Non-Blocking and Multi Wavelength Optical Router Design based on Mach-zehnder Interferometer in 3-D Optical Network on Chip

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ABSTRACT:
Due to the increasing number of cores in a chip, electronic networks on chip cannot be an effective solution for using multi-core processors. The use of optical connection technology for networks on 3D chip is an ideal choice recommended in response to delay and reliability. In optical network architecture on 3D chip, 7-port routers are used to data transfer. The structure of the optical routers in the network on the 3D optical chip affects the Performance transmission of the entire network so that the provision of optical router with minimal loss and power consumption is considered by researchers in this domain. In this study, a seven-port Non-blocking optical router based on the Mach Zehnder interferometer optical switch in the network on a 3-D optical chip is presented. This router consists of 18 Mach Zehnder interferometer optical switches that can transfer multiple wavelengths concurrently. To evaluate the proposed 7-port router in the network on the 3D optical chip, the parameters of insertion loss, bandwidth density and power consumption are considered and the simulation results represent that this router decreases the loss as much as possible and improves the use of the wavelength channel comparing to available router and has the ability to transfer 4 wavelengths simultaneously with a wavelength range of 1525-1565 nm and a data transfer rate of 20Gbps for all 42 optical links. So it is useable for optical connection on the chip.

KEYWORDS: Insertion Loss, Non-blocking, Mach-Zehnder Interferometer (MZI), Optical Router, 3D Optical Network on Chip (3D-ONoC), Power Consumption, Wavelength Division Multiplexing (WDM).

1. INTRODUCTION

In recent years, the demand for complicated computing programs has been increased. Multiple processors have appeared on the chip to improve computing performance such as more connection bandwidth, delay and lower power consumption.

Network on a chip which uses some processors for parallel calculation can be a suitable solution for the above. However, the metal connections ordinarily that are used in the network on the chip changed in limited bandwidth, long release delay, and high energy consumption [1-3]. Photonic network on chip is a hopeful solution to overcome these limitations. Their compatibility with Complementary Metal-Oxide Semiconductor (CMOS) technology, silicon photonics changed to a great candidate to make network on chip [3].

On the other hand, photonic can obtain higher bandwidth densities than Wavelength Division Multiplexing (WDM). Wavelength division multiplexing is a method that transfers many photonic signals in different wavelengths in parallel on a signal transferring line, which increases the network bandwidth and decreases the connection delay performance. In other words, optic transferring with high bandwidth can be obtained by using WDM technology [3], [4].

Topology selection in network design shows the whole system characteristics. There are multiple various topologies of optical networks on chip such as Mesh, Torus, Fat-Tree and flattened butterfly.

Mesh topology is useful in a wide range of applications because it has a simple and ordered structure that is appropriate for designing two-dimensional layers on silicon chips. In two-dimensional

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mesh networks, each routing node consists of the main ports (north, south, east, and west) to connect to other nodes, and also uses a local port to support connections with calculation elements [2-4].

One of the major components in the optical network on chip is the optical router, which can be used to choose the way between the input and output ports. An optical router is also used to connect between one processing core and other remote processing cores in optical networks. These routers contain several optical switches that are connected to each other based on a specific topology [1-4].

In recent years, optical routers based on the Micro Ring Resonator (MMR) and Mach Zehnder interferometer (MZI) have been presented. Routers based on Mach-Zehnder are able to routing with high-speed for transferring data at nanosecond switching times, while the microring resonator switching speed is microsecond. Mach Zehnder -based router design also decreases the number of switching elements and waveguide crossing, and improves performance in terms of power consumption, bandwidth, and waveguide crossing, in contrast to the type of microring resonator [3-8].

In this paper, a seven-port multi-wavelength optical router is presented, which contains Mach Zehnder 2×2 optical switches. Comparing to the previous researches, number of optical switches used in this router has been significantly decreased, which means that the power consumption of the optical switch in the network can be reduced. The simulation results indicate that 42 input/output paths have been successfully confirmed by transferring 20 Gbps data over a 7-port optical router.

