WHITE PAPER

CISCO OC-192/STM-64 LINK UPGRADE PLANNING

OVERVIEW

Telecommunications service providers are exploring cost-efficient ways to meet the growing bandwidth demand in metropolitan networks. Most existing metro networks have deployed 2.5-Gbps SONET (OC-48) systems. As demand for more bandwidth increases, service providers are looking for the most cost-efficient, reliable, and flexible means to increase their network bandwidth and maximize their return on capital investment. Service providers believe upgrading their existing fiber links from 2.5-Gbps systems to 10-Gbps (OC-192) systems is the easiest method for increasing their network bandwidth. However, much of the service providers' installed base of optical fiber in the metropolitan environment is of older vintage. Some of the older optical fibers exhibit optical characteristics that make operation at these higher speeds difficult, if not impossible.

The transport of 10-Gbps and dense wavelength-division multiplexing (DWDM) systems brings with it issues of old versus new fiber. New fiber types (such as dispersion-shifted fiber [DSF] and nonzero DSF [NZDSF]) maximize the benefits of the new technology by adhering to more stringent specifications for attenuation, dispersion, and so on. These newer fiber types are available from several vendors under various brand names. The old fiber versus new fiber issue creates some incompatibility concerns for service providers with an installed base of conventional single-mode fiber (SMF). These service providers may now be forced to either upgrade their fiber or add new equipment (such as regenerators or dispersion compensation devices) to enable their present fiber, and its 2.5-Gbps engineered spans, to meet the stringent demands of 10-Gbps speeds and multiwavelength DWDM optically amplified systems. When increasing bandwidth on existing, older fiber links, the proper testing tools and procedures are crucial to properly qualify the fiber.

The Cisco® ONS 15454 Multiservice Provisioning Platform (MSPP) is widely deployed in many service provider networks. The support of 10-Gbps (OC-192/STM-64) long-reach/long-haul optics enables service providers to take full advantage of their embedded fiber plant by upgrading their existing OC-48/STM-16 optical spans to OC-192/STM-64, without incurring the high cost of upgrading their fiber or adding new DWDM equipment. This paper is designed to help service providers understand the relevant issues when they are deploying or upgrading fiber spans to 10 Gbps; in addition, it describes how to successfully qualify fiber facilities before attempting an upgrade or activation.

FIBER TESTING

Fiber testing for use in 10-Gbps systems is important in all cases. Regardless of whether a service provider is installing new fiber, using existing fiber for a system upgrade, or leasing or selling fiber, proper testing is critical. If existing fiber is used for a bandwidth upgrade, savings come at a cost: older fiber is more likely to have significant problems that will contribute to system impairment. This is a general rule based on four important optical fiber parameters: attenuation, chromatic dispersion, polarization mode dispersion (PMD), and fiber cabling and installation issues.

The following areas must be thoroughly understood before installed fiber can be considered for upgrading transmission systems to 10 Gbps:

- *Fiber type*—Spectral attenuation, zero dispersion point, zero dispersion slope, PMD, index profile
- *Original quality of the cable*—Potential problems include twisted fibers, stressed fibers, and microbends
- *Quality of installation*—Quality of splices, quality of connectorization, concentricity of fiber, attention to laying cable without twisting or bending, quality of underground enclosures
- *Quality of documentation of original install and subsequent maintenance*—Type of fiber, optical time-domain reflectometer (OTDR) traces, loss measurements, and installation date
- *Quality of ongoing maintenance*—Periodic testing, identification, and documentation of degradation with age

Fiber type, quality of the cabling, and quality installation are generally verified by standard fiber-optic testing procedures that measure numerous important parameters for a span. The following sections explain these parameters and their methods.

Link Loss (Attenuation)

Attenuation includes intrinsic fiber loss, losses associated with connectors and splices, and bending losses due to cabling and installation. The OTDR is used when a comprehensive accounting of these losses is required. OTDRs also give information about fiber uniformity, splice characteristics, and total link distance. For the most accurate loss test measurements, a loss test set (LTS) that consists of a calibrated optical source and detector is used. However, the LTS does not provide information about the various contributions (including contributions related to splice and fiber) to the total link loss calculation. A combination of OTDR and LTS tests is needed for accurate documentation of the fiber facilities being tested. In cases where the fiber is very old, testing loss as a function of wavelength (also called spectral attenuation) may be necessary. This is particularly important for qualifying the fiber for multiwavelength operation. Portable chromatic dispersion measurement systems often include an optional spectral attenuation measurement.

