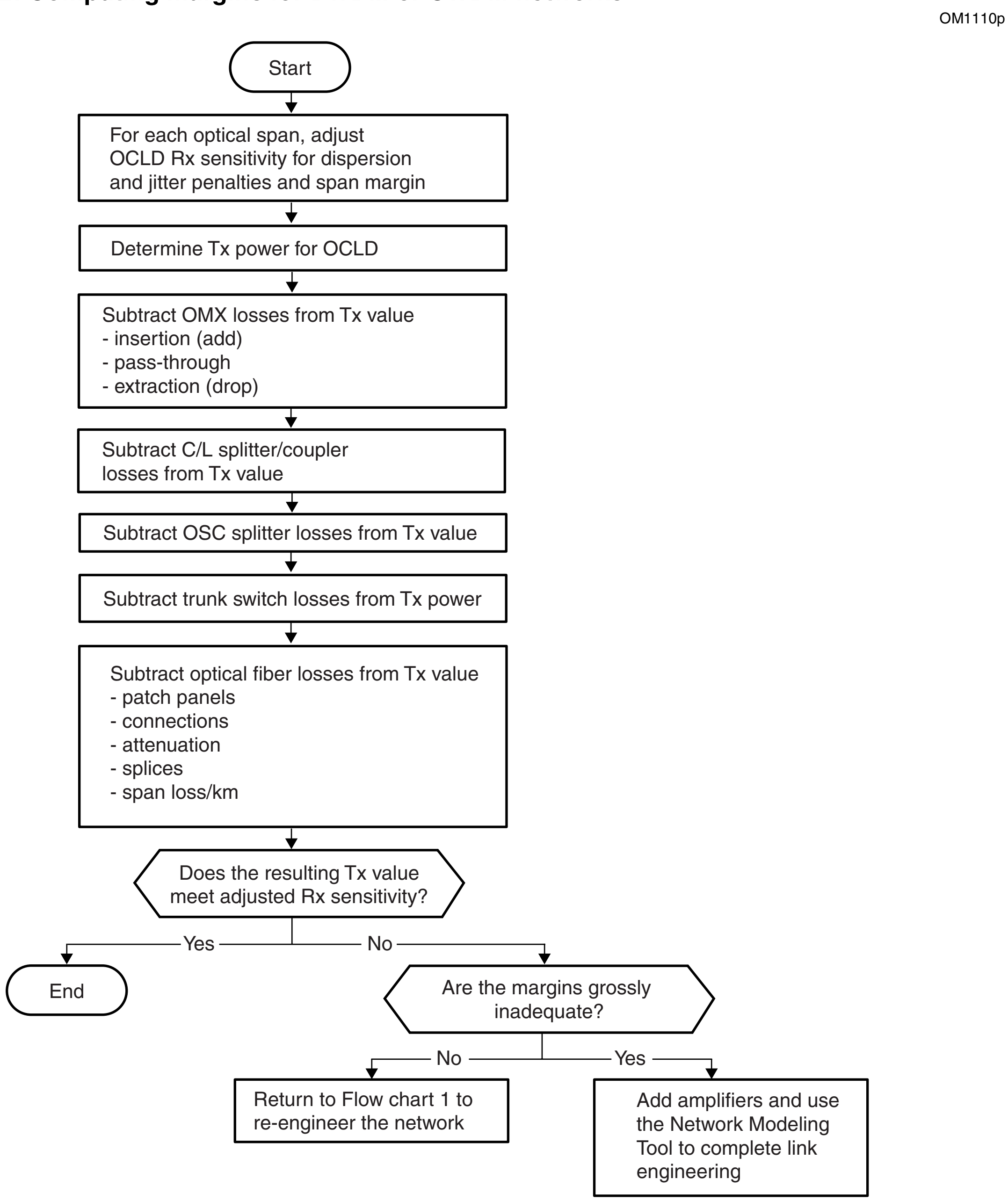


Figure 8-3 shows the process for computing margins for optical spans in unamplified DWDM networks that use OMX 16CH.

Figure 8-3
Flow chart 3: Computing margins for DWDM networks that use OMX 16CH

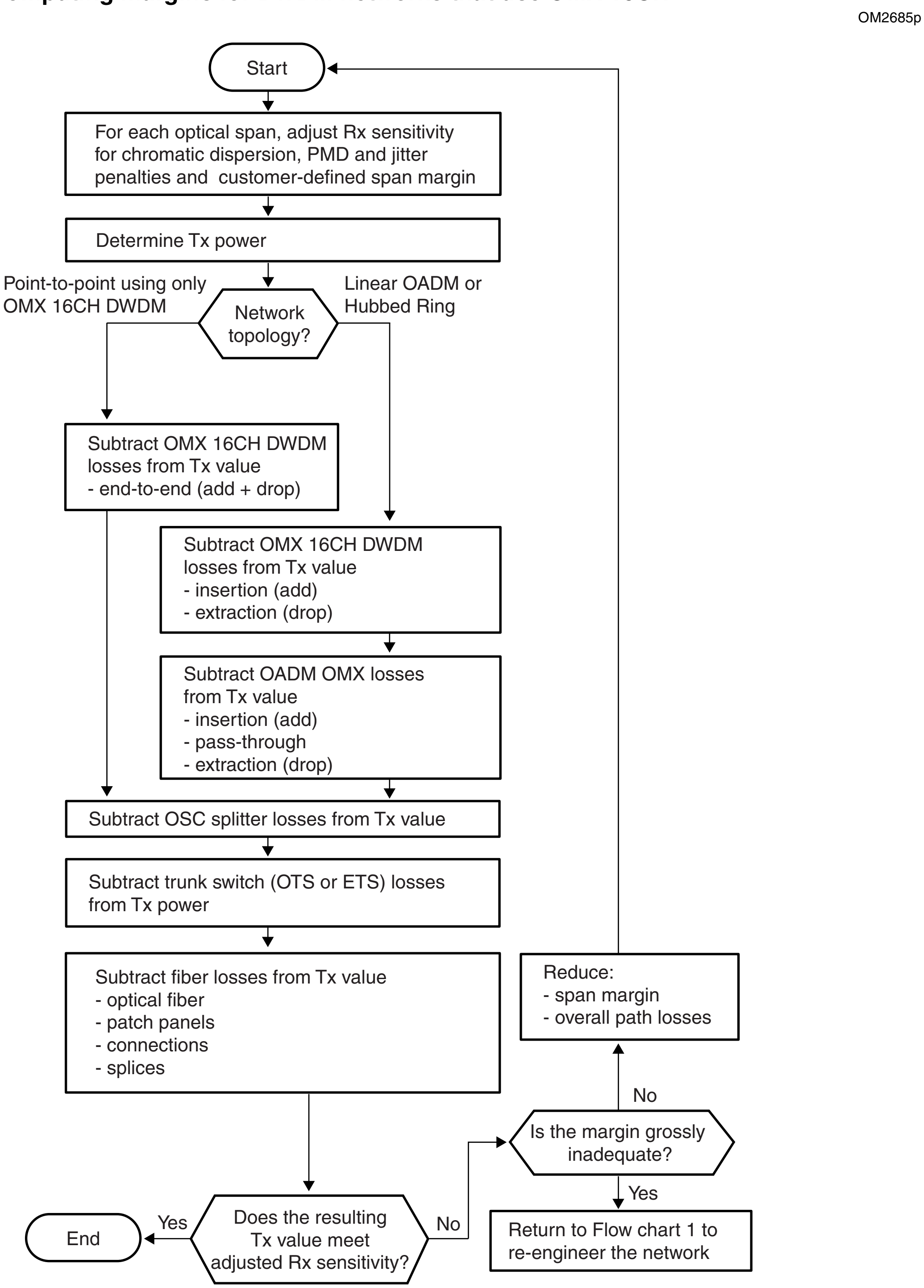


Figure 8-4 shows the process for computing margins for optical spans in ITU CWDM networks.

Figure 8-4
Flow chart 4: Computing margins for ITU CWDM networks

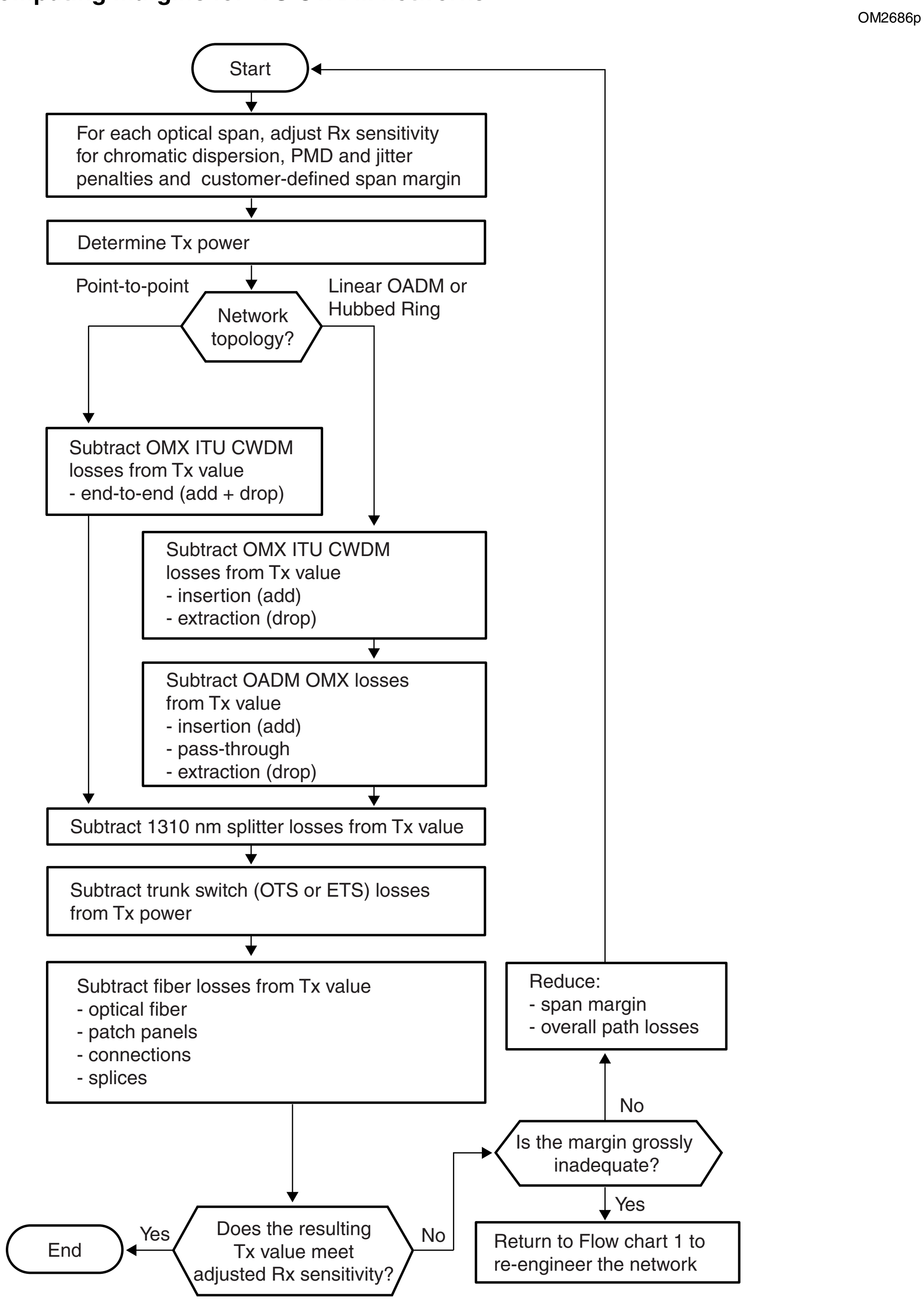
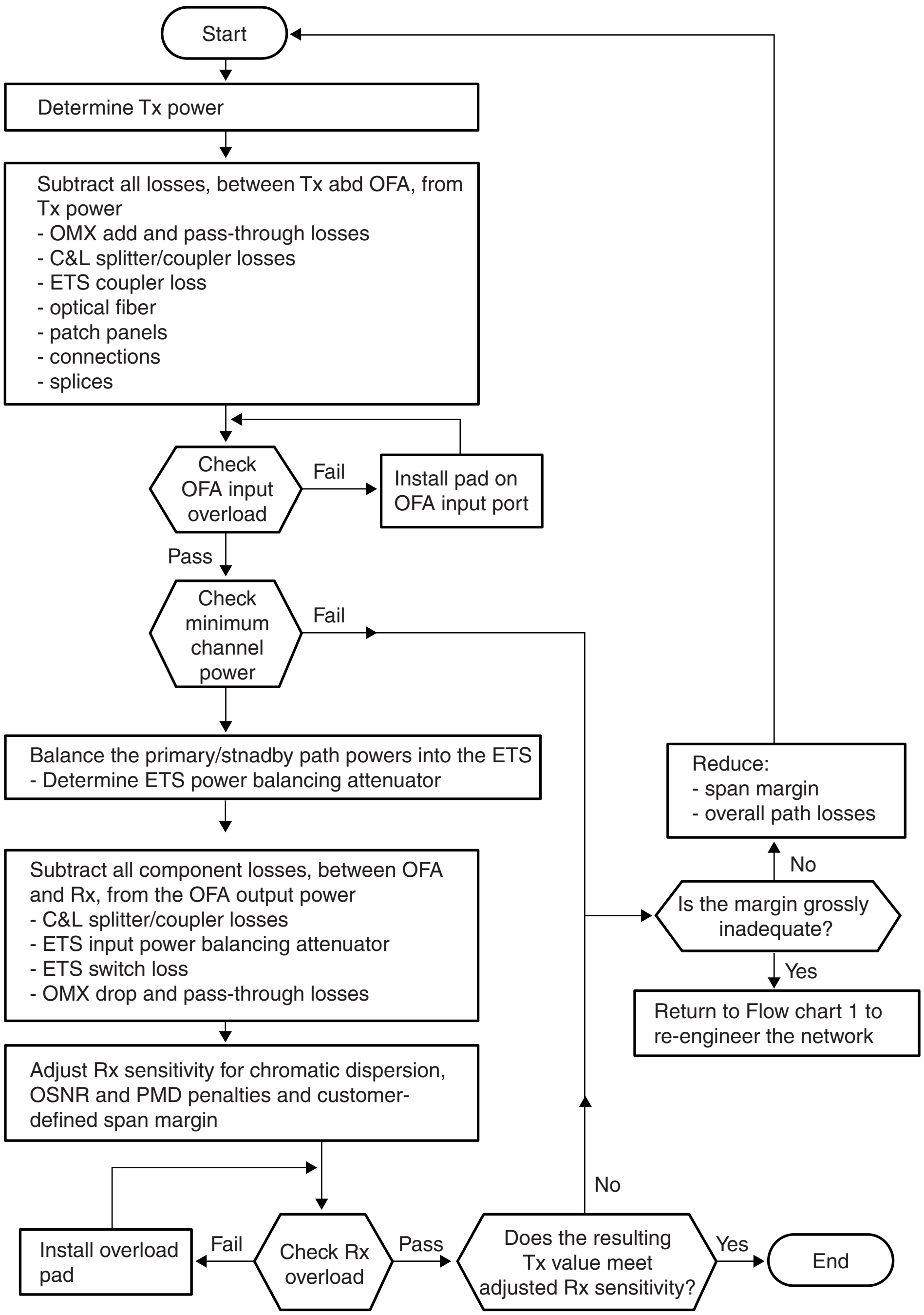


Figure 8-5 shows the process for computing margins for optical spans in amplified ETS networks.

Figure 8-5
Flow chart 5: Computing margins for amplified ETS networks



Performing fixed value link engineering for CWDM or DWDM networks

Use the following guidelines for unamplified DWDM or CWDM networks using OCLD 1.25 Gbit/s or OCLD 2.5 Gbit/s circuit packs.

When performing link engineering for unamplified spans, you will calculate the power levels along a span from OCLD transmitter to OCLD receiver.

> ***Note:*** In addition to ensuring adequate power levels along the span, you must adhere to all link engineering rules as defined in the "Link engineering rules" chapter in this book.

Determining OCLD receiver sensitivity

The first step in performing link engineering for an unamplified span involves calculating the receiver sensitivity for the terminating OCLD receiver in the span. You must derate the OCLD receiver sensitivity for chromatic dispersion and jitter penalties, and any customer-defined span margin.

OCLDs have alarms that warn of potential problems with power levels, and therefore have higher threshold values than the OCLD receiver sensitivity. To avoid alarms use the Rx Power Low degrade threshold value as the receiver sensitivity value, and then derate this value for chromatic dispersion and jitter penalties and span margin. Use the following tables for the calculations:

- for Rx Power Low degrade threshold values use Table 6-2 on page 6-4
- add the dispersion penalties using Table 7-13 on page 7-28 or Table 7-14 on page 7-29
- add the jitter penalties using Table 7-12 on page 7-26
- add any customer-defined span margin

The result of the calculation is the acceptable power level for the receiving OCLD at the terminating point of the span.

Determining OCLD transmit power

After you have established the derated receiver sensitivity, you must determine the output power of the transmitting OCLD at the originating point of the optical span. You will then subtract the various component and fiber losses from the OCLD transmit power. To determine the initial OCLD transmit power, see Table 6-1 on page 6-2.

Accounting for OMX losses

You must add losses for all of the OMXs in the span, and then subtract the total loss from the OCLD transmit power.

When you consider OMX losses, you must account for the method used for connecting OMXs within or between shelves. This is particularly important for the originating and terminating sites for the band. The OMX connection method determines how many add and drop filters a signal passes through at the originating and terminating sites.

Once you determine the total OMX losses for the span, subtract this total from the OCLD transmit power.

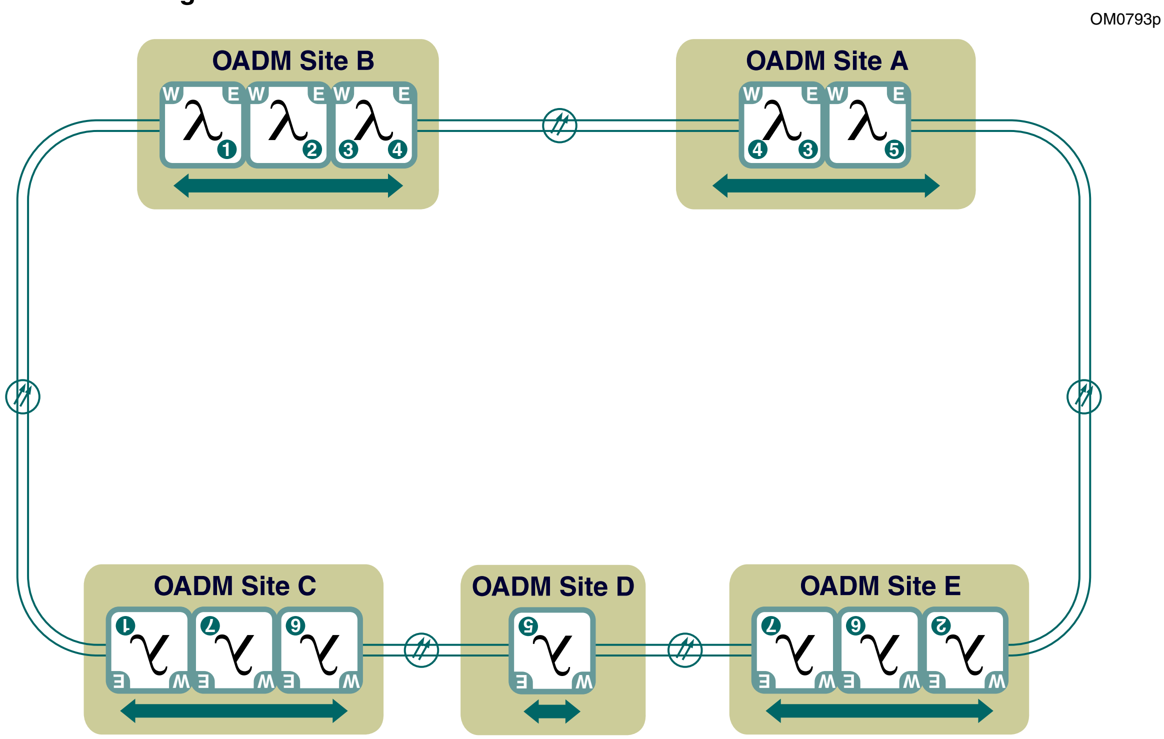
Example for single-shelf and standard OMX connections

The network shown in Figure 8-6 on page 8-10 has five OADM sites.

- Site A has two shelves, one with one band and one with two bands. The multi-band shelf has been fibered with band 4 as the first band in the shelf. This site uses standard OMX connections.
- Site B has three shelves, two with one band and one with two bands. The multi-band shelf has been fibered with band 3 as the first band in the shelf. This site uses standard OMX connections.
- Site C has three shelves, all with one band. This site uses standard OMX connections.
- Site D has one shelf with one band. This site uses single-shelf OMX connections.
- Site E has three shelves, all with one band per shelf. This site uses standard OMX connections.

This DWDM network uses standard OMXs.

Figure 8-6
A network with single-shelf and standard OMX connections



Based on this example, calculate the OMX losses for the east-bound span for band 1 originating at site B and terminating at site C.

From the OMX specifications (see Table 6-8 on page 6-20):

- the add loss is 3.0 dB (typical)
- the drop loss is 3.3 dB (typical)
- the pass-through loss for each add/drop filter is .7 dB (typical)

The optical span for band 1 traverses sites B, A, E, D, and then C. Based on the specifications, you can now calculate the OMX losses around the optical span.

Site B (the originating site) uses standard OMX connections, which dictates that the east-bound signal flow sequence is:

- drop (band 1), drop (band 2), drop (band 3), drop (band 4), and then
- add (band 1), add (band 2), add (band 3), add (band 4)

Therefore, when band 1 is added in the east-bound direction, the signal passes through the add filters of bands 2, 3, and 4 before flowing to the downstream site A. Table 8-1 shows the OMX losses for band 1 at site B in the east-bound direction.

Table 8-1
OMX loss calculations for band 1 at site B

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	**B**	**C (B x .7 dB)**	**D**	**E (C - D)**	**F**	**G (A+E+F)**
		# of filters passed through	**Loss from filters passed through**	**Connector adjustment for single-shelf sites**	**Total losses from filters passed through**		
B	3.0	3	2.1	N/A	2.1	N/A	5.1

The total OMX losses for band 1 at site B are 5.1 dB.

Now calculate the OMX losses for the sites A and E. These sites are both OADM sites with standard OMX connections. Table 8-2 shows the OMX losses for band 1 at sites A and E in the east-bound direction.

Table 8-2
OMX loss calculations for band 1 at sites A and E

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	**B**	**C (B x .7 dB)**	**D**	**E (C - D)**	**F**	**G (A+E+F)**
		# of filters passed through	**Loss from filters passed through**	**Connector adjustment for single-shelf sites**	**Total losses from filters passed through**		
A	N/A	6	4.2	N/A	4.2	N/A	4.2
E	N/A	6	4.2	N/A	4.2	N/A	4.2

Therefore the total OMX losses for each site are 4.2 dB.

Now calculate the OMX losses for site D. Site D is a single-shelf site with single-shelf OMX connections. Note that single shelf sites have one less connector than all others, so you must account for this difference in the calculation. In the example, the estimated connector loss is 0.2 dB. Table 8-3 shows the OMX losses for band 1 at site D in the east-bound direction.

Table 8-3
OMX loss calculations for band 1 at site D

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
D	N/A	2	1.4	0.2 (see Note)	1.2	N/A	1.2
Note: The connector adjustment only applies to an OMX (Standard), not an OMX + Fiber manager 4 CH.							

The OMX losses for band 1 at site D are 1.2 dB.

Now calculate the final OMX losses for the optical span for band 1. Site C (the terminating site) is an OADM site with standard OMX connections. The sequence for the east-bound signal flow through this multishelf site is:

- drop (band 6), drop (band 7), drop (band 1), and then
- add (band 6), add (band 7), add (band 1)

Therefore, when band 1 is dropped, the signal passes through the drop filters of bands 6 and 7 before being dropped from the ring. Table 8-4 shows the OMX losses for band 1 at site C in the east-bound direction.

Table 8-4
OMX loss calculations for band 1 at site C

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
C	N/A	2	1.4	N/A	1.4	3.3	4.7

The OMX losses for band 1 at site C are 4.7 dB.

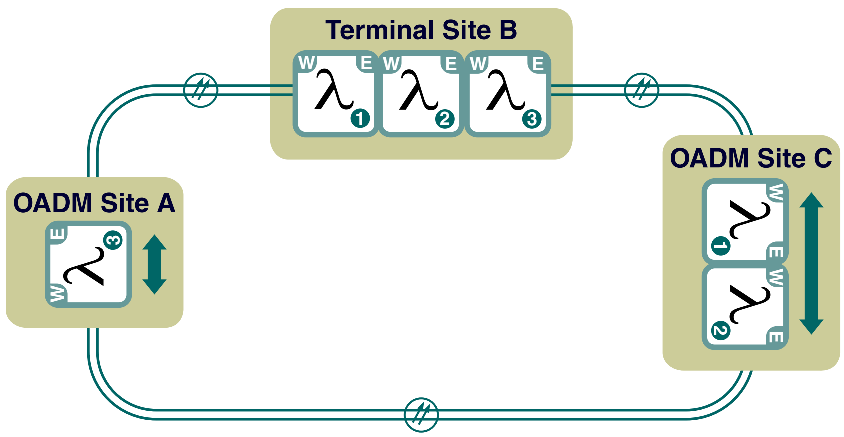
Now add the total OMX losses for all sites to calculate the total OMX losses for the optical span for band 1. The total OMX losses for the east-bound span for band 1 are:
5.1 + 4.2 + 4.2 + 1.2 + 4.7 = 19.4 dB.

Example for single-shelf, standard, and stacked OMX connections

The network shown in Figure 8-7 has one OADM site with single-shelf OMX connections (Site A), one OADM site with standard OMX connections (Site C), and one terminal site with stacked OMX connections (Site B). This DWDM network uses standard OMXs.

Figure 8-7
A network with single-shelf, standard, and stacked OMX connections

OM0511t



Based on this example, calculate the OMX losses for the east-bound span for band 1 originating at site B and terminating at site C.

From the OMX specifications (see Table 6-8 on page 6-20):

- the add loss is 3.0 dB (typical)
- the drop loss is 3.3 dB (typical)
- the pass-through loss per add/drop filter is .7 dB (typical)

The optical span for band 1 originates at site B and terminates at site C. Based on the specifications, you can now calculate the losses around the optical span.

Site B (the originating site) uses stacked OMX connections, which dictates that the east-bound signal flow sequence is:

- drop (band 1), drop (band 2), drop (band 3), and then
- add (band 3), add (band 2), add (band 1)

Therefore, when band 1 is added, the signal does not pass through any more add or drop filters at site B before flowing to the downstream site C. Table 8-5 shows the OMX losses for band 1 at site B in the east-bound direction.

Table 8-5
OMX loss calculations for band 1 at site B

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
B	3.0	0	0	N/A	0	N/A	3.0

The total OMX losses for band 1 at site B are 3.0 dB.

Now calculate the OMX losses for site C. Site C is an OADM site with standard OMX connections, which dictates the east-bound signal flow sequence of:

- drop (band 1), drop (band 2)
- add (band 1), add (band 2)

Therefore, band 1 is dropped from the ring before passing through any of the add or drop filters of the colocated shelves. Table 8-6 shows the OMX losses for band 1 at site C in the east-bound direction.

Table 8-6
OMX loss calculations for band 1 at site C

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
C	N/A	0	0	N/A	0	3.3	3.3

The OMX losses for band 1 at site C are 3.3 dB.

Now add the total OMX losses for all sites to calculate the total OMX losses for the east-bound optical span for band 1. The total losses for this optical span are:
3.0 + 3.3 = 6.3 dB.

Accounting for C&L splitter/coupler losses

If C&L splitter/couplers without VOAs are present in the network, you must subtract the losses from the OCLD transmit power. There are losses associated with the splitter and the coupler. Using Table 6-14 on page 6-25, subtract the total splitter and coupler losses from the OCLD transmit power.

Accounting for OSC losses

If OSCs are present in the network, you must subtract the OSC losses from the OCLD transmit power. There are losses associated with the add and drop filters in the OSC. Traffic-carrying signals experience losses as they pass through the filters. Using Table 6-24 on page 6-34, subtract the total OSC pass-through losses from the OCLD transmit power.

Accounting for OTS losses

If the network includes an Optical Trunk Switch (OTS), you must subtract the OTS losses. Using Table 6-25 on page 6-35, subtract the total OTS losses from the OCLD transmit power.

Accounting for fiber losses

Using measured or estimated fiber losses, add the losses for each fiber span in the optical span. Subtract the total from the OCLD transmit power.

This is the final transmit power for the optical span.

Comparing transmit power to receiver sensitivity

You now compare the final transmit power to the derated OCLD receiver sensitivity.

If the transmit power is greater than the receiver sensitivity, the power margin is positive. No further link engineering is necessary. If the transmit power is less than the receiver sensitivity, the power margin is negative and the link will not be functional.

If the deficiency is marginal, you can replan the network and possibly gain enough margin by reordering the shelves or reconfiguring the sites. For more information about reordering shelves or reconfiguring sites for optimal link budgets, see the chapter "Remodeling a network plan for optimal link budgets" in this book.

If the deficiency is major, the network may require amplification.

Checking for receiver overload

When you have established that the power levels in your network are sufficiently high, you must ensure that the levels do not cause receiver overload. Check the power levels at the input to every receiver in the network and compare them to the Rx Power High clear threshold value listed in Table 6-2 on page 6-4. If the power levels exceed the maximum allowable limits, you must install fixed pads to attenuate the signal.

Performing fixed value link engineering for DWDM networks using OMX 16CH

Use the following guidelines for unamplified DWDM networks that use OMX 16CH. When using the OMX 16CH:

- amplification is not supported
- optical pass-through is not supported by the OMX 16CH, it can only be used at terminal or hub sites
- mixing the OMX 16CH with any other OMX type is not supported at the same site
- only the OMX 4CH + Fiber Manager DWDM and the OMX 4CH DWDM Enhanced are supported at remote OADM sites, the OMX (Standard) DWDM is not supported
- OCLD 1.25 Gbit/s, OCLD 2.5 Gbit/s and OTR 10 Gbit/s circuit packs are not supported
- OCLD 2.5 Gbit/s Flex, OTR 2.5 Gbit/s Flex, OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs are supported

When performing link engineering for unamplified spans, you will calculate the power levels along a span from transmitter to receiver.

> ***Note:*** In addition to ensuring adequate power levels along the span, you must adhere to all link engineering rules as defined in the "Link engineering rules" chapter in this book.

Determining receiver sensitivity

The first step in performing link engineering for an unamplified span involves calculating the receiver sensitivity for the terminating receiver in the span. You must derate the receiver sensitivity for chromatic dispersion, and jitter penalties, and any customer-defined span margin. For 10 Gbit/s, you must also derate the receiver sensitivity for PMD.

OCLDs, OTRs and Muxponders have alarms that warn of potential problems with power levels, and therefore have higher threshold values than the OCLD, OTR or Muxponder receiver sensitivity. To avoid alarms use the Rx Power Low degrade threshold value as the receiver sensitivity value, and then derate this value for chromatic dispersion and jitter penalties and span margin. Use the following tables for the calculations:

- for circuit pack Rx Power Low degrade threshold values use
  - — Table 6-2 on page 6-4 for OCLD circuit packs

    — Table 6-4 on page 6-9 for OTR circuit packs
    — Table 6-6 on page 6-12 for Muxponder circuit packs

- add the dispersion penalties using "Link engineering rules" chapter of this book
- add the jitter penalties using "Link engineering rules" chapter of this book
- add the PMD penalties using "Link engineering rules" chapter of this book
- add any customer-defined span margin

The result of this calculation is the minimum acceptable power level for the receiver at the terminating point of the span.

Determining transmit power

After you have established the derated receiver sensitivity, you must determine the output power of the transmitter at the originating point of the optical span. You will then subtract the various component and fiber losses from the transmit power. To determine the initial transmit power, see

- Table 6-1 on page 6-2 for OCLD circuit packs
- Table 6-3 on page 6-5 for OTR circuit packs
- Table 6-5 on page 6-10 for Muxponder circuit packs

Accounting for OMX losses

You must add losses for all of the OMXs in the span, and then subtract the total loss from the transmit power.

