An Energy Efficient Resources Allocation Scheme for Flexible Translucent Optical Transport Networks

Bakhe Nleya[1], Mlungisi Molefe[2], Richard Chidzonga[3]

[1,2,3] Durban University of Technology, Department of Electronic and Computer Engineering, Durban, South Africa
Email: [1]bakhen@dut.ac.za, [2]21345559@dut4life.ac.za, [3]21855549@dut4life.ac.za

ABSTRACT

The present study attempts to explore how academic streams and learning styles play role in the preferences of coping strategies among prospective teachers. A quantitative approach was selected to explore the relationship. A survey was conducted with 300 prospective teachers (150 of science stream and 150 of humanities stream). A multi-stage random sampling technique was used to collect relevant information. Research instrument to measure coping strategies was developed by the researcher himself and Learning Style Inventory (LSI) by Ritu Dangwal & Sugata Mitra, 1997 was used to measure learning styles of prospective teachers. Statistical techniques i.e. mean, S.D., multivariate ANOVA were applied. Results revealed an essential significant effect of academic streams and learning styles on preference of coping strategies among prospective teachers. It is recommended that teacher training institutions should establish guidance or counseling centers to provide counseling to prospective teachers regarding coping skills and learning styles.

Keywords

Translucent Optical Transport networks, spectral efficiency, energy efficiency
Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

Things (IOT) and 5G has resulted in the booming of new network passed applications and services. These have led to a significant rise in bandwidth demands to accommodate the resulting traffic. Optical dense wavelength division multiplexing (DWDM) coupled with switching paradigms such as optical burst switching (OBS) have been explored as possible transmission and switching network solutions for the huge bandwidth demands. Notably however, is the fact that the native DWDM networks are characterized by inefficiencies as far as key network resources such as spectrum are concerned, since an entire wavelength's capacity is allocated to a single lightpath connection [1], [2], [3]. Of late strides have been made towards providing granularity in a bid to improve resource allocation efficiencies, and this has given rise to elastic spectrum-sliced based elastic optical networks been proposed. These are also referred to as flexible optical transport networks. The flexible is on the strength that they provide spectrum allocation efficiencies by way of accommodating multiple data rates, thus various applications and services can be supported. In the process each service or application is allocated the actual bandwidth demand. This development, however, leads to new challenges for flexible as well as dynamic routing algorithms that energy efficient. Such algorithms should also take into consideration the presence of physical layer impairments (PLIs). Note that there is a direct relationship between PLIs levels versus energy efficiency of any given network. The number of network end users continues to surge, this also leading to a corresponding rise of network power consumption. The amount of power consumption globally, averages about 12% annually. Studies as well as statistics have shown that network traffic growth trends on an annual basis always surpass technology system capacity increases. For that reason, it might be worthwhile introducing novel scaling interface rates as well as system bandwidth to match the traffic volumes.

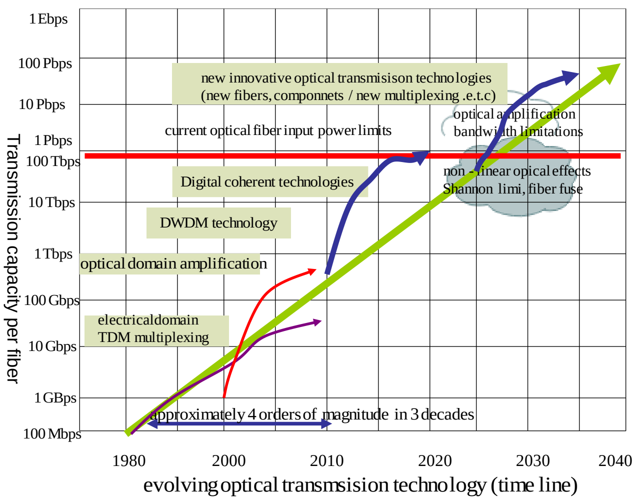

Figure 1. Evolving in Optical transmission speeds [4].

