Research article
INFORMATION AND COMMUNICATIONS TECHNOLOGIES

Using Artificial Intelligence in Optical Networking

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SUMMARY

> The increasing complexity of optical networks designed to meet a multitude of services generates massive amounts of data. In addition, any service interruption, even momentary, can cause huge data losses, leading to bad customer experience. Machine learning has been proposed and applied in several fields in the last decades. In this study, the Network Technology Laboratory is introducing a tool that estimates the quality of transmission (QoT) of lightpaths before their implementation in the network, based on machine learning algorithms. This tool could help in routing and wavelength assignment by first discarding bad QoT connections. An evaluation of three machine learning techniques for optical networks was performed: the support vector machine (SVM), the K nearest neighbours (K-NN) and the random forest (RF). Keywords: Machine Learning, Quality of Transmission (QoT), lightpaths, K nearest neighbors (K-NN), Random Forest (RF), Support Vector Machine (SVM)

Model Presentation and Purpose

The emergence of multiple services and network traffic volume requirements are driving the design of heterogeneous optical networks that can support different data rates and modulation formats, as well as different types of services. Cognition is introduced to control these complex networks. And machine learning techniques—which make it possible to base decisions on past experiences stored in a database—are increasingly in demand to implement this functionality in optical networks. Several tools and models have been introduced. However, based on the No Free Lunch theorem, in [1]—arguing that no machine learning solution can be declared optimal for one set of data—a study of SVM, K-NN and RF machine learning techniques, applied to a set of synthetic data generated from an algorithm built on MATLAB, is presented in this project.

Estimating QoT using analytical models covering physical layer degradations generally requires a high computing time. The first QoT prediction methods based on machine learning were developed for systems not exceeding 10 Gb/s and using intensity modulation format. More recently, other models have been developed for higher bit rates, and amplitude and phase modulation formats. However, in these models, system penalties due to nonlinear effects are taken into account through safety margins in determining the minimum optical signal-to-noise ratio (OSNR) required for QoT. The underlying question in this work is this: Could the Gaussian QoT calculation noise model developed by Poggiolini [4] be used in a cognitive control tool for coherent optical links based on advanced modulation formats? The Gaussian noise model evaluates the effect of noise and nonlinear propagation phenomena occurring in optical fiber links.

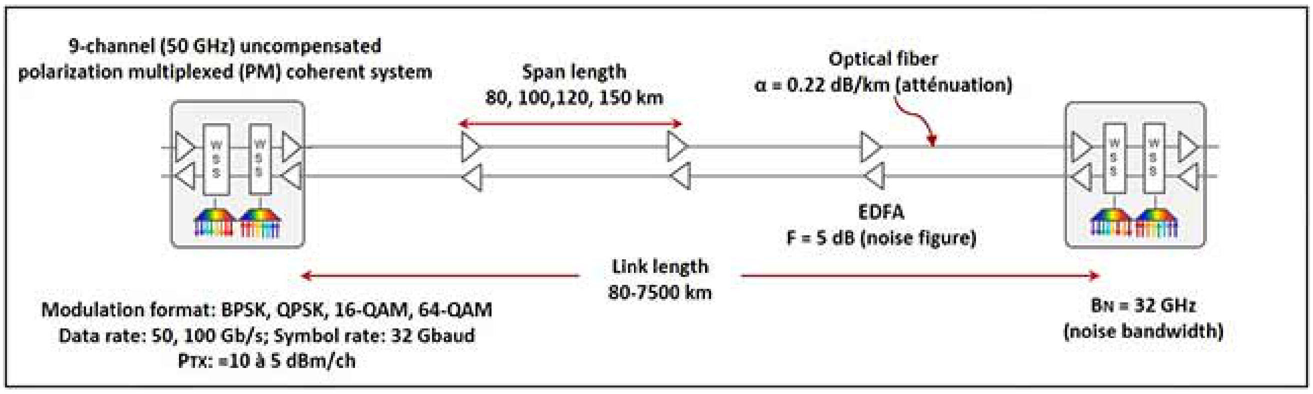

Figure 1 Example of an optical fibre link in a coherent optical network [2]

The overall objective of this project is therefore to develop a cognitive model of QoT estimation based on machine learning techniques and taking into account the linear and nonlinear effects of lightpaths in a coherent optical link, as shown in Fig. 1.

Methodology

The overall process for QoT estimation is described in Fig. 2.