Case 1: The network uses only the OMX 16CH type in a point-to-point network
In this case, when calculating the OMX losses it is possible to take advantage of the end-to-end combined Add/Drop loss for a pair of OMX 16CH. See Table 6-9 on page 6-21 for OMX 16CH losses. The following considerations apply:

- C-band only networks, use the Add and Drop (16 channel C-band only, end-to-end) loss
- L-band only networks, use the Add and Drop (16 channel L-band only, end-to-end) loss
- C&L band networks, use the Add and Drop (32 channel C- and L-band, end-to-end) loss

Case 2: The network uses a mixture of OMX 16CH and other OMX variants
Mixing the OMX 16CH with other OMX types mainly occurs in networks that contain remote OADM sites. In this case, it is no longer appropriate to use the end-to-end combined Add/Drop loss for the OMX 16CH, instead each filter in the network must use its Add or Drop loss when inserting or extracting channels, respectively.

When you consider OMX pass-through losses at remote sites, you must account for the method used for connecting OMXs within or between shelves. The OMX connection method determines how many add and drop filters a signal passes through at a given site.

Once you determine the total OMX losses for the span, subtract this total from the transmit power.

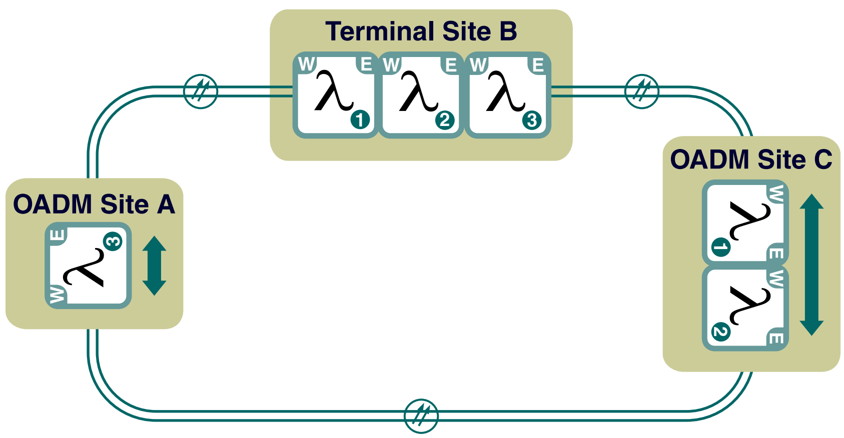
Case 2 example: C-band OMX 16CH and standard OMX connections at remote nodes

The network shown in Figure 8-8 has two OADM sites and one terminal site. This DWDM network uses C-band OMX 16CH at the terminal site and OMX 4CH Enhanced at the OADM sites.

This DWDM network uses C-band OMX 16CH and OMX 4CH Enhanced.

Figure 8-8
A network with C-band OMX 16CH and standard OMX connections at remote nodes

OM0511t



Based on this example, calculate the OMX losses for the east-bound span for band 1 originating at site B and terminating at site C.

From the OMX specifications (see Table 6-8 on page 6-20 and Table 6-9 on page 6-21):

- the add loss for OMX 4CH Enhanced is 2.1 dB (typical) and the add loss for the C-band OMX 16CH is 3.9 dB (typical)
- the drop loss for OMX 4CH Enhanced is 2.4 dB (typical) and the drop loss for the C-band OMX 16CH is 3.9 dB (typical)
- the pass-through loss for each add/drop filter is 0.7 dB (typical)

Based on the specifications, you can now calculate the OMX losses around the optical span.

Site B (the originating site) uses the OMX 16CH.

Table 8-7 shows the OMX losses for band 1 at site B in the east-bound direction.

Table 8-7
OMX loss calculations for band 1 at site B in the east-bound direction

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
B	3.9	0	0	N/A	0	N/A	3.9

Table 8-8 shows the OMX losses for band 1 at site C in the east-bound direction.

Table 8-8
OMX loss calculations for band 1 at site C in the east-bound direction

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
C	N/A	0	0	N/A	0	2.4	2.4

Now add the total OMX losses for all sites to calculate the total OMX losses for the optical span for band 1. The total OMX losses for the east-bound span for band 1 are:
3.9 + 2.4 = 6.3 dB

Table 8-9 shows the OMX losses for band 1 at site B in the west-bound direction.

Table 8-9
OMX loss calculations for band 1 at site B in the west-bound direction

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	**B**	**C (B x .7 dB)**	**D**	**E (C - D)**	**F**	**G (A+E+F)**
		# of filters passed through	**Loss from filters passed through**	**Connector adjustment for single-shelf sites**	**Total losses from filters passed through**		
B	3.9	0	0	N/A	0	N/A	3.9

Table 8-10 shows the OMX losses for band 1 at site A in the west-bound direction.

Table 8-10
OMX loss calculations for band 1 at site A in the west-bound direction

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	**B**	**C (B x .7 dB)**	**D**	**E (C - D)**	**F**	**G (A+E+F)**
		# of filters passed through	**Loss from filters passed through**	**Connector adjustment for single-shelf sites**	**Total losses from filters passed through**		
A	N/A	2	1.4	N/A	1.4	N/A	1.4

Table 8-11 shows the OMX losses for band 1 at site C in the west-bound direction. The sequence for the west-bound signal flow through this multishelf site is:

- drop (band 2), drop (band 1), and then
- add (band 2), add (band 1)

Therefore, when band 1 is dropped, the signal passes through the drop filters of band 2 before being dropped from the ring.

Table 8-11
OMX loss calculations for band 1 at site C in the west-bound direction

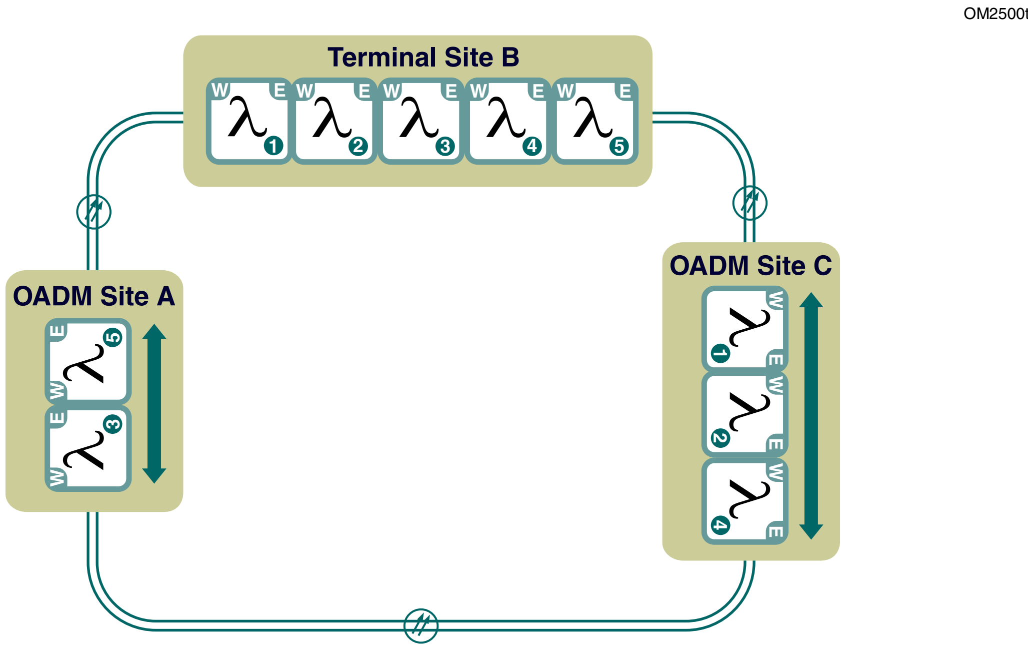
Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
C	N/A	1	0.7	N/A	0.7	2.4	3.1

Now add the total OMX losses for all sites to calculate the total OMX losses for the optical span for band 1. The total OMX losses for the west-bound span for band 1 are:
3.9 + 1.4 +3.1 = 8.4 dB

Case 2 example: C-band OMX 16CH and L-band OMX 16CH and standard OMX connections at remote nodes

The network shown in Figure 8-9 has one OADM site with standard OMX connections (Site A), another OADM site with standard OMX connections (Site C), and one terminal site with C-band OMX 16CH and L-band OMX 16CH (Site B). This DWDM network uses C-band OMX 16CH, L-band OMX 16CH and OMX 4CH Enhanced.

Figure 8-9
A network with C-band OMX 16CH and L-band OMX 16CH and standard OMX connections at remote nodes



Based on this example, calculate the OMX losses for the east-bound span for band 5 originating at site B and terminating at site A.

From the OMX specifications (see Table 6-8 on page 6-20 and Table 6-9 on page 6-21):

- the add loss for OMX 4CH Enhanced is 2.1 dB (typical) and the add loss for the L-band OMX 16CH is 3.5 dB (typical)
- the drop loss for OMX 4CH Enhanced is 2.4 dB (typical) and the drop loss for the L-band OMX 16CH is 3.5 dB (typical)
- the L-band upgrade port add/drop loss is 0.8 dB (typical)
- the pass-through loss for each add/drop filter is 0.7 dB (typical)

The optical span for band 5 originates at site B, traverses site C and terminates at site A. Based on the specifications, you can now calculate the losses around the optical span.

Site B (the originating site) uses the C-band OMX 16CH and the L-band OMX 16CH.

Table 8-12 shows the OMX losses for band 5 at site B in the east-bound direction.

Table 8-12
OMX loss calculations for band 5 at site B

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x 0.8 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
B	3.5	1	0.8	N/A	0.8	N/A	4.3

The total OMX losses for band 5 at site B are 4.3 dB.

Now calculate the OMX losses for the site C. This site is an OADM site with standard OMX connections. Table 8-13 shows the OMX losses for band 5 at site C in the east-bound direction.

Table 8-13
OMX loss calculations for band 5 at site C

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	B	C (B x .7 dB)	D	E (C - D)	F	G (A+E+F)
		# of filters passed through	Loss from filters passed through	Connector adjustment for single-shelf sites	Total losses from filters passed through		
C	N/A	6	4.2	N/A	4.2	N/A	4.2

Therefore the total OMX losses for site C are 4.2 dB.

Now calculate the OMX losses for site A. Site A is an OADM site with standard OMX connections, which dictates the east-bound signal flow sequence of:

- drop (band 3), drop (band 5), and then
- add (band 3), add (band 5)

Therefore, when band 5 is dropped, the signal passes through the drop filters of band 3 before being dropped from the ring. Table 8-14 shows the OMX losses for band 5 at site A in the east-bound direction.

Table 8-14
OMX loss calculations for band 5 at site A

Site	Add loss	Pass-through losses				Drop loss	Total OMX losses
	A	**B**	**C (B x .7 dB)**	**D**	**E (C - D)**	**F**	**G (A+E+F)**
		# of filters passed through	**Loss from filters passed through**	**Connector adjustment for single-shelf sites**	**Total losses from filters passed through**		
C	N/A	1	0.7	N/A	0.7	2.4	3.1

The OMX losses for band 5 at site A are 3.1 dB.

Now add the total OMX losses for all sites to calculate the total OMX losses for the east-bound optical span for band 5. The total losses for this optical span are:
4.3 + 4.2 + 3.1 = 11.6 dB.

Accounting for C&L splitter/coupler losses

If C&L splitter/couplers are present in the network, you must subtract the losses from the transmit power. There are losses associated with the splitter and the coupler. Using Table 6-14 on page 6-25, subtract the total splitter and coupler losses from the transmit power.

Accounting for OSC losses

If OSCs are present in the network, you must subtract the OSC losses from the transmit power. There are losses associated with the add and drop filters in the OSC. Traffic-carrying signals experience losses as they pass through the filters. Using Table 6-24 on page 6-34, subtract the total OSC pass-through losses from the transmit power.

Accounting for OTS or ETS losses

If the network includes an Optical Trunk Switch (OTS) or an Enhanced Trunk Switch (ETS), you must subtract the OTS or ETS losses. Using Table 6-25 on page 6-35 or Table 6-26 on page 6-36, subtract the total OTS or ETS losses from the transmit power.

Accounting for fiber losses

Using measured or estimated fiber losses, add the losses for each fiber span in the optical span. Subtract the total from the transmit power.

This is the final transmit power for the optical span.

Comparing transmit power to receiver sensitivity

You now compare the final transmit power to the derated receiver sensitivity.

If the transmit power is greater than the receiver sensitivity, the power margin is positive. No further link engineering is necessary. If the transmit power is less than the receiver sensitivity, the power margin is negative and the link will not be functional.

If the power margin is negative, try to reduce the overall path losses (for example, by cleaning all connectors and checking fiber splices). You can also choose to reduce the span margin.

Checking for receiver overload

When you have established that the power levels in your network are sufficiently high, you must ensure that the levels do not cause receiver overload. Check the power levels at the input to every receiver in the network and compare them to the Rx Power High clear threshold value, as listed in

- Table 6-2 on page 6-4 for OCLD circuit packs
- Table 6-4 on page 6-9 for OTR circuit packs
- Table 6-6 on page 6-12 for Muxponder circuit packs

If the power levels exceed the maximum allowable limits, you must install fixed pads at the channel drop port of the OMX 16CH to attenuate the signal.

Performing fixed value link engineering for ITU CWDM networks

Use the following guidelines for ITU CWDM networks. For ITU CWDM networks that combine OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs with OTR/OCLD 2.5 Gbit/s Flex circuit packs on the same spans, link engineering of the 10 Gbit/s channels takes precedence.

For ITU CWDM networks that use OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs:

- it is recommended to ensure that the span PMD is 5 ps or less for best OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit pack performance.
- you must pair specific OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs with specific ITU CWDM add/drop filters. Table 8-15 lists the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit pack wavelength plan, and the corresponding ITU CWDM wavelength plans. None of the existing OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs can be used with the 1471 nm, 1491 nm, and 1511 nm channels of the ITU CWDM add/drop filters.

Table 8-15
Correspondence between OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs and the ITU CWDM wavelength plan

ITU CWDM channel center wavelength (nm) (see Note)	**Recommended OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs**
1471	not supported
1491	not supported
1511	not supported
1531	B1C3
1551	B3C3
1571	B5C1

Table 8-15
Correspondence between OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs and the ITU CWDM wavelength plan

ITU CWDM channel center wavelength (nm) (see Note)	**Recommended OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs**
1591	B7C1
1611	B8C2

Note: Some Optical Metro 5100/5200 ITU CWDM hardware introduced before the ITU CWDM standard (G.695) was finalized will have labels with a center wavelength that differs by 1 nm with respect to the finalized ITU CWDM standard (G.695). For example, for the 1471 nm wavelength, the label will show 1470 nm. However, there is no wavelength incompatibility since the passbands are the same. For example, the pre-finalized ITU CWDM standard 1470 nm channel specified a range of –5.5 to +7.5 nm, that is, a passband of 1464.5 to 1477.5 nm. The finalized ITU CWDM standard 1471 nm channel specifies a range of ±6.5 nm, that is, the passband is still 1464.5 to 1477.5 nm. The only difference is one of labeling.

When performing link engineering for ITU CWDM networks, you will calculate the power levels along a span from transmitter to receiver.

If an ITU CWDM network is overlaid onto a network using a 1310 nm signal, you must ensure that the 1310 nm transmitter output power is less than 9.4 dBm (8.8 mW), to comply with Class 1 requirements. Failure to meet this requirement will also invalidate the link engineering procedure described in this section.

> ***Note:*** In addition to ensuring adequate power levels along the span, you must adhere to all link engineering rules as defined in the "Link engineering rules" chapter in this book.

Determining receiver sensitivity

The first step in performing link engineering for a span in an ITU CWDM network involves calculating the receiver sensitivity for the terminating receiver in the span. You must derate the receiver sensitivity for chromatic dispersion, jitter penalties, and any customer-defined span margin. For ITU CWDM networks that use OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit packs, the receiver sensitivity must also be derated for PMD (< 5 ps). The PMD penalty is zero in the case of ITU CWDM networks that exclusively use 2.5 Gbit/s circuit packs.

OCLDs, OTRs and Muxponders have alarms that warn of potential problems with power levels, and therefore have higher threshold values than the actual receiver sensitivity. To avoid alarms use the Rx Power Low degrade threshold value as the receiver sensitivity value, and then derate this value for chromatic dispersion, PMD, jitter penalties and span margin. Use the following tables for the calculations:

- for Rx Power Low degrade threshold values use:
  - Table 6-2 on page 6-4 for OCLD circuit packs
  - Table 6-4 on page 6-9 for OTR circuit packs
  - Table 6-6 on page 6-12 for Muxponder circuit packs
- add the dispersion penalties using the tables in the "Link engineering rules" chapter of this book
- add the jitter penalties using "Link engineering rules" chapter of this book
- add the PMD penalties using "Link engineering rules" chapter of this book
- add any customer-defined span margin

The result of the calculation is the minimum acceptable power level for the receiver at the terminating point of the span.

Determining transmit power

After you have established the derated receiver sensitivity, you must determine the output power of the transmitter at the originating point of the optical span. You will then subtract the various component and fiber losses from the transmit power. To determine the initial transmit power, see:

- Table 6-1 on page 6-2 for OCLD circuit packs
- Table 6-3 on page 6-5 for OTR circuit packs
- Table 6-5 on page 6-10 for Muxponder circuit packs

Accounting for OMX losses

You must add losses for all the OMXs in the span and then subtract the total loss from the transmit power.

Case 1: The network uses only the OMX ITU CWDM types in a point-to-point network (OMX OADM ITU CWDM types are not used)

In this case, when calculating the OMX losses it is possible to take advantage of the end-to-end combined Add/Drop loss for a pair of OMXs. See Table 6-12 on page 6-23 for OMX 4CH ITU CWDM and OMX 8CH ITU CWDM Add and Drop end-to-end losses.

Case 2: The network uses a mixture of OMX ITU CWDM and OMX OADM ITU CWDM types

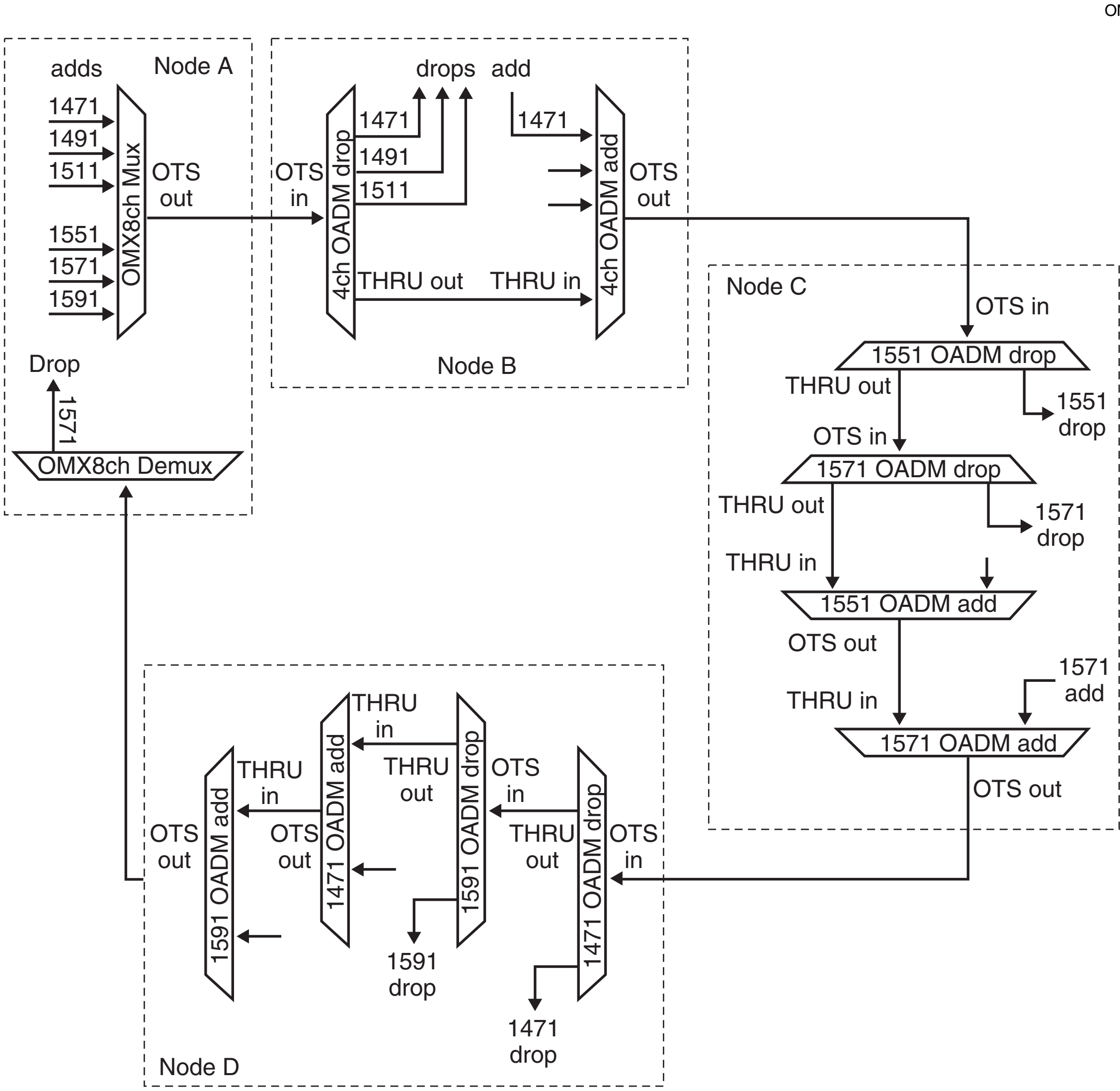
Mixing OMX ITU CWDM and OMX OADM ITU CWDM types occurs in networks that contain remote OADM sites. In this case, it is no longer appropriate to use the end-to-end combined Add/Drop loss, instead each filter in the network must use its Add or Drop loss when inserting or extracting channels, respectively.

See Table 6-12 on page 6-23 for OMX 4CH ITU CWDM and OMX 8CH ITU CWDM Add and Drop losses and Table 6-13 on page 6-24 for OMX 1CH OADM ITU CWDM and OMX 4CH OADM ITU CWDM Add, Drop and pass-through losses.

Once you determine the total OMX losses for the span, subtract this total from the transmit power.

Case 2 example:
The network shown in Figure 8-10 shows a sample network. In the example, we'll show how to calculate OMX losses in one direction of the ring.

Figure 8-10
A network with a mixture of OMX ITU CWDM and OMX OADM ITU CWDM types



OMX loss calculations for 1471, 1491 and 1511 nm channels added at node A and dropped at node B

- OMX 8CH ITU CWDM add loss at node A: 1.9 dB
- OMX 4CH OADM ITU CWDM drop loss at node B: 1.7 dB
- Total OMX losses: 1.9 + 1.7 = 3.6 dB

OMX loss calculations for 1551 nm channel added at node A and dropped at node C

- OMX 8CH ITU CWDM add loss at node A: 1.9 dB
- OMX 4CH OADM ITU CWDM pass-through losses at node B: 0.8 + 1.1 = 1.9 dB
- OMX 1CH OADM ITU CWDM drop loss at node C: 0.8 dB
- Total OMX losses: 1.9 + 1.9 + 0.8 = 4.6 dB

OMX loss calculations for 1571 nm channel added at node A and dropped at node C

- OMX 8CH ITU CWDM add loss at node A: 1.9 dB
- OMX 4CH OADM ITU CWDM pass-through losses at node B: 0.8 + 1.1 = 1.9 dB
- OMX 1CH OADM ITU CWDM pass-through loss at node C: 0.8 dB
- OMX 1CH OADM ITU CWDM drop loss at node C: 0.8 dB
- Total OMX losses: 1.9 + 1.9 + 0.8 + 0.8 = 5.4 dB

OMX loss calculations for 1591 nm channel added at node A and dropped at node D

- OMX 8CH ITU CWDM add loss at node A: 1.9 dB
- OMX 4CH OADM ITU CWDM pass-through losses at node B: 0.8 + 1.1 = 1.9 dB
- OMX 1CH OADM ITU CWDM pass-through losses at node C: 0.8 + 0.8 + 0.5 + 0.5 = 2.6 dB
- OMX 1CH OADM ITU CWDM pass-through loss at node D: 0.8 dB
- OMX 1CH OADM ITU CWDM drop loss at node D: 0.8 dB
- Total OMX losses: 1.9 + 1.9 + 2.6 + 0.8 + 0.8 = 8.0 dB

OMX loss calculations for 1471 nm channel added at node B and dropped at node D

- OMX 4CH OADM ITU CWDM add loss at node B: 1.4 dB
- OMX 1CH OADM ITU CWDM pass-through losses at node C: 0.8 + 0.8 + 0.5 + 0.5 = 2.6 dB
- OMX 1CH OADM ITU CWDM drop loss at node D: 0.8 dB
- Total OMX losses: 1.4 + 2.6 + 0.8 = 4.8 dB

OMX loss calculations for 1571 nm channel added at node C and dropped at node A

- OMX 1CH ITU OADM CWDM add loss at node C: 0.8 dB
- OMX 1CH OADM ITU CWDM pass-through losses at node D: 0.8 + 0.8 + 0.5 + 0.5 = 2.6 dB
- OMX 8CH ITU CWDM drop loss at node A: 2.2 dB
- Total OMX losses: 0.8 + 2.6 + 2.2 = 5.6 dB

Accounting for 1310 nm splitter/coupler losses

If 1310 nm splitter/couplers are present in the network, you must subtract the associated losses from the transmit power. There are losses associated with the splitter and the coupler. See Table 6-15 on page 6-26 for the splitter and coupler losses.

Accounting for OTS or ETS losses

If the network includes an Optical Trunk Switch (OTS) or an Enhanced Trunk Switch (ETS), you must subtract the OTS or ETS losses. Using Table 6-25 on page 6-35 or Table 6-26 on page 6-36, subtract the total OTS or ETS losses from the transmit power.

Accounting for fiber losses

Using measured or estimated fiber losses, add the losses for each fiber span in the optical span. Subtract the total from the transmit power. This is the final transmit power for the optical span.

Comparing transmit power to receiver sensitivity

You now compare the final transmit power to the derated receiver sensitivity. If the transmit power is greater than the receiver sensitivity, the power margin is positive. No further link engineering is necessary. If the transmit power is less than the receiver sensitivity, the power margin is negative and the link will not be functional. If the power margin is negative, try to reduce the overall path losses (for example, by cleaning all connectors and checking fiber splices). You can also choose to reduce the span margin.

Checking for receiver overload

When you have established that the power levels in your network are sufficiently high, you must ensure that the levels do not cause receiver overload. Check the power levels at the input to every receiver in the network and compare them to the Rx Power High clear threshold value, as listed in:

- Table 6-2 on page 6-4 for OCLD circuit packs
- Table 6-4 on page 6-9 for OTR circuit packs
- Table 6-6 on page 6-12 for Muxponder circuit packs

If the power levels exceed the maximum allowable limits, you must install fixed pads at the OTS IN port of the OMX ITU CWDM to attenuate the signal.

Guidelines for link engineering a 1310 nm signal

If an ITU CWDM network is overlaid onto a network using a 1310 nm signal, you must perform link engineering on the 1310 nm signal in addition to the ITU CWDM signals. Use the specifications for your transmitters and receivers, in addition to the following guidelines:

- If an ITU CWDM network is overlaid onto a network using a 1310 nm signal, you must ensure that the 1310 nm transmitter output power is less than 9.4 dBm (8.8 mW), to comply with Class 1 requirements. Failure to meet this requirement will also invalidate the link engineering procedure described in the previous section.
- NDSF fiber loss is higher at 1310 nm than at 1550 nm by approximately 0.1 dB/km. For example, the fiber losses for a 1310 nm signal on a 40 km span of NDSF fiber would be approximately 4 dB higher than for a 1550 nm signal.
- If the span contains Optical Trunk Switches or Enhanced Trunk Switches, use Table 6-25 on page 6-35 or Table 6-26 on page 6-36 for the loss specifications.
- For 1310 nm splitter/coupler losses, use Table 6-15 on page 6-26.

Performing fixed value link engineering for Enhanced Trunk Switch amplified networks

Use the following guidelines when designing Enhanced Trunk Switch amplified networks. The following restrictions apply:

- only High Input Power OFAs are supported in a pre-amplifier topology, see on page 3-9
- OCLD 2.5 Gbit/s Flex, OTR 2.5 Gbit/s Flex, OTR 10 Gbit/s Enhanced and Muxponder 10 Gbit/s GbE/FC circuit packs are supported
- OCLD 1.25 Gbit/s, OCLD 2.5 Gbit/s and OTR 10 Gbit/s circuit packs are not supported
- the OMX 16CH is not supported
- OSC is not required as line amplifiers are not supported

  Note: In addition to ensuring adequate power levels along the span, you must adhere to all link engineering rules as defined in the "Link engineering rules" chapter in this book.

Determining transmit power

The first step in performing link engineering for an amplified span is to determine the output power of the transmitter at the originating point of the optical span. You will then subtract the various component and fiber losses from this transmit power. To determine the initial transmit power, see

- Table 6-1 on page 6-2 for OCLD circuit packs
- Table 6-3 on page 6-5 for OTR circuit packs
- Table 6-5 on page 6-10 for Muxponder circuit packs

Determining the OFA input channel powers

Next it's necessary to calculate the power reaching the pre-amplifier. To do this the various filter and link losses, that connect the transmitter to the amplifier, have to be summed together and their total subtracted from the transmit power. Depending on the specific network configuration some or all of the following components will have to be accounted for:

- At the originating site:
  - OMX insertion (Add) and pass-through losses, see Table 6-8 on page 6-20
  - C&L splitter/coupler loss, see Table 6-14 on page 6-25
  - ETS coupler loss, see Table 6-26 on page 6-36
- Optical fiber
  - Fiber loss
  - Patch panel, connector and splice losses
- At the terminating site (up to the amplifier)

— C&L splitter/coupler splitter loss, see Table 6-14 on page 6-25

You must add together the losses for the above components, and then subtract the total loss from the transmit power.

When you consider OMX losses, you must account for the method used for connecting OMXs within or between shelves. The OMX connection method determines how many add filters a signal passes through at the originating site.

This step is repeated for each transmitter.

Checking for OFA aggregate input power overload

Once all the channel powers at the OFA input are known, use the following formula to calculate the OFA aggregate input power:

$$P_{agg} = \frac{\sum P_i}{N} + 10_{\log N}$$

where: P_{agg} is either the C- or L-band aggregate power in dBm; P_i is either the i^{th} C- or L-band channel power in dBm, and N is the number of C- or L-band channels, respectively.

If the aggregate input power exceeds the maximum recommended input power for a HIP OFA, see Table 6-7 on page 6-15, an attenuator is required on the input port to prevent an OFA overload. To facilitate future upgrades, it is important that this aggregate power check and subsequent attenuator selection, if required, is performed with all 16 channels present at the amplifier. This can be achieved by either:

- adding 10log(16/N) to the input aggregate power calculated above, where N is defined above, or
- designing the network with all the components (that is, OMXs, C&L splitter/couplers and OCLDs/OTRs/Muxponder circuit packs) required to support full channel count (16 C-band and/or 16 L-band channels) installed.

This step must be repeated for both C and L band amplifiers, if present.

Before continuing with this procedure, it is important to account for each overload attenuator by subtracting its loss from its corresponding aggregate input power and channel powers.

Checking OFA minimum channel power requirements

Each channel present at the OFA should meet the minimum input power requirements given in Table 7-4 on page 7-11. If any of the channel powers calculated above are too low, try to reduce the overall path losses (for example, check that the fiber and patch-panel losses accurately model their physical counterparts). You can also choose to reduce the span margin.

Determining the OFA output channel powers

Calculate the OFA output channel powers by adding the maximum OFA gain to each OFA input channel power. See Table 6-7 on page 6-15 for the maximum gain specification for the High Input Power OFA.

Balancing the primary/ standby path powers into the ETS

For networks that intend to support the OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC circuit pack from the time of initial installation or as a future upgrade, it is important to balance the primary and standby aggregate powers into the ETS. This ensures that the system protection switch time is reduced to a minimum. Use the following procedure to balance the primary and standby powers:

> ***Note:*** In order to simplify the calculation, a single channel power will be used in place of the aggregate power into the ETS, as an attenuator will affect both the channel powers and aggregate power equally.

- select a channel and determine its power into the ETS; use its OFA output channel power calculated above and subtract the C&L coupler loss, if required, to give its channel power into the ETS
- for the same channel, determine which path has the lower channel power into the ETS
- use a fixed pad to attenuate the high power path, such that its value is within 2 dB of the low power path

> ***Note:*** A patch panel (NT0H43CA) is needed to house the fixed pad attenuator and it is recommended that the patch panel is always used to facilitate final power balancing at installation time.

Determining the power level at the line receiver

To calculate the power at the receiver, the total loss of the various components, between the OFA and receiver, must be subtracted from the amplified channel power. Depending on the specific network configuration some or all of the following components will have to be accounted for:

At the terminal site (after the amplifier):

- C&L splitter/coupler loss, see Table 6-14 on page 6-25
- Attenuator for power balancing into the ETS
- ETS switch loss, see Table 6-26 on page 6-36

- OMX extraction (Drop) and pass-through losses, see Table 6-8 on page 6-20

You must add together the losses for the above components, and then subtract the total loss from the OFA output channel power.

