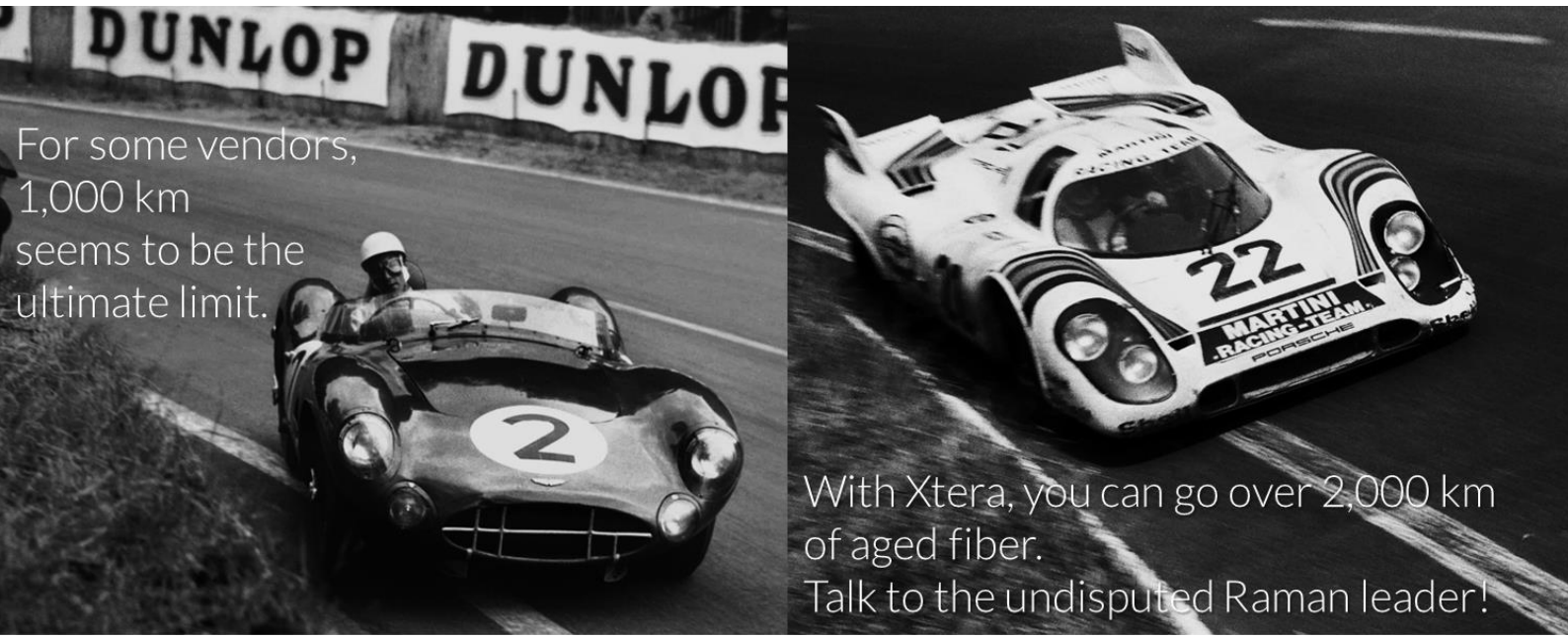
16QAM Reach Performance with Xtera's Wise Raman™



In the past few years, we have seen a tremendous surge in fiber capacity enabled by 100G optical channels built upon PM-QPSK (Polarization Multiplexing Quadrature Phase Shift Keying) modulation format. The quest for extreme bandwidth in optical backbone networks, however, seems never ending. To address the capacity needs of the near-future, more sophisticated modulation formats (like 16QAM – 16-state Quadrature Amplitude Modulation) have been developed to supersede the current 100G technology with the objective of increasing spectral efficiency (equal to the bit rate divided by channel spacing, expressed in bit/s/Hz) within the limited optical spectrum offered by the customarily utilized Erbium-Doped Fiber Amplifiers (EDFAs). 16QAM modulation is the key technology for high-capacity optical networking as it is the basic foundation for 200G carriers, with optical channels at 400G or higher rates (e.g. 1 Tbit/s) being based on the combination of two or more 200G optical carriers.

From a transmission reach performance perspective, this strategy suffers from a fundamental limitation. The higher the spectral efficiency, the higher the Optical Signal to Nose Ratio (OSNR) requirement at the output end of the optical path. The OSNR figure could theoretically be enhanced by increasing the signal power but, unfortunately, fiber nonlinearities impose an upper limit upon the per channel power that can be launched into the fiber span.

Optical networking systems based on EDFAs are not conducive to long transmission reach for 16QAM signals because of the discrete nature of EDFA amplifiers (they provide local optical gain, turning the amplifier sites into hot spots leading to nonlinear impairments) and their intrinsic suboptimal noise performances (resulting in OSNR figures that can be unacceptable for proper detection of the signals).

Some hero experiments with "exotic" fibers (exhibiting ultra-low loss and very large effective area, i.e. not representative of what is buried in the ground) have been reported over long distances. However, in field conditions (with loss close to or larger than 0.2 dB/km, non-uniform span length, margins for repair, lumped losses caused by, e.g., bad connectors or imperfect fiber cut repairs), the practical reach for 16QAM signals over EDFA links is limited to about 600 km.

With the advent of 100G and beyond channel rates, the performance benefits of Raman optical amplification, compared to the traditional EDFA approach, are more relevant and necessary than ever to extend reach and eliminate regeneration sites for long-haul optical networking. Raman optical amplifiers offer better reach performance than EDFAs for two main reasons:

- Raman optical amplifiers create distributed optical amplification inside the line fiber, mitigating the nonlinear effects experienced by the optical WDM channels;
- Raman amplifiers superior noise performance leads to higher OSNR figure, enabling transmission through more intermediate amplification sites over longer distances.

Recent field trials using only modules with part numbers, and conducted on the Verizon network, demonstrated that Xtera's commercially-available Raman line equipment enables 400G transmission over more than 2,000 km on an aged high-loss fiber plant in a real network environment.

Wise Raman™ is Xtera's field-proven, future-proof solution to extend optical reach and expand the optical spectrum in existing and future long-haul optical transmission infrastructures, enabling an unrivalled Capacity – Reach combination in field conditions. Wise Raman™ represents a critical tool in solving the Capacity – Cost equation in both the short- and midterms for operators.