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FIBER BRAGG GRATING BASED AN OPTIMAL OADM FOR PERFORMANCE ENHANCEMENT IN DWDM USING ARTIFICIAL NEURAL NETWORK

Parveen Bajaj
Department of Electronics & Communication Engineering, Desh Bhagat University, Punjab, India
E-mail: erpareen@rediffmail.com

Abstract

IDense Wavelength Division Multiplexing (DWDM) system offers a persistently aggregate demand for transmission capacity to promote their networks periodically to high data rates or large number of wavelengths. This paper proposed a new method for performance enhancement of Optical Add or Drop Multiplexer (OADM) with the DWDM based on the artificial intelligence.)The training and testing of the FF-NN is implemented in MATLAB platform by interfacing the results from OptiSystem. In addition, the performance of the proposed method is also analyzed in terms of Transmitted & Received Signal Power and compared with the conventional DWDM OADM with multiple filters.

Applications/improvements: The proposed method offers a viable solution to increase the performance of OADM with the DWDM. The improvement includes the use of hybrid algorithms, to further increase the performance.

Keywords: Fiber Bragg Grating, Optical Multiplexer, Dense Wavelength Division Multiplexing, Feed Forward Artificial Neural Network, Performance Enhancement, Signal Power.

Introduction

Optical networks have to face some technical challenges which are very important in case of increasing traffic. (1).The optical communication network employs different techniques for the efficient routing of information via the optical signals among number of users among those Wavelength Division Multiplexing (WDM) is the most famous approach for optical transmission systems. (2).With the use of WDM network the signals with moderate and high data rates can be transmitted over a single fiber together at different wavelengths (3). Total bandwidth of the system also increases without increasing the speed of clock (4).

The problem of increasing communication channels solved easily without requirement of new cables or by using limited cables by DWDM technique making this system very attractive not only for communication purposes (5). By using DWDM technique, 132 colors or wavelength can be combined or multiplexed through single mode fiber (6).DWDM employs semiconductor optical amplifier (SOA) in conjunction with an arrayed waveguide grating (AWG) based multiplexing and de-multiplexing scheme and it improves the overall power budget(7). Even though the DWDM network may be suspected to some impairment related to the system level they can be tackled with the help of some special type of modulators (8).

Now- a- days SONET has been displaced by DWDM technique and primarily chosen by fast growing telecom & metro networks (9). OADM plays a vital role in empowering more connectivity and adaptability in DWDM systems (10). A group of researchers implemented a new technique called terabit interferometric drop, add and extract multiplexer (11). Lot of techniques was employed, out of which the Fiber Bragg Grating (FBG) is the most attractive one(12).

FBG can be used as a wavelength multiplexer/de-multiplexer in OADM for adding / dropping of number of wavelengths (13). That specific wavelength may be passed through various optical elements like optical cross-connects or optical add-drop multiplexer along with any other particular route (14).The wavelength that has to be leaving or entering into the network will be controlled by the FBG based on its nature of the reflectivity (15).The reflection spectrum of the FBG can also be optimized using the Harmony Search Algorithm for achieving maximum reflectivity (16). Another one method optimizes the reflection spectrum of FBG by considering different phase shifts of the grating (17).

In this paper we have developed an artificial intelligence based OADM which is based on the parameters obtained from the simulation of the DWDM network in OptiSystem software. In section 2, related work has been discussed. The motivation for considering the present work and proposed methodology is given in section 3. The simulation results and the comparison of the proposed method with other existing technologies for improving performance of the OADM is presented and discussed in section 4. Finally, section 5 concludes the paper.

2. Related Works

Duan Liu et.al(19) have proposed a improved DE algorithm for identifying the Bragg wavelengths of fiber Bragg gratins when the wavelength moves connected with one completely sensor overlaps the other. His system beats the restrictions of the customary CPD .

Lazzeri et.al (20) have proposed the design of OADM hub which demonstrated that the hub has the capacity to work as a “language translator”.

Jung-Chieh Chen et.al (21) have proposed the method for solving the problem of low-dispersion FBG filter. This problem can’t be solved by using traditional methods.So Optimization (CEO) method has been used.

Jing Chen et.al(22) have proposed an effective optimization method based on a self-adaptive differential evolution (DE) algorithm to design fiber Bragg grating (FBG) filters with high-channel-count. They have numerically presented a 1037-channel 50-GHz spaced FBG filter to cover the whole bands.