The rest of the paper is organized as follows: section 2 explains the basic concepts in optical network on chip. Such as network architecture on optical chip and network on 3-D optical chip and Mach Zehnder optical switch characteristics are discussed.

Section 3 introduces a review on optical routers used in the 3-D topology to decrease network loss on the optical chip.

In section 4, the proposed optical seven port router are explained. Part 5 also compares and analyzes the performance of the proposed router with other current routers.

Conclusion is presented in part 6.

2. BASIC CONCEPTS

2.1. Photonic Network on Chip Architecture

The outline of the optical network on chip consists of 3 logical layers: Processor layer, Memory layer and Photonic network layer [9].

Processor Layer is where the processing cores are placed and act as calculating resources for all connections. The upper layers, the Photonic network layer, provide high-speed optical connection between each pair of processing cores via optical links and routers. However, the Photonic layer is not able to adjust all optical devices and needs to be adjusted before any optical data can be transferred, which is the job of the Memory layer. It is also responsible to convert electrical data into photonic and vice versa. Fig. 1 indicates topology plane [9].

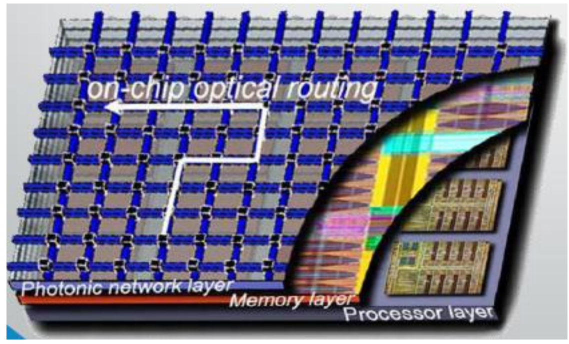


Fig. 1. 3 layer photonic plane [9].

2.2. 3D Optical Network on Chip

One of the solutions to overcome the bandwidth limit of electrical connections is to use three-dimensional structures. Nowadays 3D technology has been presented to meet the need for higher efficiency and speed as well as lower power consumption in integrated circuits [3-8]. In 3-D design, each chip will be separated into a number of blocks and each block will be placed vertically on top of each other in a separate layer of silicon. Vertical layer connections will be made by vertical interlayer links [10]. One of the most important cases in 3-D integrated circuits is heat transferring. The effect of heat has a great influence on proficiency and reliability in today's integrated circuits. The effects of heat generated in 3-D circuits are of special importance. 3-D integration technology enables the realization of combined technology with optical networks on an electrically controlled chip. The electrically controlled optical network is implemented in a two-layer 3-D chip in which the optical layer is stacked on top of the CMOS electrical layer. Fig. 2 indicates a photonic network on a chip architecture according to a 3-D mesh [5-8].

2.1. Characterization of MZI Optical Switch

Since a lot of attention must be paid on matching the data bandwidth with the switch bandwidth to transfer the optical signal at high data rates, optical routers based on Mach Zehnder interferometer switches are very appropriate. Mach Zehnder Interferometer is a 2 × 2 optical switch with wide bandwidth that is useful in the optical routers' design because of its remarkable advantages. The structure of a Mach Zehnder interferometer switch is shown in Fig. 3. This switch consists of two values of 0.1 dB loss per directional coupler (DC1, DC2) and two waveguides (Wg1, Wg2). In fact, the switch consists of two 50% directional couplers and two arms connected to the couplers, one of which is optically longer and causes a phase difference in these arms [11-13].

Fig. 4 shows that when the Mach Zehnder optical switch is in the cross mode, the optical signal is transferred from $Port1_{IN}$ ($Port2_{IN}$) to $Port2_{OUT}$ ($Port1_{OUT}$).

When the Mach Zehnder optical switch is in Bar mode, the π phase change causes the optical signal to be transmitted from $Port1_{IN}$ ($Port2_{IN}$) to $Port1_{OUT}$ ($Port2_{OUT}$).

