White paper

Revisiting Link Loses: Cable cuts, Link Reliability and Emerging Markets

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Abstract
With the growing requirements of high data intensive bandwidth supplies of 100-200 Gb/s transmission systems in many emerging markets such as India, one of the principal requirements is predictable optical link loss and received Optical Signal to Noise Ratio (R-OSNR) over a period of time. In this paper, we present results of a study to understand impact of the influential factors like macro-bend loss, splice loss, installed fiber attenuation and unscheduled fiber/cable cut rate to sustain optical link loss within designed loss budget of regenerated (point to point) fiber optic links.

Key Words
ROSNR, Fiber optics link loss

Introduction

With the adoption of capital intensive 10-100 Gb/s transmission systems in many emerging markets such as India, the requirement of a predictable delivered OSNR in the outside plant is of paramount importance. In such economies, intense construction activity and poor installation practices lead to severe restrictions on predictable signal quality.

Network links are generally categorized as point-to-point links and amplified links as shown in figure 1 and figure 2 respectively. Point-to-point links are the regenerated links whereas in amplified links the signal gets propagated optically through the in-line amplifiers to their destined terminal location. In point-to-point links, optical link loss is the crucial factor, whereas signal quality (like BER: Bit-Error-Rate) is guaranteed by the optical link loss budget. In case of amplified links, signal is propagated optically until BER exceeds a threshold. For such type of inks, the amplifier gains, optical link loss and the noise are the critical factors of link designing.

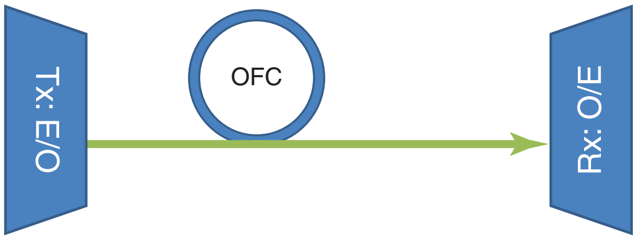

Figure 1 Point-to-point (P2P) link

Optical link loss (attenuation) levels rise considerably beyond the beginning-of-life (BOL)/time of installation values. As a consequence of increased attenuation and the change in R-OSNR, premature link failures especially at 100Gb/s – 200Gb/s and increased costs due to cable replacement are an operational reality. Service providers in emerging markets are challenged in the optimal allocation and utilization of network routes.

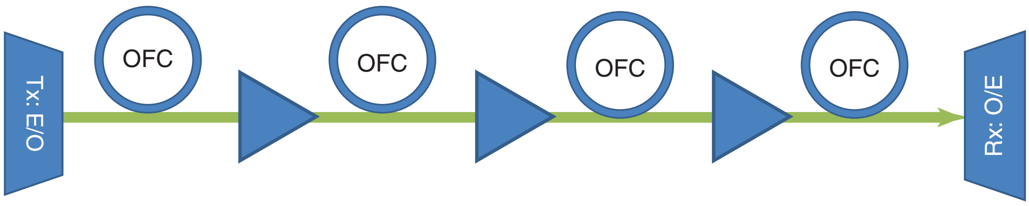

Figure 2 Amplified Link

Total optical loss of a concatenated link is basically summation of attenuation of the fiber cables and loss of the splices and/or connectors [1,2]. In a typical Telco's network, the attenuation of the optical fiber cable network increase over the period of time due to multiple factors. In the previous study, loss due to unplanned and incidental bends was found one of the prevalent factors in the installed optical link in emerging markets [3]. It was found that the existence of multiple macro-bends at joint closures or fiber termination systems, significantly increased the link loss in addition to other sources. Overall, ROSNR of a regenerated (point to point) fiber optic link is mainly depend on four factors: BOL (beginning of life) optical fiber cable drum attenuation, fiber splice / joint loss, macro-bend loss and unscheduled cable cut, restoration of which basically introduces more splice loss & potential macro-bend loss points. Service providers in the emerging markets are challenged in the optimal allocation and utilization of network routes to achieve designed optical link loss over a period of time. In this paper, results of a statistical study is presented to understand impact of macro-bend loss, splice loss, installed cabled fiber attenuation and unscheduled cable/fiber cut rate on optical link loss of regenerated (point to point) fiber optic links.