A promising trend is in the ever-evolving optical domain transmission related technologies in the past 30 years or so (Fig. 1). The technologies range from, time division multiplexing (TDM), also referred to as time division multiple access (TDMA), space division multiple access (SDMA), and related digital coherent technologies. Despite all these transmission technology strides, currently it is not practical to achieve speeds of 1 Pbps and above since existing multiplexing approaches are fast reaching physical limits. However, emerging industrial automation trends will further exponentiate global traffic levels. It is generally noted that optical transparency nature of flexible Optical Transport networks will always suffer from performance degradation due to the presence of PLIs that tend to be accumulative along the established end-to-end lightpath. Several literatures have ascertained that PLIs' impact on QoT in the network depends on network configuration, denseness of wavelengths per fiber, type of technology used in the switching and other network elements, and the nature traffic's characteristics (i.e real-time or non-real time) [5],[6]. Ultimately the accumulative tendency of PLIs nature leads to an overall degradation of the optical signal to noise rations (OSNR) at the receiving end. The degraded OSNR leads to increased bit errors and consequently high levels of loss and blocking probabilities. The trend therefore is to design routing algorithms that have both PLIs awareness, and energy efficiency but at the same time ensuring that overall network performance does not degrade.

It therefore follows that proper routing decision making enhancements can be achieved by way of incorporating network mechanisms that analyze PLIs levels and ultimately relaying then to the control plane. generally, the fundamental PLIs aware routing and wavelength assignment (RWA) problem is in identifying a set of least cost candidate routes between the desired source and destination pair (s,d) considering impairments levels as well as energy efficiency. The route that best satisfies the two constraints is assigned as the primary path, whereas the others will be relegated to backup candidate alternate (secondary) routes. Making such a routing decision by way of solving the RWA problem can be carried out dynamically (online solution) or on a fixed basis (offline provisioning). Notwithstanding the aforesaid, the objective solution is in maximizing the number of simultaneous end-to-end lightpath connections with minimal possible resources provisioning. In this paper, we overview resource provisioning at wavelength routing level versus energy efficiency and ultimately propose a general resource provisioning framework for such networks. The paper 's outline is as follows: Section II overviews a generic flexible translucent network architecture, followed by the proposed algorithm in section III. In the final section we evaluate the efficacy of a Q-factor based tool as well as analyzing energy efficiencies of the network overall.

Overview network architecture

As discussed in the previous section, IoT together with 5G wireless network's device-to device (D2D) communication standards will generate massive data volumes. It is estimated that communication capable devices and objects may exceed 76 billion in just under 4 years from now (2025). This is bringing an urgent demand for scalable optical interfaces from the current 10 Gb/s, 40 Gb/s and 100Gb/s to 2-3Tb/s by 2030[7].

A flexible Optical Transport Network Configuration is illustrated in Fig. 2 With such a configuration the network is being provisioned with capabilities to dynamically adjust it's the available resources such as assigned wavelength channels, path configurations, transmission formats and data rates in an elastic and optimum way depending on the always varying traffic conditions and demands thereof. In the process it may not compromise the Quality of Transmission (QoT) as well as general performance of the network with regards existing connections.

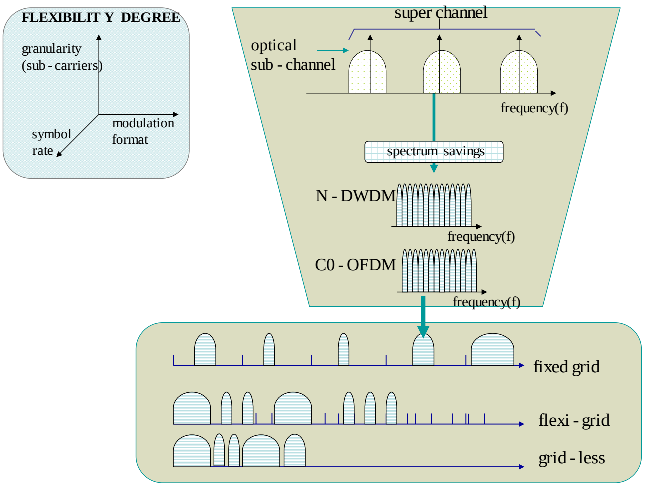

Figure. 2. A Flexible Optical Transport Network Configuration.

The flexibility in the provisioning is enabled by the use of a combination of orthogonal frequency division multiple access OFDMA, Nyquist DWDM (N-DWDM) and spatial coherent transmission. In that way we should be able to provision lighpath bandwsith demands according to actual needs.[8].

