Optical Networks

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I. INTRODUCTION

It is almost guaranteed that this paper is being read on a device with internet access. By 2023, 66% of the global population will be Internet users, an increase of 15% from 2018 [1]. The currently projected growth of traffic demands would cause significant bandwidth bottlenecks within the conventional optical network technology [2]. This rapidly increasing demand on bandwidth is pushing the evolution of more flexible, efficient, and scalable optical networks. The traditional wavelength division multiplexing (WDM) networks are limited by their fixed wavelength assignment which leads to underutilized spectrum. One solution to this problem and the main candidate for the future of optical transmission technology is elastic optical networks (EON) [3].

A. Importance of Elastic Optical Networks

Many of the parameters which had to be constants in the WDM networks, such as modulation format and wavelength space between channels, can now be dynamically changed based on the demands of the systems. The newer optical orthogonal frequency-driven multiplexing (O-OFDM) technology allows for greater bandwidth efficiency by allocating spectrum into multiple, narrow slices according to the request.

However, the increase in the elasticity of these networks requires more sophisticated and dynamic algorithms which can utilize the new flexible spectrum technologies to handle high traffic without violating the constraints of the system [4]:

- ***Spectrum contiguity, spectrum continuity and slice opacity:*** the required spectrum slots must be adjacent, they must be available in all the links of the route, and until the assignment is finished, they cannot be reallocated [5]

To meet all of those challenges, researchers are implementing RMSA algorithms.

B. The RMSA Problem

Routing, modulation, and spectrum assignment (RMSA) are the features that the algorithm will choose for each request.

A route is the path the light travels on from source to destination. When a route is static, the route from source to destination can be set before the light has started traveling through the network, while with a dynamic route, the route may be adjusted in path, depending on the resources available [4].

Modulation is how the light wave carrying data through the optical fiber is altered. The data that is coded and sent through the beam is not changed in modulation, but the beam itself is altered. We can think of this as similar to refracting light or changing the amplification of a wavelength. There are six modulation formats that we will consider in the scope of this project: BPSK, QPSK, 8-QAM, 16-QAM, 32-QAM, and 64-QAM. Each modulation has benefits or tradeoffs to consider for each signal, depending on the path length, bit rate, and Optical Signal to Noise Ratio (OSNR) [3].

Spectrum assignment is how we allocate segments of the signal spectrum to carry client requests, avoiding frequency overlapping. There are different kinds of allocation policies- or ‘fits’ for assigning connection requests to spectrum segments [3].

C. Reinforcement Learning Strategy

Reinforcement learning is a type of machine learning which is well suited for sequential decision making due to the action-value learning cycle which defines ‘good’ behavior incrementally [7]. Reinforcement learning can provide strong, adaptive, and economical solutions to complicated and large-scale challenges.

Q-learning is an off policy reinforcement learning algorithm as it learns from acts outside the existing policy by doing all possible actions. In particular, q-learning is about learning a strategy which maximizes the overall reward. So by trying all actions in all states repeatedly, it learns which are best overall, judged by long-term discounted reward [8]. Reinforcement Learning can provide strong, adaptive, and economical solutions to complicated and large-scale challenges. Different algorithms with specific structures were suitable for different problems and specialized in different data types.

D. Related Works

Different methods for optimizing just the spectrum assignment portion of RMSA have been researched. Some of the most common methods include: First Fit provides lower call blocking probability and computation complexity [3]. Random Fit is good for reducing the possibility of multiple connections being allocated to the same spectrum [3]. First-Last Fit is expected to provide more contiguous aligned segments than Random and First Fit [6]. It is also the most efficient with the least blocking [6], and that Exact Fit is a good way to reduce the fragmentation problem in optical networks [3].

Other papers focus specifically on the routing and or the modulation [9][10]. Savory prioritized shortest route paths which avoid the links with highest spectral usage [11].

Many researchers who are proposing entire RMSA solutions, as opposed to those focusing on one portion, are doing it with machine learning. Zhou et al demonstrate an adaptive genetic algorithm [12].

Machine learning algorithms are being used in numerous areas, such as traffic prediction [13], and regenerator placement optimisation [14]. Our approach is trying to reduce the blocking percentage (BP) by tuning the metrics used in ARMA, starting with tuning the penalties for using different modulation formats in different link usage. We will implement our Q-learning algorithm within the CEONS simulator [15].

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