Issued: June 2007

Sergey Ten, Corning Incorporated
Helen Xenos, Nortel

Nortel Long-Haul Transmission Gear and Corning® Ultra-Low-Loss Fiber Enable Longer Span and Longer Reach Network Designs

White Paper

Introduction: Market Environment and Technology Innovations

Despite and since the telecom downturn more than five years ago, there has been steady progress in the development of innovative optical networking technologies that deliver improved performance and cost savings to long-haul system construction and operation. These optical fiber and system innovations have been built to accommodate recent market requirements which include flexibility and simplicity, lower first installed costs, and lower operational and maintenance costs. In addition, competitive systems today must show bandwidth and data rate scalability and agility to handle network evolutions in a cost effective manner.

Historically, the market environment drives innovation in system technologies and optical fiber. Industry leaders understand the increased demands being placed on the infrastructure of long-haul networks as well as the need to accommodate these demands in a manner that limits complexity and costs.

Today the long-haul market is once again seeing growth and new network builds, especially in developing markets where designers and operators are often encountering many challenges: logistical (availability of land and power for amplifiers/regenerators), economical (first installed cost and OPEX) and technical (skill set required to operate the network). As a result, opportunities for reduced network complexity and lower costs exist in these developing networks.

Corning Incorporated and Nortel have long enjoyed a collaborative relationship, pursuing opportunities to provide combined system solutions aimed at solving network challenges. The idea behind this collaboration is that some innovations in fiber and systems can be combined in a clever way to further enhance their overall value for the network operator. For example, recently at the Optical Fiber Conference 2007 in Anaheim, Corning and Nortel jointly demonstrated an 800 km long-haul link composed of 160 km spans (twice longer than typical span in today networks) using Nortel's Adaptive All Optical Intelligent network equipment and Corning's ultra-low-loss optical fiber, SMF-28® ULL [1]. Error free performance was demonstrated without the use of dispersion compensation equipment or Raman amplification, showcasing the inherent network design simplicity using commercially available products. In

the remainder of this paper we detail the benefits of combining Nortel's Adaptive All Optical Intelligent network equipment and Corning's SMF-28® ULL fiber to achieve greater flexibility in system design and ultimately reduce total network cost.

Nortel and Corning Products Facilitate Longer Spans and Longer Reach

Optical Fiber:

Corning ultra-low-loss standard single mode SMF-28® ULL fiber [ii] is one of the key components of the proposed solution that enables longer spans and longer reach of the long haul high speed system. It provides very low attenuation (as low as 0.17 dB/km at 1550 nm) with other fiber attributes like mode field diameter (MFD), dispersion, etc. that are ITU-T G.652 compliant. For the 100 km span the difference in the span loss between generic G.652 fiber with attenuation of 0.2 dB/km and SMF-28® ULL fiber with attenuation of 0.17 dB/km is 100 km X (0.2-0.17) dB/km = 3 dB (or twice lower span loss). This advantage in span loss is converted in optical signal to noise ratio (OSNR) at the end of the link, providing additional margin network improvement. It is clear that the longer the span length the higher the OSNR advantage that can be reached with this ultra-low–loss fiber.

In addition, Corning SMF-28® ULL fiber offers very low PMD with link design values (PMDq) below 0.04 ps/km$^{0.5}$. Previously, these very low PMDq values were available only for the non-zero dispersion shifted (NZDS) fibers.

Transmission System:

There are two key features of Nortel's Adaptive All Optical Intelligent network equipment, consisting of the Common Photonic Layer (CPL) and Optical Multiservice Edge (OME) 6500, that enable the network designer to take advantage of additional margin provided by Corning® SMF-28® ULL fiber and convert this advantage into longer span length or longer optical reach.

First, is OME 6500's electronic Dynamically Compensating Optics (eDCO) that allows wavelengths to be transmitted up to 2000 km without the need of optical compensation in the form of lossy dispersion compensation modules (see Figure 1 a) and b)) and their associated amplifiers, and without all the engineering involved with this equipment. eDCO transmitter pre-distorts 10 Gb/s signal in such way that after propagation through the dispersive media (e.g. typical dispersion value of G.652 fibers is 17 ps/nm-km at 1550 nm), the signal evolves to the "correct" shape where ones and zeros are represented by respective optical power levels [iii].