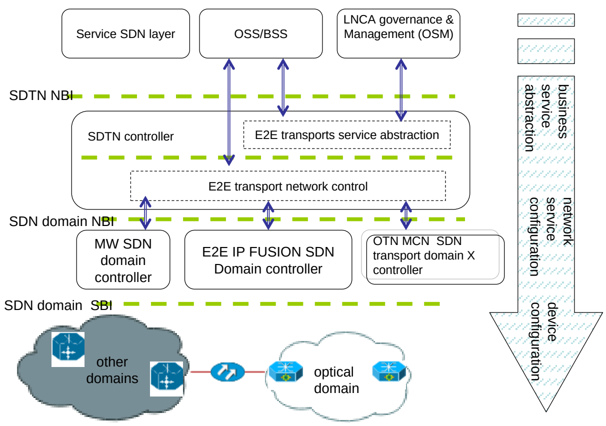

Figure. 3. SDN architecture

ITUT's G.709 standard has also proposed a commensurate control plane based on software defined networking (SDN). This control plane (sub architecture) will facilitate a better overall view of the entire network such that optimal resources optimization can easily be achieved thus leading to a better overall utilization of the entire network's resources as well as QoS[4]. Its centralized nature will immensely facilitate improved flexibility and adaptability with respect to the demanding PLIs and energy efficient RWA scenarios [9]. This is because it will assist in enhancing envisaged functionalities such as dynamic assigning of wavelengths and other related bandwidth related resources to end-to-end lightpath connections.

Proposed Algorithm

We commence the section by briefly defining the overall resources allocation framework followed which takes into account the presence of accumulative PLIs as together with energy efficiency in the operation of a flexible Translucent Optical Transport Network. Such a network would be regarded as comprising standard optical network elements including wavelength converters and line repeaters (amplifiers). Typical network elements include; variable rate , colourless and directionless reconfigurable optical add drop multiplexers (VR, CL & DL ROADMs), variable transponders (VTR-TPND), as well as transponder aggregators (TPND aggregators). All links can be susceptible to the effects of PLIs. Which generally lower the received OS.N.R) and consequently overall QoT and bit error rates (BER) on the affected paths/links.

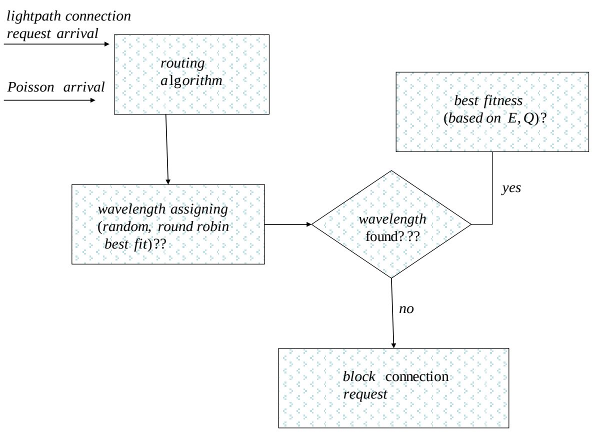

Figure 4. Routing and wavelength assigning

The resources framework approach ensures PLIs aware RWA ,routing, coupled with energy efficiency operation of the entire network [11].

Provided below in Fig 4 is a summary of the proposed The resources allocation framework in block diagram form.

Once a candidate wavelength on a shortest path route is identified, it is further checked for best fitness considering energy efficiency as well as path quality in terms of PLIs levels and a quality factor Q which characterizes the levels of PLIs along the chosen path. The actual implementable algorithm is described and explained as follows. Firstly, we defines an and end to end light path connection request (s,d), where s and d are the ingress and egress nodes respectively

A few assumptions are made:

- m and n representing the network nodes.
- i and j representing logical nodes in a virtualized equivalent network topology.
- $G(V,E)$ is an equivalently defined physical network topology which consists of V switches (nodes) and E unidirectional link interconnecting them. Each link can be considered implemented in the form of one or more fiber cables each with W, $\lambda = w = [1,2,3,...W]$ .Each fiber between nodes m and n is of average length $L_{m,n}$ and there are $A_{m,n}$ repeaters along it.
- $T = \lfloor \wedge_{s,d} \rfloor$ is a summary indication of the actual traffic matrix forecast.
- $\wedge_{s,d}$ is the aggregate demand between a given (s,d) pair.