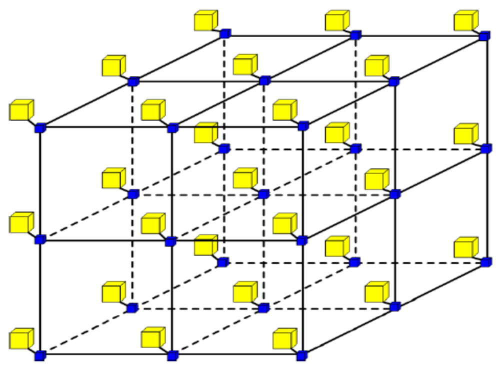


Fig. 2. The topology structure of 3-D mesh-based ONoC [7].

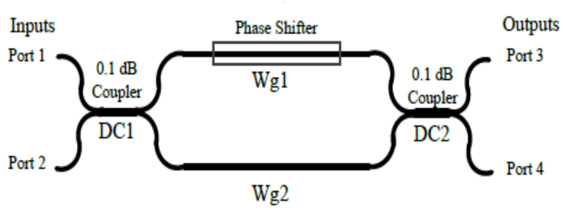


Fig. 3. The schematic of a directional coupler 2×2 MZI- based optical switch.

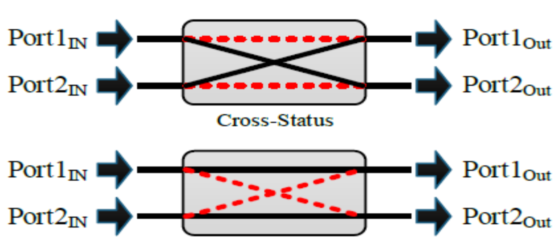
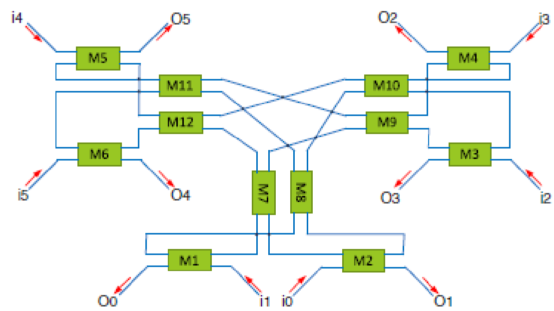


Fig. 4. Schematic of the 2×2 MZI in Cross status and Bar status.

2.2. Related Work

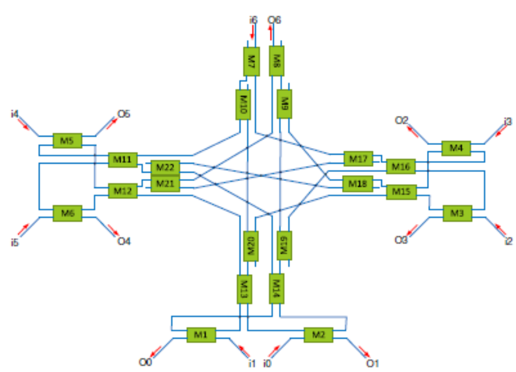
Optical routers are an important element on the network on optical chips. Most of these designs are based on the microring resonator, while the routers can be designed by using Mach-Zehnder interferometer switches. The common purpose of all these routers is to increase system performance and obtain the desired values in parameters of the physical layer of the optical network. Because of the benefits of Mach-Zehnder interferometer switches over microring resonator switches, such as wide connection bandwidth and high thermal tolerance, researchers have paid attention to the design of optical routers by using these elements [14-17]. Routers in this classification have been of great notices to researchers, and in this part, the most important ones in the network on the 2-D and 3-D chips that have been presented in recent years are investigated [17-27].

In 2015, Elham Yaghoubi et al. presented the first six-port and seven-port optical routers based on Mach-Zehnder interferometers, as indicated in Fig. 5 [26]. The six-port router has 12 Mach-Zehnder interferometer switch and 11 waveguide crossing. The advantage of this design over a similar model with microring resonator is a decrease of about 50% in the number of switching elements and the number of waveguide crossing; this improves power consumption, insertion loss and crosstalk noise [26].



(a)

Fig. 5. (a) The first 6-port router based on Mach-Zehnder interferometer [26].

