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Original Paper

Implementation of a model of artificial intelligence based on free software for estimating failures in 50 Gbps passive optical network

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Abstract

One of the most notable advances in the telecommunications are the passive optical network (PON) protocols in the access segment. For example, the GPON protocol operates at 2.5 Gbps per optical port, or up to 10, 40, and now 50 Gbps, in both point-to-point and point-to-multipoint topologies, allowing Internet service users to enjoy higher bandwidths. The aforementioned protocols are defined in the recommendations of the International Telecommunication Union as G-PON under G.984, XG-PON (asymmetric) and XGS-PON (symmetric) under G.9807, or the most recent 50G-PON under G.9804. Current management interfaces for these protocols only allow for the identification of signal absence or degradation problems without further details and only at the time of the incident. This work proposes to predict the conditions that lead to signal degradation using artificial intelligence model to analyze the eye diagram under normal and different degradation conditions. This data is used to train neural networks that can estimate the conditions that lead to irregular operation of PON before they happens. Matlab and Python tools will be used to implement the neural networks.

Keywords: Passive optical network, 50G-PON, artificial intelligence, neural network, eye diagram, free software

1. Introduction

The development of protocols for passive optical networks (PON) allows end users to use applications and devices with higher bandwidth requirements. Even other operators such as 5G and 6G mobile providers can use this platform for their technological evolution. In particular, this new version, which allows for a connection of up to 50 Gbps, uses advanced modulation and multiplexing techniques that alternate WDM with TDM in what is known as TWDM, which allows combining up to four wavelengths in a single port, multiplying capacities. New optical fibers have even allowed for better use of the available bandwidth around 1300 nm and 1550 nm, since these new protocols operate on separate wavelengths. For this reason, in order to determine the degradation of the signal in these links, the eye diagram can be analyzed, calculating the extinction ratio using expression (1). The lower this value is, the more deteriorated the signal quality is (as established in ITU recommendations G.9804.1 and G.9804.3, 2021).

$$ER = 10\log\left(\frac{P_1}{P_0}\right) \quad (1)$$

Where: ER is the extinction ratio, P_1 is the average value of a high level at the center of the pulse and P_0 is the average value of a high level also at the center of the pulse, measured on the eye diagram.

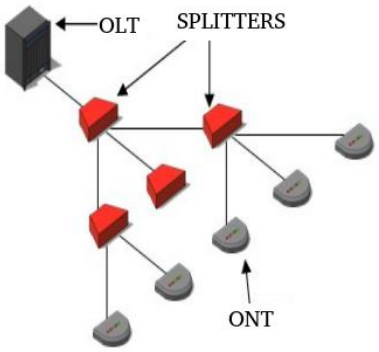
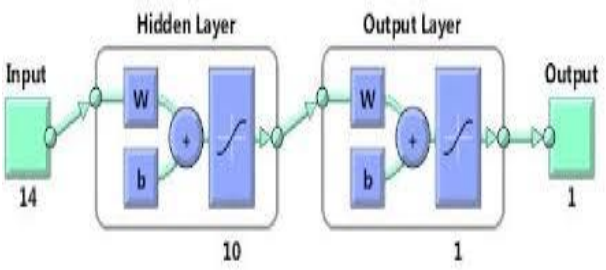
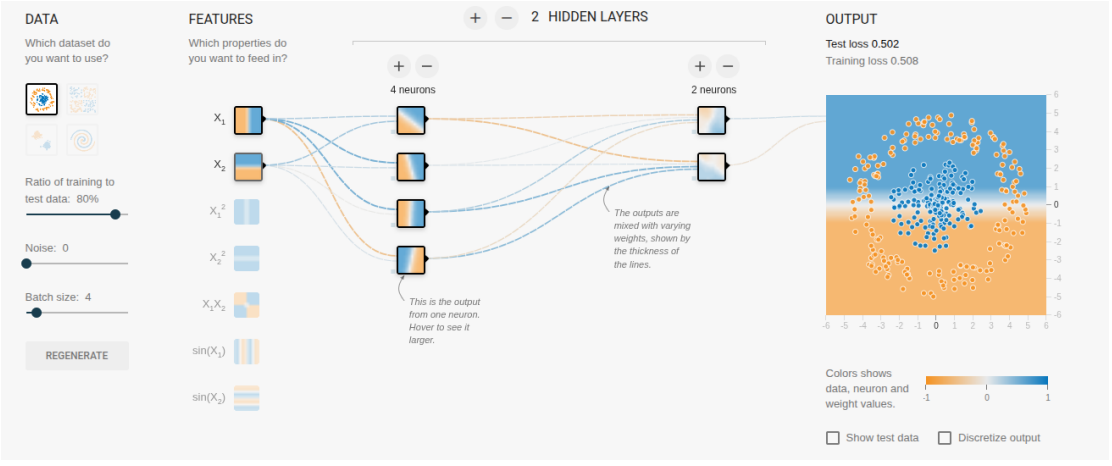