A scheme based on Pareto-based multi-objective optimization technology was proposed by Hao Jiang et al.(23) The cross-entropy optimization (CEO) method was proposed by Jung-Chieh Chen et al.(24) in searching down the optimal index modulation profiles, An improved index modulation profile was created in this method. A proof of idea Few-mode fiber (FMF) compatible OADM was demonstrated by Xi Chen et al. (25) which empowers add/drop functionality for MDM super channels.

Pincemin et.al (26) has demonstrated phenomena of optical switching over a 100Gbps multiband optical frequency division multiplexing (MB-OFDM) based on a experimental setup. Through this demo, the authors have opened a different way to optically meshed networks with flexibility of high degree. Consequently bandwidth of optical fiber managed properly.

3.Optical Add or Drop Multiplexer With Feed Forward Neural Network

The method consists of three phases:
1. Initial data generation
2. Training the ANN
3. Testing the ANN

The block diagram of the proposed work is below in figure 1. In the testing phase shown the incoming optic signal at the entrance of OADM is processed by the trained neural network and then the signal is either dropped from the fiber or passed through the fiber without any hindrance.

3.1. DWDM network simulation with OptiSystem

Number of closely spaced signals can be transmitted through Dense Wavelength Division Multiplexing (DWDM) as compared to wavelength division multiplexing (WDM). There are various simulation tools are available for simulating

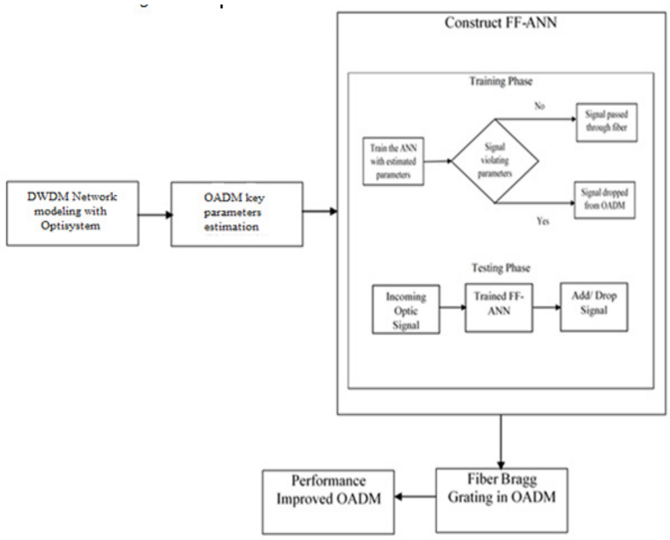

Figure 1: Functional Block diagram of the proposed method

the optical networks among them OptiSystem is found to be an efficient one
for the simulation of all kind of optical networks.

OptiSystem [27] software is used for the simulation and design of various optical communication systems and especially it is designed for the higher propagation schemes
such as OFDM (Orthogonal Frequency Division Multiplexing), PM-QPSK (Polarization Multiplexed Quadrature Phase Shift Keying) and D (Q) PSK (Differential Quaternary Phase Shift Keying). OptiSystem works by interconnecting different blocks of different optical components. The parameters used for the simulation are given as input such as data rate, symbol rate, carrying capacity of the fiber, length of the fiber.

3.2. Parameters Estimation

The parameters used for constructing the ANN are obtained from the performance analysis of the DWDM network in the simulation. The parameters considered in the formation of ANN based OADM are BER for each channel, OSNR, jitter measured from the eye diagram and chromatic dispersion calculated from the spectra of the signal [28]. The detailed description about these parameters is as follows.