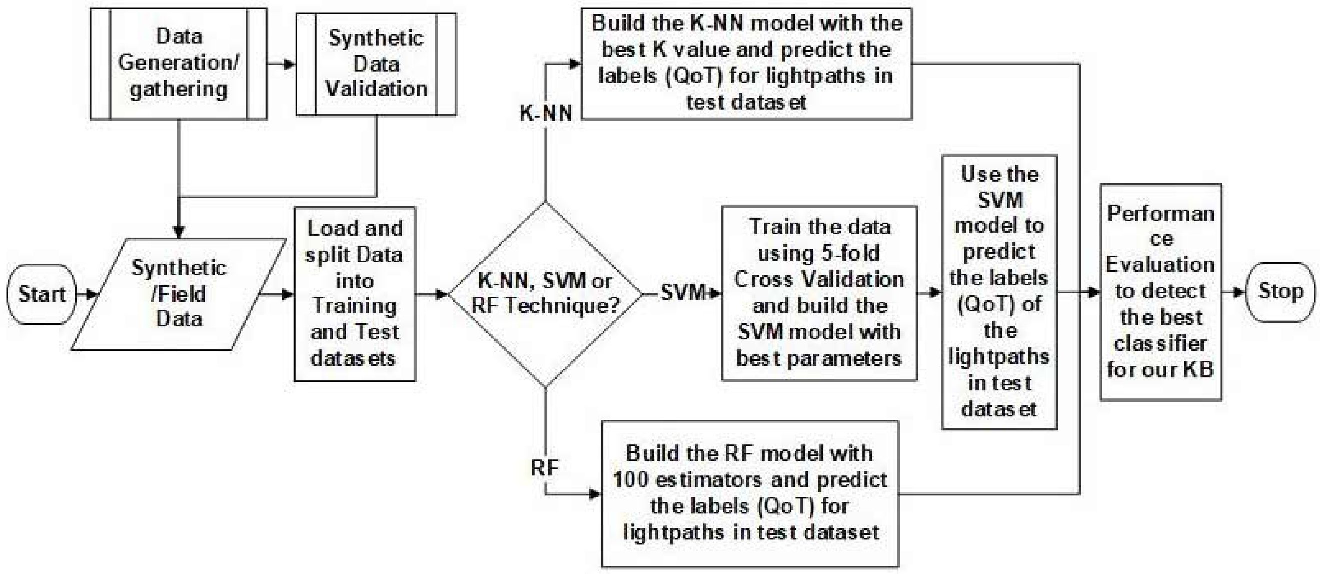

Figure 2 Overview of QoT estimation process, from [3]

The data generation algorithm, developed in MATLAB, takes into account the nonlinear propagation effects in an optical fiber link using OSNR analytical calculation formulae. The bit error rate (BER) is then estimated. This metric, defined as the ratio of the number of bit with errors to the total number of transmitted bits, is an important parameter in determining the QoT of an optical signal. The data, once generated, are validated using the Non-Linear Interference Noise (NLIN) Wizard tool developed by Dar [5] before applying the three machine learning techniques.

Results

The SVM technique provides the best classification accuracy (good or bad QoT): 99.15% versus 96.32% for RF and 96.7% for K-NN. The classification accuracy obtained with the proposed QoT tool is higher than the 98.7% obtained with the case-based reasoning method (CBR) developed in the European CHRON project [6], and exceeds the 96% obtained with the E-Tool using the RF technique [7]. These results show the potential benefits of cognition in evaluating the QoT of lightpaths.

In addition, the SVM requires a processing time of 1.26 seconds for a dataset of 23,040 instances. This is greater than the 35 ms needed for the CBR technique, but less than the 3.6 s used by the Q-Tool for a database of fewer than 15,000 instances, which shows the advantage of using cognition with the SVM technique in the QoT estimation process [8]. Fig. 3 shows the classification results of lightpath samples using SVM.

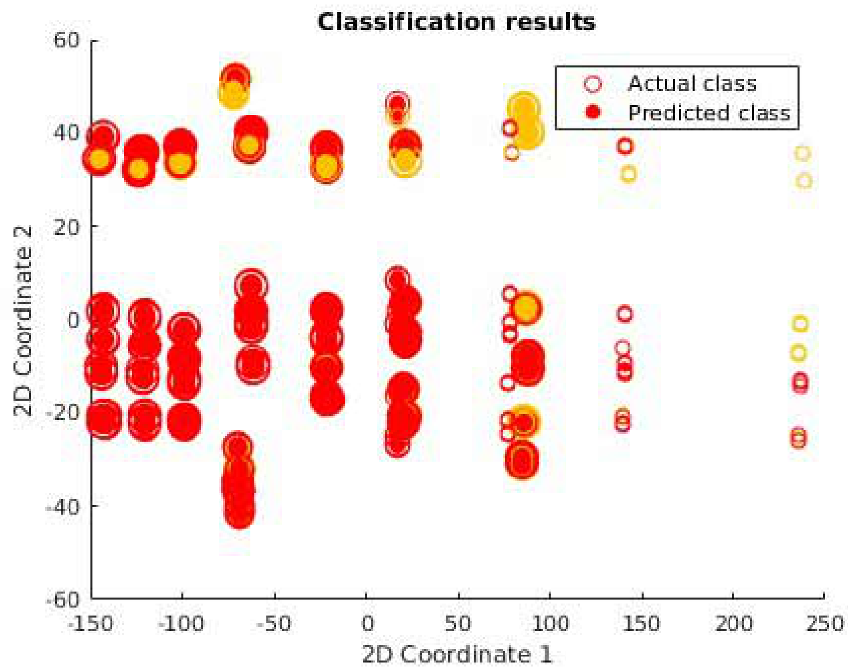

Figure 3 Classification of lightpath samples using SVM

Conclusions

The lightpath QoT estimation tool, using the SVM technique with synthetic performance data, yields good classification accuracy performances. And the relatively low processing time for classifying lightpaths shows the advantage of using cognition in the network control process.

Future work includes the use of field performance data captured in an operator network to construct a classification model.

Additional information

For more information on this research, please refer to the following paper:

Tremblay C., Aladin S., (2018). "Machine Learning Techniques for Estimating the Quality of Transmission of Lightpaths". IEEE Photonics Society, Summer Topicals Meeting Series, July 2018.

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Images references