Figure 1. Model of passive optical network (PON)

On the other hand, recent works such as those by Usman (2024), Zin (2022) and Wang (2022) show the use of artificial intelligence and neural networks to estimate the conditions of PON and improve their performance. Therefore, this research proposes the use of computational tools based on the principles of free software to predict the degradation conditions of the signal traveling in an optical fiber under a high-speed PON protocol. The proposed tool is TensorFlow developed in python, which allows the development of machine learning solutions from training with large amounts of data on neural networks to predict patterns and correlations.



a)



b)

Figure 2. Models of artificial neural networks: a) Matlab b) TensorFlow

2. Method

For the development of this work, the logical model of the 50 Gbps passive optical network was defined using the VPI TransmissionMaker software for performance simulation and obtaining network training data from eye diagram measurements. The logical model of the 50G-PON protocol is established in the ITU-T recommendation G.9804 (2021), which allows symmetrical access network speeds of 50 Gbps for both the down-link and up-link and asymmetrical speeds of up to 50 Gbps in the down-link and 25 Gbps in the up-link. These bandwidth capacities can be shared through optical splitters, by up to 256 users connected to the same OLT optical port.

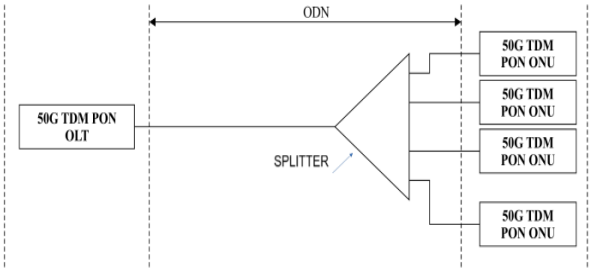


Figure 3. Logical model of 50 Gbps PON

Figure 4 describes the implementation of the logical model for passive optical networks at 50 Gbps in VPI TranmissionMaker, which was used to simulate performance and obtain the eye diagram, and with this data train the neural network to identify link degradation conditions as seen in Figure 5.

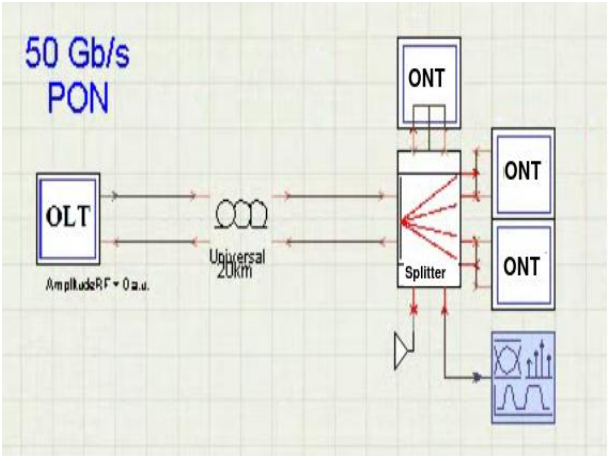


Figure 4. Model of 50 Gbps PON

With the data collected from the simulations, the available ANN models of Matlab and Playground of TensorFlow are trained, with more than 2000 input data, in order to obtain the prediction of the extinction radius of the eye diagram based on the degradation of the optical fiber link signal.

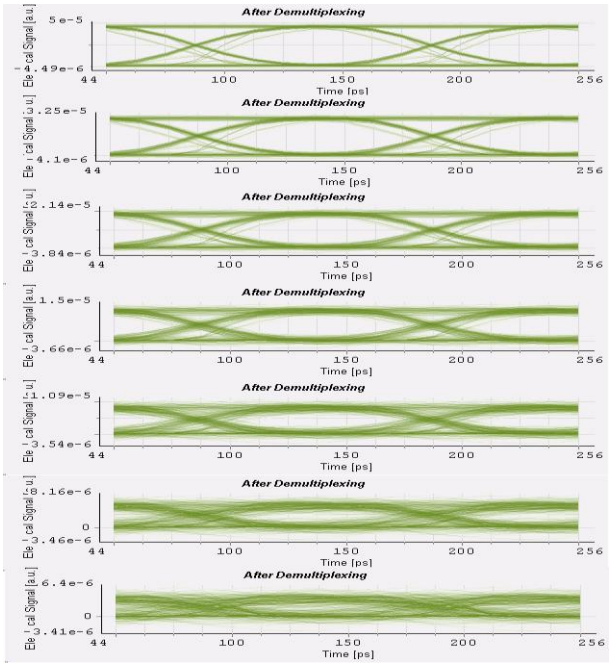


Figure 5. Simulation and data collection from eye diagram

3. Results

The results obtained from ANN of Matlab and TensorFlow are shown in figures 6 and 7, for the estimation of the extinction ratio of the 50 Gbps PON model.