Statistical model

In the emerging market, usually telecom operator triggers to replace the optical fiber cable when the optical link losses go beyond ~0.4 dB/km at 1550 nm, as after this range either very high transmit power optical equipment would be required which will not be viable solution or in some amplified links, signal transmission will not be possible. Therefore, the increase in optical link losses will directly reduce the performance cycle of the optical link. Unscheduled cable cut is the most critical factors in link reliability as reported by telecom operators in emerging markets. Cable cut rate varies randomly between operators and geographical regions. In this study, we assumed cable cut rate associate Poisson distribution with a 'mean cut rate'.

We developed a model to calculate the time (years) taken to reach optical link attenuation 0.4 dB/km at 1550 nm by varying the factors which include:

1. Splice loss (dB): 0.01, 0.05, 0.1
2. Macrobend loss at 1550 nm (dB): 0.03, 0.05, 0.1
3. Fiber cable drum attenuation (dB/km) at 1550 nm: 0.20, 0.21, 0.22, 0.23
4. Mean cable cut rate (Number of cable cuts/1000 km/ month): 2, 3, 5, 7, 10, 15, 25

The cable cut values were taken from telecom operator's field survey. All the above impairments lead to increase the overall optical link losses. Using the statistical model we simulated all the possible outcomes, by considering entire value factor of above mentioned parameters.

In the simulation, we considered the test bed of 1000 links in which the route link lengths vary from 3 to 25 km following Gaussion distribution with mean link length of 14 km. Further, we considered the attenuation failure threshold 0.4 dB/km at 1550 nm of a single link and the simulation has been performed for 50 trials over 50 years of scale. Failure probability was calculated with various combinations. 75% failure probability means 750 out of 1000 links exceeding 0.4 dB/km link attenuation at 1550 nm. Influence of each factors are quantified in terms of change in time period to reach failure thresholds.

Results and Discussions

Figure 3 shows impact of changes in BOL attenuation on failure probability, where other factors are kept constant i.e. 15 cuts/month/1000 km, 0.1dB splice loss and 0.1dB macrobend loss at 1550 nm. As depicted in figure 3, the time taken to reach failure threshold is increased by a year while reducing the cable BOL attenuation from 0.23dB/km to 0.20 dB /km at 75% failure probability level.

Figure 4 shows the influence of cable cuts at different BOL attenuations keeping macrobend and splice loss constant. Bringing cuts down from 15/month/1000km to 5/month/1000km adds 12-14 years' time period to reach failure threshold at 75% failure probability.

Figure 5 & 6 show impact of macrobend loss and splice loss respectively. In these figures, time to reach failure threshold are presented at different BOL attenuation levels and two cable cut scenarios i.e. 5 and 15 cuts/month/1000 km. Reducing macrobend & splice loss from 0.1 to 0.01 dB adds 6 to 18 years at 75% failure probability.

Overall, reducing cable cut is the pre-dominant factor to keep optical link loss within designed value. According to the statistical model, the parameters to cross 40 years to reach failure threshold (estimated at 75% failure to exceed 0.4 dB/km at 1550 nm link attenuation) from currently 6-8 years in emerging market like India, are

- BOL cabled fiber attenuation at 1550 nm: 0.20 dB/km
- Cable cut rate: 3 cuts/ month/ 1000 km
- Macrobend loss: 0.03 dB
- Splice loss: 0.05 dB

Conclusion

A statistical model is used to calculate time-period to reach failure threshold (i.e. optical link loss exceeding 0.4 dB/km at 1550 nm) by varying four factors e.g. splice loss from 0.01 to 0.1 dB, macrobend loss from 0.03 to 0.1 dB, BOL cabled fiber attenuation from 0.20 to 0.23 dB/km at 1550 nm, and cable cut rate from 2 to 25 cuts/1000 km/ month. Influence of each factors are quantified at different failure probability levels. Cable cut rate is found to be most influential factor. A combination of these four factors is determined to achieve 40 years to reach failure threshold from currently around 8-12 years in many emerging markets such as India.