When you consider OMX losses, you must account for the method used for connecting OMXs within or between shelves. The OMX connection method determines how many drop filters a signal passes through at the terminating site.

This step is repeated for each channel.

Determining receiver sensitivity

The receiver sensitivity must be derated for chromatic dispersion, OSNR penalties, and any customer-defined span margin. For 10 Gbit/s, you must also derate the receiver sensitivity for PMD.

OCLDs, OTRs and Muxponders have alarms that warn of potential problems with power levels, and therefore have higher threshold values than the OCLD, OTR or Muxponder receiver sensitivity. To avoid alarms use the Rx Power Low degrade threshold value as the receiver sensitivity value, and then derate this value for chromatic dispersion and jitter penalties and span margin. Use the following tables for the calculations:

- for Rx Power Low degrade threshold values use:
  - Table 6-2 on page 6-4 for OCLD circuit packs
  - Table 6-4 on page 6-9 for OTR circuit packs
  - Table 6-6 on page 6-12 for Muxponder circuit packs
- add the dispersion penalties using the tables in the“Link engineering rules” chapter of this book
- add the maximum (22 dB) OSNR penalties using “Link engineering rules” chapter of this book
- add the PMD penalties using “Link engineering rules” chapter of this book
- add any customer-defined span margin

The result of this calculation is the minimum acceptable power level for the receiver at the terminating point of the span.

Checking for receiver overload

As the network uses a pre-amplifier, the power levels in the network may be high enough to overload one or more of the receivers, in which case overload pads are required. Check the power levels at the input to every receiver in the network and compare them to the Rx Power High clear threshold value, as listed in:

- Table 6-2 on page 6-4 for OCLD circuit packs

- Table 6-4 on page 6-9 for OTR circuit packs
- Table 6-6 on page 6-12 for Muxponder circuit packs

If the power levels exceed the maximum allowable limits, you must install fixed pads to attenuate those signals. The fixed pads can be installed at the OMX BAND RX port.

Comparing received power to receiver sensitivity

You now compare the final received power to the derated receiver sensitivity. If the received power is greater than the receiver sensitivity, the power margin is positive. No further link engineering is necessary. If the received power is less than the receiver sensitivity, the power margin is negative and the link will not be functional.

If the power margin is negative, try to reduce the overall path losses (for example, check that the fiber and patch-panel losses accurately model their physical counterparts). You can also choose to reduce the span margin.

Alternatively, this negative power margin may be due to the attenuation required to balance a large difference between the primary and standby powers, for instance when only one path is amplified and the unamplified path is close to sensitivity. When this happens it may be necessary to add an amplifier to the unamplified path.

Remodeling a network plan for optimal link budgets

In this chapter

Overview

With a knowledge of the link engineering process, you can adjust a network plan for optimal link budgets. By ordering shelves or configuring sites for optimal link budgets, you may save equipment costs.

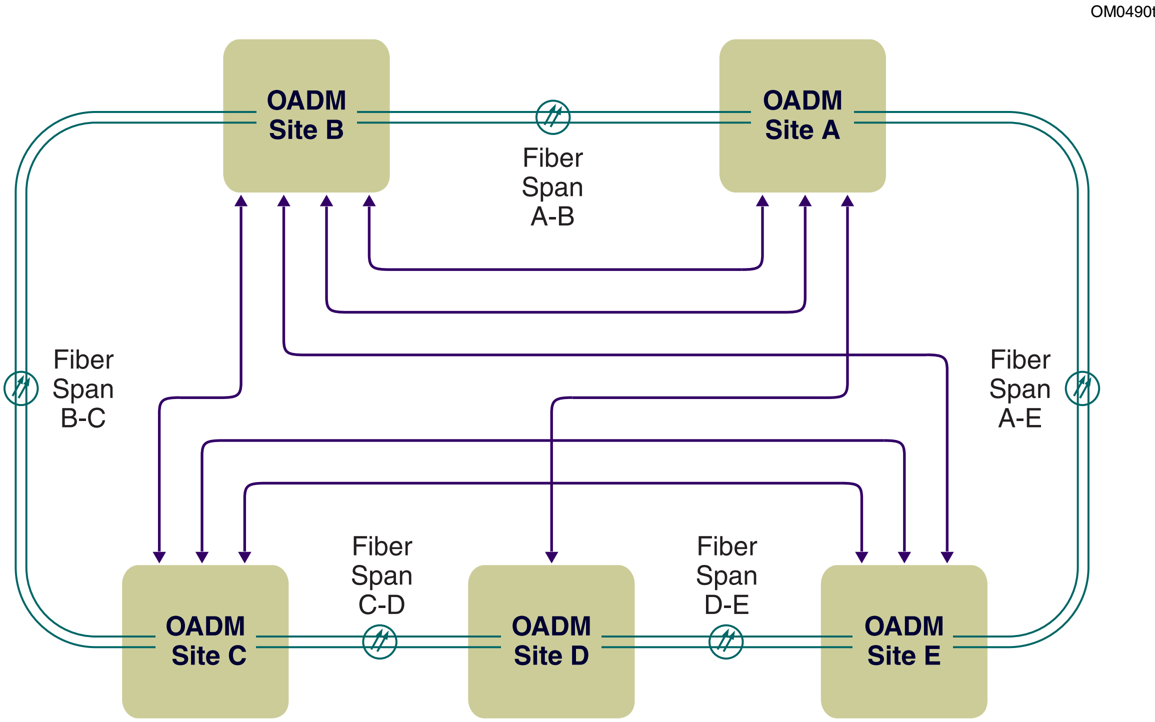
Understanding traffic demands

Optical Metro 5100/5200 shelves are placed in a network to provide access to channels on the optical system for delivery of services, such as ESCON, Fibre Channel, Gigabit Ethernet, and SONET. Before you can plan sites and equipment placement, you should know the following:

- does the channel require diverse routing
- does the channel require physical layer protection
- is the channel protected by another means
- how should you use wavelengths to provide optimum service
- what is the growth potential of the network

Figure 9-1 shows an example of a five-site system with traffic demands. Five sites are interconnected by five fiber spans with channel demands as illustrated.

Figure 9-1
Example of a five-site system with traffic demand



Establishing the physical connectivity

After the traffic demands are established, you can place wavelength division multiplexing (WDM) shelves to suit these traffic demands. In the example, site A may require three shelves, while site B requires four, and so on. Thus, the logical connectivity of the system is established, while the physical connectivity is also known and understood. The key aspects of the physical connectivity are:

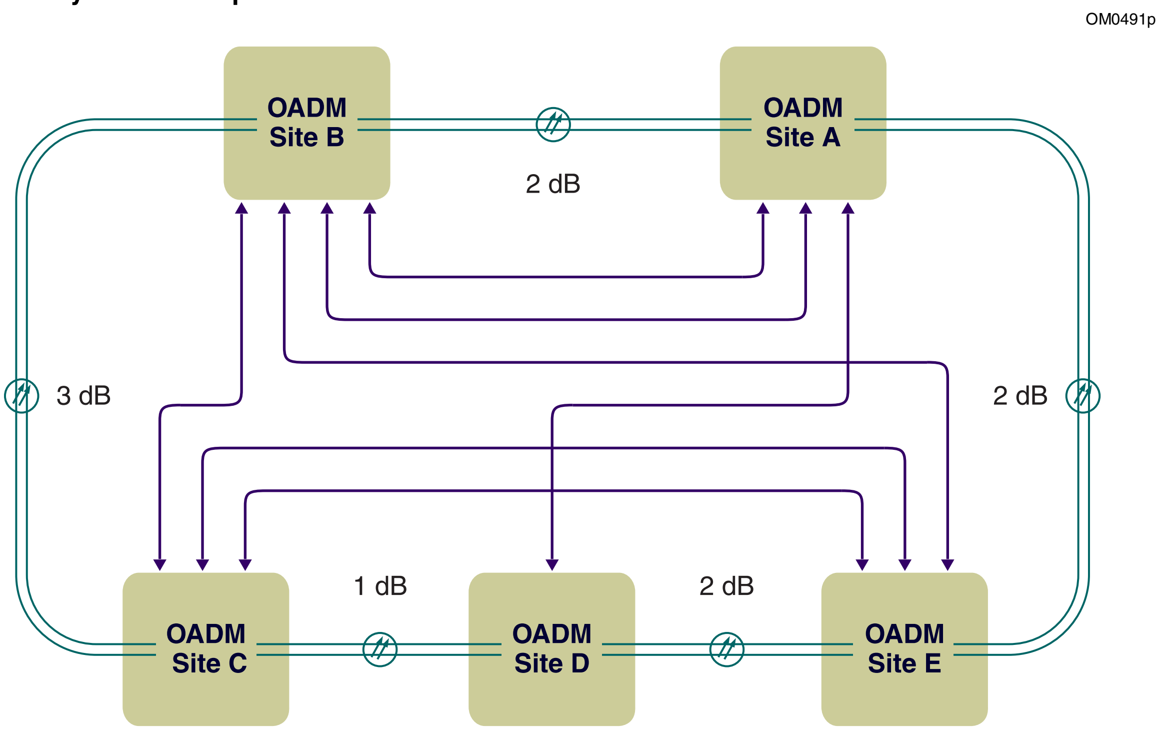
- optical fiber spans (length of optical fiber, type, losses, margins for repair, and fiber management system (FMS))
- site locations, names, available space, power

You associate a single channel from site to site with an Optical Metro 5100/5200 shelf at each site. You can have up to four protected channels or eight unprotected channels. The example in Figure 9-1 would require seven wavelength bands and 14 shelves. This assumption is not always true because the total network cost often depends on whether or not an entire band is assigned to deliver a single channel. Based on this method, you can note the following:

- This system is a seven-band, five-site system.
- There are 14 WDM shelves required.
- There is no terminal site, because there is no site with all bands.
- Therefore, all sites are OADM sites.

Figure 9-2 shows the physical information for each span.

Figure 9-2
Five-site system with optical fiber losses



In this network, five sites are named A through E, and the optical fiber span losses are shown (including FMS and margin).

You can now place the shelves to satisfy the traffic demands, and allocate the bands.

Allocating the bands

Bands can be arbitrarily allocated to any terminal and OADM shelf; however, each wavelength band can be used only once for an OADM and terminal shelf pair in a ring, hub and spoke, or point-to-point system. In some cases, a wavelength can be used more than once when unprotected connections are provisioned in meshed-ring and linear OADM configurations.

Worksheet

Copy and complete Table 9-1 to allocate the bands and channels for your network.

Table 9-1
Band and channel allocation worksheet

Site	Signal type		Number of		Band assignment	Channel assignment
	SONET	GE	Shelves	Bands		

Examples

Figure 9-3 shows an example of how bands can be allocated in a two-shelf, meshed-ring configuration. The figure shows the logical connections between the shelves. The number in each icon represents the wavelength band.

Figure 9-3
Allocation of bands—meshed-ring configuration

OM0036t

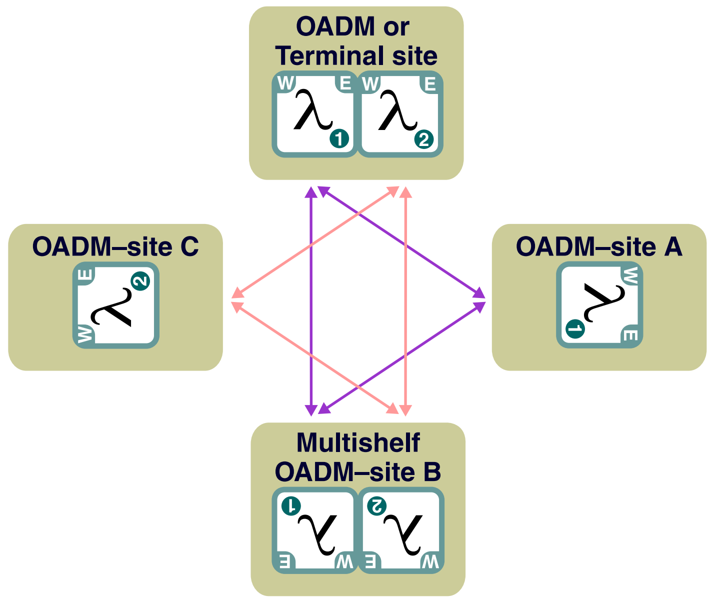


Figure 9-4 shows an example of how bands are allocated in a three-shelf, hubbed-ring configuration. The figure shows the logical connections between the shelves. The number in each icon represents the wavelength band.

Figure 9-4
Allocation of bands—hubbed-ring configuration

OM0024t

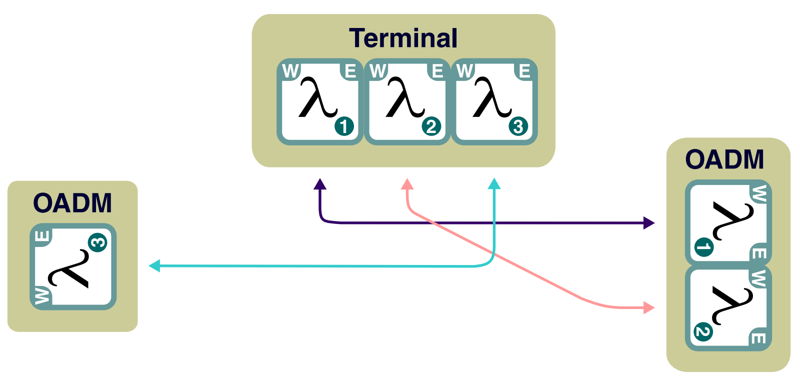


Figure 9-5 shows an example of how bands are allocated in a three-shelf, point-to-point configuration. The figure shows the logical connections between the shelves. The number in each icon represents the wavelength band.

Figure 9-5
Allocation of bands—point-to-point configuration

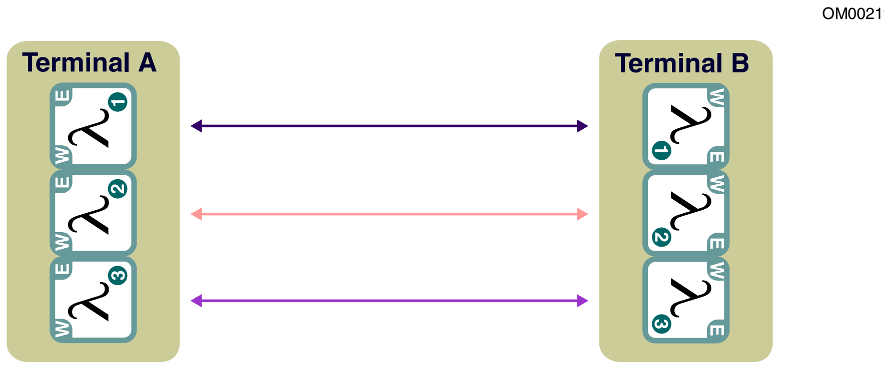


Figure 9-6 shows an example of how bands are allocated in a two-shelf linear OADM configuration. The figure shows the logical connections between the shelves. The number in each icon represents the wavelength band.

Figure 9-6
Allocation of bands—linear OADM configuration

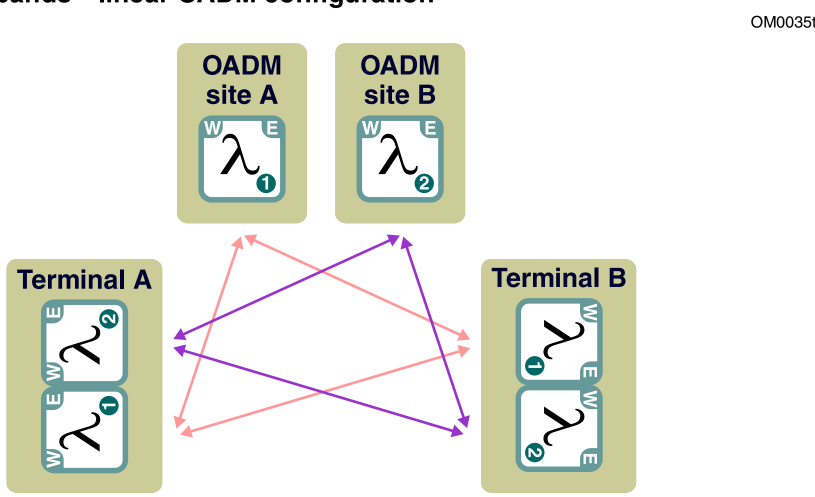
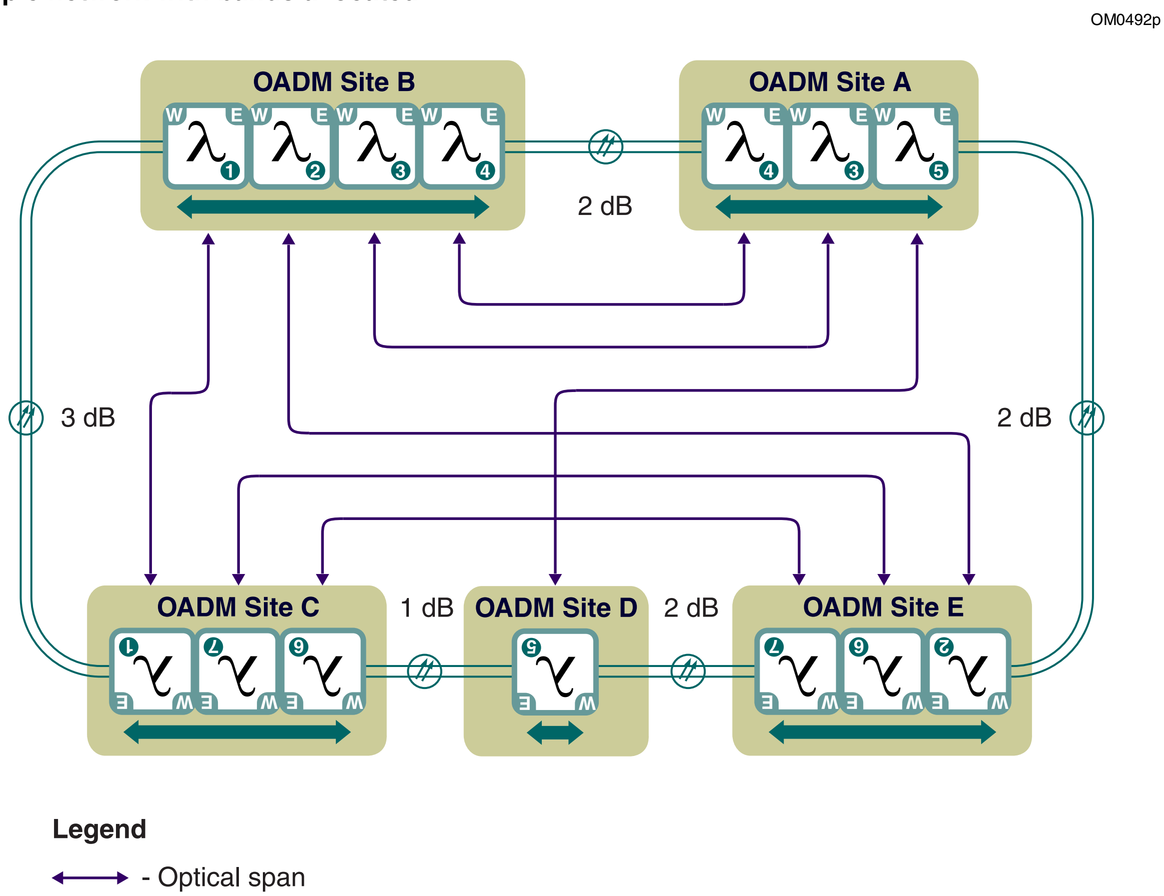


Figure 9-7 shows a basic system diagram with losses, once you have allocated the bands in the example network.

Figure 9-7
Sample network with bands allocated



Remodeling a network plan for optimal link budgets

If the link budgets in a network are marginally low, you may be able to improve the link budgets enough to avoid the use of amplifiers.

There are two remodeling options for improving link budgets without amplifiers:

- reordering bands
- using parallel site configurations

Estimating total system losses

Before you start modeling a network in detail, you may be able to determine whether or not the network will require amplification. Do this by making a quick estimate of total system losses. In the network shown in Figure 9-7 on page 9-7, the total ring loss is 10 dB for optical fiber loss, as well as approximately 19.6 dB for OMX losses (14 shelves x approximately 1.4 dB OMX loss per shelf), which is approximately 30 dB in total losses.

This network may require amplification. You can concentrate on remodeling the network to optimize link budgets, and possibly avoid the need for amplifiers.

Reordering bands in Optical Metro 5100 and Optical Metro 5200 networks

By changing the ordering of bands in sites, you can change the number of OMX filters that signals pass through. If one or two signals are marginally low, you may be able to change the ordering of bands to improve the link budgets for those signals. You must, however, ensure that all affected signals maintain sufficient link budgets.

> ***Note:*** The band order for networks using intrasite fault sectionalization (IFS) is fixed, and cannot be changed.

Using parallel site configurations in Optical Metro 5200 networks

In Optical Metro 5200 networks, depending on the number of shelves present in a site, it may make sense to fiber all C-band and L-band WDM shelves in sequence (serial configuration), or it may be advantageous to separate the C-band and L-band WDM shelves (parallel configuration). The determining factor for the advantages of serial or parallel configurations is the amount of OMX filter losses versus the amount of loss due to the splitter and the coupler.

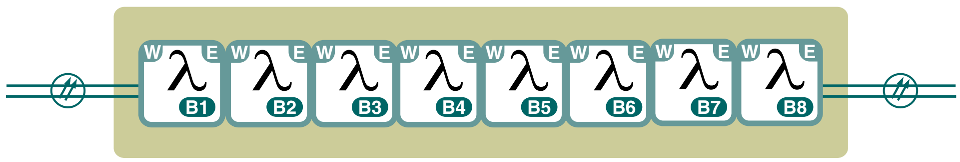
If you have a site with few shelves, the OMX filter losses are most likely not significant and a serial configuration would be appropriate.

If you have bands that experience significant power loss from passing through numerous shelves at a site, a parallel configuration at that site may be advantageous. You must weigh any advantages gained from avoiding OMX filter losses against the losses associated with the C&L splitter/coupler.

Serial configuration
For a serial site configuration, all C-band and L-band WDM shelves are fibered in sequence. Figure 9-8 shows a site with a serial configuration. In this example, band 1, when added in the west-bound direction, would pass through the OMX filters of bands 2 through band 8 before travelling to downstream sites. Similarly, band 8, when dropped from the west-bound direction, would pass through the OMX filters of bands 1 through band 7 before being dropped from the network.

Figure 9-8
Unamplified serial site

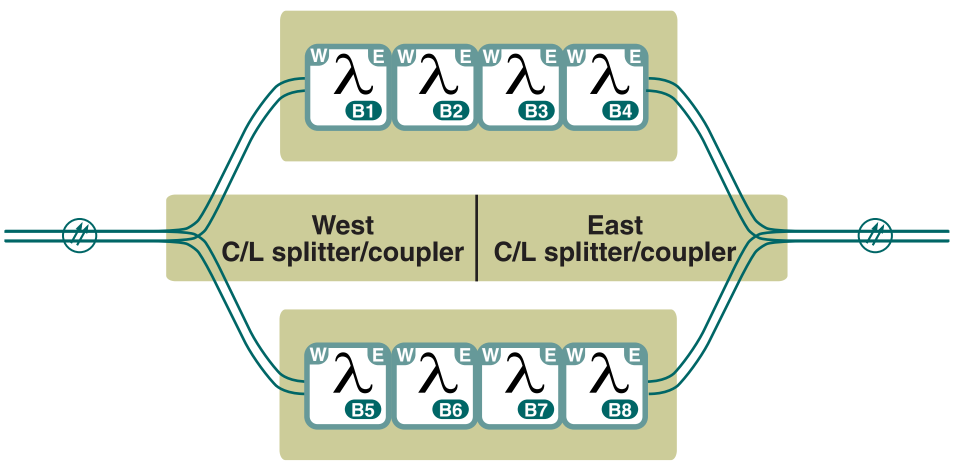
OM0520p



Parallel configuration
In Optical Metro 5200 networks, you can use C/L splitters and C/L couplers to separate and recombine the C-band and L-band shelves in a site. Figure 9-9 shows a site with a parallel configuration. In this example, band 1, when added in the west-bound direction, would pass through the OMX filters of bands 2 through band 4 before travelling to downstream sites. Similarly, band 8, when dropped from the west-bound direction, would pass through the OMX filters of bands 5 through band 7 before being dropped from the network. Although the OMX losses would be less than in a serial site, the C&L splitter/couplers would introduce additional losses for each signal.

Figure 9-9
Unamplified parallel site

OM1041p



Example of reordering bands for optimal link budgets

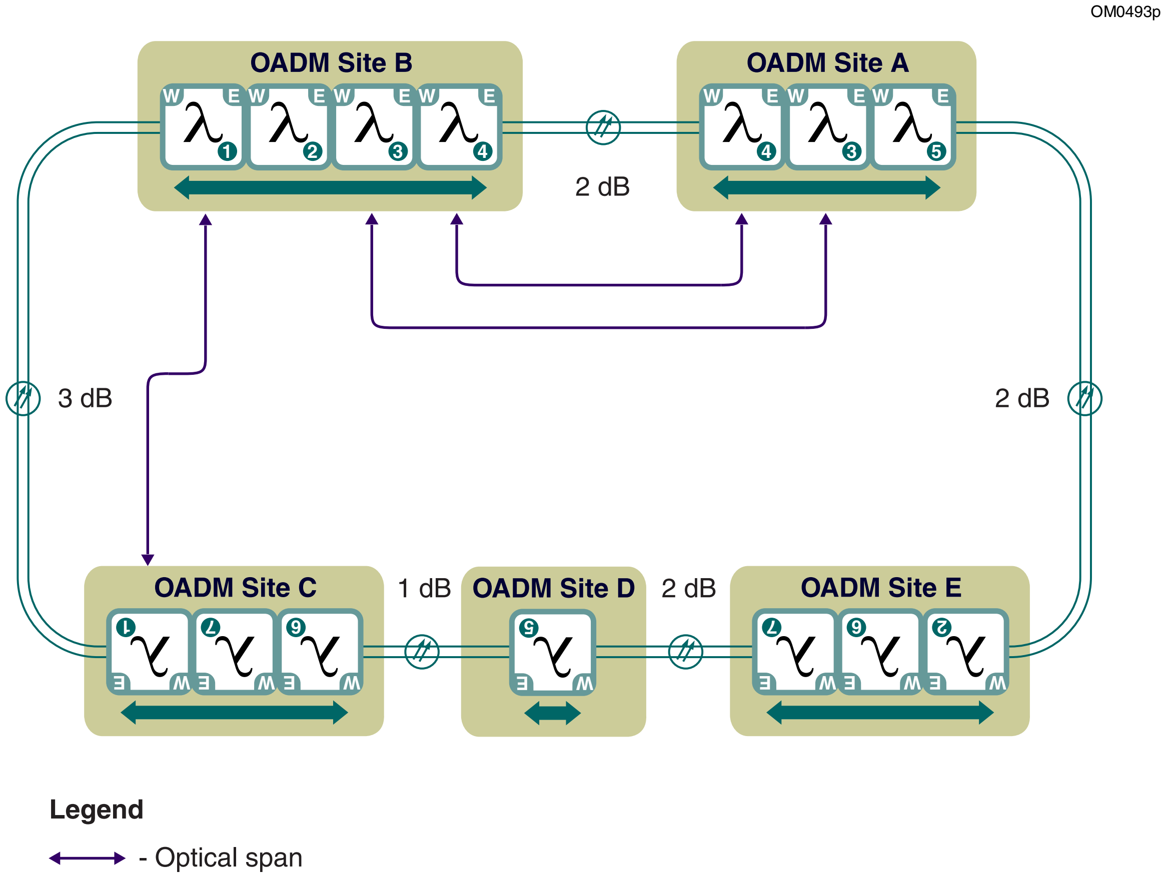
This example describes how to reorder bands to achieve optimal link budgets. By reordering bands, you may be able to lower the OMX losses for some optical spans.

Use the sample network from the previous section (see Figure 9-7 on page 9-7), and assume the following:

- Sites A, B, C, and E have standard OMX fibering.
- Site D, with only one shelf, has single-shelf OMX fibering.
- All OCLDs are the same type in this network (1.25 Gbit).
- The optical fiber is NDSF.
- The distance between all sites is less than 10 km.
- You require a span margin of 4.5 dB.
- This DWDM network uses standard OMXs.

To begin modeling the example network, look in detail at the optical spans that seem to be the most problematic. Bands 1, 3, and 4 have the worst-case optical spans (see Figure 9-10).

Figure 9-10
Worst-case optical spans



With the shelf ordering as illustrated, these spans have the least margin because they have the greatest total loss (greatest optical fiber loss plus the highest number of shelves to pass through).

Before you calculate optical spans, note that, because this system is unamplified, the eastbound spans and westbound spans are symmetrical. In this case, you do not need to repeat the optical span calculation.

In band 1, the source is Site B and the destination is site C: the worst optical span for band 1 traverses Sites A, E, and D. The source for bands 3 and 4 is site A and the destination is Site B: the worst optical span for band 3 and 4 traverses Sites C, D, and E.

The worst optical spans for bands 1, 3 and 4 include:

- 1 single-shelf OADM site
- 6 shelves in multishelf OADM sites
- 5 colocated shelves in the source and destination sites

Based on the example, Table 9-2 lists the optical span calculations for bands 1, 3, and 4.

Table 9-2
Optical span calculations for bands 1, 3, and 4

	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D)**	**Power at OCLD Rx (B-E)**	**Margin (F-A)**
1	–24.5 dBm	0.5 dBm	19.4 dB	7 dB	26.4 dB	–25.9 dBm	–1.4 dB
3	–24.5 dBm	0.5 dBm	18.0 dB	8 dB	26.0 dB	–25.5 dBm	–1.0 dB
4	–24.5 dBm	0.5 dBm	19.4 dB	8 dB	25.4 dB	–24.9 dBm	–0.4 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

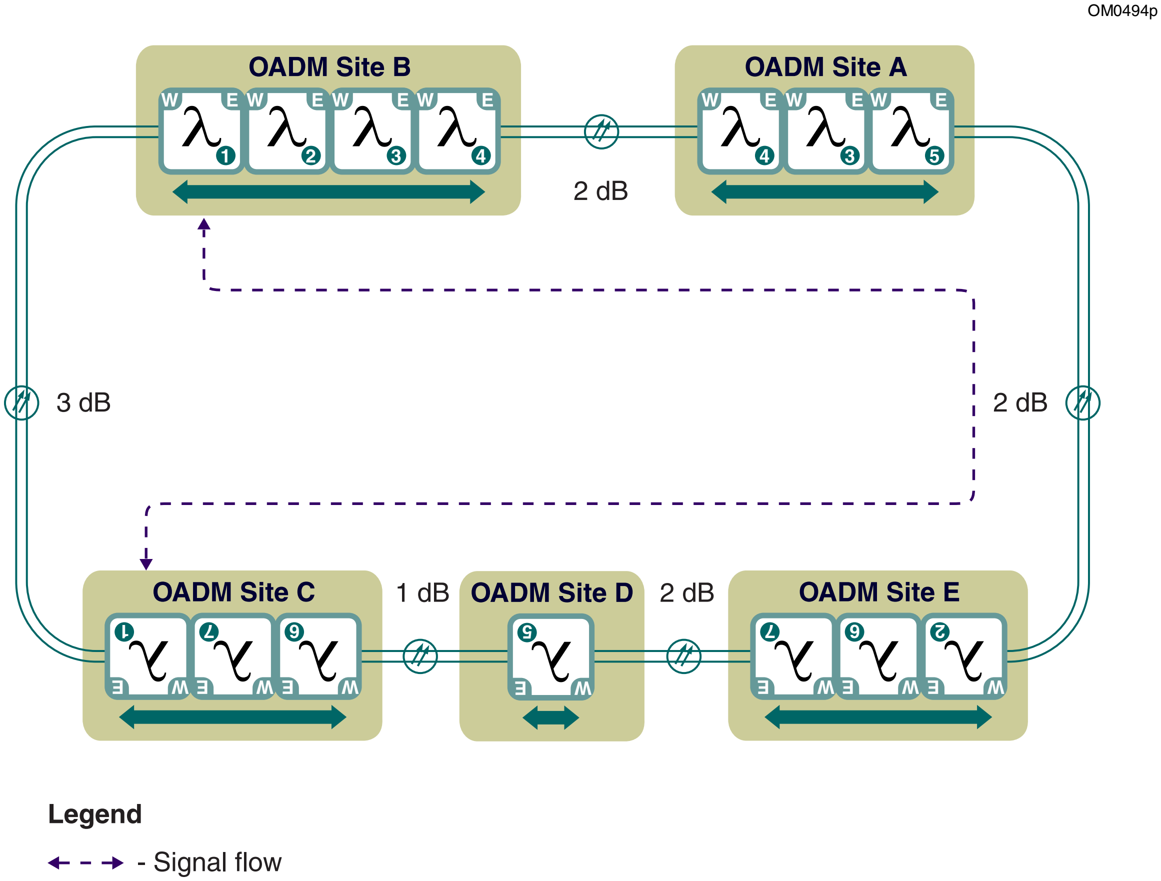
Note 2: For detailed information on calculating OMX losses, see the section Performing fixed value link engineering for CWDM or DWDM networks in the chapter "Basic fixed value link engineering".