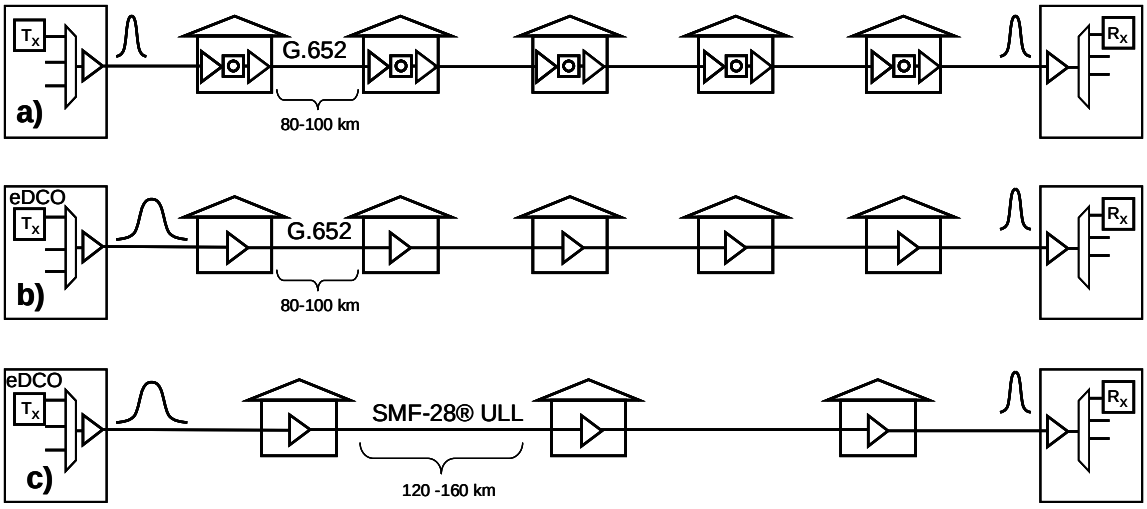

Figure 1. a) Typical 10 Gb/s long-haul link design over conventional G.652 fiber – link dispersion is compensated using dispersion compensation modules that are accommodated in the mid-stage of dual stage amplifier b) The same 10 Gb/s link designed with Nortel OME 6500 eDCO and CPL amplifiers c) Longer span length between amplification huts enabled by Corning® SMF-28® ULL optical fiber and optimized performance of the Nortel system.

Second, the Common Photonic Layer platform represents a set of optical amplifiers that can be combined in different ways to achieve various system design objectives. For example, if CPL is used with eDCO transponders, and dual amplifiers are not required, then CPL provides an opportunity to use the gain block that is used as single stage amplifier. However, if Reconfigurable Optical Add Drop Multiplexer (ROADM) has to be deployed, CPL provides gain blocks to assemble dual stage amplifier. Thus CPL provides off-shelf flexible amplifier designs that can accommodate a wide variety of amplifier gain configurations.

Value of Corning and Nortel Solution: Longer Span Lengths and Longer Optical Reach

Now let's explain why the combination of Corning SMF-28® ULL, Nortel eDCO and CPL seamlessly provides an opportunity to increase the span length in the long-haul link and save cost on hut construction in green field networks.

1) Due to lower attenuation of Corning SMF-28® ULL fiber, the span length can be increased depending on the total length of the link. Simply based on attenuation difference, the span length could increase by 15% compared to standard G.652 fiber. In reality, this span length increase is larger, since a system with fewer spans has lower nonlinearity (fewer optical amplifiers that launch high optical power) and higher power per channel could be employed. Rigorous design is required to take full advantage of the lower attenuation of Corning® SMF-28® ULL fiber. The joint demonstration at OFC 2007 featured 5x160 km (28 dB per span) system at 10 Gb/s that operated error free without Raman amplification.

2) Traditional 10 Gb/s system with longer spans (See Figure 1 a) and c)) would require dispersion compensation modules designed for up to 160 km of G.652 fiber. Currently, commercially available dispersion compensation modules are offered to compensate up to 100 km of G.652 fiber. Nortel eDCO eliminates the need for dispersion compensation modules completely, thus removing the concern about availability of large dispersion range dispersion compensation modules.

3) Traditional 10 Gb/s systems with longer spans also require an in-line amplifier that has sufficient mid-stage loss to accommodate large dispersion compensation modules (see previous paragraph). Since a conventional two stage amplifier has a predetermined mid-stage loss limit it may need extensive redesign to be able to use lossier dispersion compensation modules. Nortel CPL amplifiers eliminate this problem by offering, what is effectively a single stage amplifier. In other words, a traditional dual stage amplifier with a large mid-stage loss for large dispersion compensation modules is replaced by simple CPL amplifier, where dispersion compensation modules are not required since they are eliminated by eDCO.

