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Comparison of Technical Efficiency of Dense Wavelength Division Multiplexing Channels Using Constant and Variable Return to Scale Models

[1]Abdoulie M. Sunkary Tekanyi, [2]Joseph Stephen Soja,[3] Emmanuel Adewale Adedokun and Samaila Peter Hammajauda

[1,2,3] Department of electrical and computer Engineering
Ahmadu Bello University, Zaria Kaduna state Nigeria
[4] Department of Electrical and Electronics Engineering, American University of Nigeria

Email: sojasteve@gmail.com amtekanyi@abu.edu.ng, wale@abu.edu.ng and samailapeter@gmail.com

Abstract—The Technical Efficiency (TE) of Dense Wavelength Division Multiplexing (DWDM) channels implemented in the metropolitan area network for the purpose of deploying higher bit rates have been neglected and this pause a great challenges. Recent researches conducted on DWDM concentrated largely on the effectiveness of the DWDM channels and not on its performance efficiency. In this paper, Data Envelopment Analysis (DEA) is employed to determine and compare the TE of DWDM channels by input oriented assumption using Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models. The simulation results obtained show that CRS model has better performance at the multiplexer than the VRS model and vice versa when considered at the de-multiplexer.

Index Terms— DWDM, DEAP, Efficiency, Constant Return to Scale and Variable Return to scale

1 INTRODUCTION

Prior to the introduction of Data Envelopment Analysis (DEA), traditional performance measurement system offers distorted result of performance that can mislead researchers of an important opportunity to provide improvement on problem. The most common method of comparison or performance evaluation is stochastic frontier analysis. One of the parametric methods of efficiency measurement includes the stochastic frontier approach and this method measures economic efficiency [6]. A non-parametric method like DEA is a linear programming problem that provides a means of calculating the efficiency levels of entities or a group of organisations. Nowadays, this concept has been applied in various fields of Engineering to determine the performance efficiency of two or more algorithms or systems [9]. The most common efficiency concept in DEA is TE, which is defined as the conversion of physical inputs and outputs relatives to best practise [5]. In other words, TE is the success with which the DWDM channels use its resources to produce outputs or desired results. DWDM is an optical system that allows for simultaneous transmission of light at different wavelengths on a single strand of fibre. It is often used in public optical telecommunications networks, such as Local Area Network (LAN), Metropolitan Area Network (MAN) and Wide Area Network (WAN) to link heavy groups of users over different geographic regions [3]. This research work is an extension of the research conducted by [7], where the performance of DWDM channels with EDFA and without EDFA was studied.

The TE of the DWDM channels using DEA has been neglected by most researchers, focusing mostly on the effectiveness of the DWDM Channels in order to ensure that the output of the DWDM channels meet the objectives for which it is designed. The performance efficiency of such channels was largely neglected and hence the need to determine the TE of the DWDM Channel with EDFA using a number of channels as inputs and the power margins as outputs.

DWDM technology has been developed to meet growing demands for bandwidth by multiplying the capacity of a single fibre. Optical add/drop filter is required for adding and dropping required WDM channel(s) at each subscriber's node in the optical access network [8]. This optical DWDM ring is composed of multiple channels (four, eight, sixteen, thirty two, or sixty four) wavelengths each driven by a distinct transmitter on a common fibre.

The paper is presented in different sections: Section I covers introduction, section II deals with the review of related works, section III reports on DEA models, input, and output orientated measures. Section IV presents DEA mathematical models. Section V discusses the experimental results of the Data Envelopment Analysis Program (DEAP), while section VI summarises and concludes the paper.

II. Related Works

In recent times, considerable amount of work has been carried on DEA using different approaches and models, some of these researches are as follows:
[3], conducted DEA command in a state that allowed users to conduct the standard optimization procedure and extended managerial analysis using single and two stage DEA model. Both CRS and VRS input and output oriented model were carried out. But the TE measures were not conducted.
[7], studied the performance analysis of four DWDM channels with and without EDFA over a ring MAN. The aim of the research was to examine the effect of attenuation on the DWDM channels. Simulation results showed that the DWDM channels with EDFA Travelled longer distances and limited distances for the channels of the DWDM system without EDFA. This signified that coverage increase in these channels is limited unless amplifiers are incorporated into the system to provide gain that compensates for the signal losses. However, the efficiency of the DWDM channels was neglected.
The efficiency of bandwidth utilization during multicast using DEA was studied by [4]. DEA was applied on the simulation results of the Improved Network Coding Algorithm (INCA) with two and three parameters using the assumption of CRS model. The results showed that the INCA with two parameters was the most efficient in terms of bandwidth utilization during multicast.
In this paper, however, the TE of the DWDM channels with EDFA using CRS and VRS models is carried out with a view to determine which of two models has advantage over the other.