By focusing on the worst case optical spans and noting the symmetry between eastbound and westbound spans, only three calculations are needed. These calculations indicate negative margin, so it is necessary to improve these margins before proceeding.

Since you have negative margin, you must resolve this by remodeling the sites to lessen OMX losses to improve margin, or you must resort to amplification. In fact, in this case, you can reorder the shelves in these sites to optimize the network and then recalculate the margin to see if it is positive.

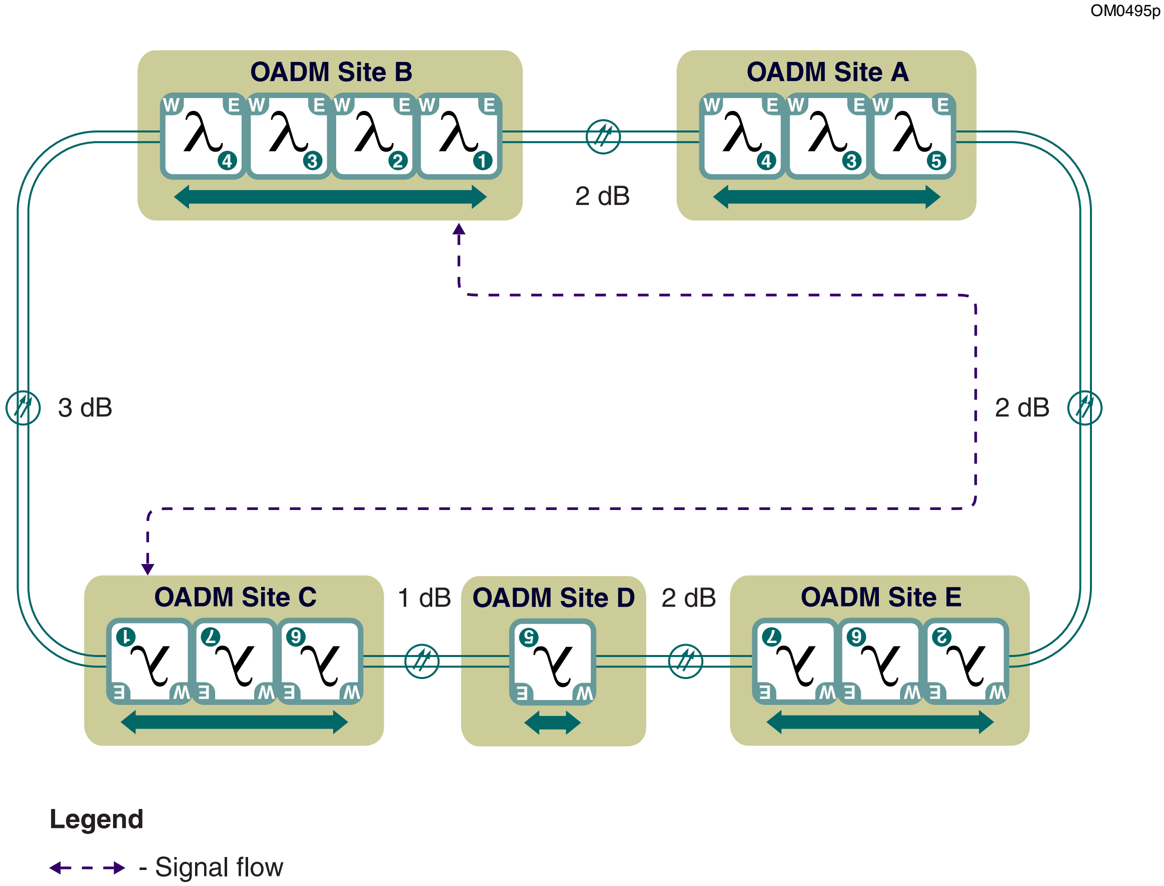
Begin with band 1. The signal flow for the worst case span originates from Site B, traverses Sites A, E, and D, and terminates at Site C (see Figure 9-11).

Figure 9-11
Signal flow for band 1 before reordering bands



Reorder Site B to allow for less loss at Site B, which may resolve the margin issue on band 1. Figure 9-12 shows the new signal flow for band 1.

Figure 9-12
Signal flow for band 1 after reordering bands



Now recalculate the losses for band 1 (see Table 9-3).

Table 9-3
Optical span calculations for band 1

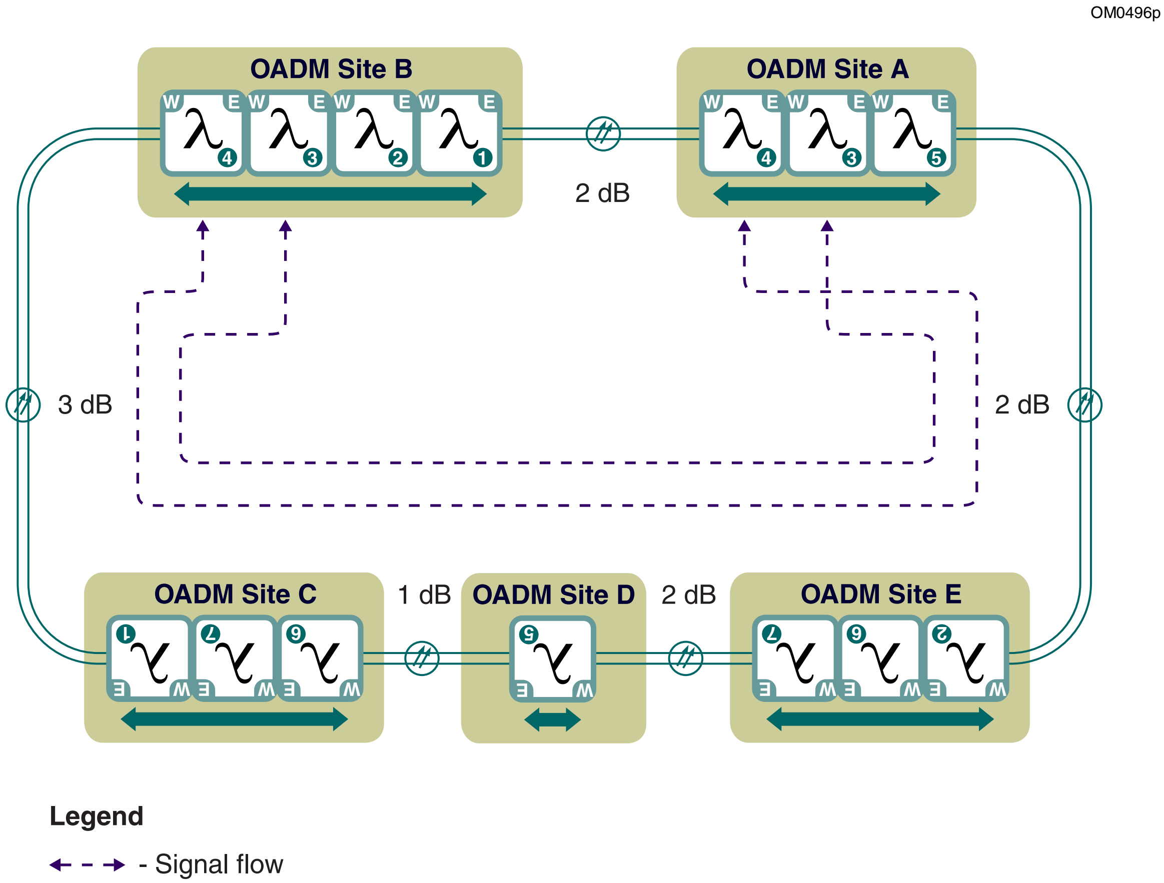
	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D)**	**Power at OCLD Rx (B-E)**	**Margin (F-A)**
1	–24.5 dBm	0.5 dBm	17.3 dB	7 dB	24.3 dB	–23.8 dBm	0.7 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section Performing fixed value link engineering for CWDM or DWDM networks in the chapter "Basic fixed value link engineering".

When you reordered Site B for band 1, you also improved the spans for bands 3 and 4. Before you recalculate bands 3 and 4, you can further reorder the bands for optimized link budgets. Figure 9-13 shows the signal flow for bands 3 and 4 after the changes to Site B.

Figure 9-13
Signal flow for bands 3 and 4 before reordering bands



To further reduce OMX losses for bands 3 and 4, you can reorder the bands in Site A. Figure 9-14 shows the signal flow for bands 3 and 4 after the changes to Site A.

Figure 9-14
Signal flow for bands 3 and 4 after reordering bands

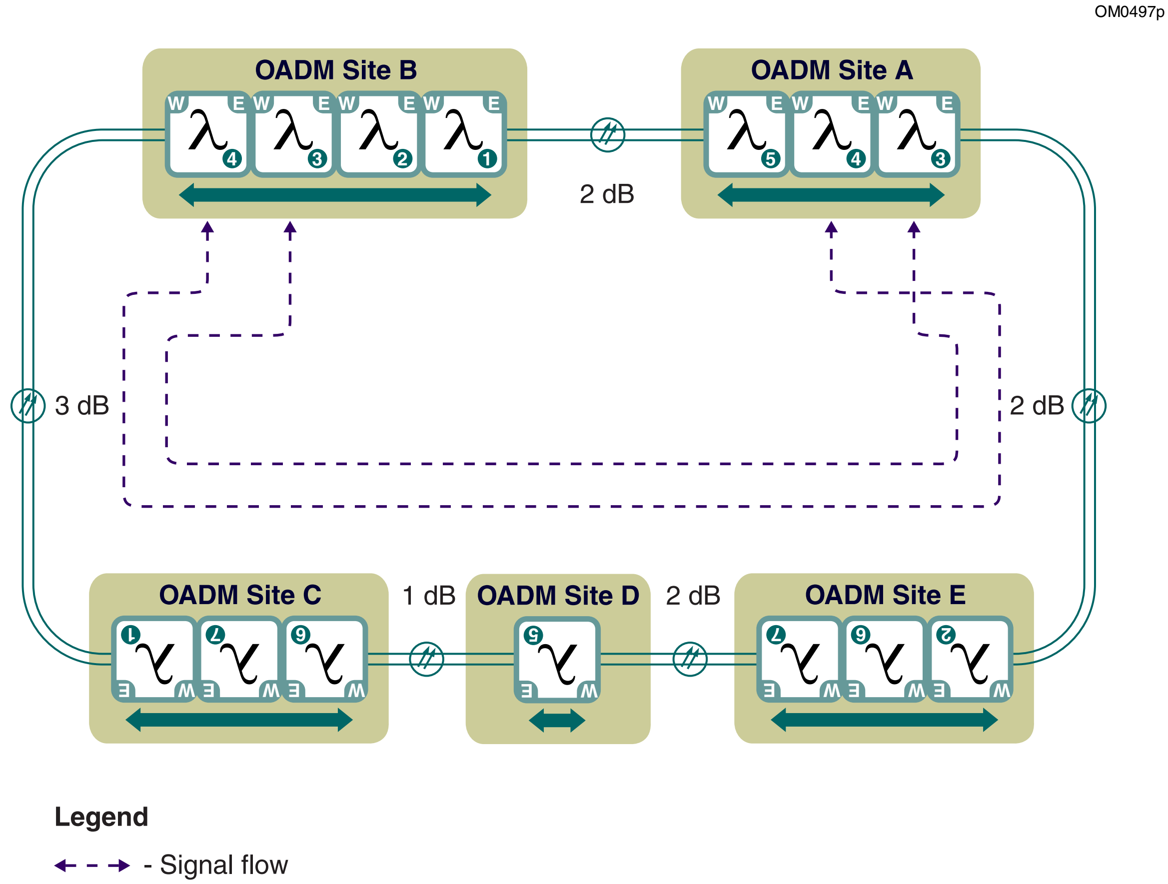


Table 9-4 lists the new calculations for bands 3 and 4.

Table 9-4
Optical span calculations for bands 3 and 4

	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D)**	**Power at OCLD Rx (B-E)**	**Margin (F-A)**
3	–24.5 dBm	0.5 dBm	16.6 dB	8 dB	24.6 dB	–24.1 dBm	0.4 dB
4	–24.5 dBm	0.5 dBm	16.6 dB	8 dB	24.6 dB	–24.1 dBm	0.4 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section Performing fixed value link engineering for CWDM or DWDM networks in the chapter “Basic fixed value link engineering”.

You have resolved the margin issue on bands 1, 3 and 4. Notice that Sites C and E are not positioned optimally for bands 6 and 7 because at both sites band 7 must pass through band 6 to exit the site on the long span. Now compute the remaining spans to find any remaining problems (see Table 9-5). Choose the long span for each band for this calculation:

- band 2 traverses Sites B, C, D, and E
- band 5 traverses Sites A, B, C, and D
- band 6 traverses Sites C, B, A, and E
- band 7 traverses Sites E, A, B, and C

Table 9-5
Optical span calculations for bands 2, 5, 6, and 7

	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D)**	**Power at OCLD Rx (B-E)**	**Margin (F-A)**
2	–24.5 dBm	0.5 dBm	14.5 dB	6 dB	20.5 dB	–20.0 dBm	4.5 dB
5	–24.5 dBm	0.5 dBm	16.1 dB	6 dB	22.1 dB	–21.6 dBm	2.9 dB

Table 9-5 (continued)
Optical span calculations for bands 2, 5, 6, and 7

	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D)**	**Power at OCLD Rx (B-E)**	**Margin (F-A)**
6	–24.5 dBm	0.5 dBm	18.2 dB	7 dB	25.2 dB	–24.7 dBm	–0.2 dB
7	–24.5 dBm	0.5 dBm	18.2 dB	7 dB	25.2 dB	–24.7 dBm	–0.2 dB

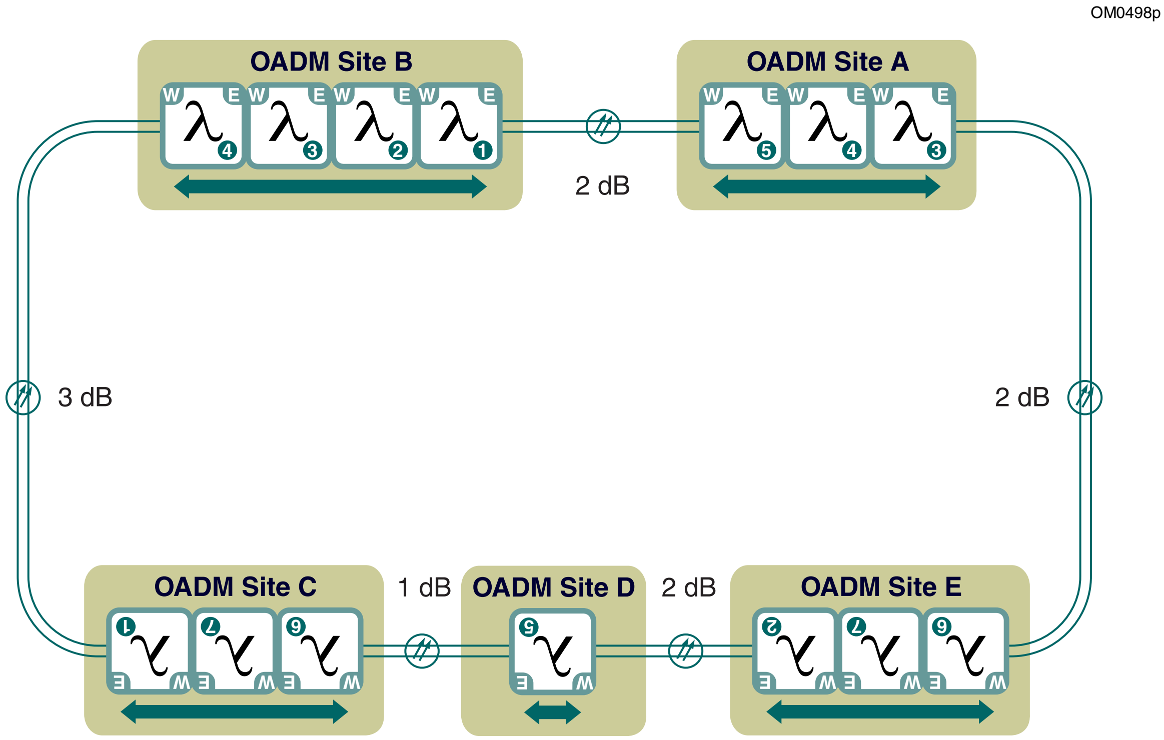
Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section “Performing fixed value link engineering for CWDM or DWDM networks” in the chapter “Basic fixed value link engineering”.

Bands 6 and 7 have slightly negative margin, and you must attempt to remodel the sites again. You can reorder Site E to optimize bands 6 and 7.

If, while remodeling to optimize bands 6 and 7, you change the link budgets for the other spans, you must recalculate all spans. In this case, where you have reordered Site E only, spans 2, 6, and 7 are the only affected bands, so you need to recalculate only those spans. Figure 9-15 shows the remodeled network.

Figure 9-15
Remodeled site



Based on the latest reordered bands, Table 9-6 lists the new calculations for bands 2, 6, and 7.

Table 9-6
Optical span calculations for bands 2, 6, and 7

	A	B	C	D	E	F	G
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**Total fiber losses**	**Total losses (C+D+E)**	**Power at OCLD Rx (B-F)**	**Margin (G-A)**
2	–24.5 dBm	0.5 dBm	13.1 dB	6 dB	19.1 dB	–18.6 dBm	5.9 dB
6	–24.5 dBm	0.5 dBm	17.5 dB	7 dB	24.5 dB	–24.0 dBm	0.5 dB
7	–24.5 dBm	0.5 dBm	17.5 dB	7 dB	24.5 dB	–24.0 dBm	0.5 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section "Performing fixed value link engineering for CWDM or DWDM networks" in the chapter "Basic fixed value link engineering".

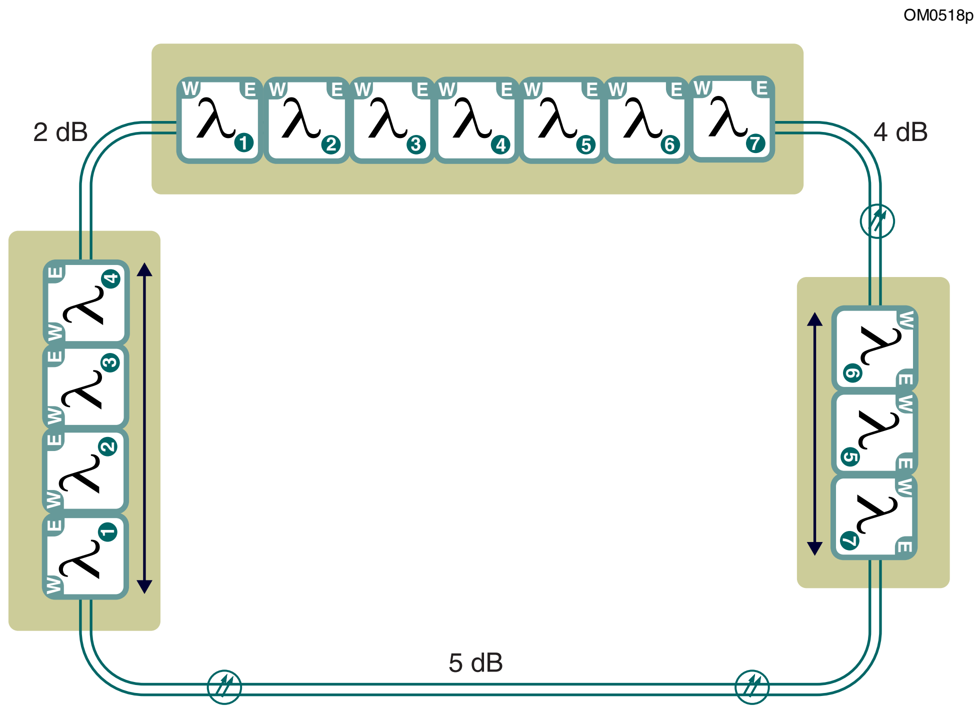
You improved the margins for all three bands, and the end result is a network with positive margins for all bands. No amplification is required.

Example of reconfiguring serial and parallel sites for optimal link budgets

Another way of obtaining optimal link budgets in Optical Metro 5200 networks is to reconfigure shelves at OADM and terminal sites using C&L splitter/couplers to split and recombine C-band and L-band signals. By reconfiguring shelves, you may be able to lower the OMX losses for some optical spans.

For this example, you have a network with one terminal site and two OADM sites, with optical fiber losses as shown in Figure 9-16.

Figure 9-16
Three-site network



For this example, assume the following:

- The terminal site has standard OMX fibering.
- Both OADM sites have standard OMX fibering.
- All OCLDs are the same type in this network (1.25 Gbit).
- The fiber is NDSF.
- The distance between all sites is less than 10 km.
- You require a span margin of 6.4 dB.
- This DWDM network uses standard OMXs.

First, calculate the losses for all the worst-case optical spans. In this case, the worst-case optical span for bands 1, 2, 3, and 4 is the eastbound span, and the worst-case optical span for bands 4, 5, 6, and 7 is the westbound span. Table 9-7 lists the total losses for all worst-case spans.

Table 9-7
Optical span calculations for all bands

	A	B	C	D	E	F	G	H
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**C/L s/c losses**	**Total fiber losses**	**Total losses (C+D+E)**	**Power at OCLD Rx (B-F)**	**Margin (G-A)**
1	–22.6 dBm	0.5 dBm	14.7 dB	N/A	9 dB	23.9 dB	–23.4 dBm	–1.3 dB
2	–22.6 dBm	0.5 dBm	14.7 dB	N/A	9 dB	23.9 dB	–23.4 dBm	–1.3 dB
3	–22.6 dBm	0.5 dBm	14.7 dB	N/A	9 dB	23.9 dB	–23.4 dBm	–1.3 dB
4	–22.6 dBm	0.5 dBm	14.7 dB	N/A	9 dB	23.9 dB	–23.4 dBm	–1.3 dB
5	–22.6 dBm	0.5 dBm	15.4 dB	N/A	7 dB	22.4 dB	–21.9 dBm	0.7 dB
6	–22.6 dBm	0.5 dBm	16.8 dB	N/A	7 dB	23.8 dB	–23.3 dBm	–0.7 dB
7	–22.6 dBm	0.5 dBm	16.1 dB	N/A	7 dB	23.1 dB	–22.6 dBm	0 dB

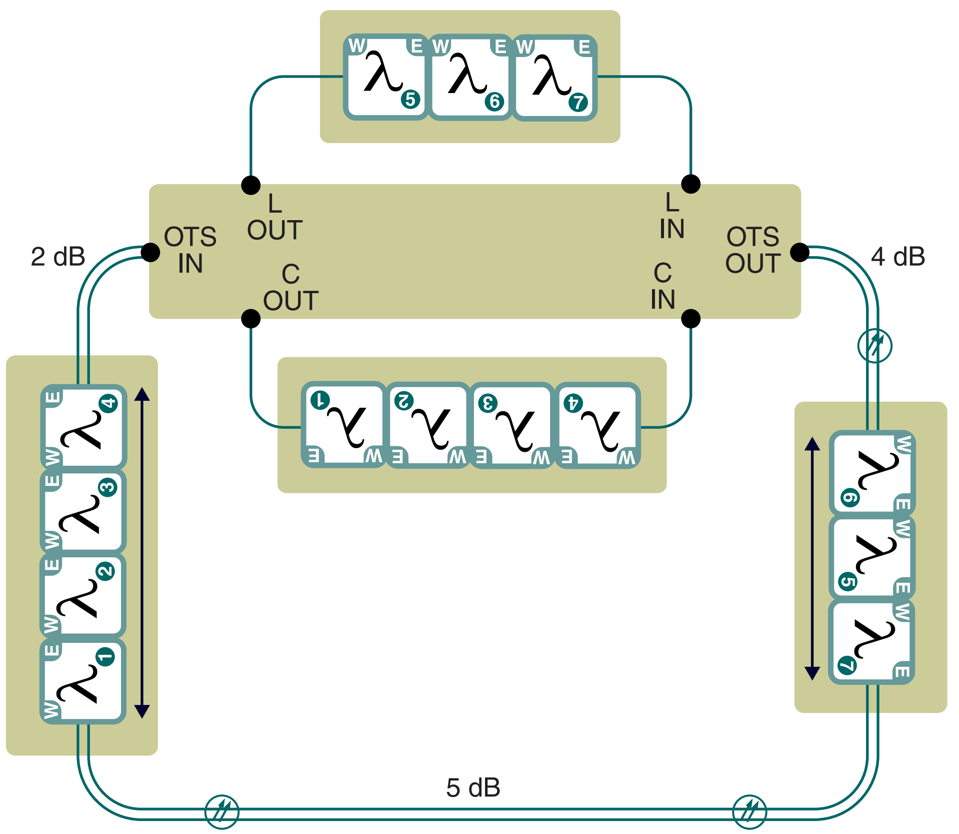
Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section “Performing fixed value link engineering for CWDM or DWDM networks” in the chapter “Basic fixed value link engineering”.

The calculations show that the margins for bands 1, 2, 3, 4, and 6 are negative. Band 7, although not negative, could use some improvement. If you introduce a C/L splitter/coupler at the terminal site, you can lower the number of colocated shelves that each band must traverse before being added to, or dropped from, the ring.

Figure 9-17 on page 9-24 shows the new configuration with a C&L splitter/coupler installed for eastbound traffic. For demonstration purposes, this graphic shows only one splitter/coupler for eastbound traffic. Two splitter/couplers are required to reconfigure a site for both eastbound and westbound traffic.

Figure 9-17
Reconfigured terminal site



Recalculate the eastbound spans for bands 1, 2, 3, and 4 originating from the terminal site. For these calculations, you must account for the losses associated with the splitter/coupler (see in the chapter "Link engineering components"). Using the typical loss values for this example, Table 9-8 lists the new calculations.

Table 9-8
Optical span calculations for bands 1, 2, 3, and 4

	A	B	C	D	E	F	G	H
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**C&L s/c losses**	**Total fiber losses**	**Total losses (C+D+E)**	**Power at OCLD Rx (B-F)**	**Margin (G-A)**
1	–22.6 dBm	0.5 dBm	12.6 dB	1.4 dB	9 dB	23.0 dB	–22.5 dBm	0.1 dB
2	–22.6 dBm	0.5 dBm	12.6 dB	1.4 dB	9 dB	23.0 dB	–22.5 dBm	0.1 dB

Table 9-8 (continued)
Optical span calculations for bands 1, 2, 3, and 4

	A	B	C	D	E	F	G	H
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**C&L s/c losses**	**Total fiber losses**	**Total losses (C+D+E)**	**Power at OCLD Rx (B-F)**	**Margin (G-A)**
3	–22.6 dBm	0.5 dBm	12.6 dB	1.4 dB	9 dB	23.0 dB	–22.5 dBm	0.1 dB
4	–22.6 dBm	0.5 dBm	12.6 dB	1.4 dB	9 dB	23.0 dB	–22.5 dBm	0.1 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section "Performing fixed value link engineering for CWDM or DWDM networks" in the chapter "Basic fixed value link engineering".

You have improved the link budgets for bands 1, 2, 3, and 4 and you now have positive margins. Now recalculate the west-bound spans for bands 5, 6, and 7 originating from the terminal site. As before, for these calculations you must account for the losses associated with the splitter/coupler (see the chapter "Link engineering components"). Using the typical loss values for this example, Table 9-9 lists the new calculations.

Table 9-9
Optical span calculations for bands 5, 6, and 7

	A	B	C	D	E	F	G	H
Optical span	**OCLD Rx sensitivity** (see Note 1)	**OCLD transmit power**	**OMX losses** (see Note 2)	**C&L s/c losses**	**Total fiber losses**	**Total losses (C+D+E)**	**Power at OCLD Rx (B-F)**	**Margin (G-A)**
5	–22.6 dBm	0.5 dBm	12.6 dB	1.1 dB	7 dB	20.7 dB	–20.2 dBm	2.4 dB
6	–22.6 dBm	0.5 dBm	14.0 dB	1.1 dB	7 dB	22.1 dB	–21.6 dBm	1.0 dB
7	–22.6 dBm	0.5 dBm	13.3 dB	1.1 dB	7 dB	21.4 dB	–20.9 dBm	1.7 dB

Note 1: To avoid alarms, use the Rx power low degrade threshold. In this example, there are only two shelves that involve O-E-O conversion, so jitter is not a concern. Because of short optical fiber spans, dispersion is not a concern. The Rx sensitivity has been derated for span margin.

Note 2: For detailed information on calculating OMX losses, see the section "Performing fixed value link engineering for CWDM or DWDM networks" in the chapter "Basic fixed value link engineering".

You have resolved all the margin issues for the worst-case spans. In this case, it would be prudent to reconfigure our terminal site using a parallel configuration. The benefit gained from less OMX loss outweighs the additional splitter/coupler loss for the spans in the example.

Note: This is a simplified example of the potential benefits of using splitter/couplers to split C-band and L-band signals for parallel site configuration. Care must be taken to ensure that the additional losses incurred from the splitter/coupler do not cause insufficient margin for otherwise acceptable optical spans. For example, you must ensure that any bands that pass through a parallel site can withstand the additional splitter/coupler losses incurred.

Data communications in the Optical Metro 5100/5200 network

In this chapter

Before you begin

Before you begin engineering data communications in the Optical Metro 5100/5200 network, you must:

- have a good understanding of IP addressing and IP networks
- have a good understanding of routing information protocols
- be familiar with the Optical Metro 5100/5200 architecture and optical layer. See the "System description" chapter in this book.

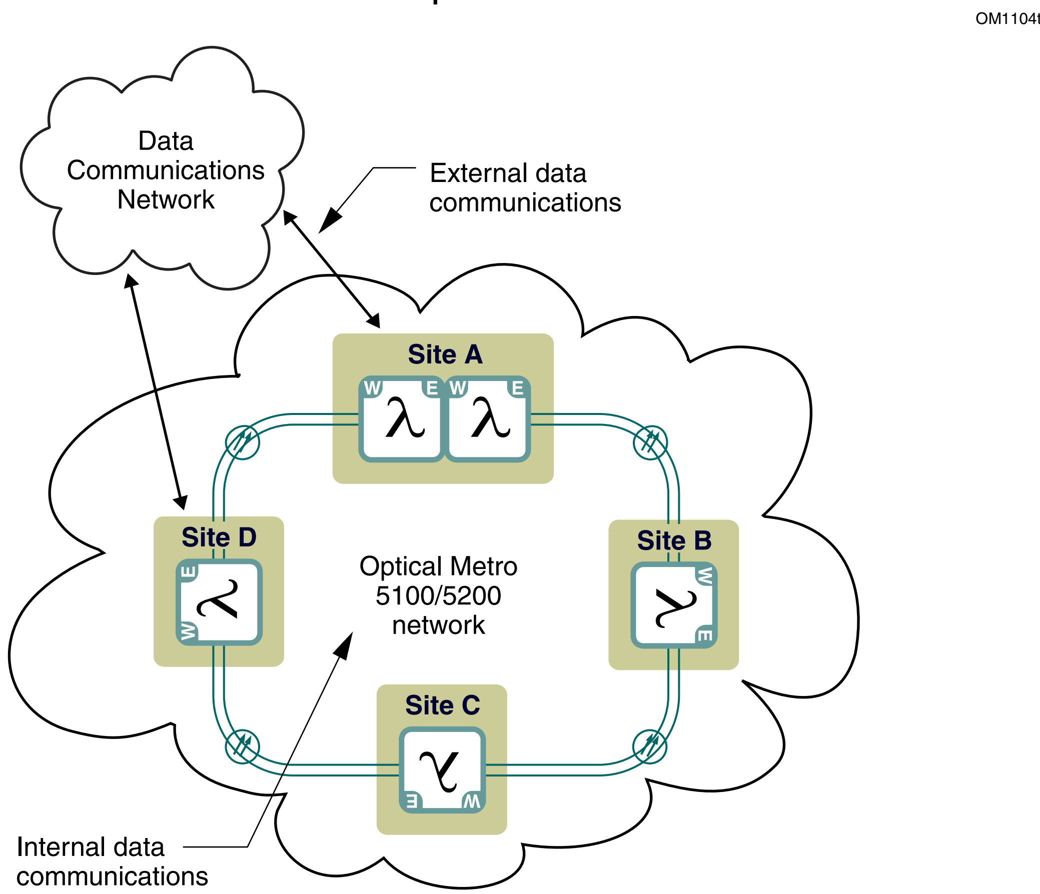
Data communications overview

The Optical Metro 5100/5200 platform supports a complete data communications overlay on the optical network. The data communications overlay is required for network surveillance and shelf management (operations, administration, maintenance, and provisioning [OAMP]) of the optical network from anywhere in the customer's data communications network (DCN).