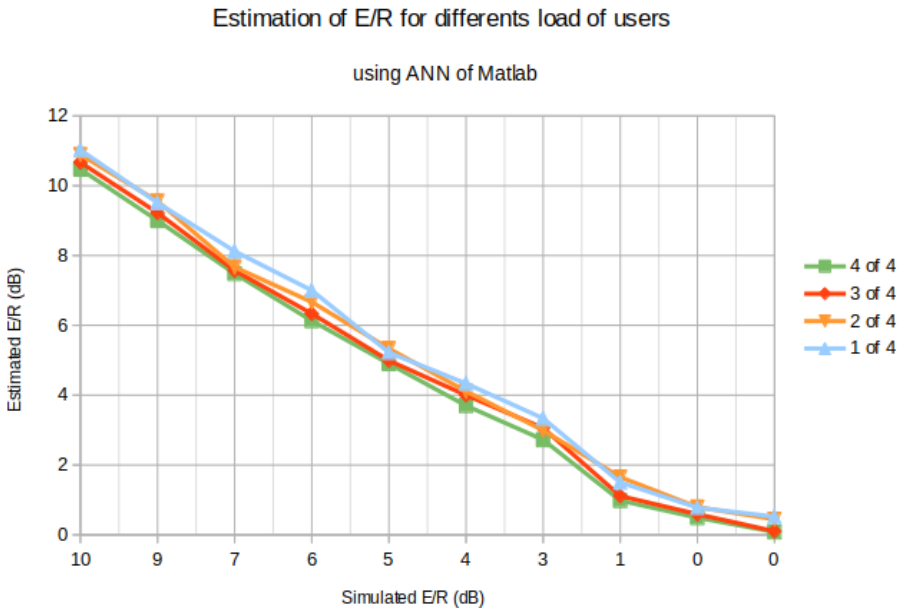


Figure 6. Estimation of extinction ratio using ANN of Matlab for 50 Gbps PON model

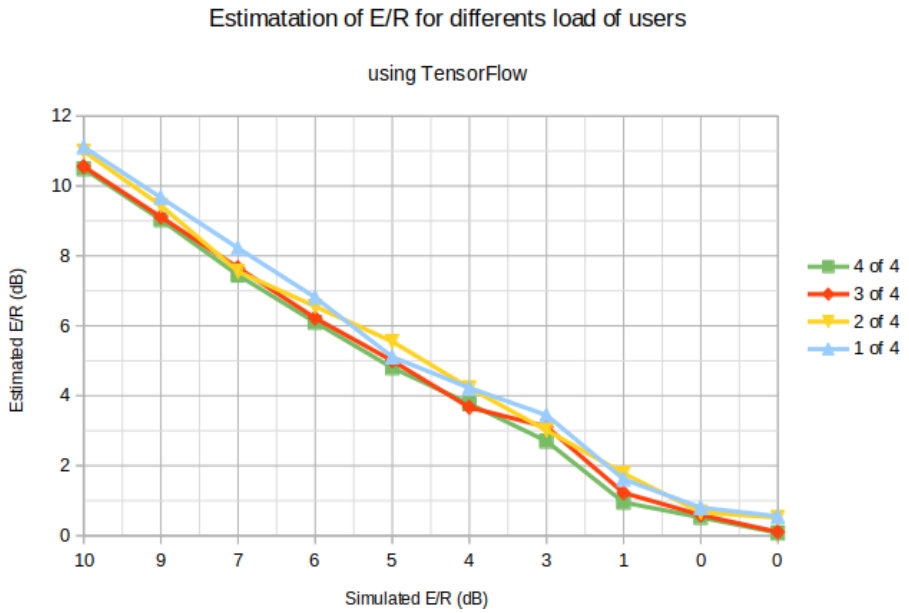


Figure 7. Estimation of extinction ratio using TensorFlow for 50 Gbps PON model

4. Conclusions

An artificial intelligence model based in free software such as TensorFlow was used to predict the extinction ratio of 50 Gbps PON model and the results were compared with the predictions from Matlab's ANN tool. Thanks to these results it was possible to predict faults in the optical link under different user loads, based on input data obtained via simulation in VPI TransmissionMaker that was used to train the neural networks.

Acknowledgments

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