In summary, the combination of Corning® SMF-28® ULL fiber, Nortel eDCO and CPL provides network design a smart off-shelf toolkit to achieve longer spans in the green field network and reduce the cost associated with land acquisition, hut construction and in future maintenance of the amplifier huts.

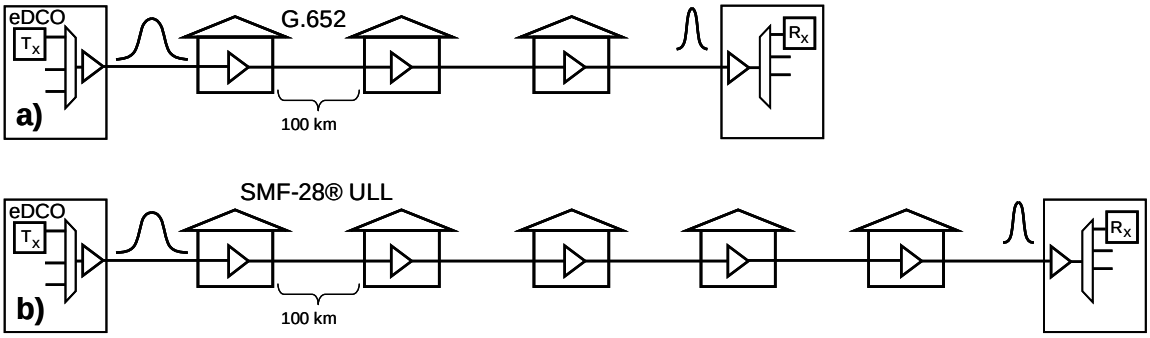

Figure 2. a) 10 Gb/s link designed with Nortel OME 6500 eDCO and CPL amplifiers b) Longer reach (distance between regenerators) that can be achieved with Corning® SMF-28® ULL optical fiber

Figure 2 shows another example of how Corning® SMF-28® ULL fiber with Nortel eDCO and CPL can benefit the network design. Lower attenuation of Corning® SMF-28® ULL fiber with the same span length (i.e. network design objective does not target increase of the span length) will result in higher OSNR margin that can be used to extend the number of spans or in other words increase optical reach (distance between regenerators). This scenario can apply to greenfield networks, where longer unregenerated reach is a primary design objective, or to the overbuild scenario, where huts are already built.

In the latter case, the value of longer optical reach can be utilized by using all-optical networking, i.e. eliminating unnecessary O-E-O regeneration. In its simplest form optical networking is using Reconfigurable Optical Add Drop Multiplexer (ROADM) to add and drop wavelengths at the destination node and pass express the wavelengths that will be terminated at further nodes. Nortel CPL includes a ROADM as a functional module that simplifies service provisioning and management, allowing operators to quickly react to changes in service requirements. In addition to facilitating basic add/drop of individual wavelengths, Nortel's ROADM enables remote redirecting of wavelengths to any span, at any time, to up to five different optical paths. With support of both 50-GHz and 100-GHz wavelength spacing for increased spectral efficiency, Nortel's ROADM can be cost effectively deployed in metro, regional, and long haul applications.

Thus, Corning SMF-28® ULL fiber provides longer reach (compared to traditional G.652 fiber) and Nortel eDCO and CPL (together with ROADM) enable network designers to reduce network cost by eliminating unnecessary O-E-O employing the power of all-optical networking.

Real Network Examples

Using an actual customer network example, for a 7,000 km link in a Greenfield application capital equipment savings of greater than 30% were observed when using Corning® SMF-28® ULL with Nortel eDCO and CPL over more traditional solutions.

References

[i] Press release "Corning and Nortel Combine Optical Expertise to Lower the Cost of Long-Haul Networks" http://www.corning.com/opticalfiber/media_center/press_releases/2007/2007032201.aspx

[ii] SMF-28® ULL optical fiber product information sheet: http://www.corning.com/opticalfiber/products__applications/products/smf_28_ULL.aspx

[iii] "Electronic dispersion compensation" McGhan, D. O'Sullivan, M. et. Al. Optical Fiber Communication Conference, 2006 Anaheim, CA 2006