This chapter provides an overview of the protocols supported both internally and externally on the Optical Metro 5100/5200 network and describes how they apply to the Optical Metro 5100/5200 network. This chapter also describes the data communications configurations and features supported by the Optical Metro 5100/5200 platform.

Figure 10-1 shows where the internal and external data communications occur in Optical Metro 5100/5200 network.

Figure 10-1
Data communications in the Optical Metro 5100/5200 network



Internal data communications

To have a managed Optical Metro 5100/5200 network, all the shelves need to intercommunicate. For internal data communications between shelves and sites in an Optical Metro 5100/5200 network, the following are used:

- data link layer
- IP layer
- routing protocols

Data link layer

Per-wavelength optical supervisory (PWOSC) channel

Each traffic wavelength on the Optical Metro 5100/5200 supports an overhead channel for bidirectional data communications. For communications between shelves in the same band at different sites, up to four bidirectional overhead channels per band (one per wavelength) are available to pass management information.

The overhead channel supports PPP (point-to-point protocol). The overhead channel originates at the OCLD, OTR or Muxponder circuit pack on one shelf and terminates on the OCLD, OTR or Muxponder circuit pack of a remote shelf.

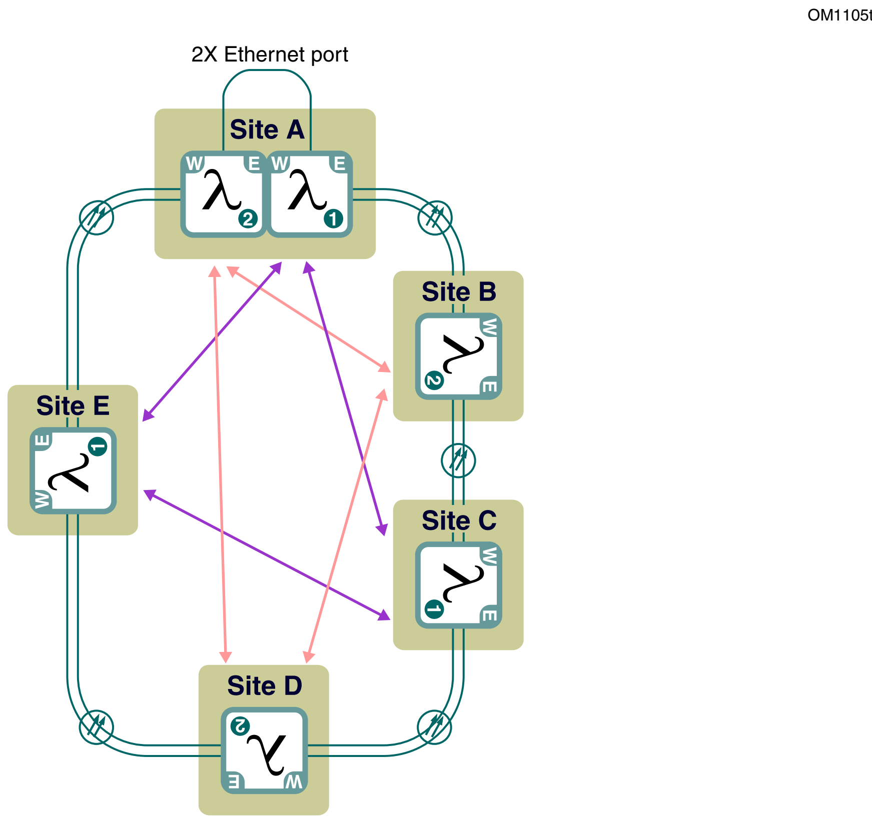
In Figure 10-2, the arrows represent the overhead channel between, for example, the OCLD circuit packs (band 2, channel 1) at Site A, Site B, and Site D. There is also an overhead channel between, for example, the OCLD circuit packs (band 1, channel 1) at Site A, Site C, and Site E.

> ***Note:*** If there are no OCLD, OTR or Muxponder circuit packs installed in the shelf, there is no overhead channel data communications to that shelf.

In some interoperable network applications, the PWOSC is not required and can cause the circuit pack to raise data communications related alarms (for example, Overhead Link Failure). The System Manager and TL1 interfaces can be used to disable PWOSC which will shutdown PPP (point-to-point protocol) and suppress any data communication alarms. By default, PWOSC is enabled.

> ***Note:*** It is strongly recommended that the PWOSC remain enabled in Optical Metro 5100/5200 networks, unless there is a clear understanding of the implications of having it disabled. Improper use of the PWOSC disabling feature can cause loss of communications between NEs and loss of contact, resulting in the inability to properly manage the network. Also, features like Remote Fault Notification, Fiber Mismatch alarming and Correct Alarm Severity for protected and passthrough channel assignments, which use the PWOSC, are no longer operational when PWOSC is disabled.

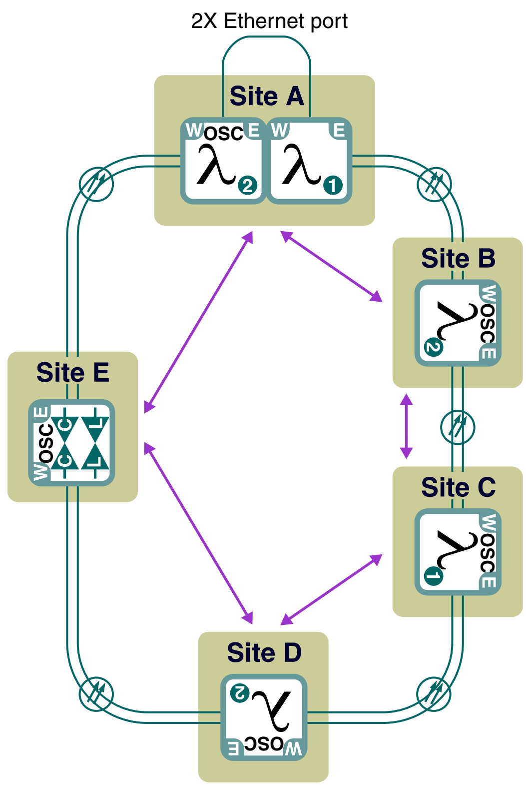
Figure 10-2
Example of overhead channel



Optical supervisory channel (OSC)
The OSC circuit pack implements an out-of-band wavelength (1510 nm) along with the bundled traffic wavelengths on the same fiber. When an OSC circuit pack is present at a site, it supports a 10 Mbit/s data communications channel to the adjacent site, including OFA sites.

If you install an OSC circuit pack in one shelf at every site in the Optical Metro 5100/5200 network, you have internal data communications to all sites in your network, see Figure 10-3.

Figure 10-3
Example of OSC data communications channel



The OSC circuit pack also provides a transparent communications channel to allow customers to carry their own management traffic from site to site on an Optical Metro 5100/5200 ring. This functionality, referred to as wayside channel (WSC), takes advantage of the unused bandwidth of the OSC. WSC is a communications channel within the OSC intended to carry customer Ethernet traffic.

> ***Note:*** The WSC does not interact with the Optical Metro 5100/5200 internal data communications.

For the WSC specifications, see the chapter “Circuit pack specifications” in *Technical Specifications*, 323-1701-180.

Ethernet

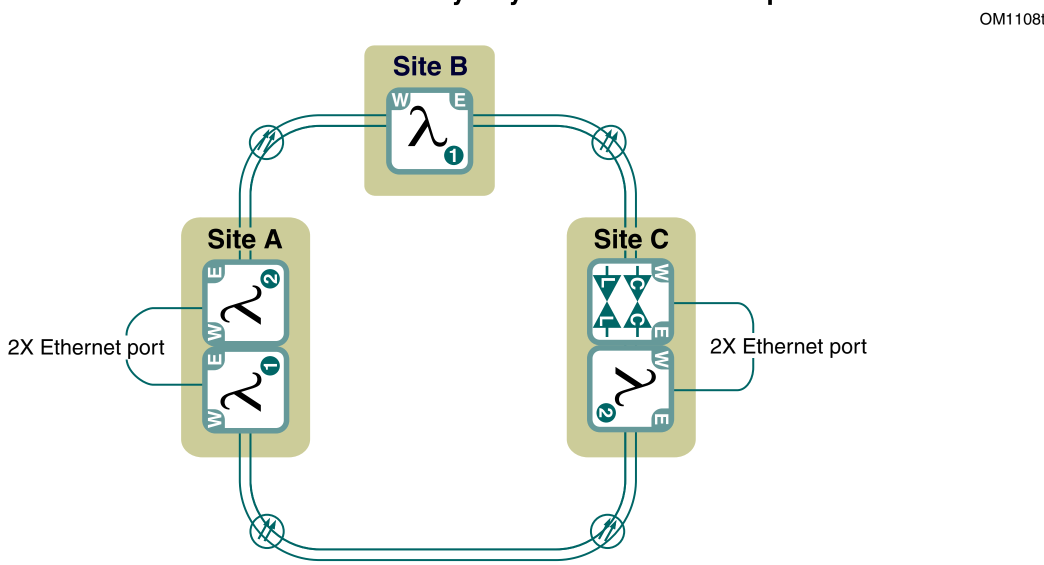
Each Optical Metro 5100/5200 shelf has an Ethernet port labeled 10Base-T 2X (referred to as the “2X Ethernet port” throughout this chapter). At sites with more than one shelf present, the 2X Ethernet port provides intershelf data communications between the colocated WDM or OFA shelves.

An Ethernet hub is required to hub the shelves together if there are more than two shelves at the site. If there are two shelves at the site, a cross-over Ethernet cable can be used to connect the shelves.

> ***Note:*** The overhead channel and OSC circuit pack do not support intershelf data communications between colocated shelves in different bands.

Figure 10-4 shows a Optical Metro 5100/5200 network with colocated shelves connected by way of the 2X Ethernet port.

Figure 10-4
Colocated shelves connected by way of the 2X Ethernet port



Ethernet Port 2 access control
The Ethernet port 2 access control feature can be used to protect intershelf communications by rejecting data received on the 2X Ethernet port that originated from an unauthorized source. The following modes are available:

- None—Use this mode to disable the feature. This is the default mode for new shelves.
- Filter—Use this mode to filter incoming packets. Incoming packets from Optical Metro 5100/5200 shelves are accepted and unrecognized packets are rejected. This mode is recommended for networks that use switches.
- Encrypt—Use this mode to encrypt outgoing packets and to reject incoming packets that are not encrypted. This mode is recommended for networks that use hubs.

You can set the Ethernet port 2 access control feature using System Manager or TL1. When you set this feature on one Optical Metro 5100/5200 shelf, all of the shelves in the hubbing group are automatically updated with the same feature settings.

IP layer

Internal IP addressing

To allow communications within the network to adhere to standard IP addressing principles, the Optical Metro 5100/5200 uses private IP address ranges 10.0.0.0 to 10.4.255.255 for internal communications (used for circuit packs, 2X Ethernet port, OSC).

You can manually change some of the Optical Metro 5100/5200 internal IP addresses. If you change one of the internal IP addresses, you can reuse that IP address elsewhere in the customer DCN.

Table 10-1 lists the IP addresses that are used for Optical Metro 5100/5200 communications. The system assigns these IP addresses during shelf commissioning and uses provisioned parameters to define these addresses.

Table 10-1
IP addresses used by Optical Metro 5100/5200

IP address	Details	User-assignable
10.0.0.x (x = 1 to 20)	Used for intrashelf communications	No, reserved
10.0.shelfID.x (x = 1 to 254)	Used for intershelf communications	No, reserved
10.1.254.1	Uncommissioned shelf address	No, reserved
10.1.shelfID.1 (see Note 2)	IP address for 1X Ethernet port	No, reserved
10.1.shelfID.2 (see Note 2)	DHCP address for 1X Ethernet port	No, reserved
10.2.hubbinggroup.(shelfID + 128)	DHCP address for 2X Ethernet port	Yes, Ethernet Port 2
10.2.hubbinggroup.shelfID	IP address for 2X Ethernet port	Yes, Ethernet Port 2
10.3.shelfID.1	DTE local	Yes, Serial port 1
10.3.shelfID.2	DTE remote	Yes, Serial port 1
10.4.shelfID.1	DCE local	Yes, Serial port 2 (see Note 3)
10.4.shelfID.2	DCE remote	Yes, Serial port 2 (see Note 3)

Note 1: You set the hubbing group (Ethernet hubbing group) and shelf ID when you run the shelf commissioning wizard.

Note 2: These addresses are only used by the Optical Metro 5100/5200 shelf when the shelf subnet mask is 255.255.255.255.

Note 3: Serial port 2 is not supported.

Routing protocols

OSPF

Optical Metro 5100/5200 uses open shortest path first (OSPF) as an interior gateway protocol (IGP) to route IP traffic between shelves within the Optical Metro 5100/5200 network.

OSPF determines the shortest path from any source IP address to any destination IP address in the Optical Metro 5100/5200 network using the data link layers (overhead channel, OSC, Ethernet).

OSPF allows the management communications from shelves within the Optical Metro 5100/5200 network to be forwarded to a local management terminal or to the gateway network element (GNE) that is connected to an external DCN.

> ***Note:*** The GNE (alternately known as the DCN gateway), is the Optical Metro 5100/5200 shelf that is designated as the communications gateway between the Optical Metro 5100/5200 network and the customer's DCN.

The Optical Metro 5100/5200 shelves communicate internally using OSPF, and therefore need to be configured as a non-backbone OSPF area. To allow communication between all shelves in the same OSPF area, you must assign the same internal OSPF area ID to all the shelves. The default for the internal OSPF area ID is 0.0.0.0. If you specify 0.0.0.0, the Optical Metro 5100/5200 network uses the primary shelf IP address as the OSPF area ID. If you specify a non-0.0.0.0 value then that value is used as the internal OSPF area ID.

> ***Note:*** It is recommended to set the internal OSPF area ID explicitly, in order to avoid routing disruption and possible loss of contact with some shelves in the event where the IP address of the primary node needs to be changed.
> If the IP address of the primary shelf needs to be changed and the internal OSPF area ID was set to the default value of 0.0.0.0, loss of contact may be avoided by explicitly setting the OSPF area ID of all shelves in the Optical Metro 5100/5200 network to the IP address of the primary shelf before the primary shelf IP address is changed.
> Refer to "Primary Node" on page 10-17.

External data communications (to DCN)

External data communications is needed to pass the OAM&P data from the System Manager or other management platform to the Optical Metro 5100/5200 network. For external data communications between Optical Metro 5100/5200 and the customer DCN, the following are used:

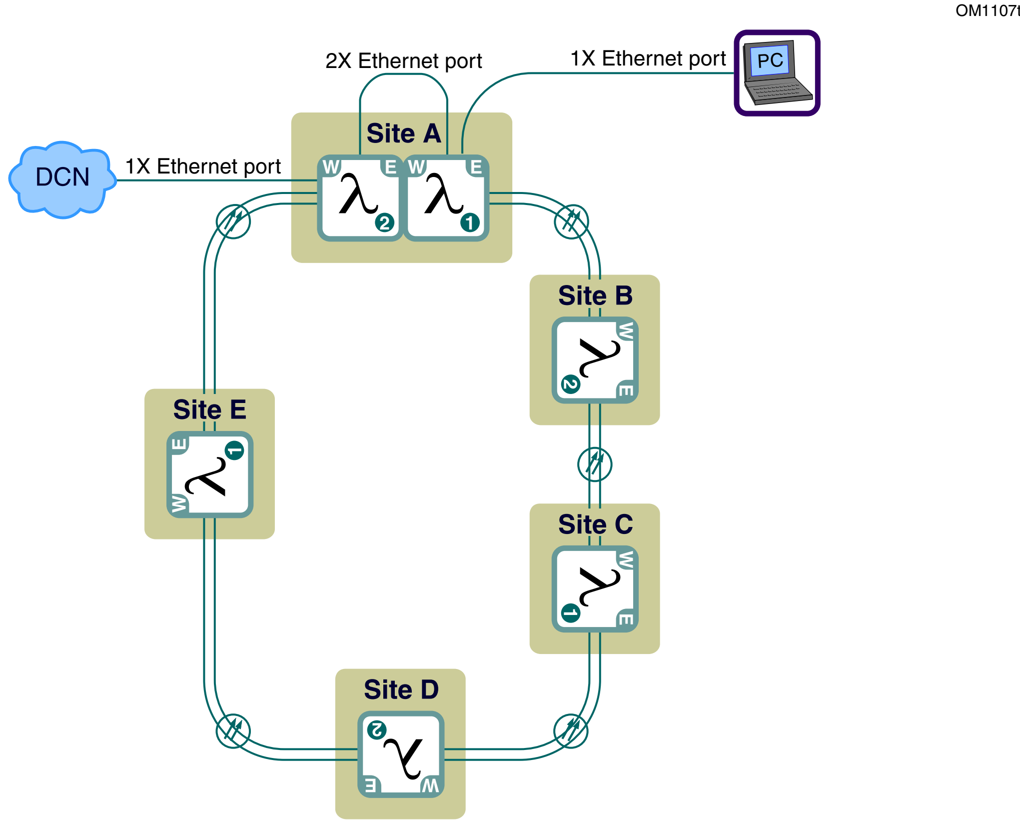
- data link layer
- IP layer
- routing protocols

Data link layer

Ethernet

An Optical Metro 5100/5200 shelf has an Ethernet port labeled 10Base-T 1X (referred to as the "1X Ethernet port" throughout this chapter). The 1X Ethernet port provides access to the DCN by way of a customer router. Alternately, you can connect a PC directly to the 1X Ethernet port to run System Manager. See Figure 10-5.

Figure 10-5
External data communications by way of the 1X Ethernet port



Serial/PPP

An Optical Metro 5100/5200 shelf has an RS-232 serial port that can be used for debugging and when remote access is required.

The RS-232 serial interface has a throughput that is limited to 38.4 kps. Therefore it is not recommended as a primary management link. With large systems and high alarm rates, throughput is slow and information may be lost.

IP layer

External IP addressing

The 1X Ethernet port on every Optical Metro 5100/5200 shelf requires a unique IP address to communicate with the management platform. The unique IP address cannot duplicate any IP address in the customer DCN or any internal Optical Metro 5100/5200 IP address.

The subnet mask assigned to the shelf determines the number of IP addresses required from the DCN address space for the shelf, and also determines the way in which IP addresses are assigned to the 1X Ethernet port.

For non-GNE shelves, the recommended subnet mask is 32 bits (255.255.255.255), since only a single IP address from the DCN address space is needed for the shelf. The 1X Ethernet port is assigned a private address, separate and distinct from the shelf address. Refer to Table 10-1 on page 10-7 for more information about internal IP address assignment.

Non-GNE shelves may be configured with a larger subnet, by setting the subnet mask to 30 bits or less (for example, 255.255.255.252). In this case, the number of IP addresses that need to be allocated from the DCN address space corresponds to the size of the subnet assigned to the shelf. For example, with a subnet mask of 255.255.255.252, four IP addresses from the DCN address space are used (corresponding to the subnet address, the shelf address, an address allocated through DHCP, and the subnet broadcast address). In this configuration, the shelf address and the 1X Ethernet port address are one and the same. When the recommended subnet mask of 32 bits is not used, a System Manager PC connected to 1X Ethernet port has access to the entire DCN, although the use of usernames and passwords can limit unauthorized access to systems and Optical Metro 5100/5200 networks.

GNE shelves must be configured with a subnet mask of 30 bits or less. The size of the subnet is determined by the type of GNE (proxy ARP, OSPF, BGP, or SNMP proxy) and the configuration of the DCN segment to which the GNE is connected.

Table 10-2 shows how IP addresses are assigned to the 1X Ethernet port, depending on the subnet mask setting.

Table 10-2
1-X Ethernet port IP addresses and subnet mask settings

Subnet mask	1X Ethernet port IP address	1X Ethernet port subnet mask
255.255.255.255	10.1.shelfID.1	255.255.255.0
255.255.255.252	same as shelf IP address	same as shelf subnet mask

Private IP addresses

Optical Metro 5100/5200 systems with multiple Gateway Network Elements (GNE) can be configured to use a private IP address scheme. In private IP address mode, only the Optical Metro 5100/5200 GNEs use IP addresses that are visible to the customer's data communication network (DCN). All other Optical Metro 5100/5200 network elements (NE) use private IP addresses.

Private IP addresses can be configured through System Manager or TL1. TL1 managers must use the TL1 gateway (TID Routing) model from any of the GNEs in order to manage the Optical Metro 5100/5200 system. SNMP managers must establish their management session with one of the GNEs. For SNMP management purposes, each NE can be reached through a specific UDP port on any of the GNEs. SNMP managers can send SNMP requests to a specific NE by addressing the SNMP request messages to the GNE UDP port corresponding to the target NE. SNMP response messages come back to the SNMP manager from the same GNE port.

IP forwarding control

IP forwarding control on the 1X Ethernet interface is a network security feature for GNE shelves configured in private IP address mode.

When 1X Ethernet IP forwarding is disabled, any IP access to the customer's DCN via that GNE's 1X Ethernet interface initiated from any remote shelf is blocked (that is, intercepted IP packets are dropped). Only the GNE can exchange IP packets with computers on the customer's DCN.

DHCP

Dynamic host configuration protocol (DHCP) is used to centrally manage and automate the assignment of IP addresses. When you plug into the 1X or 2X Ethernet port on the Optical Metro 5100/5200 shelf, if your management platform is provisioned to obtain an IP address using DHCP, the management platform computer will be set up with a DHCP address from the shelf DHCP server and will be able to manage the Optical Metro 5100/5200 network.

> ***Note:*** DHCP addresses can be assigned. See Table 10-1 on page 10-7.

Network address translation (NAT)

The inbound network address translation (NAT) feature translates the IP addresses of packets entering the Optical Metro 5100/5200 network from the 1X Ethernet port to a customer-specified address range. The translated address is used within the Optical Metro 5100/5200 network to route the packets to the destination shelf. Reply packets are translated back to the original address when they leave the 1X Ethernet port on their way back to the DCN.

If an external device in the customer's DCN is using one of the internally assigned reserved Optical Metro 5100/5200 IP addresses, NAT can be used to ensure that the Optical Metro 5100/5200 network can properly communicate with the external device. The GNE provides NAT support, which eliminates the need for an external router to perform this function.

> ***Note 1:*** All external manager sessions using Optical Metro 5100/5200 internal IP addresses must be de-registered before Inbound NAT is disabled or the alias is changed.
>
> ***Note 2:*** All System Manager sessions using Optical Metro 5100/5200 internal IP addresses must be restarted after an alias change.

DNS proxy service

Domain Name Service (DNS) is an address mapping protocol that provides name/address resolution, correlating a domain name to an IP address. DNS provides the foundation for "user-friendly" identifiers by allowing a host to be accessed by name rather than IP address.

The DNS proxy service, in conjunction with one or two DNS servers located in the customer data communications network (DCN), provides DNS functionality to a PC that is directly connected to 1X or 2X Ethernet ports. This service is available if the Optical Metro 5100/5200 system is configured in a public-IP address mode (GNEs and all remote NEs have a public IP address). If the Optical Metro 5100/5200 system is configured in private-IP mode, DNS Proxy Service is not available, but a simple name service function is still available (see a description of this name service on page 10-13).

The PC must be configured to retrieve DNS information automatically through the DHCP service. The DNS proxy service acts as an intermediary between the DNS server(s) and the PC, relaying DNS queries from the PC to the DNS server, and responses from the DNS server back to the PC.

To use the DNS proxy service on an Optical Metro 5100/5200 shelf, you must:

- Configure the DNS server(s):
  - Assign a "domain name" to every shelf on the DNS server. This establishes the name/address correlation. We recommend using the shelf's Target identifier (TID) or Shelf Name as a domain name in the DNS server.
- Configure the DNS proxy server (only on the primary shelf):
  - Assign an IP address of one or two (for redundancy) DNS servers to which DNS queries are forwarded.
  - Assign a DNS suffix (optional). A DNS suffix simplifies the entering of a domain name by allowing the user to enter a non-Fully Qualified Domain Name (FQDN). A FQDN is a domain name that contains the complete set of labels that uniquely identifies a node

in the domain name space. DNS servers only process FQDNs. When the user assigns the DNS suffix, the resolver appends the suffix to what the user enters to create a FQDN. If the user enters a FQDN, the resolver does not attach the suffix.

– Enable the service.

Configuration information is distributed to all other shelves in the shelf list. If the DNS suffix is provisioned, all shelves must be restarted with the DNS proxy service enabled.

If the Optical Metro 5100/5200 system is configured in private-IP mode, a simple name service function is provided to allow the use of the shelf Target Identifier (TID) or the string “om5000” (case insensitive) to access a shelf. This service is available whether the DNS Proxy Service is enabled or not. Note that the PC that is directly connected to the 1X or 2X Ethernet ports must be configured to retrieve DNS information automatically through the DHCP service.

To use this name service, no configuration of the Optical Metro 5100/5200 system is necessary or possible. You simply enter the TID of the shelf to connect to, rather than the shelf IP address. You can access any shelf in the Optical Metro 5100/5200 system by entering its corresponding TID, from any other shelf.

> ***Note 1:*** On some Windows operating systems, when the operating system fails to resolve a name, it stops trying to resolve any name for 30 seconds after the failed attempt. Some Windows applications can attempt name resolution in the background without knowledge of the user, and if failures occur, they can affect subsequent attempts by the user as described above.
>
> ***Note 2:*** If the operating system is Windows XP, and no DNS suffix is provisioned on the NE, you must add a period (.) after the shelf name to initiate the DNS query from Windows XP.

Optionally, if you enter the string “om5000”, you can access the shelf to which the PC is connected. This procedure can be used on any shelf.

SNMP proxy service

SNMP is a protocol that can be used with Optical Metro 5100/5200 as a management interface for OAM&P activities, through System Manager or a third-party SNMP browser (see “Management protocols” on page 10-15).

In public IP mode, (where all Optical Metro 5100/5200 NEs are visible from the customer DCN), SNMP manager uses standard UDP port 161 to gain access to the MIB on those NEs.

In private IP mode—where only the DCN gateway NEs (GNEs) from the Optical Metro 5100/5200 system have network visibility to the customer DCN while the remaining NEs are "invisible"— System Manager will automatically detect the network configuration and use the SNMP proxy service provided on those GNEs to gain access to the MIB of those invisible remote NEs. Instead of using standard UDP port 161, System Manager will send SNMP requests to the GNE with specific UDP ports that are mapped with the shelf ID number of the remote NEs in the following way:

UDP port number = SNMP proxy service base port + NE shelf ID number, where:

- the SNMP proxy service base port is fixed to 8000,
- the NE shelf ID number is from 1 to 64.

When an external SNMP manager is used, it must be setup so that each network node has its IP address and port number manually configured. When using private IP addressing, the SNMP manager can only send requests to the GNE's IP address. However, to issue requests to remote (that is, non-GNE) shelves, the SNMP manager must use the IP address of the GNE along with a UDP port number of "8000 + Shelf ID" (the Shelf ID is of the shelf which the SNMP Manager wants to access).

For example, if there are 3 shelves in the system in private IP mode, with Shelf IDs "1, 2, and 3" respectively (with a GNE IP address of 47.134.99.1), then the SNMP manager must be configured with the following information for it to communicate with each of the three shelves:

Shelf #1 GNE: 47.134.99.1 / default UDP port (that is, 161)
Shelf #2 RNE: 47.134.99.1 / UDP port # 8002
Shelf #3 RNE: 47.134.99.1 / UDP port # 8003

The only way any SNMP manager can gain access to a Remote NE (RNE) is by using the GNE's IP address along with the appropriate UDP port number. The GNE's SNMP Relay function relays the packet to appropriate RNE based on the UDP port number of "8000 + Shelf ID".

Routing protocols

Proxy ARP

When an IP host communicates to a destination IP host within the same IP subnetwork (on the same ethernet link layer), address resolution protocol (ARP) is used to determine the media access control (MAC) address for the destination host. The destination MAC address is required for the hosts to communicate using the data link layer.

The source IP host (such as a workstation) broadcasts an ARP request packet which includes the IP address of the destination host (the host for which the MAC is required). All IP hosts on the subnetwork receive the ARP request.

The host configured with the IP address in the ARP request packet sends an ARP response packet containing its IP address and MAC address. This lets all IP hosts on the subnetwork store the MAC address that corresponds to its IP address (this storage is called the ARP cache). All packets destined for this IP address will now be sent using the stored MAC address. This process allows MAC addresses to be resolved using the IP address.

The Optical Metro 5100/5200 proxy ARP function responds to ARP requests received for one of the other shelves. The GNE responds with it’s MAC address, allowing Ethernet packets to be sent to the GNE for the other NEs it services.

OSPF

OSPF can be used as an exterior gateway routing protocol (EGRP) to communicate with the customer routing network. OSPF allows the DCN router to detect failures of a GNE and to use another GNE in the event of a failure. If you do not require this type of functionality, you do not need to use OSPF.

To run OSPF on the 1X Ethernet port, the port must be connected to a LAN configured as the OSPF backbone area (0.0.0.0) in the customer DCN. The Optical Metro 5100/5200 GNE shelf acts as an Area Border Router (ABR) between the DCN backbone area and the OSPF area of the internal data communications of the Optical Metro 5100/5200 network.

To avoid conflicting area IDs, you can provision the internal OSPF area ID for the Optical Metro 5100/5200 network.

BGP

Border gateway protocol (BGP) can be used as an EGRP to communicate with the customer routing network. BGP allows the DCN router to detect failures of a GNE and to use another GNE in the event of a failure. If you do not require this type of functionality, you do not need to use BGP.

BGP isolates changes in the Optical Metro 5100/5200 internal OSPF network by stopping the propagation of the internal OSPF routing information into the DCN. BGP allows GNE shelves to exchange routing information directly with customer routers while providing the control over what routing information is propagated throughout the customer’s network.

Management protocols

SNMP for Optical Metro 5100/5200 shelves

The Optical Metro 5100/5200 shelves support a Simple Network Management Protocol (SNMP) interface for OAM&P functionality. The Optical Metro 5100/5200 supports a management information base (MIB) model for integration with SNMP-based network management systems.

System Manager uses the SNMP agent for the OAM&P of the Optical Metro 5100/5200 network. System Manager allows you to perform provisioning and surveillance operations on any shelf or circuit pack in the Optical Metro 5100/5200 network.

> ***Note:*** A third-party SNMP browser can be used for the surveillance of the Optical Metro 5100/5200 network using the Optical Metro 5100/5200 SNMP interface.

For SNMP OAM&P to work properly, the management system must be able to access all the shelves in the network using IP. For craft access, the management system PC can be plugged directly into the 1X Ethernet port.

> ***Note:*** The management system PC must be provisioned for DHCP.

By connecting the Optical Metro 5100/5200 network to a DCN, you can run the management system PC from anywhere in your DCN and be able to monitor the Optical Metro 5100/5200 network.

> ***Note:*** When using the Private IP address feature, only the GNE shelves are visible to the DCN.

SNMP for Enhanced Trunk Switch shelves

The ETS shelves support a Simple Network Management Protocol (SNMP) interface for OAM&P functionality. The ETS supports a management information base (MIB) model for integration with SNMP-based network management systems.

> ***Note:*** A third-party SNMP browser can be used for the surveillance of the ETS shelves using the ETS SNMP interface.

For SNMP OAM&P to work properly, the management system must be able to access all ETS shelves equipped with the ETS Comms module in the network using IP. For craft access, the management system PC can be plugged directly into the ETS shelf Ethernet port.

By connecting the ETS to a DCN, you can run the management system PC from anywhere in your DCN and be able to monitor the ETS.

TL1 for Optical Metro 5100/5200 shelves

The Optical Metro 5100/5200 shelves support a transaction language 1 (TL1) user interface for OAM&P. This makes it possible for a third-party TL1 network management system to perform OAM&P in the Optical Metro 5100/5200 network.

The TL1 network management system must be able to communicate with at least one shelf in the Optical Metro 5100/5200 network using IP. This shelf is the TL1 gateway. The TL1 gateway shelf uses TL1 to access all the other shelves in the Optical Metro 5100/5200 network.

> ***Note:*** If the TL1 network management system supports redundant TL1 gateways, the network management system must be able to communicate with each of the TL1 gateways using IP.

For more information on TL1, refer to *TL1 Interface*, 323-1701-190, Part 1 and Part 2.