The available channel rates are also defined by a set $R = \phi_1, \phi_2, ...\phi_k$. For this same network, the is a set of available channel rates. The energy cost per repeater unit is $E_{r,k}$ at a rate ϕ_k. Similarly, for transponders at nodes the average energy usage per TPND is $E_{R,k}$ at a rate ϕ_k .

Further assumptions as follows:

- E_p defines average energy cost of processing by electronic components.
- $P_{m,n}$ is the aggregate set of lightpaths connections traversing each link.
- $F_{m,n}$ is the variable that denotes the number of fibers on a link (m and n).
- $f_{i,j}^{s,d}$ denotes the volume of traffic from source to destination on lightpath (i,j).
- Z_j is an integer that represents the amount of data that is transported by lightpaths that terminate at node j .
- $l_{i,j,k,\lambda}$ represents the lightpath between (i,j) node pair in the logical topology at rate ϕ_k over λ .
- $\alpha_{i,j,k,\lambda}$ stands for the feasibility of lightpath establishment for a given lightpath $l_{i,j,k,\lambda}$ between i and j nodes at rate ϕ_k for wavelength λ. The feasibility is based on the comparison with an acceptable preset threshold Q-factor.
- $X_{i,j,k,\lambda}$ is a variable that represents the number of lightpaths on link (i,j), and thus should be an integer.

The objective is to:

$$\text{minimize}: \; 2 \times \sum_{\lambda}\sum_{i,j}\sum_{k} X_{i,j,k,\lambda} E_{r,k} + \sum_{m,n} A_{\min} * F_{\min} + \sum_{j} Z_j * E_p \tag{1}$$

This is subject to the following constraints:

Capacity constraint:

$$\sum_{\lambda}\sum_{k} \phi_k * X_{i,j,k,\lambda} * \alpha_{i,j,k,\lambda} \geq \sum_{s,d} f_{i,j}^{s,d} \quad \forall (i,j) \tag{2}$$

Wavelength-continuity constraint is as follows:

$$\sum_{(i,j)\in P_{m,n}} \sum_{k} X_{i,j,k,\lambda} * \alpha_{i,j,k,\lambda} \leq F_{m,n} \quad \forall (m,n), \;\; \forall \lambda \tag{3}$$

To maintain equilibrium between incoming and outgoing traffic at nodes we have:

$$\sum_{i} f_{j,i}^{s,d} - \sum_{i} f_{j,i}^{s,d} = \begin{cases} \wedge_{s,d} & \text{if } s = 1 \\ -\wedge_{s,d} & \text{if } d = j \\ 0 & \text{otherwise}, \; \forall_j, \; \forall (s,d) \end{cases} \tag{4}$$

It should be noted that each new lightpath connection demand will admitted or rejected based on both PLIs awareness and energy efficiency.

For that, initially a set of $k-$shortest candidate paths from source to destination are calculated. This is followed by checking for contiguity in desired wavelength line rates as well as Q threshold.

Algorithm I: RWA New lightpath connection demand

LowestMetric PC = 0

compute k candidate paths s,d; (k – shortest paths)

publish all line rates sets on the shortest path (reach ≥ path length)

for publish_ascending order[], line rates based on Metric + EC;

for publish_ascending order[], line rates based on $Q^{lp} \leq Q_{threshold}$;

determine requested number of wavelengths wavelength/line speed)

while published list ≠ 0;

for each candidate path

if _true (optical reach ≥ path length) & &($Q^{lp} \leq Q_{theshold}$)

if _10G in line rate set)

search for all availables wavelength setsc on 1st of links (s,d)

if allocation = FALSE

search for all availables wavelength setsc by moving Δf to LEFT

end

end

if allocation = TRUE

Calculate_*Metric_EC*

if (*Metric_EC* < Lowest_*Metric_EC*) or (Lowest_*Metric_EC* == 0)

Lowest_Metric_PC = Metric_PC

Save → MOst_Efficient_Allocation

end

end

end

end

if Lowest_Metric_PC == 0

break

else

remove considered sets from list

end

end

if Most_Efficient_allocation exists
wavelength assignment for path = most_Efficient_allocation = true

else

lightpath connection = block

end

Finally if the allocation is possible , energy consumption on the candidate end-to-end light paths (Metric_EC) is computed as well. It is an aggregate energy consumption by the transponders (EC_{TPNDS}) and data carriers(EC_{trans}).

