An Overview on Application of Machine Learning Techniques in Optical Networks

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***Abstract*—Today's telecommunication networks have become sources of enormous amounts of widely heterogeneous data. This information can be retrieved from network traffic traces, network alarms, signal quality indicators, users' behavioral data, etc. Advanced mathematical tools are required to extract meaningful information from these data and take decisions pertaining to the proper functioning of the networks from the network-generated data. Among these mathematical tools, Machine Learning (ML) is regarded as one of the most promising methodological approaches to perform network-data analysis and enable automated network self-configuration and fault management.**

The adoption of ML techniques in the field of optical communication networks is motivated by the unprecedented growth of network complexity faced by optical networks in the last few years. Such complexity increase is due to the introduction of a huge number of adjustable and interdependent system parameters (e.g., routing configurations, modulation format, symbol rate, coding schemes, etc.) that are enabled by the usage of coherent transmission/reception technologies, advanced digital signal processing and compensation of nonlinear effects in optical fiber propagation.

In this paper we provide an overview of the application of ML to optical communications and networking. We classify and survey relevant literature dealing with the topic, and we also provide an introductory tutorial on ML for researchers and practitioners interested in this field. Although a good number of research papers have recently appeared, the application of ML to optical networks is still in its infancy: to stimulate further work in this area, we conclude the paper proposing new possible research directions.

***Index Terms*—Machine learning, Data analytics, Optical communications and networking, Neural networks, Bit Error Rate, Optical Signal-to-Noise Ratio, Network monitoring.**

I. Introduction

Machine learning (ML) is a branch of Artificial Intelligence that pushes forward the idea that, by giving access to the right data, machines can learn by themselves how to solve a specific problem [1]. By leveraging complex mathematical and statistical tools, ML renders machines capable of performing independently intellectual tasks that have been traditionally solved by human beings. This idea of automating complex tasks has generated high interest in the networking field, on the expectation that several activities involved in the design and operation of communication networks can be offloaded to machines. Some applications of ML in different networking areas have already matched these expectations in areas such as intrusion detection [2], traffic classification [3], cognitive radios [4].

Among various networking areas, in this paper we focus on ML for optical networking. Optical networks constitute the basic physical infrastructure of all large-provider networks worldwide, thanks to their high capacity, low cost and many other attractive properties [5]. They are now penetrating new important telecom markets as datacom [6] and the access segment [7], and there is no sign that a substitute technology might appear in the foreseeable future. Different approaches to improve the performance of optical networks have been investigated, such as routing, wavelength assignment, traffic grooming and survivability [8], [9].

In this paper we give an overview of the application of ML to optical networking. Specifically, the contribution of the paper is twofold, namely, i) we provide an introductory tutorial on the use of ML methods and on their application in the optical networks field, and ii) we survey the existing work dealing with the topic, also performing a classification of the various use cases addressed in literature so far. We cover both the areas of optical communication and optical networking to potentially stimulate new cross-layer research directions. In fact, ML application can be useful especially in cross-layer settings, where data analysis at physical layer, e.g., monitoring Bit Error Rate (BER), can trigger changes at network layer, e.g., in routing, spectrum and modulation format assignments. The application of ML to optical communication and networking is still in its infancy and the literature survey included in this paper aims at providing an introductory reference for researchers and practitioners willing to get acquainted with existing ML applications as well as to investigate new research directions.

A legitimate question that arises in the optical networking field today is: why machine learning, a methodological area that has been applied and investigated for at least three decades, is only gaining momentum now? The answer is certainly very articulated, and it most likely involves not purely technical aspects [10]. From a technical perspective though, recent technical progress at both optical communication system and network level is at the basis of an unprecedented growth

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