TL1 for Optical Trunk Switch and Enhanced Trunk Switch shelves

The OTS and ETS shelves support a transaction language 1 (TL1) user interface for OAM&P. This makes it possible for a third-party TL1 network management system to perform OAM&P.

The TL1 network management system must be able to communicate with each OTS or ETS shelf equipped with an ETS Comms module using IP.

For more information on TL1, refer to *TL1 Interface*, 323-1701-190, Part 1 and Part 2.

Primary Node

A Primary Node must be designated in an Optical Metro 5100/5200 network The Primary Node propagates information associated with each shelf throughout the network. This makes it possible for each shelf to maintain information about all the other shelves. This information is stored in a shelf list that can be viewed using System Manager.

When a shelf is added to or removed from an Optical Metro 5100/5200 network, the shelf list on every shelf must be properly updated. For this to happen, communication with the Primary Node must be maintained.

If you change the IP address of the Primary Node, every shelf in the network needs to be assigned the new Primary Node address.

> **CAUTION**
> **Risk of losing shelf contact**
> Before changing the Primary Shelf Address in any of the shelves, ensure that the Internal OSPF Setting - OSPF Area ID in the Advanced Communications Settings panel is set to a value other than 0.0.0.0. Failure to do so will result in loss of IP routing capability between some of the shelves, which in turn will produce loss of contact with those shelves. Refer to "Routing protocols", "OSPF" on page 10-8.

> ***Note:*** The Primary Node can be any Optical Metro 5100/5200 shelf and does not have to be the GNE but normally is one of the GNEs.

Engineering data communications

The following sections provide information and guidelines for engineering data communications in an Optical Metro 5100/5200 network. You must choose an IP address plan, GNE mode configuration, the protocols, and features you need.

IP address restrictions

Table 10-3 lists the generic restrictions that apply to user-assignable IP addresses.

Table 10-3
Generic IP address restrictions

Restriction #	Description
#1	Not permitted: any IP address with a first octet of “0” (0.nnn.nnn.nnn)
#2	Not permitted: any IP address with a first octet of “127” (127.nnn.nnn.nnn)
#3	Not permitted: any IP address with a first octet of “10” and a second octet of “0” (10.0.nnn.nnn)
#4	Not permitted: any IP address with a first octet of “224 or greater” (224.n.n.n, 225.n.n.n, etc.)

Table 10-4 lists how the generic restrictions apply to all user-assignable IP addresses, as well as any special restrictions.

Table 10-4
Specific IP address restrictions

IP address	Restrictions
Shelf address	• generic restrictions #1, #2, #3, #4
Subnet mask	• if shelf is GNE, must be less than or equal to 30 bits
DHCP address	• if shelf is GNE, must be “0.0.0.0” • if shelf is not GNE, generic restrictions #1, #2, #3, #4 apply, plus address must be in same subnet as Shelf address
Primary shelf address	• generic restrictions #1, #2, #3, #4
Default gateway address	• generic restrictions #1, #2, #3, #4 plus • can only be set to non-zero address if OSFP and BGP are disabled, DHCP address is 0.0.0.0, and mask is less than or equal to 30 bits
Enet port2 IP	• generic restrictions #1, #2, #3, #4
Enet port2 DHCP	• generic restrictions #1, #2, #3, #4

Table 10-4 (continued)
Specific IP address restrictions

IP address	Restrictions
Enet port2 mask	• no restrictions
Serial port1 local/remote IP	• generic restrictions #1, #2, #3, #4
Serial port2 local/remote IP (see Note)	• generic restrictions #1, #2, #3, #4
BGP peer1/peer2 IP address	• generic restrictions #1, #2, #3, #4
DNS server address	• generic restrictions #1, #2, #4
Note: Serial port 2 is not supported.	

Gateway network element modes

Depending on your data communications requirements, you must decide on the gateway network element configuration for each shelf in the Optical Metro 5100/5200 network. The following configurations are available:

- single GNE (uses proxy ARP)
- multiple GNE with OSPF
- multiple GNE with BGP
- single or multiple GNE with SNMP proxy (used when configuring non-gateway shelves with private (non-DCN visible) IP addresses)
- non-gateway shelf

  Note: When reconfiguring a GNE shelf from a proxy ARP configuration to either an OSPF or a BGP configuration, you may temporarily lose contact with some shelves.

For each GNE shelf, you need the following:

- an IP address
- a subnet mask
- a default gateway address (for proxy ARP or SNMP proxy GNE configurations only)

For non-gateway shelves, you need to assign an IP address based on how the GNE shelves are configured, as follows:

- If the gateway shelf is running proxy ARP, the NEs must be in the same subnet as the GNE
- If the gateway shelves are running OSPF backbone, the NEs can be, but do not have to be, in the same subnet as a GNE

- If the gateway shelves are running BGP, the NEs cannot be in the same subnet as the GNEs
- if the gateway shelves are not running proxy ARP, OSPF, or BGP, private IP addresses can be used as shelves are accessed via the SNMP proxy mechanism

Table 10-5 shows the supported protocols for data communications between the DCN and the Optical Metro 5100/5200 network depending on the chosen gateway mode. Table 10-6 shows the parameters for configuring the different gateway modes.

See Table 7-33, “Configuration—Naming or Communications—Shelf Configuration window” in *Software and User Interface*, 323-1701-101, for the description and values that can be set for the various data communications parameters. See “Configuration examples” on page 10-22 for examples on how to set up IP addressing in the network for different GNE configurations.

Table 10-5
Supported protocols based on GNE configuration

GNE configuration	NAT	Proxy ARP	External OSPF	External BGP	SNMP Proxy
Single GNE	√	√	√	√	√
Multiple GNE	√	X	√	√	√

Note: Proxy ARP, External OSPF, External BGP, and SNMP Proxy are mutually exclusive. That is, only one may be running at any given time on a particular shelf.

Table 10-6
Gateway network element configuration

Default gateway address	Gateway routing protocol setting	Resulting shelf configuration
0.0.0.0	None	Non-gateway shelf
non-0.0.0.0, e.g. 172.1.1.8	Proxy ARP	Proxy ARP gateway
non-0.0.0.0, e.g. 172.1.1.8	None	SNMP Proxy gateway
0.0.0.0	OSPF	OPSF backbone gateway
0.0.0.0	BGP	BGP gateway routing

Note: Because GNEs can be on the same external DCN LAN, and the network management platforms are permanently provisioned, DHCP is automatically disabled on all GNEs.

Frequently asked questions

The following section provides the answers to some frequently asked questions related to setting up data communications in an Optical Metro 5100/5200 network.

I manage my Optical Metro 5100/5200 network with a management system PC that has an Optical Metro 5100/5200 reserved internal IP address. How do I get my management system to see the Optical Metro 5100/5200 network?

Enable the Inbound NAT feature on the GNE and provide an alias address for inbound NAT.

See the procedure “Defining or changing IP addressing and advanced communications settings for the network” in *Provisioning and Operating Procedures*, 323-1701-310.

I want the unique IP address of the 1X Ethernet port on the Optical Metro 5100/5200 shelf to be an Optical Metro 5100/5200 system-assigned internal IP address. Can I use one of the Optical Metro 5100/5200 system-assigned internal IP addresses?

You can change some of the internal Optical Metro 5100/5200 network IP addresses except for Ethernet port 1 (1X port).

If a shelf is assigned a subnet mask of 255.255.255.255, the 1X Ethernet port is assigned the 10.1.shelfID.1 address, and its associated DHCP lease address is 10.1.shelfID.2.

However, if the subnet mask is different from 255.255.255.255, the 1X Ethernet port address is the same as the shelf address. Refer to Table 10-1 on page 10-7 for reserved IP addresses used in the Optical Metro 5100/5200.

I monitor my DCN with a third-party SNMP browser. Can I use this browser to monitor the Optical Metro 5100/5200 network?

An SNMP Surveillance MIB is available to provide surveillance of the Optical Metro 5100/5200 through a third-party SNMP browser.

I monitor my DCN with a third-party TL1 network management system. Can I use this TL1 network management system to monitor the Optical Metro 5100/5200 network?

Using your TL1 network management system documentation, configure the interface to connect to the IP address of the GNE and the TRUE TCP/IP port 10001.

See the “Introducing TL1” chapter in *TL1 Interface*, 323-1701-190, Part 1.

Configuration examples

This section provides configuration examples of IP addressing for networks with both single and multiple gateway network elements (GNEs).

The table that follows each example shows the wizard information entered during the commissioning of the shelf in the network. The information in Table 10-7 applies to all of the examples.

Table 10-7
Common example network information

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Shelf ID	1	2	8	9	10
Shelf Type	OADM	OADM	OADM	OADM	OFA
Ethernet Hubbing Group	1	1	2	3	3

Single GNE

The single GNE provides a transparent way to add the Optical Metro 5100/5200 network to an existing DCN, using the standard ARP mechanism on a LAN to support the ring.

Enabling proxy ARP on the GNE results in a default route “0.0.0.0” being injected into the internal OSPF routing table and communicates to all shelves that all other IP addresses (including the IP address of the System Manager) are through the GNE.

For the proxy ARP configuration, the subnet mask is defined large enough to include all the LAN connected devices and all the Optical Metro 5100/5200 IP addresses in the subnetwork. The IP address of the GNE is allocated to the 1X Ethernet port.

The Proxy ARP configuration only supports a single gateway configuration.

Single GNE as the default gateway

If the System Manager is on the same IP subnetwork as the shelves, define the the default gateway address as the IP address of the GNE shelf. Defining the default gateway address as the IP address of the GNE shelf ensures that the "Proxy ARP" is enabled and that all IP addresses not in the internal routing tables are forwarded to the external DCN LAN.

Figure 10-6 shows a single GNE as the default gateway.

Figure 10-6
Example 1 — Single GNE as the default gateway

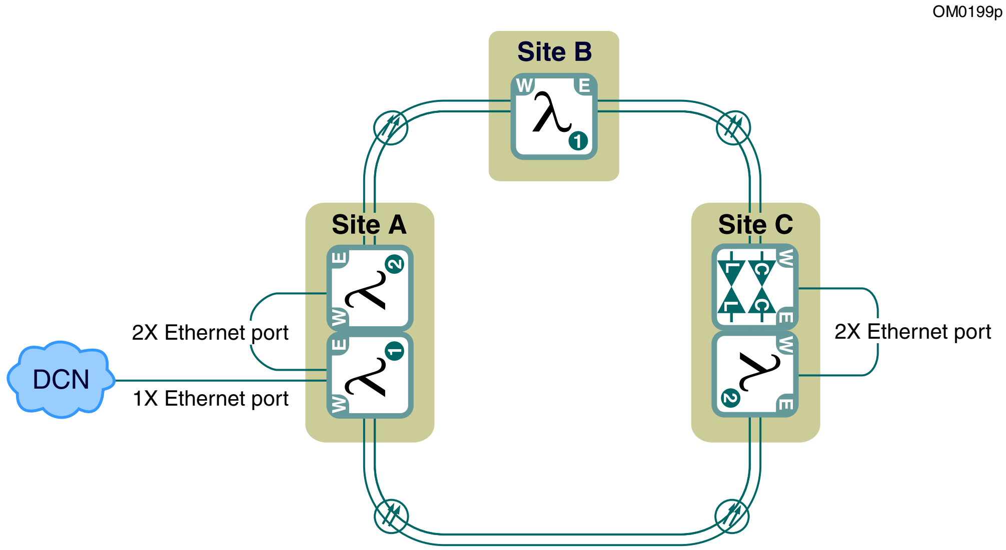


Table 10-8 lists configuration information for Example 1.

Table 10-8
Example 1 — Single GNE as the default gateway

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.1	172.16.19.1	172.16.19.1	172.16.19.1	172.16.19.1
Shelf Address	172.16.19.1	172.16.19.2	172.16.19.3	172.16.19.5	172.16.19.9
Subnet Mask	255.255.255.0	255.255.255.255	255.255.255.255	255.255.255.252	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.6	172.16.19.10
Default Gateway Address	172.16.19.1	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0
GNE ("shelf is DCN GW" flag)	Yes	No	No	No	No
External Routing Mode	Proxy ARP	None	None	None	None

The band 1 OADM shelf at site A is the only GNE shelf that acts as proxy ARP server for other shelves in the ring. Site A band 1 also acts as a communication bridge between shelves in band 1 and band 2. The default gateway address is set to itself. The GNE will transmit an ARP request for destination IP addresses different from those assigned to the Optical Metro 5100/5200 ring, even when the destination IP address is not in the same subnet as the IP address assigned to the GNE.

The band 2 OADM shelf at site A communicates with the GNE shelf by way of an Ethernet hub (the same hubbing group as the GNE, hubbing group 1). The Ethernet hub also acts as a communication bridge between the shelves in band 1 and band 2. There can be no communication to other band 2 shelves if shelf 2 band 2 is down. There is one IP address assigned to the shelf (the subnet mask of 255.255.255.255). The shelf recognizes the assigned IP address as its home address; however, the shelf assigns the default IP address of 10.1.2.1 with the netmask of 255.255.255.0 to the 1X Ethernet port and the related DHCP of 10.1.2.2. This configuration allows a PC plugged into 1X Ethernet to communicate with all shelves in the ring by way of the 1X Ethernet.

The band 1 OADM shelf at site B communicates with the GNE shelf by way of the overhead channel. As with site A band 2, there is one IP address assigned to the shelf. The default IP address of 10.1.8.1 with netmask of 255.255.255.0 and DHCP address of 10.1.8.2 is assigned to the 1X Ethernet port.

The band 2 OADM shelf at site C communicates with the GNE shelf by way of site A band 2 and with site A band 2 by way of the overhead channel. The shelf has a subnet of 4 IP addresses starting from 172.16.19.4 to 172.16.19.7. IP address 172.16.19.5 is assigned to the shelf and the other host address of 172.16.19.6 is used for DHCP. This configuration allows a PC plugged into the 1X Ethernet port to communicate with other IP devices on the LAN that connect to the GNE.

In this example, the OFA shelf is installed at the same site as site C band 2. Site C band 2 acts as a communication bridge between the OFA shelf and the other shelves in the ring. The OFA shelf is in the same hubbing group as site C band 2. Communication between the GNE shelf and the OFA shelf passes through site A band 2 and site C band 2.

Single GNE and router (default gateway)

If the System Manager is on a different IP subnetwork, IP routers can be used between the IP subnetworks. On the GNE shelf, configure the Default Gateway Address as the local LAN IP address of the router. Defining the IP gateway address as the IP address of the router with the “Shelf is DCN gateway” option set to “yes” and the “External routing mode” option set to “Proxy ARP”, ensures that all IP addresses not in the internal routing tables are forwarded to the external DCN LAN or router depending on the destination of the management traffic.

Figure 10-7 shows a single GNE and a router.

Figure 10-7
Example 2 — Single GNE and router

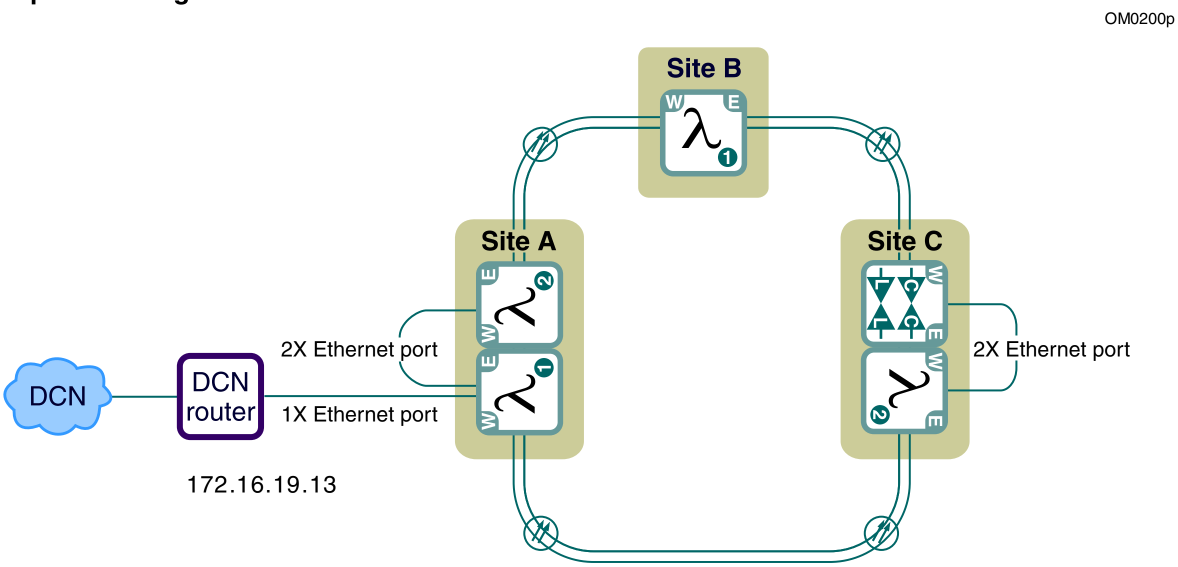


Table 10-9 lists configuration information for Example 2.

Table 10-9
Example 2 — Single GNE and router

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2
Shelf Address	172.16.19.1	172.16.19.2	172.16.19.3	172.16.19.5	172.16.19.9
Subnet Mask	255.255.255.0	255.255.255.255	255.255.255.255	255.255.255.252	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.6	172.16.19.10

Table 10-9 (continued)
Example 2 — Single GNE and router

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Default Gateway Address	172.16.19.13	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0
GNE (“shelf is DCN GW” flag)	Yes	No	No	No	No
External Routing Mode	Proxy ARP	None	None	None	None

Example 2 is like Example 1, but the GNE shelf at site A band 1 is not the default gateway and the primary node is site A band 2. The GNE shelf connects to a DCN router but they do not exchange routing information. The GNE shelf acts as proxy ARP server for the other shelves in the ring. The GNE shelf does not transmit an ARP request for any destination IP address that is not in the same subnetwork. The GNE shelf sends packets directly to the DCN router. In this example

- the IP address of the DCN router is 172.16.1.1
- the GNE shelf is on the same LAN as the DCN router (that is, subnet 172.16.19.0 as defined by the subnet mask of 255.255.255.0)

Dual GNEs and the OSPF backbone

One way to support dual gateways is to use the OSPF backbone feature. Enabling the OSPF backbone feature makes the GNE an area border router (ABR) between the internal Optical Metro 5200 OSPF area and the OSPF backbone area. By enabling the OSPF backbone, you automatically configure the 1X Ethernet port in area 0.0.0.0.

As an OSPF ABR, the GNE advertises the OSPF learned routes into the subnetwork and advertises only the external shelf IP addresses to the external DCN network.

> ***Note:*** The internal 10.0.0.0 to 10.4.255.255 range of addresses are blocked, and therefore are not advertised to the external DCN.

In accordance with the OSPF standards, routes learnt by one GNE (from the OSPF backbone) are not advertised back into the OSPF backbone from the other GNEs.

To provide resilience, each shelf is advertised as a subnetwork with a mask that is configured for the shelf. The shelf IP address is advertised as a host route with a 255.255.255.255 mask.

The routing protocol matches the most precise address (longest subnet mask entry) when multiple routes are advertised into the external DCN. For example, if the cable between one of the GNEs to the DCN hub fails, the router still advertises the GNE sub-network (for example, 172.1.1.0 255.255.255.240), but internally, the GNE advertises its IP address as a host route (for example, 172.1.1.1 255.255.255.255) which is advertised through the other GNE to the external DCN. In the DCN network, when the System Manager sends a packet towards the isolated GNE, the router forwards the communications through the longest match (the 172.1.1.1 255.255.255.255) which is through the other gateway shelf.

> ***Note:*** If using the Bay RS (BAY router software), ensure that you are using the latest version.

Dual GNEs and router (OSPF backbone)

Figure 10-8 shows dual GNEs and a router.

Figure 10-8
Example 3 — Dual GNEs and router

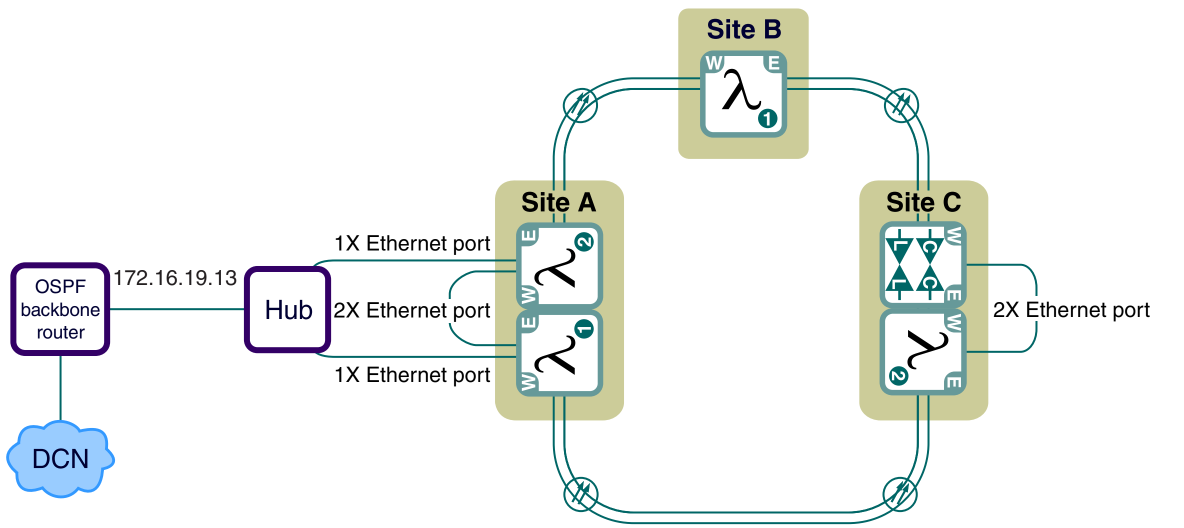


Table 10-10 lists configuration information for Example 3.

Table 10-10
Example 3 — Dual GNEs and router

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2
Shelf Address	172.16.19.1	172.16.19.2	172.16.19.3	172.16.19.5	172.16.19.9
Subnet Mask	255.255.255.0	255.255.255.0	255.255.255.255	255.255.255.252	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.6	172.16.19.10
GNE ("shelf is DCN GW" flag)	Yes	Yes	No	No	No
External Routing Mode	OSPF	OSPF	None	None	None

Example 3 is like Example 2, but there is an additional GNE shelf at site A band 2. The netmask of site A band 2 is changed to 255.255.255.0 so that it can communicate with the DCN router. Both GNE shelves can exchange routing information with the DCN router by way of OSPF routing protocol in the backbone area (the OSPF area 0.0.0.0).

The DCN router must have its interface enabled for OSPF backbone. With OSPF backbone activated the proxy ARP server in each GNE is disabled. The DCN router and the GNE shelves detect each other by way of the OSPF routing protocol (the default gateway field is not used in this configuration and must be set to 0.0.0.0). The DCN router directs packets to the Optical Metro 5100/5200 network by way of either GNE shelf.

Dual GNEs and dual routers (OSPF backbone) on the same LAN

Figure 10-9 shows dual GNEs and dual routers on the same LAN.

Figure 10-9
Example 4 — Dual GNEs and dual routers on the same LAN

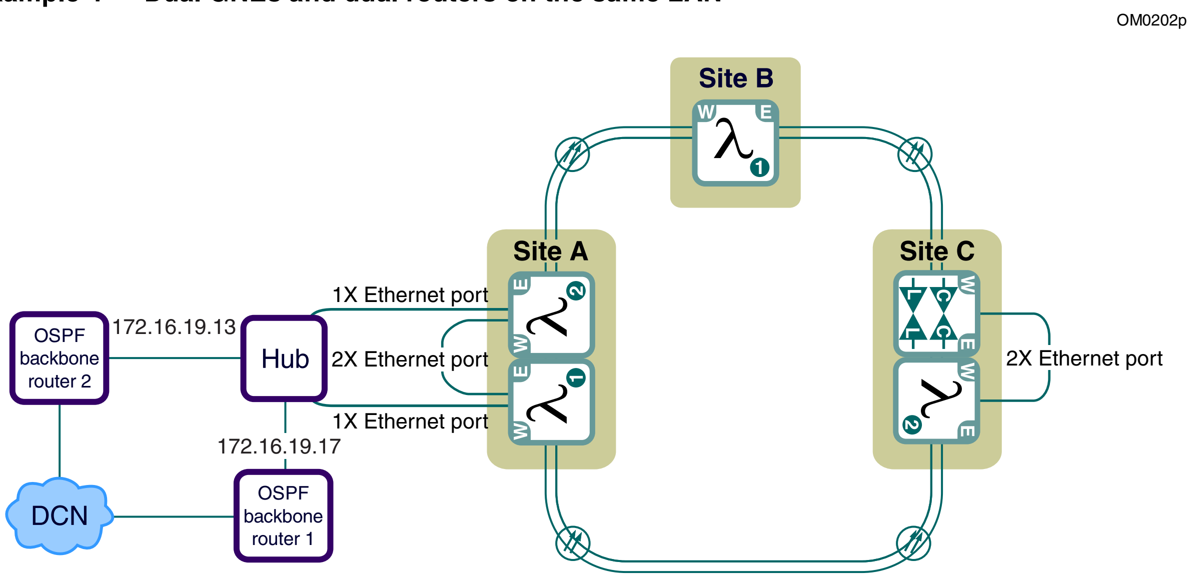


Table 10-11 lists configuration information for Example 4.

Table 10-11
Example 4 — Dual GNEs and dual routers on the same LAN

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2
Shelf Address	172.16.19.1	172.16.19.2	172.16.19.3	172.16.19.5	172.16.19.9
Subnet Mask	255.255.255.0	255.255.255.0	255.255.255.255	255.255.255.252	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.6	172.16.19.10
Default Gateway Address	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0
GNE (“shelf is DCN GW” flag)	Yes	Yes	No	No	No
External Routing Mode	OSPF	OSPF	None	None	None

Example 4 is like Example 3, but there is an additional DCN router. Both GNE shelves and DCN routers are in the same subnetwork (that is, on the same physical LAN). As with Example 3, GNE shelves and DCN routers detect each other by way of the OSPF protocol. The OSPF backbone interface must be enabled on all DCN routers.

Dual GNEs and dual routers (OSPF backbone) on a different LAN

Figure 10-10 shows dual GNEs and dual routers on a different LAN.

Figure 10-10
Example 5 — Dual GNEs and dual routers on a different LAN

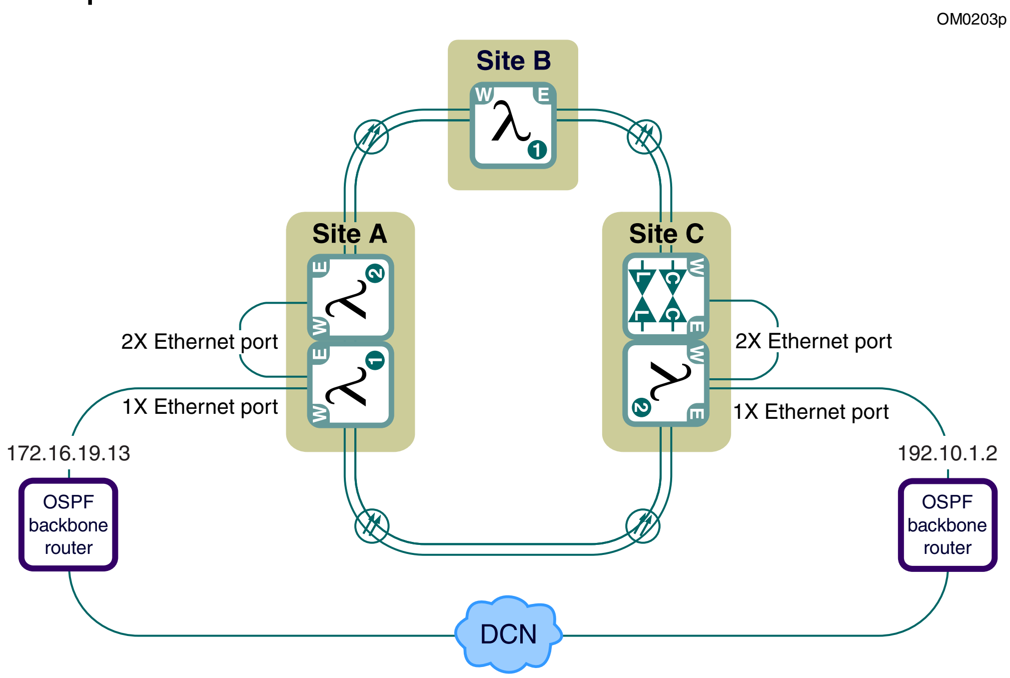


Table 10-12 lists configuration information for Example 5.

Table 10-12
Example 5 — Dual GNEs and dual routers on a different LAN

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2	172.16.19.2
Shelf Address	172.16.19.1	172.16.19.2	172.16.19.3	192.10.1.1	172.16.19.9
Subnet Mask	255.255.255.0	255.255.255.255	255.255.255.255	255.255.255.0	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.10

Table 10-12 (continued)
Example 5 — Dual GNEs and dual routers on a different LAN

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Default Gateway Address	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0
GNE (“shelf is DCN GW” flag)	Yes	No	No	Yes	No
External Routing Mode	OSPF	None	None	OSPF	None

Example 5 is like Example 4, but site A band 2 is not a GNE shelf and site C band 2 is the GNE shelf. Site C band 2 connects to a DCN router at a different LAN than site A band 1.

Multiple GNEs and border gateway protocol (BGP)

To support multiple GNEs without additional routers, the Optical Metro 5100/5200 IP network can communicate using the BGP routing protocol. BGP allows GNE shelves to exchange routing information directly with customer routers while providing the customer control over what routing information is propagated throughout the backbone structure of their network.

The GNE shelves run BGP. No additional router is required to connect the Optical Metro 5100/5200 shelves to the customer network. GNE shelves act as BGP peers to the customer routers, and run OSPF within the Optical Metro 5100/5200 network.

You can configure multiple GNEs in an Optical Metro 5100/5200 ring when BGP is enabled. You must enable BGP on all the GNEs in the ring and set up a peer-to-peer connection between the customer DCN routers and the GNEs. Multiple GNEs in an Optical Metro 5100/5200 ring provide extra gateways to the customer DCN. With multiple GNEs, if one GNE or one LAN segment goes down, the customer DCN can still connect to the Optical Metro 5100/5200 ring by way of one of the other GNEs.

The various IP addresses and subnet masks must be chosen and configured such that all non-gateway NE IP addresses reside outside of the subnet space defined between the GNEs and their peer BGP routers. See Figure 10-11 on page 10-33.

Figure 10-11
Dual GNEs running BGP

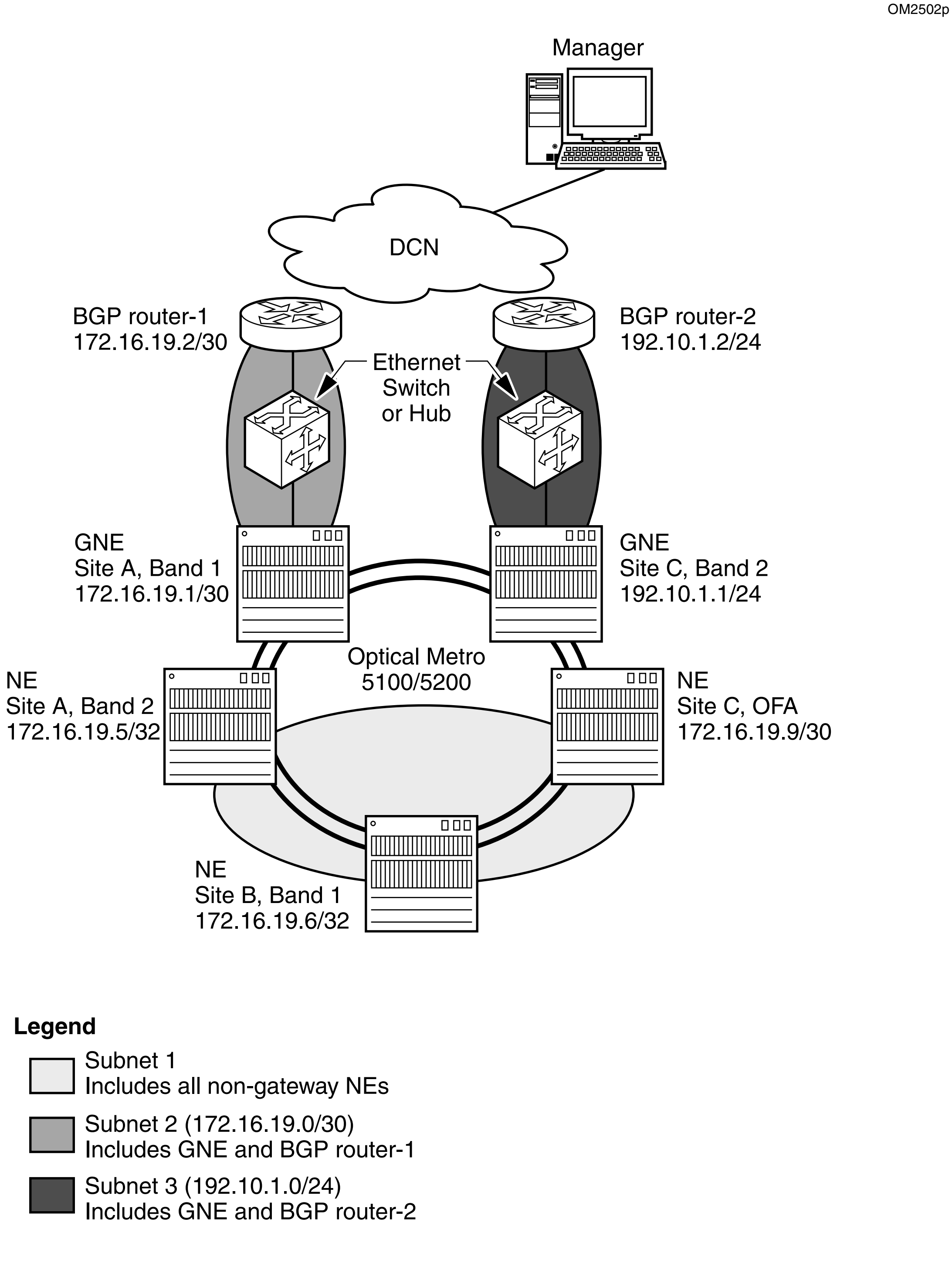


Figure 10-12 shows dual GNEs running BGP connected directly to the customer DCN.