III. DEA Model

The DEA program can consider a variety of models. [2]. proposed a model which had an input oriented and assumed CRS. This measured the efficiency of the Decision Making Units (DMUs) operating at their optimal scale. Later in a subsequent research [8], considered an alternate set of assumptions and proposed VRS model, allowing the breakdown of efficiency into technical and scale efficiencies in DEA. These models can either be input oriented model or output oriented model.
Input oriented model measures by how much input quantities can be proportionally reduced without changing the output quantities produced [10]. Similarly, output oriented model measures by how much can output quantities be proportionally expanded without altering the input quantities used. For the purpose of this research, an input oriented model will be adopted.

IV DEA Mathematical Model

Using linear programming model, the DEA using the assumption of input oriented with CRS model is given by [5].

$$Max\, k_{jo} = \sum_{r=1}^{t} Y_{kjo} x U_K \quad (1)$$

subjected to

$$\sum_{i=1}^{m} X_{ijo} X V_i = 1 \quad (2)$$

$$\sum_{r=1}^{t} Y_{rj} X U_r - \sum_{i=1}^{m} X_{ij} X V_i \leq 0$$

J = 1,…, n

$$u_r, v_r \leq e$$

where:

y_{rj} is the quantity of output r for unit j

v_i is weight attached to input I

x_{ij} is quantity of input I for unit j

u_r weight attached to output r

k_{jo} is the efficiency scores

j_o is the DMU under analysis

The same equation can be modelled with VRS model using the assumption of input oriented as:

$$Max\, k_{jo} = \sum_{r=1}^{t} Y_{kjo} x U_K + w \quad (3)$$

subjected to

$$\sum_{i=1}^{m} X_{ijo} X V_i = 1 \quad (4)$$

$$\sum_{r=1}^{t} Y_{rj} X U_r - \sum_{i=1}^{m} X_{ij} X V_i + w \leq 0$$

J = 1,…, n

$$u_r, v_i \geq e$$

where

y_{rj} is the quantity of output r for unit j

v_i is weight attached to input I

x_{ij} is quantity of input I for unit j

u_r weight attached to output r

k_{jo} is the efficiency scores

j_o is the DMU under analysis

w is free

The only difference between CRS and VRS models as seen in equations 1 and 3 is the introduction of a constant w and the weight attached to input I for unit j. where I is the input parameter of the DEA. The weight attached to output r is greater than the efficiency in the case of VRS and is less than the efficiency in the case of CRS. This is because VRS model is optimal when it is equal to 1.

V Experimental Result of DEAP

This section presents the experimental result of the DEAP. Simulation was carried using input oriented DEA by employing CRS and VRS models.

The DEAP was applied on the power margin of the DWDM channels at the multiplexer and at the demultiplexer with a view to determine the best model to measure the TE of the DWDM channels when EDFA is deployed.

Tables 1 and 2 show the power margins of the signal dropped at multiplexer and demultiplexer.

Table 1: Signal Drop at the Multiplexer [7].

Channel Parameters		
Channel	**Distances**	**Power Margin**
1	40km	15.0dB
2	20km	7.0Db
3	4km	18.0dB
4	3km	26.8dB

Table 2: Signal Drop at the Demultiplexer [7].

Channel Parameters		
Channel	**Distances**	**Power Margin**
1	1st OADM (88KM)	17.4dB
2	2nd OADM (68KM)	13.4dB
3	3rd OADM (47KM)	5.60dB
4	4th OADM (25KM)	14.0dB

The DEAP is run with the number of channels as the DMUs and the power margins as the input parameters.

DEAP uses three text files when it conducts an analysis. These are:

- a data file (named eg1-dta.txt)
- an instruction file (named eg1-ins.txt)
- an output file (named eg1-out.txt)

All of these files are text files. They are user friendly and can be edited using many programs.

Tables 3 and 4 shows the simulation results of the DEAP for signals dropped at the multiplexer and demultiplexer using CRS and VRS models.

Columns two and three of Tables 3 and 4 show the TE of the channels at the multiplexer and demultiplexer with their corresponding means Technical Efficiencies.

Table 3: Technical Efficiency of the Channels at the Demultiplexer using CRS and VRS Models

No of channels	**Technical Efficiency of channels at demultiplexer**	
	VRS Model	**CRS Model**
1	0.322	0.161
2	0.418	0.313
3	1.000	1.000
4	1.000	0.500
Mean	0.685	00.494

Table 4: Technical Efficiency of the Channels at the Multiplexer using CRS and VRS models

No of channels	**Technical Efficiencies of channels at the multiplexer**	
	VRS Model	**CRS Model**
1	0.311	0.334
2	1.000	1.000
3	0.519	0.619
4	0.435	0.535
Mean	0.435	0.622

The graphical representations of Tables 3 and 4 are shown in in Figures 1 and 2. The Y-axis represents the TEs of the two models and the X-axis represents the number of channels at the multiplexer and demultiplexer.