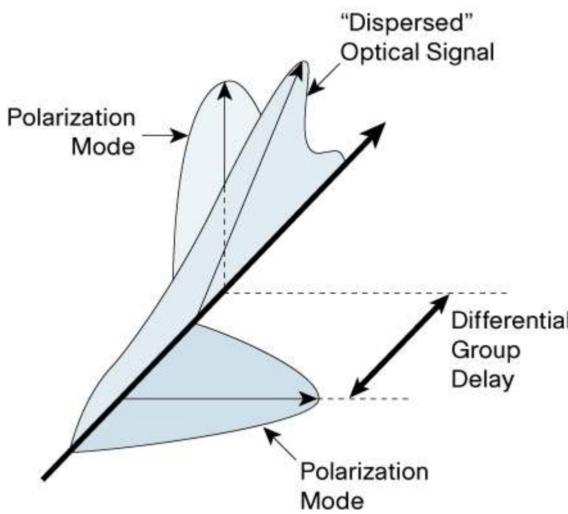
Optical Return Loss

Optical return loss (ORL) is a measure of the total fraction of light reflected by the system. Splices, reflections created at optical connectors, and components can adversely affect the behavior of laser transmitters, and they all must be kept to a minimum. Either an OTDR or a LTS equipped with an ORL meter can be used for ORL measurements, but an ORL meter yields more accurate results.

Polarization Mode Dispersion

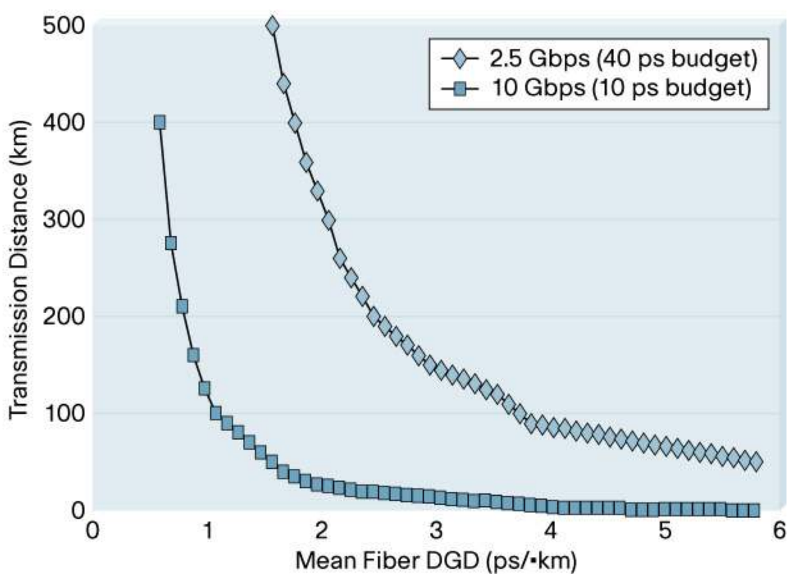
Polarization mode dispersion (PMD) has essentially the same effect on the system performance as chromatic dispersion, which causes errors due to the “smearing” of the optical signal. However, PMD has a different origin from chromatic dispersion. PMD occurs when different polarization states propagate through the fiber at slightly different velocities (Figure 1).

Figure 1
Polarization Mode Dispersion



PMD is defined as the time-averaged differential group delay (DGD) at the optical signal wavelength. It is caused by fiber core eccentricity, ellipticity, and stresses introduced during the manufacturing process. PMD is a problem for higher bit rates (OC-192/STM-64 and above) and can become a limiting factor when designing optical links (Figure 2).