Figure 10-12
Example 6— Dual GNEs running BGP

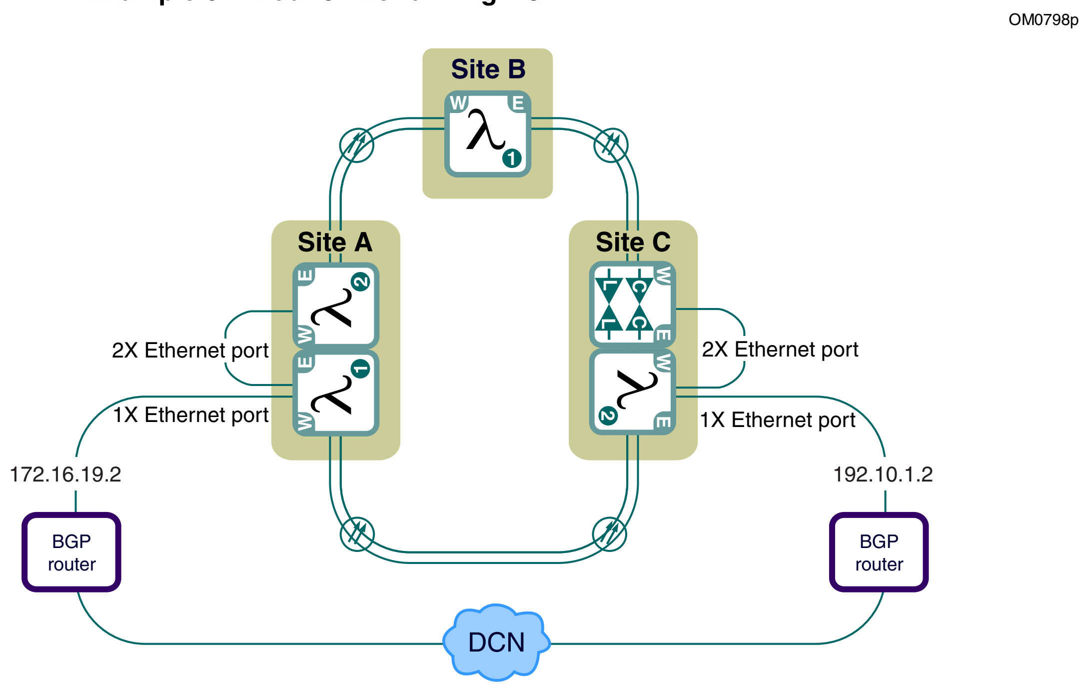


Table 10-13 lists configuration information for Example 6.

Table 10-13
Example 6— Dual GNEs with BGP

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	172.16.19.5	172.16.19.5	172.16.19.5	172.16.19.5	172.16.19.5
Shelf Address	172.16.19.1	172.16.19.5	172.16.19.6	192.10.1.1	172.16.19.9
Subnet Mask	255.255.255.252	255.255.255.255	255.255.255.255	255.255.255.0	255.255.255.252
DHCP Address	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0	172.16.19.10
Default Gateway Address	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0	0.0.0.0

Table 10-13
Example 6— Dual GNEs with BGP

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
GNE (“shelf is DCN GW” flag)	Yes	No	No	Yes	No
External Routing Mode	BGP	None	None	BGP	None
Peer IP Address	172.16.19.2	None	None	192.10.1.2	None

Example 6 is like Example 5, but the GNE shelves, Site A band 1 and Site C band 2, are running BGP. In this case, the GNE shelves are directly connected to the customer DCN with no additional OSPF backbone routers required.

The Optical Metro 5100/5200 network is assigned an autonomous system (AS) number. A BGP peer is set up between a router in the customer network and the GNE shelf. The GNE shelf is configured to run OSPF on its internal IP interfaces. With this configuration, the default gateway is not used at the GNE and the default GNE field must be set to 0.0.0.0. BGP learns the default routes to the customer router dynamically. There is no need to specify a default route to the Optical Metro 5100/5200 network at the customer router. BGP learns the routes to the Optical Metro 5100/5200 shelves through route updates between the BGP peers.

Dual GNEs and SNMP proxy

In this example, no routing protocols are used between the GNEs and the DCN. The GNEs appear as “hosts” on the DCN LAN segment to which they are connected. The non-GNE shelves are not directly accessible from the DCN, and are assigned private addresses. These shelves may be managed using TL-1 and/or SNMP proxy. SMI automatically detects the gateway configuration and uses SNMP proxy, (see “SNMP proxy service” on page 10-13).

The GNEs have the “shelf is DCN gateway” flag set and the external routing mode set to none. The IP address and subnet mask are assigned in accordance with the DCN subnet to which the they are connected. The default gateway is set to a DCN router on the attached subnet.

The non-GNE shelves do not have the “shelf is DCN gateway” flag set. They have been assigned the smallest allowable subnet using a mask of 30 bits, which includes the shelf address and a DHCP address for direct connections to the shelf. In this case, private IP addresses are used, with 10.1.shelfID.1 assigned to the shelf, and 10.1.shelfID.2 assigned for DHCP.

Figure 10-13 shows dual GNEs using SNMP proxy.

Figure 10-13
Example 7— Dual GNEs and private IP addresses

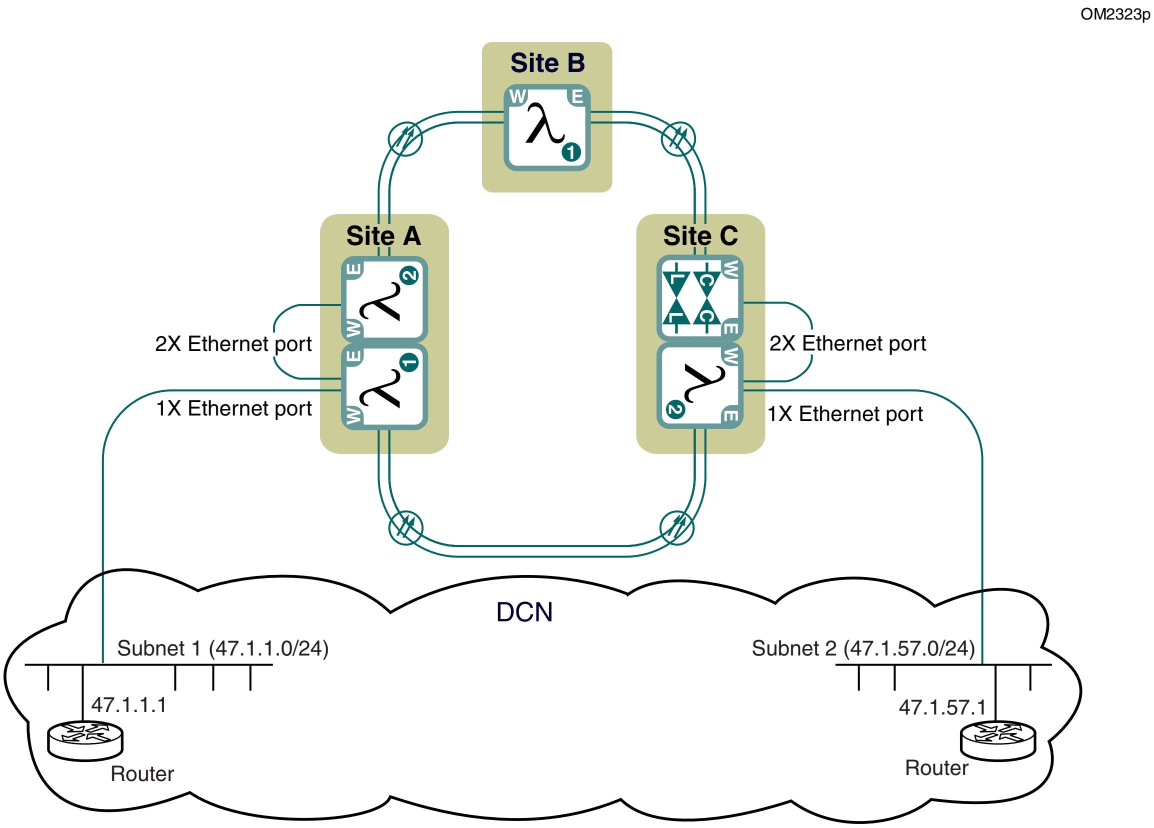


Table 10-14 lists configuration information for Example 7.

Table 10-14
Example 7— Dual GNEs and private IP addresses

Parameter	Site A Band 1	Site A Band 2	Site B Band 1	Site C Band 2	Site C OFA
Primary Shelf Address	47.1.1.2	47.1.1.2	47.1.1.2	47.1.1.2	47.1.1.2
Shelf Address	47.1.1.2	10.1.2.1	10.1.8.1	47.1.57.2	10.1.10.1
Subnet Mask	255.255.255.0	255.255.255.252	255.255.255.252	255.255.255.0	255.255.255.252
DHCP Address	0.0.0.0	10.1.2.2	10.1.8.2	0.0.0.0	10.1.10.2
Default Gateway Address	47.1.1.1	0.0.0.0	0.0.0.0	47.1.57.1	0.0.0.0
GNE (“shelf is DCN GW” flag)	Yes	No	No	Yes	No
External Routing Mode	None	None	None	None	None

Data communications engineering guidelines

Definitions

The following terms are used to describe the data communication engineering guidelines.

Data communications channel

In the context of data communication, the channel describes the data-link-layer PPP (Point-to-Point Protocol) connection provided by, for example, OSC circuit packs at two adjacent sites, or a pair of compatible OCLD/OTR/Muxponder circuit packs in two adjacent like-banded shelves.

Data communications neighbor

With respect to a given shelf, any other shelf that is accessible by one or more of the following:

- a shared Ethernet hub, or directly via a cross-over cable, using the 2X-Ethernet ports
- one or more overhead channels provided by OCLD, OTR or Muxponder circuit packs, over a single data communication hop (see following definition for data communication hop)
- a supervisory channel provided by an OSC circuit pack, over a single data communication hop. Note that normally a shelf with an OSC circuit pack has two supervisory channels, one east and one west.

Data communications hop

For a given data communications channel, a data communication hop is counted between the end-points of that channel. That is, each time a particular data communication channel passes from a given site at which it is terminated to the next site at which it is terminated, a single data communication hop is counted. For example, for an OCLD, OTR or Muxponder overhead channel, there is a single hop between a Band-1 shelf and the next Band-1 shelf in the network. For OSC, there is a single data communication hop between two adjacent shelves equipped with OSC circuit packs.

Maximum configurations

The maximum supported configurations include:

- The maximum number of shelves supported is 64, in any combination of terminal, OFA and OADM shelves.
- The maximum number of data communication neighbors is 20.
- The maximum number of sites supported depends on the topology of the data communication network. As a simple rule of thumb, the maximum number of sites is 16 if OSCs are equipped at every site. Otherwise the maximum is 9.

- If there are more than 16 sites with OSCs equipped, or OSCs are not equipped at every site, the following maximum applies: no site can be more than 8 data communication hops from any other site, under the worst-case fiber break scenario.

Data communication channel characteristics

OCLD, OTR or Muxponder circuit packs provide a per-wavelength data communication channel. This implies that the data communication channel terminates everywhere the wavelength itself terminates and passes through everywhere the wavelength itself passes through. The OCLD and OTR 2.5 Gbit/s circuit pack data communication channel operates at 128 kilobits per second. The PWOSC is superimposed on the payload signal using DPSK modulation. The OTR 10 Gbit/s, OTR 10 GBit/s Enhanced and Muxponder 10 Gbit/s GbE/FC data communication channel operates at 1.3 megabits per second using the GCC0 bytes of the digital wrapper signal. When the PWOSC is disabled on a circuit pack using System Manager or TL1, PPP (Point-to-Point Protocol) is disabled on that circuit pack and as a result, no data communications traffic is sent over it. The DPSK modulation is not disabled when the PWOSC is disabled.

OSC circuit packs provide an out-of-band data communication channel that terminates at the next nearest shelf in each direction that also contains an OSC circuit pack. When OSCs are equipped at every site in a network, the OSC data communication channel terminates at each site. The OSC data communication channel operates at 10 megabits per second.

For more information about the data communication channels, see “Internal data communications”, “Data link layer” on page 10-9.

Data communication channel costs

OSPF (Open Shortest Path First) is used as the internal routing protocol in Optical Metro 5100/5200 (see “Internal data communications”, “Routing protocols” on page 10-8). Each Optical Metro 5100/5200 shelf can be considered to be a router. OSPF determines the lowest cost path from every shelf (router) to every other shelf and subnet in the Optical Metro 5100/5200 network.

The OSPF costs associated with the various types of channels that may connect two sites are:

- 780 for OCLD and Flex OTR data communications channels
- 252 for 10 Gbit/s OTR or 10 Gbit/s Muxponder data communications channels
- 194 for OSC data communications channels

Low cost routes are preferred over high cost routes. Therefore, between two adjacent sites, if multiple types of channels are available, an OSC channel is preferred to an OTR, Muxponder or OCLD channel due to its lower cost.

Between non-adjacent sites, however, an OTR, Muxponder or OCLD channel may be chosen as a lower cost route than several OSC hops due to the way the bands may be meshed in a particular network. For example, a single OTR hop (cost of 252) is lower cost than two OSC hops (total cost of 388).

In non-trivial Optical Metro 5100/5200 network configurations, there could be several diverse routes between any given pair of shelves, spanning combinations of OSC, OTR, Muxponder and OCLD data communication channels.

It is important to note that multiple per-wavelength overhead channels, provided by OCLDs, OTRs and Muxponders between the same end points have the same total cost as a single channel. For example, the OSPF cost of four overhead channels between shelf-A and shelf-B is 780—the same as a single channel between the same shelves. The cost is not dynamically adjusted based on the available bandwidth.

Example 1—Determining the number of data communications neighbors (no OSC)

This example assumes that no OSCs are equipped at any site. See Figure 10-14. For an explanation of the number of neighbors for each shelf, see Table 10-15.

Figure 10-14
Example 1

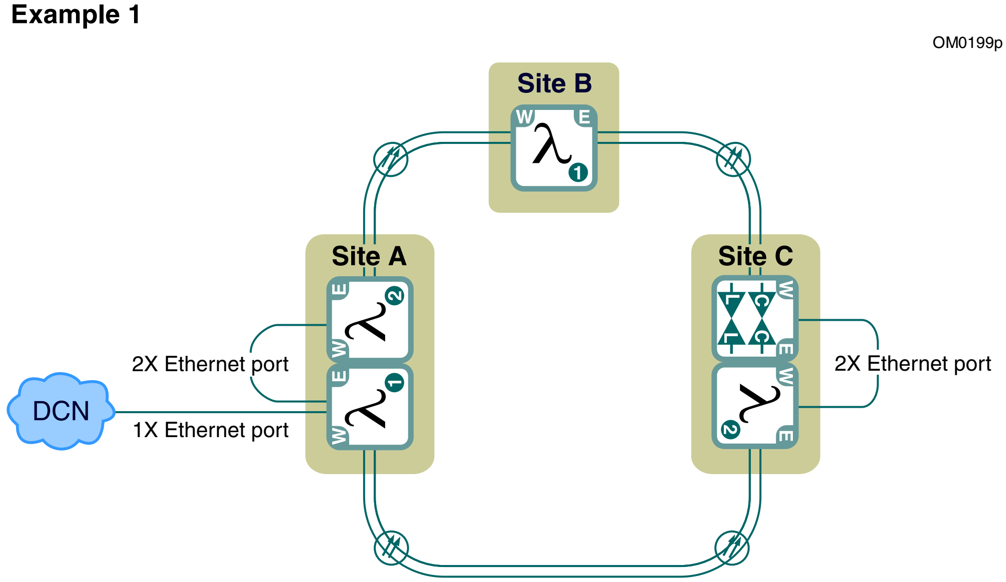


Table 10-15
Example 1

Shelf	Number of neighbors	Neighbor shelves (via channel)
Site A - Band 1	2	Site A - Band 2 (2X-Ethernet port) Site B - Band 1 (overhead channel)
Site A - Band 2	2	Site A - Band 1 (2X-Ethernet port) Site C - Band 2 (overhead channel)
Site B - Band 1	1	Site A - Band 1 (overhead channel)
Site B - Band 2	2	Site A - Band 2 (overhead channel) Site C - OFA (2X-Ethernet port)
Site C - OFA	1	Site C - Band 2 (2X-Ethernet port)

Example 2—Determining the number of data communications neighbors (with OSC)

This example assumes that OSCs are equipped at each site, in the following shelves:

- Site A - Band 1
- Site B - Band 1
- Site C - OFA

See Figure 10-14. For an explanation of the number of neighbors for each shelf, see Table 10-16.

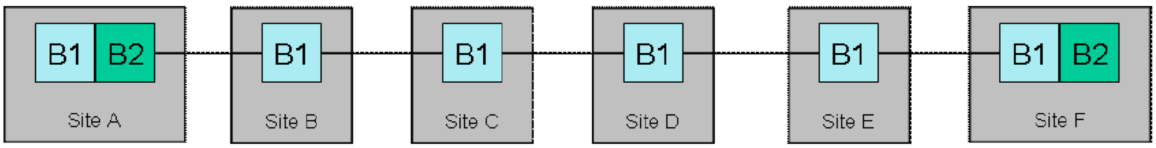
Table 10-16
Example 2

Shelf	Number of neighbors	Neighbor shelves (via channel)
Site A - Band 1	3	Site A - Band 2 (2X-Ethernet port) Site B - Band 1 (overhead and OSC channels) Site C - OFA (OSC channel)
Site A - Band 2	2	Site A - Band 1 (2X-Ethernet port) Site C - Band 2 (overhead channel)
Site B - Band 1	2	Site A - Band 1 (overhead and OSC channels) Site C - OFA (OSC channel)
Site B - Band 2	2	Site A - Band 2 (overhead channel) Site C - OFA (2X-Ethernet port)
Site C - OFA	3	Site C - Band 2 (2X-Ethernet port) Site B - Band 1 (OSC channel) Site A - Band 1 (OSC channel)

Example 3—Determining the number of data communications hops (with OCLDs, no OTRs, Muxponders or OSCs)

This example assumes that the shelves contain OCLDs, but not OTRs, Muxponders or OSCs. See Figure 10-15.

Figure 10-15
Example 3 - Six site linear network



Between Site A and Site F, there are five Band-1 data communications hops and one Band-2 data communications hop. Traffic between these sites follows the shortest path along the single hop of the Band-2 overhead channel.

Between Site A and Site E, there are four Band-1 data communications hops. However, a lower cost path exists which involves two hops: from Site A to Site F along the Band-2 channel, then from Site F to Site E along the Band-1 channel. Traffic follows the lower cost path.

Example 4—Determining the number of data communications hops (with OCLDs and OSCs)

This example assumes that the shelves contain OCLDs and OSCs. See Figure 10-15.

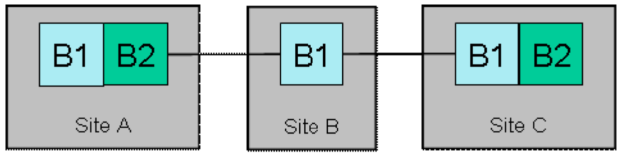
In terms of the overhead channels provided by the Band-1 and Band-2 shelves, the number of hops is the same as "Example 4—Determining the number of data communications hops (with OCLDs and OSCs)". However, since OSCs are equipped at every site, there are now also five OSC hops from Site A to Site F.

Traffic between Site A and Site F follows the Band-2 overhead channel since the OSPF cost of this single OCLD data communications hop is lower than five OSC hops. Between Site A and Site E, the lowest cost path follows the OSC channel over four hops.

Example 5—Determining the number of data communications hops (with OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC and OSCs)

This example assumes that the shelves contain OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC and OSCs. See Figure 10-16.

Figure 10-16
Example 5—Three-site linear network with OTR 10 Gbit/s, OTR 10 Gbit/s Enhanced or Muxponder 10 Gbit/s GbE/FC and OSCs



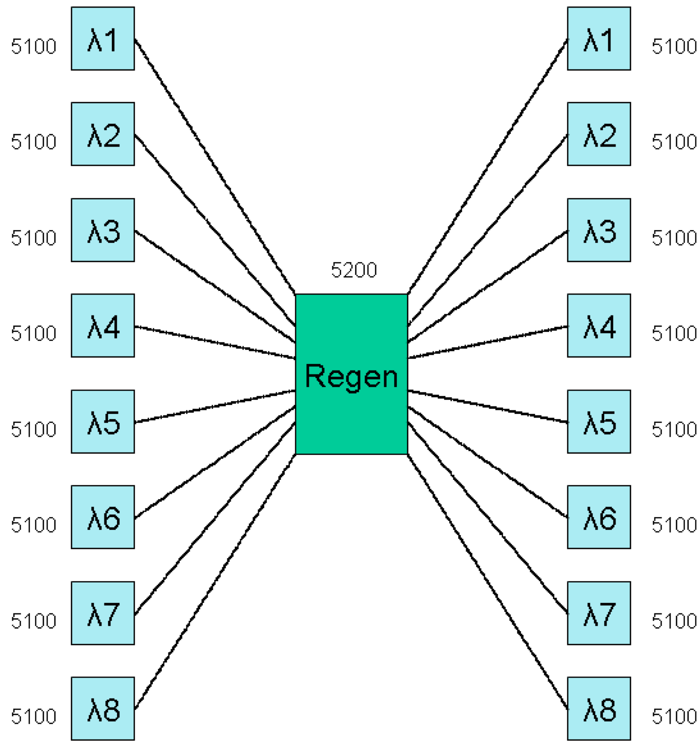
In terms of the overhead channels provided by the Band-1 and Band-2 shelves, the number of hops between Sites A and C is two for Band-1 and one for Band-2. There are also two OSC hops between these sites.

Traffic between Site A and Site C follows the Band-2 overhead channel since the OSPF cost of this single OTR/Muxponder data communications hop is lower than two OTR/Muxponder hops (Band-1) or two OSC hops. Between Site A and Site B, the lowest cost path follows the single OSC hop.

Example 6—Analyzing a network

In this example (see Figure 10-17), the network consists of eight point-to-point systems with an Optical Metro 5200 shelf regenerating the eight wavelengths. There are seventeen sites, each with one shelf, and no OSCs equipped. Since the site count exceeds nine, the number of neighbors and data communications hops must be analyzed.

Figure 10-17
Example 6—Seventeen-site point-to-point network



The number of neighbors of each of the Optical Metro 5100 shelves is one, since there is only a single shelf at each site (no shelves connected through an Ethernet hub) and a single data communications channel to the Optical Metro 5200 shelf. The number of neighbors of the Optical Metro 5200 shelf is 16, since this shelf has 16 data communications channels (one to each Optical Metro 5100 shelf).

The maximum number of data communications hops in the network is two, from any Optical Metro 5100 shelf, through the Optical Metro 5200 shelf, to the far-end Optical Metro 5100 shelf. Therefore, from the data communications perspective, this configuration is acceptable.

Data communications network considerations when using Optical Metro 5100/5200 with Common Photonic Layer

When implementing a network using the Optical Metro 5200 DWDM 100 GHz variant circuit packs with the Common Photonic Layer DWDM 100 GHz optical layer, the Optical Metro 5100/5200 OSC circuit pack cannot be used. This is because the wavelength used by the OSC (1510 nm) is also used by the Common Photonic Layer optical layer. As a result, the only data communications channel available for communicating between the Optical Metro 5100/5200 sites is the per-wavelength overhead channel (PWOSC).

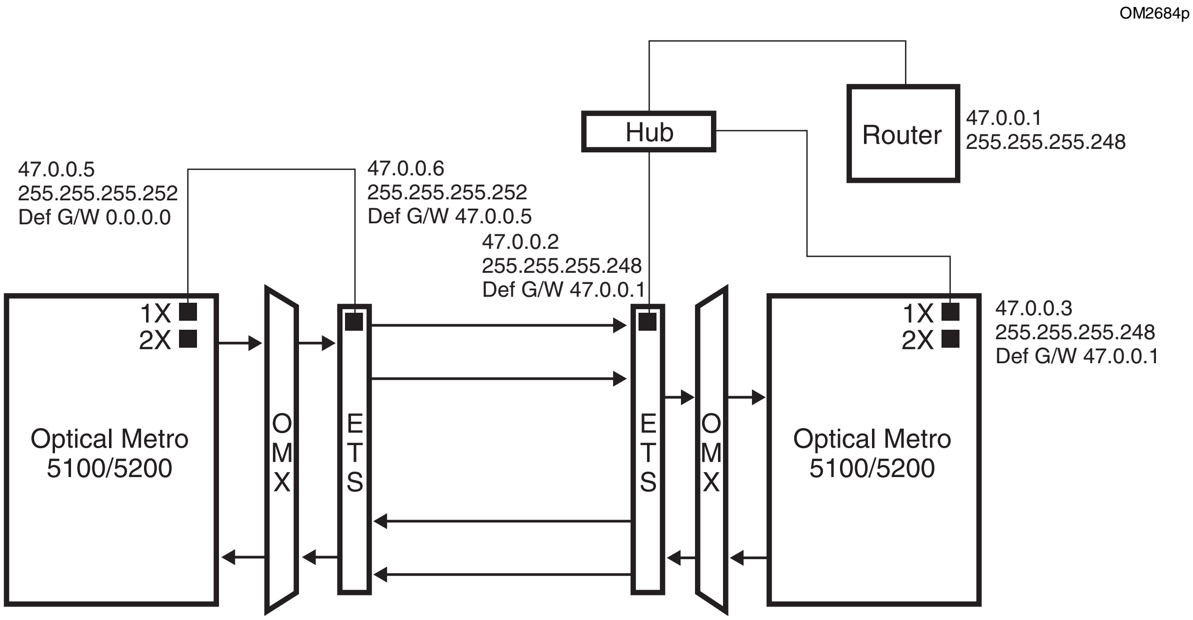
This means that the Optical Metro 5100/5200 data communication engineering guidelines which are inherent to networks without OSC must be applied. In particular:

- Maximum number of sites is 9, notwithstanding the exceptions allowed by applying the more detailed data communications engineering rules as described in this NTP.
- Wavelength configurations and traffic patterns determine the scope of the data communications network. Care must be taken to avoid creating data communication islands or sites that are isolated from each other. Ensure that the GNE always has a direct or indirect path to every other site in the network, under normal or failure (single fiber break) conditions.

ETS Remote Management using Ethernet 1X port

A remote Enhanced Trunk Switch can be managed using the Optical Metro 5100/5200 internal communications as shown in Figure 10-18 on page 10-46.

Figure 10-18
ETS Remote management



The guidelines in Table 10-17 on page 10-46 apply to an Optical Metro 5100/5200 network configured with a single GNE in Proxy ARP mode.

Table 10-17
Configuration guidelines for ETS managed through Optical Metro 5100/5200 network – Proxy ARP GNE

Entity	IP Address	Subnet Mask	Default Gateway
GNE shelf	Part of the same subnet as the DCN router	Same as DCN router. Includes all remote NEs and 1X subnets.	The IP address of the DCN router
ETS at GNE site	Part of the same subnet as the DCN router	Same as DCN router and GNE shelf	The IP address of the DCN router
Remote Optical Metro 5100/5200 shelf with ETS connected to 1X	Part of the subnet assigned to the remote NE, which is itself part of the larger subnet to which the GNE is connected.	Set 30 bits or less (255.255.255.252), to include NE and ETS IP addresses. Normally, 255.255.255.252 is sufficient. This subnet is part of the GNE subnet.	Set to 0.0.0.0. Remote NE learns default route via GNE shelf.

Table 10-17 (continued)
Configuration guidelines for ETS managed through Optical Metro 5100/5200 network – Proxy ARP GNE

Entity	IP Address	Subnet Mask	Default Gateway
ETS at remote site	Part of the subnet assigned to remote NE to which ETS is connected	Same as remote NE to which ETS is connected	IP address of NE to which ETS is connected

The guidelines in Table 10-18 on page 10-47 apply to an Optical Metro 5100/5200 network configured with one or more GNEs running OSPF or BGP.

Table 10-18
Configuration guidelines for ETS managed through Optical Metro 5100/5200 network – OSPF or BGP GNE(s)

Entity	IP Address	Subnet Mask	Default Gateway
GNE shelf	Part of the same subnet as the DCN router	Same as DCN router.	Set to 0.0.0.0. GNE learns default route, if any, via DCN router.
ETS at GNE site	Part of the same subnet as the DCN router	Same as DCN router and GNE shelf	The IP address of the DCN router
Remote Optical Metro 5100/5200 shelf with ETS connected to 1X	Part of the subnet assigned to the remote NE	Set 30 bits or less (255.255.255.252), to include NE and ETS IP addresses. Normally, 255.255.255.252 is sufficient.	Set to 0.0.0.0. Remote NE learns default route, if any, via GNE shelf.
ETS at remote site	Part of the subnet assigned to remote NE to which ETS is connected	Same as remote NE to which ETS is connected	IP address of NE to which ETS is connected

Optical Metro 5100/5200 communication ports

In a firewall environment, the communication ports listed in Table 10-19 must be opened.

Table 10-19
Optical Metro 5100/5200 communication ports

Port	Communications end-point where port is used (Remote, NE or Both)	Application	TCP or UDP based	Description
20	Both	FTP	TCP	Standard FTP data session port. For an external FTP client, using passive FTP mode, this port is not used. For an external FTP client, using active FTP mode, this port is used by the Optical Metro 5100/5200 FTP server to initiate the FTP data connection. For an internal FTP client, using active FTP mode, the Optical Metro 5100/5200 FTP client receives FTP data connection requests from this port on the external FTP server. Internal FTP client using passive FTP mode is not supported. System Manager uses passive FTP, with the client on the System Manager workstation. TL1 upgrades, backups and restores use active FTP, with the client on the NE.
21	Both	FTP	TCP	Standard FTP control session port. For an external FTP client, using active or passive FTP mode, the NE receives FTP control session requests on this port. For an internal FTP client, in active FTP mode, the NE initiates FTP control session requests to this port on the external FTP server. Internal FTP client using passive FTP mode is not supported. System Manager uses passive FTP, with the client on the System Manager workstation. TL1 upgrades, backups and restores use active FTP, with the client on the NE.
23	NE	Telnet	TCP	Used for technical support access to Optical Metro 5100/5200
53	Remote	DNS	UDP	Used only if DNS Proxy Service is enabled, the NE sends DNS requests to this port on an external Domain Name Server
80	NE	HTTP	TCP	Used to launch System Manager
161	NE	SNMP	UDP	Standard SNMP access port. Used by System Manager and 3rd-party SNMP-based managers. In public-IP mode, all shelves are accessed using this port. In private-IP mode, this port is used to access the host shelf (a GNE). Ports 8001 to 8064 are used to access the remaining shelves (see below). When System Manager is used, SNMP traps are sent from this port on the NE to a random port on the System Manager workstation, determined on System Manager startup.
162	Remote	SNMP	UDP	Standard SNMP trap listening port used only by 3rd-party SNMP based management stations.
179	Both	BGP	TCP	Standard port used for BGP peer connections. Only used when BGP is provisioned as the GNE DCN gateway routing protocol. The connection may be initiated by either the Optical Metro 5100/5200 GNE or the external router.
1024 to 5000	NE	FTP	TCP	When the NE acts as the FTP client in active FTP mode, a port in this range will be used to receive an FTP data connection from port 20 on an external FTP server. TL1 upgrades, backups and restores use active FTP, with the client on the NE.
1812	Remote	RADIUS	UDP	RADIUS requests are sent to this port by default, however the port number is provisionable. Any change to the default value would require a corresponding change to firewall settings.
1966	NE	System Manager	TCP	System Manager accesses this port for session management
8001 to 8064	NE	SNMP	UDP	Used in private-IP mode only to access non-System Manager-host shelves. The specific port for a particular NE is (8000 + shelfID). Used by System Manager and 3rd-party SNMP-based managers.
10001	NE	TL1	TCP	TL1 port
10002	NE	TL1 (Telnet)	TCP	TL1 port used for technical support access to Optical Metro 5100/5200. Not used by management platforms such as OMEA.

