Optimization of Energy Utilization in Future Internet: A Study of Existing Approaches and a Proposed Conceptual Framework based upon Neural Networks

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ABSTRACT
As the internet penetration increases, the realization for energy efficient networking has also begun, particularly in the last few years. In addition to the ecological concerns, having energy efficient networks make economic sense as well, since both energy cost and electrical equipment requirements of the telcos and internet service providers' will also proportionately increase with increase in demand for internet connectivity. The present study provides a brief insight into the work that has already been done and is being currently carried out to optimize the energy consumption of the optical networks. The paper also proposes a conceptual framework based upon neural networks which can lead to lowering of energy consumption in the optical networks.

Keywords
ALR, GPON ONU, PON

1. INTRODUCTION
In today's broadband access network, energy efficiencies are currently drawing a lot of attention. The concern is not only to reduce green house gas emission, but also to increase the operational efficiency of the network equipments. Studies have indicated that access networks (fixed and mobile) are the major users of current communication network energy consumption [4]. This primarily is due to the involvement of large number of elements. Replacing DSL (Digital Subscriber Line) based wired access networks with optical network has the potential of reducing the energy per bit consumed by the networks. Passive Optical Networks (PONs), particularly GPONs (Giga bit Passive Optical Networks), because of their certain advantages like no mess of fibers in the central office, use of passive optical splitter (unlike point to point access networks which use active electronics in the field) which require no cooling and powering and is therefore extremely stable. It has been found that within PONs, CPE (customer premises equipment) or ONUs (optical network units) are the energy hungriest devices [13]. In a given network their number is large and most of these because of low utilization of the PON capacity and the shared medium architecture are often idle but "always on".

In one of the study conducted by Miranda and Lima [3], it has been estimated that global internet penetration will reach 800 million by 2015 and will peak and subsequently saturate by 2030 – 2035 reaching approximately 1200 million. Another separate study has anticipated that optical access networks will be the largest contributors to wired optical communication network energy consumption for the next 10 years [4]. It is therefore of paramount importance that efforts are made to device means which can further help in lowering the energy requirements of these networks. Minimizing energy consumption of optical network can be generically addressed at four levels: components, transmission, networks and application .

This, article first surveys various efforts that have been made to develop methods aimed at optimizing the energy consumption of networks and then envisages developing a model using artificial neural networks.

Wong *et al* [14] suggested novel ONU architectures that selectively switch off certain elements thereby significantly reducing the clock recovery overhead while waking up from sleep mode. In another study Shen and Tucker [5] discussed power saving of IP over WDM model. They developed mixed integer linear programming (MILP) model and efficient heuristics based on lightpath bypass strategy for IP over WDM network. They found that strategy of lightpath bypass could significantly save power consumption ranging from 25 to 45 percent over the non bypass design. They also concluded that such savings increase with increase in network size. In a comparative analysis of different FTTH solutions, including 10-EGPON and TDM/WDM PON in terms of power consumption it was found that hybrid TDM/WDM PON has the potential to provide the highest energy efficiency [6]. A different kind of hybrid optical wireless access network consisting of reconfigurable optical backhaul and wireless mesh networks (WMNs) combining the complementary characteristics of wireless and optical networks to provide a broadband and ubiquitous last mile connection has been proposed by Shaw [3]

The choice of a suitable power saving mode depends upon the traffic load and any QoS (quality of service) requirements [3]. Simulation studies involving two low power modes - powering off the ONU transceiver and doze off mode involving only powering off the transmitter part of the transceiver indicated that while in the former case there is greater power saving but at the cost of reduced QoS performance and in the later case although power saving were significant, but were lower as compared to the former case, however QoS was significantly improved. Use of simple coding devices having dual Bragg gratings and forming a cavity producing periodic codes for monitoring of passive optical networks were found to reduce the cost of manufacturing, installation, inventory and operation while maintaining good performance and high capacity [6]. Meng *et al* [9] suggested a dynamic bandwidth allocation algorithm for effective resource management in STARGATE EPONs (SG

EPONs) to evolve in a pay-as-you-grow manner. The proposed algorithm ensured backward compatibility with legacy infrastructure and protecting previous investments. Another Dynamic Bandwidth Allocation (DBA) algorithm that allows mitigating the effect of the increased control-plane delay in an extended reach network was investigated by Song *et al* [8]

Wavelength Division Multiplexing Passive Optical Network (WDM PON) represents one of the current solutions to meet the different network requirements. In order to fully harness the potential of these networks an all optical approach that requires WDM/TDM conversion and avoids the use of a large number of power consuming OEO (Optical Electrical Optical) conversions has been proposed by Bogoni [2]. The proposed architecture has been demonstrated as proof of concept exploiting nonlinearities in highly-nonlinear fiber (**HNLF**), high bit rate, scalability, easy configurability, modular unbundling, minimum number of fiber links and pay as you grow strategy implementation can be enabled.