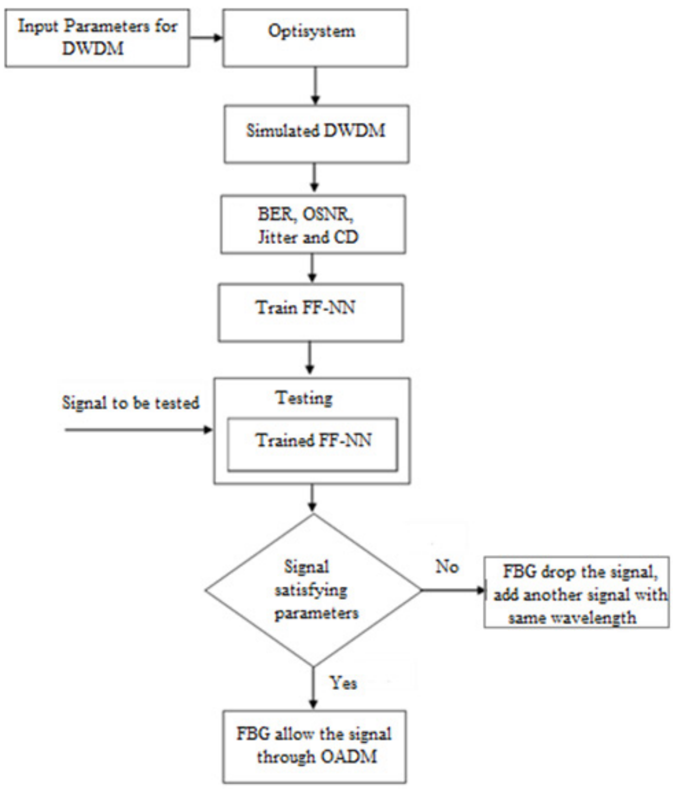

Figure 4: Processes associated with the proposed method for optimizing OADM in the DWDM network

4. Results and Discussion

In this paper we have proposed a system for adding or dropping the optical channels with in the fiber by developing the artificial neural network based Optical Add/Drop Multiplexer using feed forward type of neural network. The DWDM network is initially modeled with the OptiSystem software tool with different number of channels (Nc=32, 64,100) each with different data rates of 5 Gbps, 10 Gbps, 20 Gbps and with different channel spacing (Csp) of 30 GHz, 40 GHz and 50 GHz. The initial parameter setting for the Optisystem design is given in table 1. The wavelength of the channel used is 1550 nm and a fixed fiber length of 80km by considering the source of CW laser with frequency of 193.1 THz. For the purpose of optical transmission within the network the NRZ type of modulation is considered with Mach-Zehnder modulator. Then the parameters obtained from the simulation are used in the training and testing of the ANN such as BER, OSNR, Jitter and Chromatic Dispersion by interfacing the OptiSystem simulation results to MATLAB with the system configuration of Intel core i3 processor, 4GB RAM and Windows 8 Operating system.

Table 1: Parameter Setting for OptiSystem

Parameter	Value
Data rate	5 Gbps
	10 Gbps
	20 Gbps
Number of channels(N. ch)	32
	64
	100
Channel spacing	30 GHz
	40 GHz
	50 GHz

The parameters obtained after simulating the DWDM network in the software tool of OptiSystem is given in the following table 2. With these simulation results next the FF-NN will be trained for the addition or dropping of the optical channel based on the threshold value of the outcome FF-ANN. In this paper, we set the threshold as $0.32x10^{-10}$

Parameters			BER	OSNR	Jitter	Chromatic Dispersion
Data Rate= 5 Gbps	Csp=30 GHz	Nc=32	10-8	25.35	0.5	1.2
		Nc=64	10-8	28.17	0.5	1.2
		Nc=100	10-8	31.35	0.5	1.2
	Csp=40 GHz	Nc=32	10-9	34.98	0.5	1.6
		Nc=64	10-9	40.07	0.2	1.6
		Nc=100	10-9	47.06	0.5	1.2
	Csp=50 GHz	Nc=32	10-11	41.05	0.2	1.2
		Nc=64	10-11	43.05	0.5	1.4
		Nc=100	10-11	44.65	0.5	1.6
Data Rate= 10 Gbps	Csp=30 GHz	Nc=32	10-11	16.89	0.2	-22.8
		Nc=64	10-11	19.53	0.2	-22.8
		Nc=100	10-11	22.69	0.5	-22.8
	Csp=40 GHz	Nc=32	10-11	25.57	0.5	-22.8
		Nc=64	10-11	38.86	0.2	-22.6
		Nc=100	10-11	36.58	0.5	-22.4
	Csp=50 GHz	Nc=32	10-11	37.22	0.5	-22.8
		Nc=64	10-11	34.54	0.2	-22.8
		Nc=100	10-11	36.54	0.5	-22.4
Data Rate=20 Gbps	Csp=30 GHz	Nc=32	10-11	16.89	0.5	-30.8
		Nc=64	10-12	19.53	0.5	-30.8
		Nc=100	10-11	22.69	0.6	-30.8
	Csp=40 GHz	Nc=32	10-11	25.57	0.2	-30.8
		Nc=64	10-11	30.86	0.3	-30.4
		Nc=100	10-11	33.58	0.2	-30.7
	Csp=50 GHz	Nc=32	10-12	37.22	0.2	-30.7
		Nc=64	10-12	39.54	0.2	-30.7
		Nc=100	10-12	49.54	0.2	-30.8