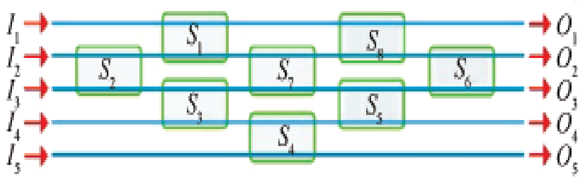


(b)

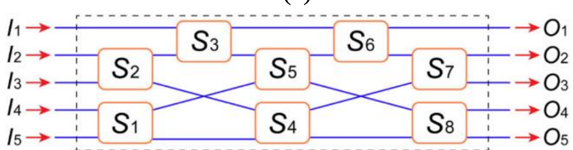
Fig. 5. (b) The first 7-port router based on Mach-Zender interferometer [26].

In 2017, Yunchou Zhao et al. [28] introduced a five-port router design by only 8 Mach-Zehnder switches. As can be noticed in Fig. (6-a), this router has no waveguide crossing and has Significant improvement in insertion loss and speed comparing to previous designs of five-port optical router based on Mach-Zehnder interferometer [28].

In 2018, Zhou et al. [30] presented a five-port optical router design based on Mach-Zehnder interferometer switches. As can be seen in Fig. (6-b), this router has 8 Mach-Zehnder switches and 2 waveguide crossing, and its designing idea is taken from the general and scalable structure of the Spanke-benes topology [29]. For this goal, after optimizing and removing the switches that are always in Cross mode, they obtained the final design [30].



(a)



(b)

Fig. 6. (a) 5-port optical router Ting Zhou [28]. (b) improved five-port optical router Benes [30].

In 2018, Haojia et al. [31] presented a 6-port router based on the spanke-benes architecture that consists of 12 Mach Zehnder interferometer switches and 2 waveguide crossing as indicated in Fig. 7. The architecture was made by replacing three Mach Zehnder interferometer optical switches in the Spanke-Benes network with waveguide crossing. Comparing with the Spanke-Benes network, the number of optical switching elements decreases by 20%, while the connection of the routing path is maintained. The purpose of this design is to provide a router with the least number of optical devices and reduce power consumption.

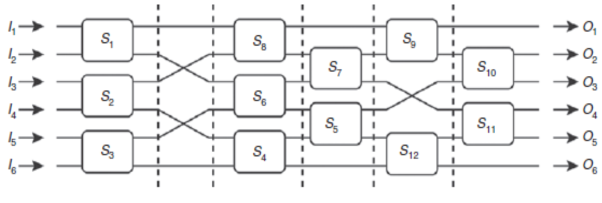


Fig. 7. 6-port optical router [31].

Table 1. Comparison between different Optical Routers.

Router	Number of Mach-Zehnder Interferometer	Number of waveguide crossing
6×6 Optical Router in [26]	12	11
7×7 Optical Router in [26]	22	24
5×5 Optical Router in [28]	8	0
5×5 Optical Router in [30]	8	2

In Table 1, the most important routers considered in recent years in terms of the parameters of the number of Mach-Zehnder interferometers and the number of waveguide crossing have been compared.

3. PROPOSED OPTICAL ROUTER ARCHITECTURE

Since in 3-D mesh architecture, a seven-port router is needed maximum, it is essential to design a seven-port router using Mach-Zehnder interferometer for using in 3-D mesh architecture of a photonic network on chip. Reducing the number of Mach-Zehnder switching elements and waveguide crossing decreases power consumption, consumption area and insertion loss, which will improve router performance.

Fig. 8 indicates the architecture of a seven-port optical router with 18 Mach-Zehnder optical switches and zero waveguide crossings. This router is able to transfer 4 wavelengths simultaneously with a wavelength range of 1525-1565 nm and data transfer rate of 20Gbps for each optical link. This router is the first seven-port optical router that can transmit multiple wavelengths. Table 2 shows the 42 physical paths for the proposed optical router. Each routing mode consists of seven routing paths that connect the seven input and output ports, and information can be transferred in parallel. The light injected at the input of each port cannot be directed to the output of the same port, in other words, there is no U-turn. An optical link between one input and output port will not block any of the probable optical links between the other input and output ports.