$$EC_{trans} = number \text{ of wavelength carriers} \times EC_{\text{single carrier}} \quad (5)$$

$$EC_{TPNDS-number\ of\ TPNDs \times EC_{TPND}} \quad (6)$$

$$Metric\_EC = EC_{trans} + EC_{TPNDS} \quad (7)$$

The allocation scheme is summarised by algorithm I. It is noted that two different bands separated by a guard band Δf . The searching is the first waveband (10Gb/s) runs from left to right (in ascending order), whereas the searching in the second band (40 and 100 Gb/ s), it starts from right to left (in descending order). In that way Δf can be shifted to increase the wavelength in a particular band. For every lightpath connection request all possible candidate $k-$ shortest paths are computed then checked for all possible sets of line rates. The list is also sorted base on energy consumption (Metric_EC) and $Q_{threshold}$ comparisons.

Evaluation

The Pan-European Network is used in this model to verify its applicability and accuracy. The network topology has 16 nodes and 23 bidirectional fiber links. We assume that the connection requests follow a Poisson distribution and the nodes do not have wavelength conversion capabilities. Furthermore, no protection or regeneration is taken into consideration. The shortest-widest path (SWP) algorithm is employed to solve the routing sub-problem and the First-fit with Ordering (FFwO) algorithm is used to solve the wavelength assignment sub-problem.

When a connection request is received, the engine looks for the shortest path that is least congested and process them in their order. The FFwO algorithm is then applied to choose an available wavelength from the available wavelengths.

Each candidate path's Q-factor is calculated and those paths that have a Q-factor that is lower than a pre-set threshold (Q_{thres}) are blocked.

We chose the whole network to consist of SSMF with a dispersion, $D = 12 \ ps/nm/km$ an attenuation constant of $\alpha = 0.25 dB/km$ and a nonlinearity constant of $\gamma = 1.5(W/Km)$. We also assume a communication channel plan a maximum of 40 wavelengths per link spaced at $50 \ GHz$. The threshold Q-factor is configurable and overall noise figure is set at $5 \ dBw$

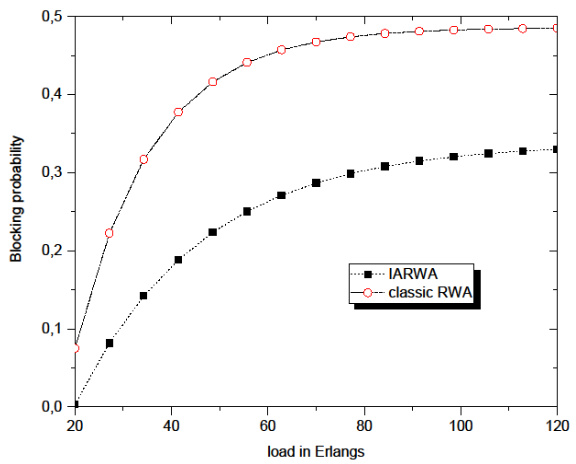

Figure 5. The relationship between blocking probability and network load for the Pan-European Network

Fig. 5 above, compares the blocking probability of the classic RWA algorithm with our proposed IA-RWA algorithm in the Pan-European Network topology. We can clearly observe that, at low network loads, the performances of the two algorithms are almost similar in the Pan-European Network, however, there is clear distinction of their performances at high loads.

Energy efficiency is an indicator of the amount of energy well spent in servicing the end-to-end lightpath connections

$$\eta_{energy} = \frac{\sum data \ traffic}{\sum Energy \ spent \ within \ the \ network} \tag{8}$$

It is the ratio of the traversed data traffic to the total energy consumption of the network.

We compare various network operation approaches namely; single line rate (SLR), mixed line rate (MLR), with the flexible –grid based OFDM. The traffic load is gradually increased from low to high. The energy efficiency performance comparisons for these various schemes are plotted in Fig. 6. From this graph it cab e observed that MLR and flexible OFDM based network operations are more or less comparable and outperforming the three example SLR cases of 10G, 40G and 100G./ Their energy efficiency superiority can be attributed to their abilities to adjust and adapt to the actual demand transmission rates. As can be observed in Fig. 6 flexible OFDM based operation will result in comparably lower service blocking. This is followed by the 100G and MLR cases respectively.