Table 2: Measurements obtained from the simulation of DWDM network using OptiSystem

The FF-NN is trained and tested in the MATLAB platform from the parameters as given in the table 1. The neural network is trained by 70 signals with different number of channels and with different data rates from the table 1 as well as it is tested with 30 signals. The following table 3 gives the results from the classification of the signals to be added or dropped as determined by the FF-NN.

Parameters	Signal Classification using FF-NN
Signals identified as valid (True Positive)	27
Signals correctly identified as not valid (True Negative)	1
Signals incorrectly identified as valid (False Positive)	2
Signals incorrectly identified as not valid (False Negative)	0
True Positive Rate $\frac{TP + TN}{Total\ number\ of\ signals}$	89. 84%
False Positive Rate $\frac{Sum\ of\ TP}{TP + FP}$	49%
Accuracy =	97. 28%
Positive Predictive value=	97. 05%

Table 3: Signal Classification performance by FF-NN

The table 3 shows that the signal classification results obtained from the FF-NN is given. The performance obtained by the classifier is acceptable. To validate the proposed method, it is compared with the conventional method in [34] which used integrated dense wavelength division multiplexing and Optical-OFDM system with OADM including the fiber nonlinearity effect and analyzed its performance. The comparisons results are shown in terms transmitted signal power are given in the following table 4 and 5.

WAVELENGTH (μm)		Transmitted Signal Power (dB)			
		Proposed		Method in [34]	
		200 km	300 km	200 km	300 km
1.	1.44	1.2703	1.2869	1.2501	0.8314
2.	1.45	1.9652	2.1256	1.0524	0.7148
3.	1.47	2.1821	2.3867	0.8011	0.5412
4.	1.49	1.5143	1.8311	0.6247	0.4143
5.	1.51	1.4487	1.7442	0.5217	0.3541
6.	1.53	2.1355	2.5155	0.4304	0.3082
7.	1.55	2.4444	2.8854	0.4070	0.2590
8.	1.57	0.9357	0.6562	0.3845	0.2199
9.	1.59	0.8233	1.5565	0.2345	0.2116
10.	1.61	1.6222	1.6475	0.2227	0.1823

Table 4: Comparison of Transmitted signal power of the proposed method and the existing method

The received signal power at the received side after optimizing the OADM with the proposed method and the one with existing method (34) is given in table 5. The comparison chart is shown in figure 5, 6, 7 and 8 for different fiber length based on the comparison with wavelength and signal power. From the table 3, 4 and 5 it is obvious that our proposed method based on artificial intelligence technique achieved better performance than the conventional method with other existing methods.

WAVELENGTH (μm)		Received Signal Power			
		Proposed		Method in [34]	
		200 km	300 km	200 km	300 km
1.	1.43	3.9487	5.4835	3.9978	4.6512
2.	1.46	2.6887	3.7681	2.7614	3.2512
3.	1.48	0.5747	2.2708	2.2781	2.6514
4.	1.50	1.7001	1.4276	1.7584	2.1451
5.	1.52	1.4386	2.5657	1.5072	1.6547
6.	1.54	1.6188	1.4218	1.3784	1.3142
7.	1.56	0.8564	2.3332	1.2004	1.2471
8.	1.58	1.1247	1.8663	1.1124	1.1112
9.	1.60	0.5113	1.1509	0.9751	1.0047
10.	1.62	0.8645	2.6715	0.8415	0.3458

Table 5: Comparison of Received Signal power of the proposed method and the existing method