A network planning approach based upon user behavior for Long Reach PONs (LR-PONs) has been proposed [10]. In another study involving LR-PONs it was demonstrated that ring duplication protection could save half the cost compared to full duplication protection with relatively high reliability (99.9925) [12]. A remote channel combine/split module for long reach wavelength division multiplexed and time division multiplexed passive optical network systems outperform the conventional systems.Remote CCS module LR WDM/TDM PON systems were found to be more cost effective, saving up to 60% investment cost at introduction stage. These systems are power efficient, saving up to 35% power consumption in take-up-rate-adaptive mode at low take up rate stages, further at fully operated stages up to 35% power saving can be achieved under traffic demand adaptive power management mode [7].

Liu *et al* [16] proposed a Downstream-Bandwidth-Reservation-based Accurate ONU Sleep Control scheme and extend it by introducing network coding (NC) in EPON by using NetFPGAs and an IEEE 802.3ah EPON network. Investigation of its benefits on the energy saving and performance by means of simulation showed that (1) NC can be implemented in PONs when there is internal traffic exchanged among ONUs via the OLT and (2) by encoding two packets into one, scheduling encoded packets in a certain order, and indicating the exact start and end time of the transmission duration of the encoded packets to each ONU, NC and its packet scheduling scheme can reduce the active time of the OLT's transmitter and the ONUs' receivers and increase the maximum downstream throughput, thereby improving the energy efficiency and performance of NG-PONs.

A hybrid mechanism involving sleep and adaptive link rate (ALR) control functions to reduce the power consumption of optical network units (ONUs) in 10 Gb/s asymmetric Ethernet passive optical network (10GEPON) systems showed effective power management of ONUs on the basis of the traffic conditions as compared with its component functions in isolation at the expense of a slight increase in queuing delay [16].

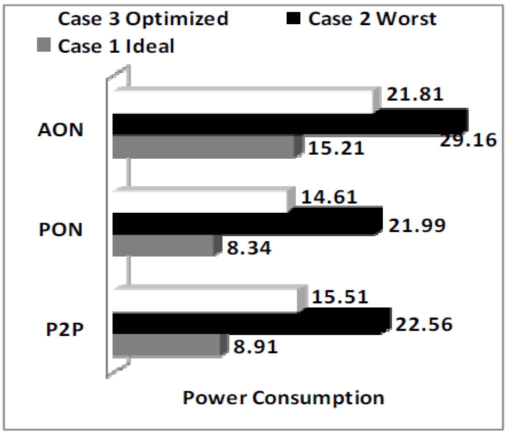

Fig 1: Power Consumption Comparison Under Various Conditions For Power Ignoring Method

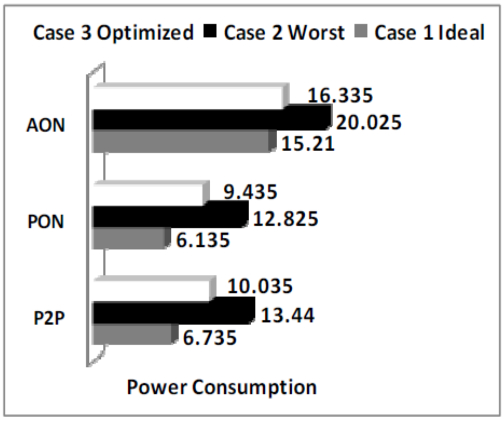

Fig 2: Performance Comparison For Power Saving Method

2. THEORY

Power consumption in GPON, depends upon the traffic flow, which in turn depends upon number of active users at a given instance, bandwidth of ONUs, payload data etc. The present study suggests a step wise procedure for developing a neural network based machine learning algorithm within GPON (optical splitter) that can help conserve energy (figure 1). The idea is to develop a neural network based algorithm which can act as a traffic controller or supervisor, who, on the basis of traffic flow can intelligently decide which Rx or Tx should remain active and for how long

2.1 IMPLEMENTATION

In our study we will be using Optical Fiber Toolbox for laying of optical fibers to conduct simulations, besides this we will be using Statistics Toolbox of MATLAB 2011b and Neural Network Toolbox of MATLAB 2011b. For the purpose of our study we will be using video data.

Step 1 – The first step in our simulation will be to develop network traffic model of video data based upon Poisson distribution. Payload data model will be based upon bit-error rate.

Step 2 – Selection of a classifier; Literature has indicated that artificial neural networks have been successfully used as classifiers in numerous fields. As such we will be using neural networks as classifiers for the traffic data which is non stationary and non linear in nature for our work. It will be of interest of to use it for sending intelligent commands (Sleep and Active) to the receiver for analysis and classification.

Step 3 – Selection of real valued input feature vectors; Since, power consumption in GPON depends upon the traffic flow, which in turn depends upon number of active users at a given instance, number of active ONUs, number of active OLTs. These vectors, refer table 1 will therefore be used as input vectors.