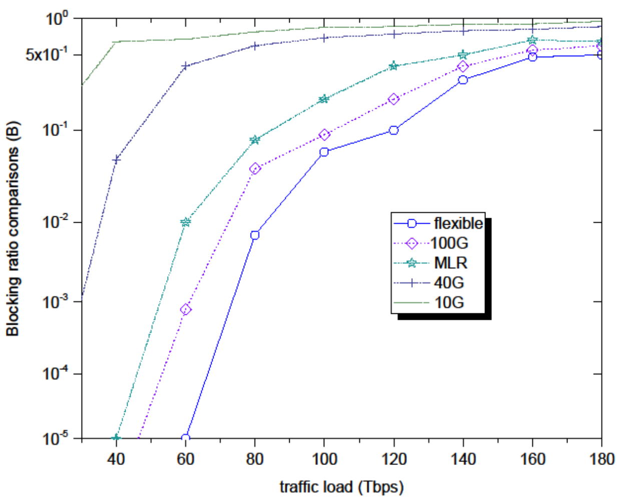

Fig. 6. Service ration blocking comparisons.

Conclusion

In this paper, an energy-efficient algorithm that considers various parameters in their decision-making processes are proposed. The algorithms potential is evaluated via simulation and consequently found to provide a good energy savings potential.

References

[1] M. Gomba, B. Nleya, A. Mutsvangwa and R. Chidzonga, "Evaluation of Wavelength Congestion in Transparent Optical Transport

Networks," 2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems , Durban, South Africa, 2020,,doi: 10.1109/icABCD49160.2020.9183819.

[2] P. Khumalo and B. Nleya, "Sleep-Mode/Traffic Grooming Versus Device Reliability Overview," 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems , Durban, 2018, pp. 1-5, doi: 10.1109/ICABCD.2018.8465416.

[3] M. Gomba, B. Nleya and R. Chidzonga, "Availability and Operability in Optical Transport Network Architectures," 2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD), Durban, South Africa, 2020, pp. 1-6, doi: 10.1109/icABCD49160.2020.9183880.

[4] Y. Miyamoto and R. Kawamura, “Space Division Multiplexing Optical Transmission Technology to Support the Evolution of High-capacity Optical Transport Networks”, NTT Technical Review, Volume. 15, Number 6 , June 2017, pp1-7.

[5] P. Khumalo, B. Nleya, A. Mutsvangwa and R. Chidzonga, "Quality of Transmission Aware Routing and Wavelength Assignment Algorithm for Blocking Minimization in Translucent Optical Networks," 2020 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems, Durban, South Africa, 2020, pp. 1-5, doi: 10.1109/icABCD49160.2020.9183804.

[6] J. Bai, Y. Shen, C. Xu and G. Gao, "Influence of inter-channel nonlinear interference on the QoT estimation for elastic optical fiber networks," 2019 18th International Conference on Optical Communications and Networks (ICOCN), Huangshan, China, 2019, pp. 1-3, doi: 10.1109/ICOCN.2019.8934920.

[7] Bakhe Nleya, “Availability and Operability in Optical Transport Network Architectures” Solid State Technology Journal, Vol. 63 No. 4 (2020).

[8] I. Tomkos, E. Palkopoulou and M. Angelou, "A survey of recent developments on flexible/elastic optical networking," 2012 14th International Conference on Transparent Optical Networks (ICTON), Coventry, 2012, pp. 1-6.

[9] S. Azodolmolky, M. Klinkowski, E. Marin, D. Careglio, J. S. Pareta, and I. Tomkos, "A survey on physical layer impairments aware routing and wavelength assignment algorithms in optical networks," Computer Networks, vol. 53, no. 7, pp. 926–944, May 2009

[10] B. Nleya and C. Mulangu, "An Overview of GREEN Networking and Power Savings in Optical Backbone Networks," 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD), Durban, 2018, pp. 1-6, doi: 10.1109/ICABCD.2018.8465402.

[11] Y. Li, L. Gao, G. Shen and L. Peng, "Impact of ROADM colorless, directionless, and contentionless (CDC) features on optical network performance [Invited]," in IEEE/OSA Journal of Optical Communications and Networking, vol. 4, no. 11, pp. B58-B67, Nov. 2012.