To recognize the proposed Mach-Zehnder switch mode, Mi is presented in bar mode as M_i^B and Mi switch in cross mode as M_i^C. Seven-port optical router with a number of non-repetitive routing modes is N! that is fact (7) = 5040. Each routing mode contains seven connection paths for the input-output ports, which can transfer information in parallel.

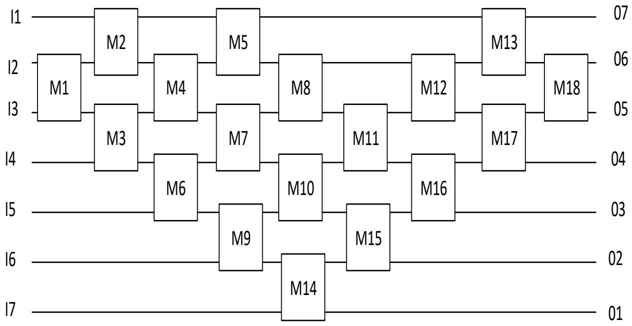


Fig. 8. The schematic of the proposed 7-port optical router.

Table 2. Routing paths of the proposed seven-port router.

	O1	O2	O3	O4	O5	O6	O7
I1	—	$M2^{C}$ $M4^{C}$ $M7^{C}$ $M10^{C}$ $M15^{C}$	$M2^{B}$ $M5^{C}$ $M8^{C}$ $M11^{C}$ $M16^{C}$	$M2^{C}$ $M4^{C}$ $M7^{B}$ $M8^{C}$ $M12^{C}$ $M17^{C}$	$M2^{C}$ $M4^{B}$ $M5^{C}$ $M13^{C}$ $M18^{C}$	$M2^{C}$ $M4^{B}$ $M5^{C}$ $M13^{C}$ $M18^{B}$	$M2^{C}$ $M4^{B}$ $M5^{C}$ $M13^{B}$
I2	$M1^{C}$ $M3^{C}$ $M6^{C}$ $M9^{C}$ $M14^{C}$	—	$M1^{B}$ $M2^{C}$ $M5^{C}$ $M8^{C}$ $M11^{C}$ $M16^{C}$	$M1^{B}$ $M2^{C}$ $M5^{C}$ $M8^{B}$ $M12^{C}$ $M17^{C}$	$M1^{B}$ $M2^{C}$ $M5^{B}$ $M13^{C}$ $M18^{C}$	$M1^{C}$ $M3^{B}$ $M4^{C}$ $M5^{C}$ $M13^{C}$ $M18^{B}$	$M1^{C}$ $M3^{B}$ $M4^{C}$ $M5^{C}$ $M13^{B}$
I3	$M1^{B}$ $M3^{C}$ $M6^{C}$ $M9^{C}$ $M14^{C}$	$M1^{B}$ $M3^{C}$ $M6^{C}$ $M9^{B}$ $M10^{C}$ $M15^{C}$	—	$M1^{C}$ $M2^{C}$ $M5^{C}$ $M8^{B}$ $M12^{C}$ $M17^{C}$	$M1^{C}$ $M2^{C}$ $M5^{B}$ $M13^{C}$ $M18^{C}$	$M1^{C}$ $M2^{C}$ $M5^{B}$ $M13^{C}$ $M18^{B}$	$M1^{C}$ $M2^{C}$ $M5^{B}$ $M13^{B}$
I4	$M3^{B}$ $M6^{C}$ $M9^{C}$ $M14^{C}$	$M3^{C}$ $M4^{B}$ $M7^{C}$ $M10^{C}$ $M15^{C}$	$M3^{C}$ $M4^{B}$ $M7^{B}$ $M8^{C}$ $M12^{C}$ $M17^{C}$	—	$M3^{C}$ $M4^{C}$ $M5^{C}$ $M13^{C}$ $M18^{C}$	$M3^{C}$ $M4^{C}$ $M5^{C}$ $M13^{C}$ $M18^{B}$	$M3^{C}$ $M4^{B}$ $M7^{C}$ $M10^{B}$ $M11^{C}$ $M12^{C}$ $M13^{C}$
I5	$M6^{B}$ $M9^{C}$ $M14^{C}$	$M6^{C}$ $M7^{B}$ $M10^{C}$ $M15^{C}$	$M6^{B}$ $M9^{C}$ $M14^{B}$ $M15^{c}$ $M16^{B}$	$M6^{B}$ $M9^{C}$ $M14^{B}$ $M15^{C}$ $M16^{B}$	—	$M9^{B}$ $M14^{B}$ $M15^{C}$ $M16^{C}$ $M17^{C}$ $M18^{C}$	$M6^{C}$ $M7^{C}$ $M8^{C}$ $M12^{B}$ $M13^{C}$
I6	$M9^{B}$ $M14^{C}$	$M9^{C}$ $M10^{B}$ $M15^{C}$	$M9^{C}$ $M10^{C}$ $M11^{B}$ $M16^{C}$	$M9^{C}$ $M10^{C}$ $M11^{C}$ $M12^{B}$ $M17^{C}$	$M9^{C}$ $M10^{C}$ $M11^{C}$ $M12^{C}$ $M13^{B}$ $M18^{C}$	—	$M9^{C}$ $M10^{C}$ $M11^{C}$ $M12^{C}$ $M13^{C}$
I7	$M14^{B}$	$M14^{C}$ $M15^{B}$	$M14^{C}$ $M15^{C}$ $M16^{B}$	$M14^{C}$ $M15^{C}$ $M16^{C}$ $M17^{B}$	$M14^{C}$ $M15^{C}$ $M16^{C}$ $M17^{C}$ $M18^{B}$	$M14^{C}$ $M15^{C}$ $M16^{C}$ $M17^{C}$ $M18^{C}$	—