Step 4 – Normalization of Input Database: In order to equalize the size or magnitude of the variability of these features, we will be applying three normalization procedures to the video traffic data. The normalization of the data will ensure that variables measured in large valued units will not dominate the computed dissimilarity and that the variables that are measured in small values will not contribute very little.

Table 1.

S.No	Attribute	Description
1	Bandwidth	Amount of Data Flow
2	No of Active ONU	How many ONU are using Power
3	No of Active OLTs	How many ONUs are using Power

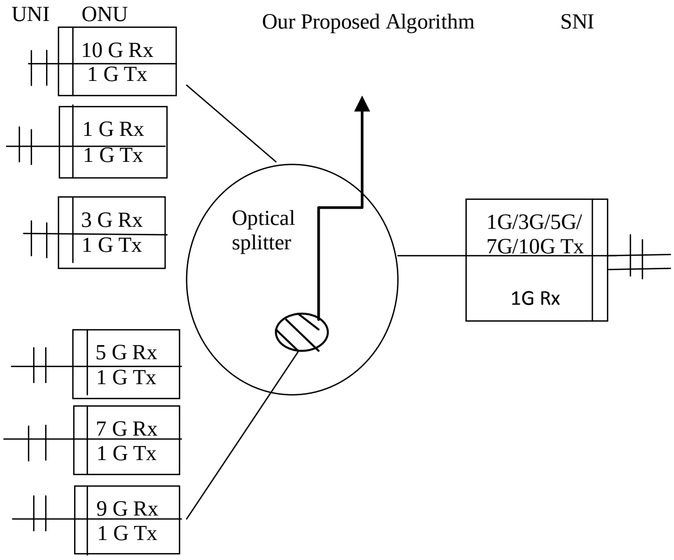

Fig3 : Placement of Proposed Algorithm

Step 5 – Neural network hidden layer number detection:A major problem in designing a neural network is about establishing the optional number of hidden layers. Regarding the input and output layers, these are normally clear and easy but showing the hidden layer to get the accurate result is designing issue of the classifiers. We will be using 'Grow up' process for designing the hidden layer.

A layer would be added after performing empirical testing of neural network for achieving better level of results. Optimal architecture of a neural network will be selected from the different developed architectures and making them learn on the set of input dataset created by simulating the video traffic data until the performance criteria will be fulfilled. The structure with minimized dimensions which ensures the use of least amount of computational resources will be selected.

Step 6 – Initializing of weights; The Mersenne Twister has been optimized for use with Monte Carlo simulations in a number of fields, including simulating complex biochemical pathways,[2] photon migration,[3] genome coalescence,[4] cellular biology,[5] and computational finance.[6]
The Mersenne twister is the default random number generator for Python, Ruby, PHP,MATLAB and also available in C++, therefore we will be choosing this random generator for giving weights to our neural network classifier. However for our research work, all the weights and biases will be set to small real random values between 0 and 1.

Step 7 – Pattern Learning Method; Supervised learning method will be adopted in our study. The efficacy of classifications will be evaluated by using Confusion matrix.

Step 8 – Output layer design; Based upon the number of Rx types or classes, the design of the output layer will be as given in table 2.

Table 2.

Target	Description	Target Code
Class A	Signifies Commands send to Rx1 for Activation	1 0 0 0 0 0
Class B	Signifies Commands send to Rx2 for Activation	0 1 0 0 0 0
Class C	Signifies Commands send to Rx3 for Activation	0 0 1 0 0 0
Class D	Signifies Commands send to Rx4 for Activation	0 0 0 1 0 0

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3. CONCLUSION

It is anticipated that by inserting a neural network based algorithm in the optical splitter, it will be intelligently able to decide, based on the usage pattern as to which ONU will remain active and which will switch off. Since, limited number of ONUs will remain active it is therefore anticipated that power consumption will come down appreciably.Thus even after using all the power saving components and mechanisms maximum power will be saved if the ALR is able to take accurate decisions.

4. FUTURE SCOPE

The traffic volume that needs to be handled by communication networks is going to grow much faster due to the continuously increasing number of end-users and due to the new and emerging services that can be accessed on the Internet. This reflects into a need for increased network capacity, which in turn introduces higher energy consumption of the network infrastructure. In view of the scale of the network of the future, it becomes evident that investigation of technologies, methodologies and approaches that can offer energy savings are of the utmost importance. Several attempts to reduce power consumption in optical networks can be found in the literature and we have also implemented a design of power management scheme which is based on Neural networks. However, so far, not much attention is paid to understand the impact of resilience in the overall network power consumption. How would the network behave when it is under some stress-strain factors or under some adversity or overload/over subscribing of multiple users of optical network resources .Therefore , for future scope it is suggested the resilience of such power schemes must also to checked by experimenting some adverse situations .

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