Figure 5: Transmitted Signal Power for Length 200 km

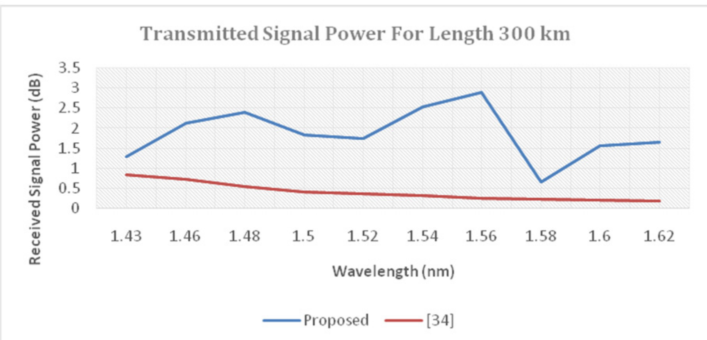

Figure 6: Transmitted Signal Power for Length 300 km

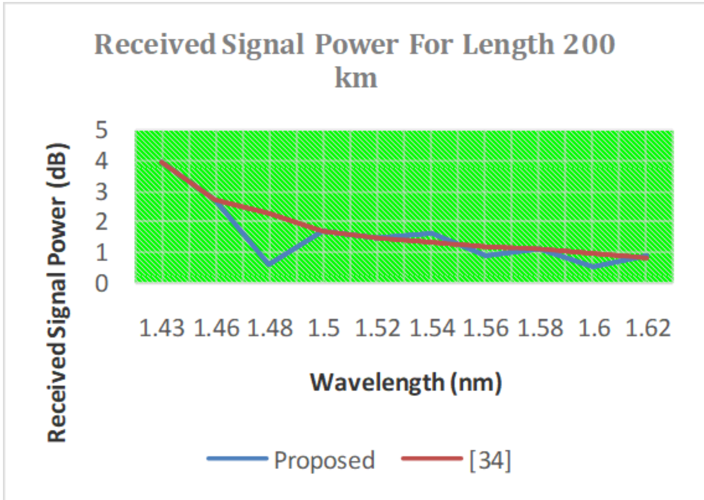

Figure 7: Received Signal Power for Length 200 km

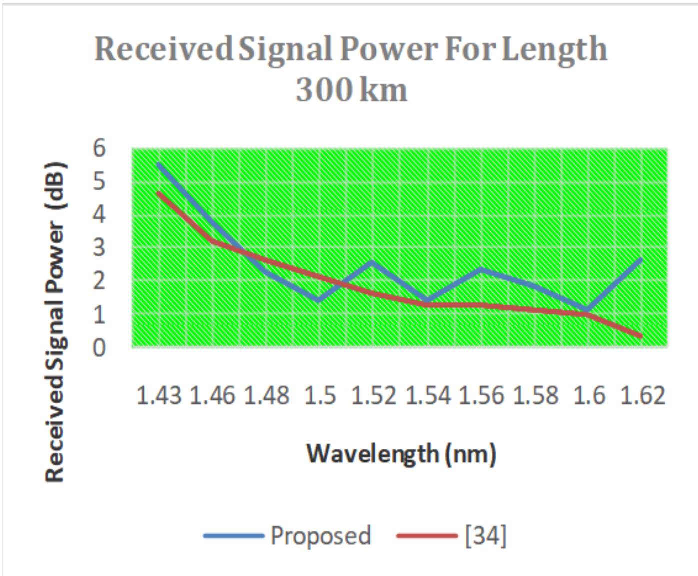

Figure 8: Received Signal Power for Length 300 km

Conclusion

Optical Add or Drop Multiplexers are used in DWDM networks for adding or dropping the signals based on the network requirements, hence this paper is proposed for a performance improved optimized OADM in the DWDM network based on the ANN. The ANN used here is the Feed Forward Neural Network and which is trained and tested with the parameters such as BER, OSNR, Jitter and chromatic dispersion obtained from the simulation of DWDM network in the optical network simulation tool known as OptiSystem. The training and testing of the neural network is carried out in the MATLAB platform based on this FBG will add/drop or allow the signal to pass and the results with the proposed method shows that better classification results are produced on comparing with the method using the SVM network. The experimental result shows that the proposed method achieves the accuracy of 97.28% on classifying the signals to be dropped from the fiber or passed through it without any interruption regarding its ability to make the transmission with minimum error. The performance of the proposed method in terms of Transmitted & Received Signal Power is also analyzed and compared with the conventional DWDM OADM with multiple filters. The proposed method is the one for classifying the signals for the OADM in DWDM network through artificial intelligence based techniques with this initiative the performance of the OADM in the DWDM network can be increased further through optimizing the performance of the classifier by any other optimization technique.

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