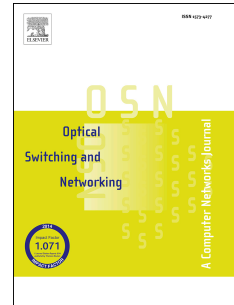


Accepted Manuscript

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PII: S1573-4277(17)30231-X

DOI: [10.1016/j.osn.2017.12.006](https://doi.org/10.1016/j.osn.2017.12.006)

Reference: OSN 468

To appear in: *Optical Switching and Networking*

Received Date: 4 December 2017

Accepted Date: 27 December 2017

Please cite this article as: J. Mata, I. de Miguel, Ramón J. Durán, Noemí Merayo, S.K. Singh, A. Jukan, M. Chamania, Artificial intelligence (AI) methods in optical networks: A comprehensive survey, *Optical Switching and Networking* (2018), doi: 10.1016/j.osn.2017.12.006.

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Artificial Intelligence (AI) Methods in Optical Networks: A Comprehensive Survey

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Abstract

Artificial intelligence (AI) is an extensive scientific discipline which enables computer systems to solve problems by emulating complex biological processes such as learning, reasoning and self-correction. This paper presents a comprehensive review of the application of AI techniques for improving performance of optical communication systems and networks. The use of AI-based techniques is first studied in applications related to optical transmission, ranging from the characterization and operation of network components to performance monitoring, mitigation of nonlinearities, and quality of transmission estimation. Then, applications related to optical network control and management are also reviewed, including topics like optical network planning and operation in both transport and access networks. Finally, the paper also presents a summary of opportunities and challenges in optical networking where AI is expected to play a key role in the near future.

Keywords: Artificial intelligence, machine learning, optical communications, optical networks, optimization

1. Introduction

Artificial intelligence (AI) entities and systems have the ability to perform operations analogous to learning and decision making by imitating biological processes, with special emphasis on human cognitive processes. AI applications such as virtual personal-assistants, smart vehicles, purchase prediction, speech recognition or smart home devices, are almost ubiquitous, and similar AI-based techniques are already changing our daily lives in ways that improve human productivity, safety or health, affecting even the way we entertain or communicate.

For the most part, AI does not deliver completely autonomous systems, but instead adds knowledge and reasoning to existing applications, databases, and environments, to make them friendlier, smarter, and more sensitive to changes in their environments. Each small breakthrough on AI research enables us to expand our skills to solve new classes and scales of problems, thereby driving research and innovation in almost every scientific discipline.

As an example, the improvement of the performance of telecommunication networks by the application of AI-based techniques has become an area under extensive research over the past decades, affecting areas of transmission, switching and network management. Optical communication networks and systems have not stayed on the sidelines, but have started to adopt this discipline towards AI-based optical networking, from photonic devices to control and management.

The aim of this paper is to review some of the currently considered approaches to increase the performance of optical networks by the use of AI mechanisms, providing a survey of the

current research within this area, as well as an overview of opportunities and challenges arising in this context.

The remainder of this paper is organized as follows. Section 2 provides an introduction to the field of AI. Since that is a very broad area, we review those AI subfields –and their associated techniques– which have had or are expected to have, in our opinion, a significant role in optical networking. Then, Sections 3 and 4 analyze the role of AI techniques in optical communication systems and networks. We first survey the use of AI in optical transmission (Section 3), and then we focus on networking issues (Section 4). Finally, in Section 5 we describe further opportunities and challenges, and we conclude in Section 6.

2. An Overview of AI and Related Techniques

AI focuses on the study of intelligent or rational agents, i.e., entities which perceive and act in an environment with the aim of achieving their goals or maximizing a performance parameter. Moreover, they can further improve their performance through learning [1].

In this section, we briefly go through some of the subfields of AI that have been successfully employed in optical networking, stating the motivation for their introduction, and providing some examples of their use in the optical networking literature. Figure 1 shows a diagram with AI subfields and techniques, and classifies the references reviewed in this survey within those categories.

The simplest type of networking scenarios that we can think of are deterministic, observable, static and completely known. For these scenarios, *search algorithms and optimization theory* are key elements of the AI area [1], and thus, they have been extensively used in optical network design and control for a long

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