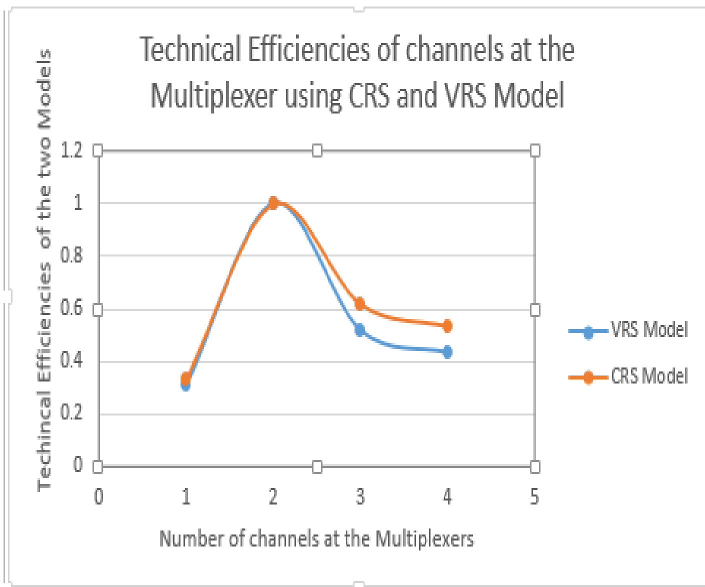

Figure 1: Technical Efficiencies of the DWDM Channels at the Multiplexer

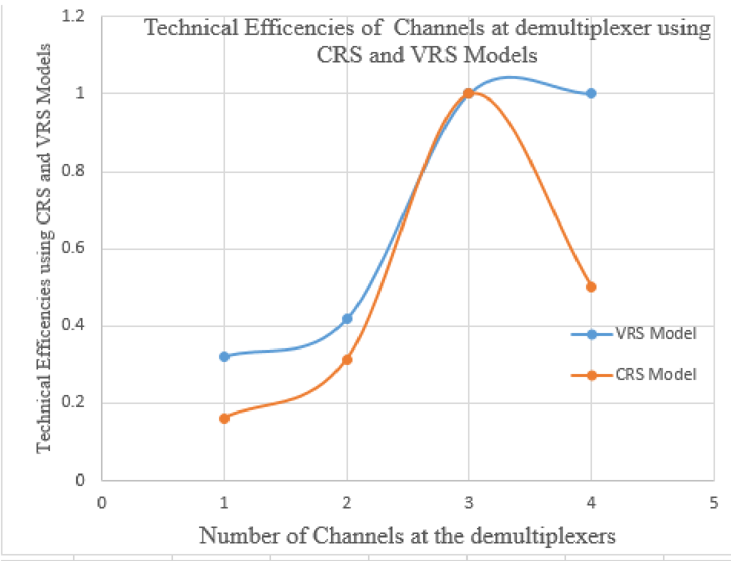

Figure 2: Technical Efficiencies of the DWDM Channels at the Demultiplexer

V. Results and Discussion

From the graphical result presented in Figure 1, it can be observed that the CRS model outperformed the VRS model for the DWDM channels at the multiplexer. Similarly, from the result presented in Table 4, the means TEs for VRS and CRS models are 0.435 and 0.622, respectively.

Also, Figure 2 evidently shows that the VRS model performs better than the CRS model for the channels at the demultiplexer. This also implies that the CRS model is more efficient than the VRS model for the DWDM channels at the demultiplexer.

This research is conducted in order to bridge the gap in most of the researches conducted on DWDM where researchers focused largely on the effectiveness of the DWDM channels rather than its Technical Efficiencies.

VI. Conclusion

In this paper, The Technical Efficiency of a four-channel dense wavelength division multiplexing ring network in metropolitan area is examined. This is accomplished by considering the Technical Efficiency of the DWDM channels with EDFA at both the multiplexers and demultiplexer using constant return to scale and variable return to scale models. This is aimed at comparing their Technical Efficiencies with a view of knowing the best model using the assumption of input oriented methods. Input oriented methods measures by how much input quantity can be proportionally reduced without changing the output quantities produced. DEA in contemporary times has become an area of intensive research in Engineering profession and in other fields of learning. Further work can consider the application of DEA and other stochastic frontier analysis on DWDM channels in order to determine the Technical and cost efficiencies of the DWDM channels.

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