References

1. ITU-T G.650.3, Amendment 1, 'Test methods for installed single-mode optical fibre cable links', 02/2011.
2. ITU-T G. Supplement 39, 'Optical system design and engineering considerations', 02/2016.
3. Sudipta Bhaumik, Puneet Agarwal, Prasanna Pardeshi, Deepak Sanghi, Praveen Kumar, Abdul Ashfaq, Gautam Billa, and Badri Gomatam, "Are Networks in Emerging Markets Ready for Terabit/s Scale Optics?", IWCS, April'2017.

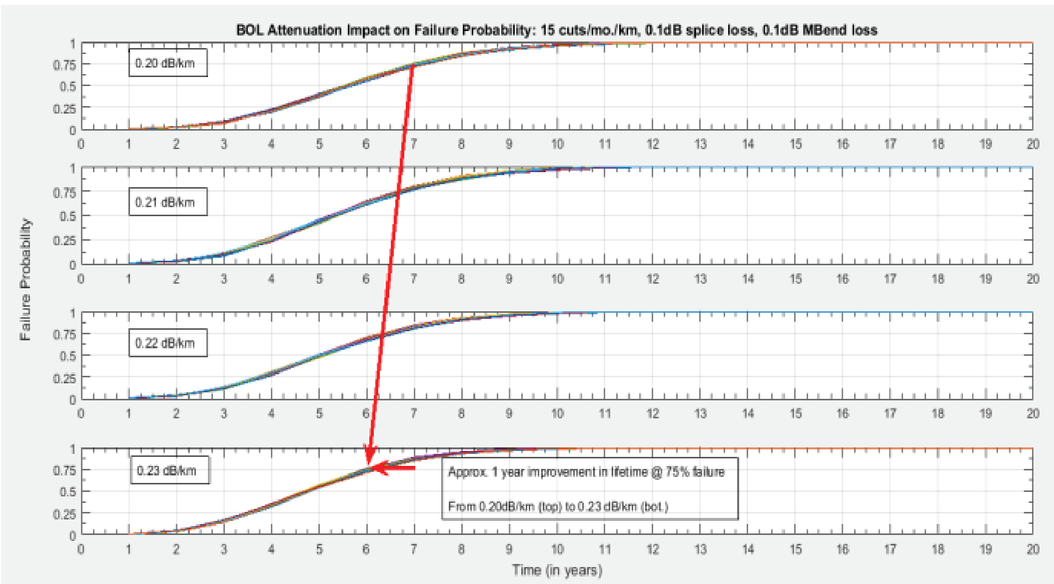

Figure 3 Impact of BOL attenuation on failure probability

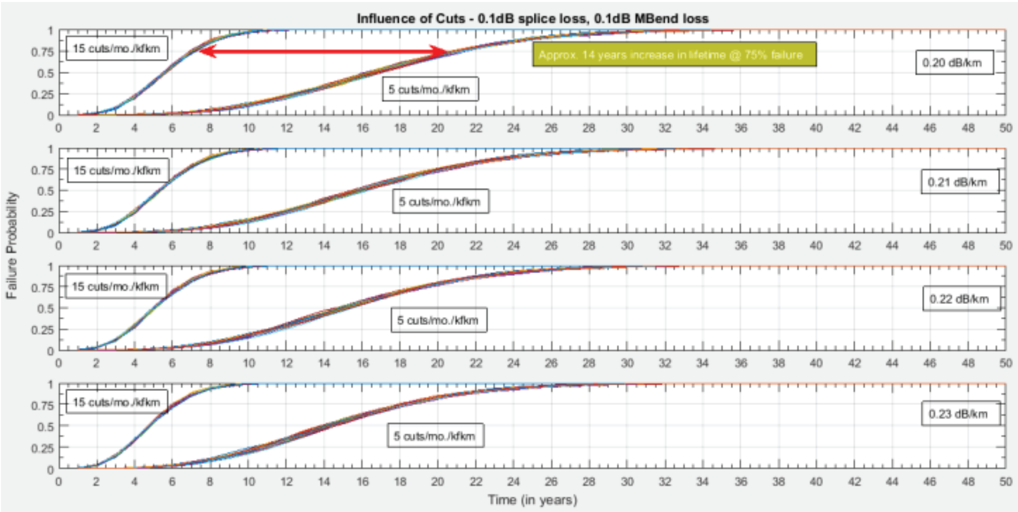

Figure 4 Impact of cable cut rate on failure probability

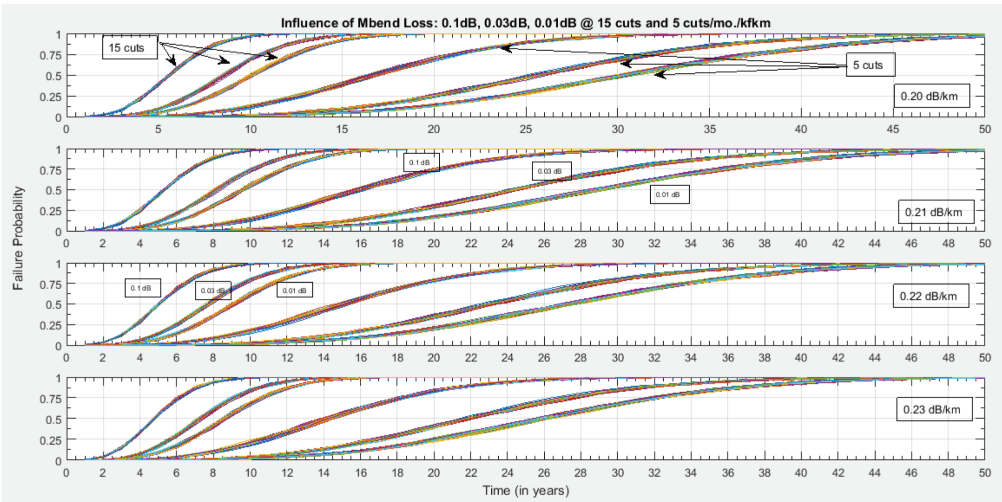

Figure 5 Impact of fiber macrobend loss on failure probability

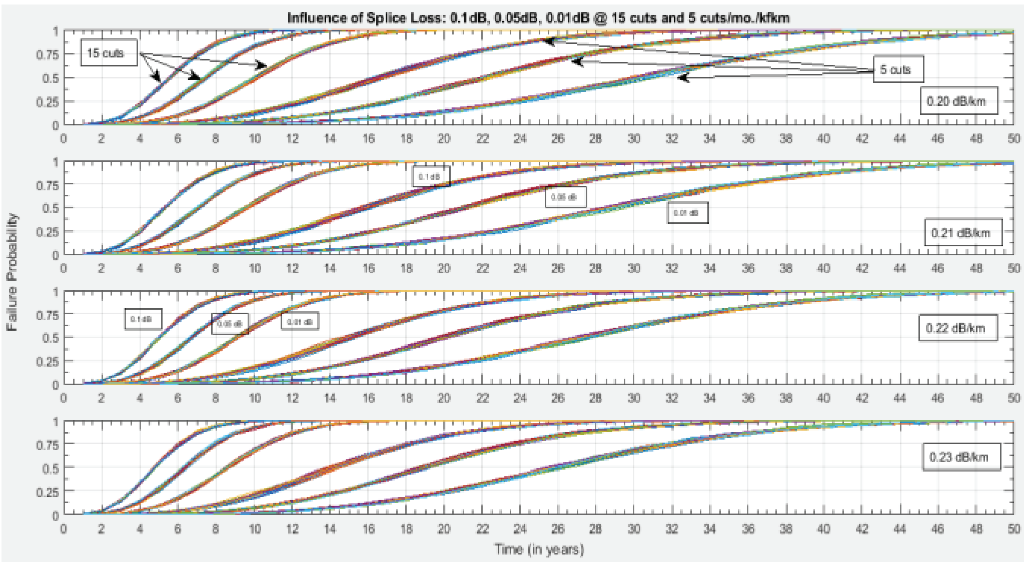

Figure 6 Impact of fiber splice loss on failure probability

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