Network security planning

In this chapter

Supported strategies

Optical Metro 5100/5200 offers two options for securing access to Optical Metro 5100/5200 shelves:

- centralized security administration
- local user authentication

Centralized security administration uses Remote Access Dial-In User Authentication Service (RADIUS). The RADIUS protocol is an IETF Draft Standard (RFC 2865) widely used to support remote access protocols (for example, SLIP, PPP, telnet, and rlogin). In this security strategy, a central RADIUS server contains all user account information, and communicates with the Optical Metro 5100/5200 shelves through security gateways. For more information about centralized security administration, see "Centralized security administration" on page 11-2. It is recommended that Optical Manager Element Adapter 2.2 be used to manage centralized security administration.

Local user authentication employs user accounts that are stored locally on Optical Metro 5100 or Optical Metro 5200 shelves. For more information about local user authentication, see "Local user authentication" on page 11-12.

Centralized security administration

> ***Note:*** If an Optical Metro 5100/5200 network is deployed with Optical Manager Element Adapter 2.2, additional security features may be available. This section describes the basic functionality available through the Optical Metro 5100/5200 management tools (System Manager and TL1).
> For information about additional security features provided through Optical Manager Element Adapter 2.2, see the *Optical Manager Element Adapter Security Administration Guide*, 450-3121-351.

The Optical Metro 5100/5200 supports the Nortel Networks Optical Manager Element Adapter (OMEA) Remote Authentication Dial-in Service (Radius) server, as well as third-party Radius servers. If you are running Nortel Networks Preside software, it is recommended that you set up the OMEA as a Radius server. If you are not running Preside software, then any standard, third-party radius software is supported by Optical Metro 5100/5200. The Radius protocol used by the Optical Metro 5100/5200 is an IETF Draft Standard (RFC 2865) that is widely used to support remote access protocols. The RADIUS Protocol is a UDP-based client-server protocol. If you require more details on Optical Metro 5100/5200 series inter-working with third-party radius servers, contact your Nortel Networks representative. For details on Optical Metro 5100/5200 vendor specific attribute information, refer to "Vendor specific attributes (VSA)" on page 11-10.

> ***Note:*** The security enhancements available when using the OMEA radius server are listed below. For details, refer to the OMEA documentation:
>
> — Password aging and expiration
>
> — Sophisticated password rules
>
> — Date, time and address of last logging
>
> — Number of unsuccessful attempts
>
> — Last failed login IP address

In a centralized security administration environment, login requests are sent (via TL1 or System Manager) to a security gateway (which is an Optical Metro 5100/5200 GNE shelf that has been provisioned as a security gateway). The security gateway sends the request to a remote RADIUS server, and returns the RADIUS server responses to the hosting Optical Metro 5100/5200 shelf. Responses can be either:

- access-accept
- access-reject (due to incorrect login information)
- server unavailable

An access-accept response grants the user access to the network with the appropriate privilege level, while an access-reject response requires further action, depending on the reason for the rejection.

If the login attempt is rejected due to invalid login information, the user can attempt the login again. The number of allowable login attempts is limited, and when the login attempt threshold is met, the user is prevented from further attempts for a period of time and/or locked out, depending on the RADIUS server capability. An alarm is also raised.

The login attempt threshold is reset when one of the following conditions exist:

- A successful login
- The lockout duration expires
- The alarm is cleared

If the login attempt is unsuccessful due to RADIUS server unavailability, two alternate methods of securing network access are available:

- local user authentication (see “Local user authentication” on page 11-12)
- challenge/response authentication (see “Challenge/response” on page 11-8)

The following login session information is available only with Optical Manager Element Adaptor (OMEA) running. Upon a successful login authentication through OMEA (or SMI when OMEA is running), the following login information is displayed to the System Manager or TL1 user:

- Last login time
- Last successful login IP address (see Note)
- Failed login attempts
- Last failed login IP address
- Password expiration warning

Upon a failed login authentication through OMEA (or SMI when OMEA is running), the following login information is displayed to the System Manager or TL1 user:

- Access failure
- If the password is expired, the Password expired message is displayed

  Note: The last login IP address is the IP address of the last NE (or the OMEA) where the Radius request is originated. ``

RADIUS server redundancy and automatic retry strategy

You can designate up to two security gateways, each with up to two different RADIUS server addresses to provide maximum redundancy against a server failure scenario.

There is a timeout period for requests sent to both the security gateway and the RADIUS server. The timeout period specifies the maximum amount of time it takes to send requests and wait for responses. If a request is sent and no response is received, a second request is automatically sent to protect against any temporary UDF message loss, and to alleviate network congestion.

This timeout period for communication between the shelf and the primary or the secondary RADIUS server can be provisioned using the System Manager Interface (SMI) or TL-1. The default value is 10 seconds.

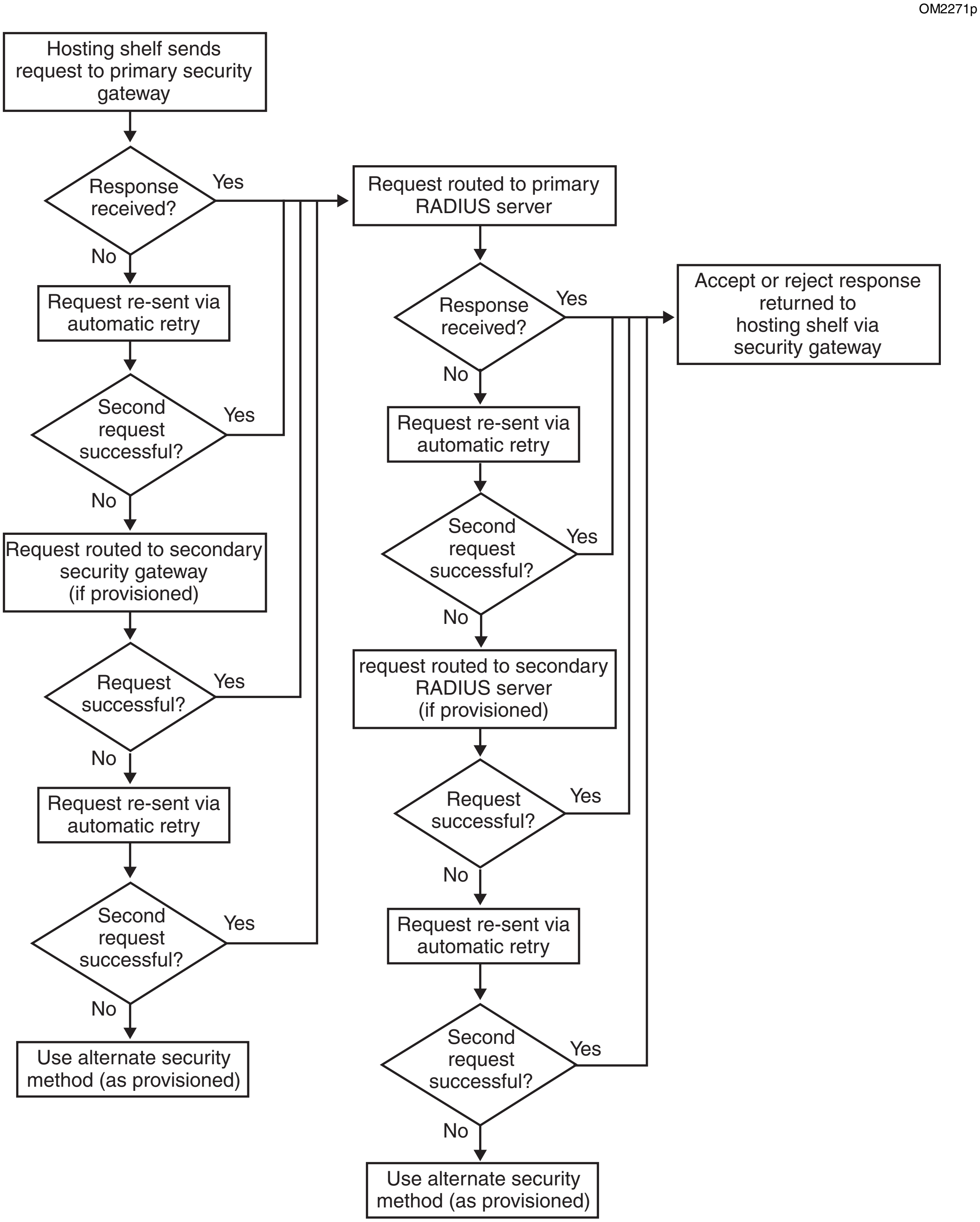
For more details on how to provision this timeout value in SMI, refer to Procedure 2-10 “Setting the primary or secondary RADIUS server attributes” in *Provisioning and Operating Procedures*, 323-1701-310.

For more details on how to provision this value (called “idle timeout”) in TL-1, refer to Table 2-44 “SET-ATTR-SECUDFLT input syntax definition” in *TL1 Interface*, 323-1701-190. In Table 2-44, there are also details on how to provision the lockout interval (DURAL parameter).

If the primary security gateway or a RADIUS server is unavailable, the request is routed to the secondary security gateway or RADIUS server, if provisioned.

Figure 11-1 shows the sequence of events for each request.

Figure 11-1
Sequence of events for network access requests



Provisioning centralized security administration

For Optical Manager Element Adapter 2.2 RADIUS server administration, see the *Optical Manager Element Adapter Security Administration Guide*, 450-3121-351. Alternately, refer to your vendor's user guide for server administration.

The settings for using a RADIUS server to secure access to an Optical Metro 5100/5200 network are provisioned through System Manager or TL1 commands.

Table 11-1 provides an overview of the provisionable settings for using a RADIUS server to secure access to an Optical Metro 5100/5200 network. For detailed information about provisioning an Optical Metro 5100/5200 network to use a RADIUS server for securing network access, see *Provisioning and Operating Procedures*, 323-1701-310, or *TL1 Interface,* 323-1701-190.

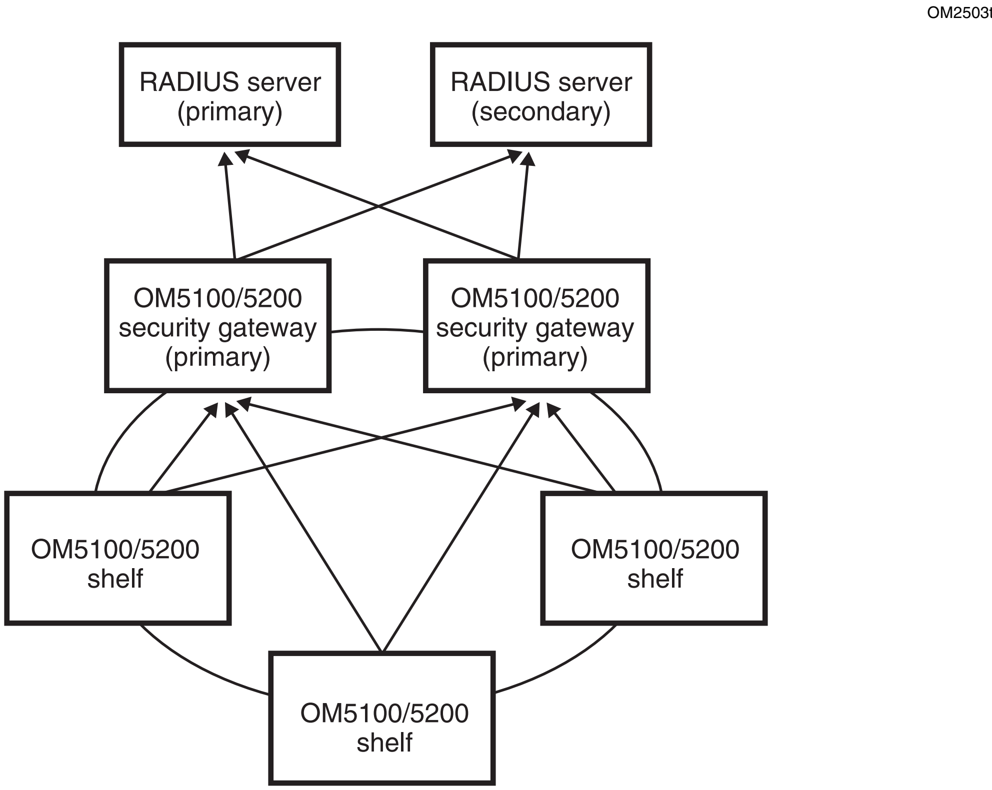
Table 11-1
Provisionable values for RADIUS server access for centralized security administration

Value	Provision using	Notes
authentication mode	System Manager, TL1	• either centralized security administration or local user authentication
alternate method	System Manager, TL1	• available only if centralized security administration selected as authentication mode • either local user or challenge/response
primary and secondary RADIUS server IP address and port	System Manager, TL1	• secondary RADIUS server is optional
shared secret for communication between the Optical Metro 5100/5200 shelf and RADIUS server	System Manager, TL1	
shared secret for challenge/response	System Manager, TL1	• mandatory if challenge/response is selected as alternate method (see "Challenge/response" on page 11-8)
security gateway IP address	System Manager, TL1	• must be an Optical Metro 5100/5200 GNE shelf • secondary gateway is optional
timeout duration for automatic retries on primary and secondary RADIUS servers	System Manager, TL1	

Supported gateway and server configurations

You can provision up to two RADIUS servers and two security gateways per system, managed by one primary network element. The Optical Metro 5100/5200 hosting shelf sends the access request first to the primary gateway. If the primary gateway is out of contact, or if a timeout response occurs, the request is resent to the secondary gateway (if provisioned). Similarly, the security gateway routes the access request first to the primary RADIUS server, and then to the secondary RADIUS server, if necessary. Figure 11-2 shows the maximum allowable configuration.

Figure 11-2
Centralized security administration



If all security gateways and/or all RADIUS servers are unavailable, the alternate method of authentication (local user authentication or challenge/response, as provisioned), will be used. An alarm (or alarms) is also generated if the primary and/or secondary servers are unavailable.

RADIUS shared secrets

Passwords are encrypted through a provisionable server shared secret. The server shared secret resides on the RADIUS server, and the security gateway. The shared secret provisioned on the server and the Optical Metro 5100/5200 shelf must be matched.

Although a default shared secret is supplied, an administrative-level user should change the default value to a different and difficult-to-guess value. The shared secret must be kept secure. There is no way to recuperate or change a lost shared secret. If the shared secret is lost, contact your Nortel Networks support group.

For more details on how to change the shared secret, refer to Procedure 2-11 “Changing the challenge/response shared secret” and Procedure 2-12 “Changing the shared secret for the primary or secondary RADIUS server” in *Provisioning and Operating Procedures*, 323-1701-310.

Password restrictions

Sophisticated password rules and restrictions are available as enforced by Optical Manager Element Adapter, and may be supplemented by additional restrictions, as defined by your network administration. For details about password restrictions as enforced by Optical Manager Element Adapter, see the *Optical Manager Element Adapter Security Administration Guide*, 450-3121-351.

Challenge/response

Challenge/response provides an alternate backup method of securing network access if the security gateways or RADIUS servers are unavailable in a centralized security administration scheme.

> ***Note:*** Alternatively, you can choose local user authentication as an alternate backup security method. For information about local user authentication, see “Local user authentication” on page 11-12.

When logging in using the challenge/response application, users are prompted with a challenge, for which they must supply a response. The user must contact their network operations centre to obtain the correct response, which network operations personnel obtain through the response generating tool, (available through Optical Manager Element Adapter or as a stand-alone tool; see Chapter 13, “Optical Metro 5100/5200 ordering information” for the product engineering code). The user then enters the given response to complete the login process.

If a challenge/response login is successful, the user privilege class level granted to the user is derived from the level encoded into the response from the response calculator.

Challenge/response shared secrets

A provisionable shared secret is stored locally on the Optical Metro 5100/5200 shelf, and is used in conjunction with other user information to generate a response in the response generating tool. The shared secret is not transmitted as part of the authentication process.

Although a default shared secret is supplied, an administrative-level user should change the default value to a different and difficult-to-guess value. The local shared secret must be kept secure. There is no way to recuperate or change a lost local shared secret. If the local shared secret is lost, contact your Nortel Networks support group.

You can provision the local shared secret using System Manager or TL1. For detailed information about provisioning the shared secret, see *Provisioning and Operating Procedures*, 323-1701-310, or *TL1 Interface,* 323-1701-190.

The challenge

The unique challenge is randomly generated at each login attempt. Because each challenge is random-generated, even if an intruder is able to gather challenge and response pairings, these pairings cannot be replayed to gain access to the equipment.

The response

Upon being contacted by a user requesting a response, the network operations personnel enter into the response generating tool the User ID, the challenge string, and the shared secret (the same shared secret stored on the Optical Metro 5100/5200 shelf) to generate a response. The response is communicated to the user, who can then complete the login process.

Vendor specific attributes (VSA)

Vendor Specific Attributes allow vendors to support their proprietary RADIUS attributes that are not included in the standard Radius attributes, such as RFC 2865. Table 11-2 lists the mandatory and the optional vendor specific attributes that are supported for the Optical Metro 5100/5200 radius inter-working with third-party radius servers. For details, contact your Nortel Networks representative.

Table 11-2
Generic VSA format with Nortel Networks vendor ID 562

Byte #	Field	Description
0	Attribute Type(26)	A value of 26 is used for Vendor Specific Attributes as defined in the Radius Protocol standard.
1	Attribute Length	The length, in bytes, of the attribute, including the Type, Length, and Data fields. The maximum value is 256 bytes.
2..5	Vendor ID(562)	The Nortel Networks SMI Network Management Private Enterprise Code of 562 as defined by RFC 1700
6	VSA Type	The VSA identifier, as defined by Nortel Networks. See Access-Accept Attributes for supported VSA IDs.
7	Sub-attribute Length	The length of sub attributes, including VSA Type and VSA Data
8..n	VSA Data	Information specific to the VSA Type definition. The maximum value is 248 bytes. Refer to Table 11-3 on page 11-11 for a list of the mandatory and optional VSAs.

Table 11-3 lists the mandatory and optional values for the VSA Data field described in Table 11-2 on page 11-10.

Table 11-3
Mandatory and optional Vendor Specific Attributes

Mandatory / Optional	Attribute ID	VSA ID	Name	Data Description	Data Format	Instances (See Note)
Mandatory (for values, refer to the table below)	26	2	UPC	UPC value for NE	4 byte integer	1
Optional	26	3	Last login time	Time of last successful login (milliseconds since Jan 1, 1970, 00:00:00 GMT)	String	0-1
Optional	26	4	Last login location	Location of last successful login (IP address, TID, or MAC)	String	0-1
Optional	26	5	Failed login attempts	Number of failed login attempts since last successful login	4 byte integer	0-1
Optional	26	6	Last failed login location	Location of last failed login attempt (IP address, TID, or MAC)	String	0-1
Optional	26	7	Password expiration warning	Warning indicating number of days before password is due to expire	4 byte integer	0-1

Note: An instance value of 1 means that one instance of the attribute is allowed. An instance value of 0-1 means that zero or one instances of the attribute are allowed.

Mandatory VSA attributes

VSA ID 2 (UPC) is mandatory in Radius Access-Accept messages. Any Radius Access-Accept messages that contain missing or invalid UPC values are rejected by Optical Metro 5100/5200 Radius Client and the access is not granted. Other VSAs are optional in Access-Accept message. Table 11-4 lists the VSA ID 2 (UPC) values.

Table 11-4
VSA Data for VSA ID 2 (UPC)

User	VSA ID 2 (UPC value)
OM5000_ADMIN	16
OM5000_OPERATOR	256
OM5000_OBSERVER	4096

Local user authentication

In a local user authentication environment, up to 10 user accounts can be stored locally on each Optical Metro 5100/5200 system. There are three default user accounts (admin, operator, observer) upon system commissioning, and up to seven additional users can be provisioned.

Provisioning local user authentication

Local user accounts are provisioned on the primary shelf, and propagated to the rest of the shelves in the Optical Metro 5100/5200 system. Table 11-5 on page 11-13 lists the provisionable values associated with local user accounts.

Administrative level users can also enable and disable local user accounts.

To provision local user authentication using System Manager, see *Provisioning and Operating Procedures*, 323-1701-310. To provision local user authentication using TL1, see *TL1 Interface,* 323-1701-190.

Table 11-5
Provisionable values for local user authentication

Value	Provision using	Notes
User Name	System Manager, TL1	
User password	System Manager, TL1	
User privilege	System Manager, TL1	cannot be changed for three default users
Status	System Manager, TL1	disable/enable
Note 1: You cannot delete the three default users. ***Note 2:*** You cannot disable the default Admin-level user.		

User Name restrictions

A User ID must be between one and ten characters in length and must consist of alphabetical and numerical characters only.

Password restrictions

Local user accounts are managed by the Optical Metro 5100/5200 shelf, which enforces the following password restrictions:

- the password must be between 8 and 10 characters
- the password cannot contain the following characters:
  - ; (semicolon)
  - : (colon)
  - & (ampersand)
  - ? (question mark)
  - , (comma)
  - (space)
  - " (double quotes)

Table 11-6 on page 11-14 summarizes the security features available described in the previous sections.

Table 11-6
Summary of available security features

RADIUS (3rd party)	OMEA	NE	Security feature
		X	An administrator can create, edit, delete and disable local accounts directly on the NE. Local user accounts are mapped to one of three NE access control groups (admin, operator, observer).
		X	Challenge / Response or Local accounts can be used when a network element cannot communicate with a radius server.
X	X		Centralized User Account Management. An administrator has the ability to create, edit, delete and disable user profiles centrally through the Optical Manager Element Adapter (OMEA) security Graphical User Interface (GUI) or a third party Radius server. Once a user account is added to the system, it becomes immediately available on the Network Elements via RADIUS authentication. NE users have one of 3 access control privileges: Admin, Operator, Observer
X	X		Password aging. After a configurable period of time, user passwords expire. Users are warned prior to password expiration (the warning time period is configurable). Accreditation period and dormant period can also be provisioned.
X	X		Prevention of password flipping. Password history list - number of last passwords that cannot be re-used. Obsolescence period - number of days during which a user cannot reuse a password.

Table 11-6 (continued)
Summary of available security features

RADIUS (3rd party)	OMEA	NE	Security feature
X	X		Strong password rules. The userid cannot be the same as the password. Can define a minimum number of alphabetic characters, minimum number of digits, and minimum number of special characters that must be part of the password.
X	X		Date / Time and number of unsuccessful attempts since last login display. This appears after a successful NE login.
	X		Global parameter provisioning and distribution. The following parameters can be set via Optical Manager Element Adapter and are globally distributed to NEs: Warning banner, number of unsuccessful login attempts, lockout period, inactive TL1 session timeout, shared secrets.
	X		Centralized audit log capturing all NE security logs. A centralized audit log capturing OM5000 security logs is available on Optical Manager Element Adapter.
		X	Advisory warning after a successful login. After a successful login has occurred on TL1, System Manager or the Optical Manager Element Adaptor interface, an advisory warning message regarding unauthorized entry/use and its possible consequences is displayed. It is user modifiable to meet local requirements and state laws. A user can edit this warning message using TL1 or globally using Optical Manager Element Adaptor. The warning message can be up to 20 lines and 1600 bytes. A user can return the warning message back to its default.
		X	Intrusion Attempt Handling. After a certain number of invalid login attempts into the OM5000 NE has been exceeded, the NE locks the port of entry and raises a security alarm. The number of attempts is configurable between 2 - 20. The default value is 5. The lockout period can be between 0 - 60 seconds. (0 is used to disable the lockout). The default value is 60 seconds. The number of attempts and lockout period can be set directly on the NE or globally via Optical Manager Element Adapter (OMEA).
		X	Inactive TL1 session timeout. TL1 sessions are terminated if they have been idle for a provisionable period of time (0 to 999 minutes, default of 30 minutes). Inactive TL1 session timeout value can be provisioned using TL1 or globally using Optical Manager Element Adaptor.

Other security features

Login warning banner

A login warning banner is displayed upon successful login to an Optical Metro 5100/5200 shelf (through System Manager or TL1), but before network access is granted. The warning banner contains a message regarding unauthorized network access and possible consequences thereof.

The warning banner can be customized through TL1. For information about customizing the warning banner, see *TL1 Interface,* 323-1701-190.

Failed login attempt threshold and lockout period

All security schemes include the functionality to limit and track failed login attempts.

The number of allowable failed login attempts is configurable as follows:

- for centralized security, the maximum number of attempts per User ID is configurable on the RADIUS server through Optical Manager Element Adapter (see the *Optical Manager Element Adapter Security Administration Guide*, 450-3121-351)
- for local user authentication, the maximum number of failed attempts is configurable on the Optical Metro 5100/5200 shelf through System Manager or TL1 (see *Provisioning and Operating Procedures*, 323-1701-310 or *TL1 Interface,* 323-1701-190)

If the threshold for the maximum allowable login attempts is reached, an alarm is generated, and the Optical Metro 5100/5200 shelf will reject login requests for a period of time. This lockout period is provisionable.

Security alarms, events, and notifications

Security related information is only accessible to the admin user class. The following security related information is available:

- events such as user logins and logouts, password changes, clock changes, and so on
- active user login session list
- security related alarms

Ability to change the centralized user password through RADIUS protocol using System Manager or TL1

Two password changing scenarios are supported:

- System forced password change
- User requested password change

The centralized users password change request and response is sent to and received from the shelf through an encrypted proprietary communication protocol.

Changing the centralized user's password through RADIUS protocol using System Manager or TL1 is only supported with OMEA that has an embedded RADIUS server. Third-party RADIUS servers require a customized solution to support password changes through the RADIUS protocol. This is due to the lack of a standard RADIUS solution for this operation.

System forced password change

In this scenario, the user is forced to change their password. Here are the steps for this scenario:

- User attempts to log into an Optical Metro 5100/5200 shelf after his/her password has expired or has been reset by the administrator.
- The System Manager or TL1 interface prompts the user to change their password.
- After the user enters the new password along with the old password, this password change request is sent to the local host shelf. This shelf forwards the request to the RADIUS client residing on the security gateway Optical Metro 5100/5200 shelf.
- The RADIUS client formats an Access-Request message with the new password as a vendor specific attribute and the old password as the standard attribute in the password field and sends this message to the RADIUS server.
- The RADIUS server processes the Access-Request with password change. If the new password is accepted, an Access-Accept message is sent to the RADIUS client and the user is granted access. If the password change is rejected, an Access-Reject is sent to the RADIUS client with a reason for the password change failure and the System Manager or TL1 interface prompts the user to change their password again.

User requested password change

In this scenario, the password change is requested by individual users. Anytime the user issues the **ED-PID** TL1 command or selects System Manager's **Change Password** menu option in the **Security** top level menu, the password change request is sent to the local host shelf. The local host shelf forwards the request to the RADIUS client and triggers the password change through the RADIUS protocol.

Alarm/event strategy

A security event is generated by the shelf when the centralized user password is changed using the System Manager or TL1 interface. No event is generated if the password is changed from OMEA.

Idle timeout configurable on a user account basis

The idle timeout configurable on a user account basis feature operates in both local and centralized authentication mode. The local user idle timeout interval is configurable on the shelf using TL1 or System Manager. The centralized user idle timeout is also configurable from OMEA and is returned to the shelf upon a successful login. Only admin level users can provision the idle timeout. The supported value range is 0 to 999 minutes. Default is 30 minutes, 0 means disable. If a shelf is upgraded from a previous release to Release 8.0, all local user idle timeout values are set to 0.

Idle timeout on System Manager sessions

System Manager session idle timeout operates in both local and centralized authentication modes. Upon a successful login, the System Manager session receives the configured idle timeout value from the shelf. From the value that is received from the shelf, the System Manager then sets its idle timer. If there is no key stroke or mouse click for the configured time interval, the System Manager prompts the user to either continue or terminate the session.

TL1 session idle timeout was introduced in Release 6.1 and continues to be supported in Release 8.0.

Enhanced Trunk Switch security features

Local user authentication

The ETS supports log-in/log-out for a maximum of two default accounts: “SUPERUSER” and “ADMINUSER”, as well as nine user accounts.

The Superuser and Adminuser accounts have the maximum authorization privileges, cannot be deleted, and are not visible to other users. These are the only accounts authorized to create and delete other user accounts, and assign user access privileges to accounts.

> ***Note:*** The <uid> and <pid> are case sensitive.

User Access Privileges

The extent of a user's access to the system is determined by the level of user access privileges (UAP) assigned to the account.

Each user that is added to the system, must have user access privileges (UAP) assigned, to identify the extent of the user's authorization level (AL) for each command function category (FC). UAPs take the following form:

[FC][AL]&[FC][AL]&[FC][AL]&[FC][AL]&[FC][AL]

Multiple functional category authorization levels (FCALs) are assigned by using single ampersands (&) as delimiters.

TL1 commands are grouped into the following five Function Categories:

- Security Administration (S)
- Provisioning (P)
- Performance Monitoring (PM) (Not supported by the ETS)
- Maintenance (M)
- Test Access (T)

For each FC, a user can have one of six authorization level values. The allowable values are:

- 0 (zero)—where 0 means the user is not authorized to issue those commands
- from 1 (low, default) to 5 (high)

 Note: At a minimum, users must be assigned at least an S1 in order to log-in, log-out, and change their own passwords.

Table 11-7 on page 11-19 lists the possible FCAL values.

Table 11-7
Functional Category Authorization Levels (FCAL)

FCAL	Description
S[1-5]	For Security Administration Authorization Level 1 through 5
P[0-5]	For Provisioning Authorization Level 0 through 5
M[0-5]	For Maintenance Authorization Level 0 through 5
T[0-5]	For Test Access Authorization Level 0 through 5

Passwords

The ETS authenticates passwords for user accounts and determines how passwords age (based on user-configurable parameters). All passwords are encrypted and have the following features:

- Default password expiration period = 60 days
- Default password expiration grace period expressed as time = 7 days
- Default password expiration grace period expressed as log-ins = 3
- Blank passwords (no characters) are not acceptable
- Passwords must be between 6 and 10 characters in length, contain at least one numeric character and one alphabet character, and may contain special characters

Note: The ETS does not prevent a user from selecting a password that is currently associated with an enabled or disabled user account.

User Identifier <UID>

A user identifier (UID) is a unique, non-confidential name, which identifies each authorized system user. UIDs are between 6 and 10 alphanumeric characters.

You must have a valid UID to activate a user login session.

The default user ID obsolescence due to non-use is 90 days.

> ***Note:*** The UID is case sensitive.

Password Identifier <PID>

A password identifier (PID) is a confidential word that validates a user's access to the account specified by the UID.

You must have a valid password to activate a user login session to the specified UID, or to change your current password.

> ***Note:*** The PID is case-sensitive.

PID Naming Rules

Password identifiers are between 6 and 10 characters in length, and are composed of a combination of alphanumeric (letters A through Z; numbers 0 through 9) and special characters.

The following special characters are supported for the password:

. # % + _ -

The password must contain at lease one alphabetic character, one numeric, and one special character.

The following characters are not supported for the password:

- semicolon (;)
- colon (:)
- ampersand (&)
- comma (,)
- question mark (?)
- and all control characters

Default Username and Password

When an ETS is first installed, you must log-in using one of the factory default usernames and passwords. The default Usernames and Passwords are:

- Username: SUPERUSER, Password: Sup%9User
- Username: ADMINUSER, Password: Admin%9

Login warning banner

A login warning banner is displayed upon successful login to an ETS. The warning banner contains a message regarding unauthorized network access and possible consequences thereof.

The warning banner can be customized through TL1. For information about customizing the warning banner, see *TL1 Interface,* 323-1701-190.

Failed login attempt threshold and lockout period

A log-in procedure is suspended after three unsuccessful attempts.

The ETS will reject login requests for a period of one minute.

Inactivity timeout

A session is terminated if it is idle for 35 consecutive minutes (user must log-in again and initiate a new session). This parameter is provisionable.

Security events and notifications

The ETS maintains a Security log (database) of events related to security management. Logged events include:

- User log-ins (both successful and unsuccessful)
- Creating user accounts
- Deleting user accounts
- Changing users' access privileges

Nortel

Optical Metro 5100/5200

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