Figure 2
Differential Group Delay



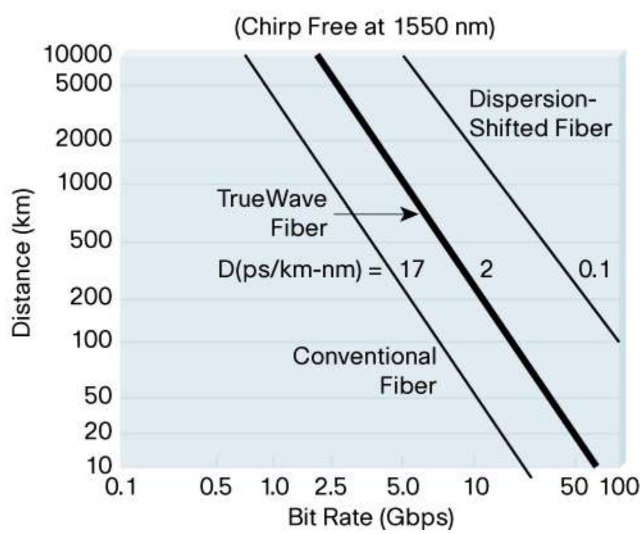
Source: JDSU-OFC2000

The time-variant nature of dispersion makes it more difficult to compensate for PMD effects than for chromatic dispersion. “Older” (deployed) fiber may have significant PMD—many times higher than the 0.5 picosecond per kilometer (km) specification seen on most new fiber. Accurate measurements of PMD are very important to guarantee operation at 10 Gbps. Portable PMD measuring instruments have recently become an essential part of a comprehensive suite of tests for new and installed fiber. Because many fibers in a cable are typically measured for PMD, instruments with fast measurement times are highly desirable.

Chromatic Dispersion

Chromatic dispersion is the most common form of dispersion found in single-mode fiber. Temporal in nature, chromatic dispersion is related only to the wavelength of the optical signal. For a given fiber type and wavelength, the spectral line width of the transmitter and its bit rate determine the chromatic dispersion tolerance of a system. To reduce fiber dispersion, new types of fiber were invented, including dispersion-shifted fiber (DSF) and nonzero dispersion shifted fiber (NZDSF), marketed under the brand names (Lucent) TrueWave or (Corning) LEAF fiber. Figure 3 illustrates the impact of the chromatic dispersion characteristics of the fiber on bit rate and distance. As shown, dispersion management is of particular concern for high bit rates (10 Gbps) using conventional SMF. Depending on the design of the 10-Gbps transceiver module, dispersion compensation might be needed to accommodate an upgrade from OC-48/STM-16 to OC-192/STM-64 to keep the same targeted distances. The Cisco ONS 15454 OC-192/STM-64 long-reach/long-haul (LR/LH) 1550-nanometer (nm) board is based on a continuous-wave laser with an externally modulated lithium niobate modulator. This breakthrough technology controls prechirp and allows 80-km reach over conventional SMF without using dispersion compensation.

Figure 3
Chromatic Dispersion



Source: JDSU-OFC2000

Portable chromatic dispersion measurement instruments are essential for testing the chromatic dispersion characteristics of installed fiber.

CISCO ONS 15454 OC-48 TO OC-192 UPGRADE REQUIREMENTS

It is possible to perform an in-service, point-to-point Cisco ONS 15454 system upgrade from OC-48/STM-16 to OC-192/STM-64 over an 80-km link of conventional SMF. To ensure success of the upgrade, the carrier must follow the testing recommendations highlighted in this paper, and the results must conform to the requirements detailed in Table 1.

Table 1. Requirements for Upgrade (up to 80 km)

Cisco ONS 15454 OC-192/STM-64 LR/LH (Models 15454-OC192-LR2 and 15454E-L64.2-1)		Tolerance Fiber Plant Requirements
Chromatic Dispersion	1600 ps per nm	<20 ps per nm km
PMD	10 ps	<1 ps per km
ORL	24 dB	>40 dB
Attenuation (BER=10E-12) (not including 2 dB dispersion penalty)	24 dB	<0.25 dB per km

To help ensure accurate results, Cisco Systems® recommends following the standard procedures for cleaning the optical jumpers between interconnections before conducting the fiber plant testing.

TEST EQUIPMENT MANUFACTURERS

The following optical test equipment manufacturers provide the necessary equipment for testing existing links for OC-192 upgrades. Please consult their respective Websites for additional information.

- NetTest: http://www.gnnettest.com
- EXFO: http://www.exfo.com
- Agilent: http://www.agilent.com

CONCLUSION

As higher-bit-rate systems become more commonplace, the revenue associated with each fiber span in the network also grows exponentially. Proper network testing of installation and OC-192/STM-64 upgrade rates is essential in order to guarantee and maintain the targeted long-reach distances of OC-48/STM-16-based systems. The new aspects of physical-layer testing highlighted in this paper are essential for taking full advantage of the existing fiber infrastructure.

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