4. SIMULATION RESULTS

In this study, an optisystem simulator is used to evaluate the performance of an optical router, and eye diagrams of each input and output path for each of the routers with 20Gbps optical signal for wavelengths of 1525-1565 nm are achieved.

In each input/output path for the proposed router, parameters such as insertion loss, bit error ratio (BER), Q-factor and power consumption are obtained.

In order to simulate the router, a laser source is used to drive the random bit sequence generated by a pulse-pattern generator. Each output port has a photo detector and a low-pass filter, and finally, the optical signals at each output port of the optical router were sent to a digital connection analyst to observe the waveforms and eye diagrams [32, 33].

Table 3. Insertion Loss Parameters in MZI Router.

Parameters	value
propagation loss in silicon[36]	1.7 dB/cm
Waveguide crossing[13]	0.03 dB
Waveguide bend[36]	$0.005\ dB/90^{0}$
MZI-Bar[13]	1.2 dB
MZI-Cross[13]	0.25 dB

4.1. Insertion Loss

To calculate the optical signal insertion loss in each of the router input / output paths with the proposed 7-port, relation (1) and the values in Table 3 has been used.

$$\text{Router}_{\text{loss}} = \sum(\text{Propagation}_{\text{loss}} + \text{Waveguide Crossing}_{\text{loss}} + \text{Waveguide Bending}_{\text{loss}} + \text{on MZI}_{\text{loss}} + \text{off MZI}_{\text{loss}}) \qquad (1)$$

Effective parameters in insertion loss consist of propagation dissipation, waveguide crossings, waveguide bending, and loss due to the passing of photonic signal through the switching elements. Since the Mach-Zehnder interferometer switch is used in these routers, in order to calculate the insertion loss of passing through the switching elements, the moods in which the Mach-Zehnder interferometer switch is in bar or cross mode must be considered. The amount of insertion loss of photonic signal propagation of waveguides is in centimeter unit, and since the size of Mach-Zehnder interferometer switches is $93 \times 1.7\ \mu m^2$ and the length of waveguides inside the router is a few hundred micrometers, the loss of light signal propagation in waveguide is not considered.

Since the design of the proposed router uses less Mach Zehnder switches and the number of waveguide crossing in this router has reached zero, the proposed router has less design complexity comparing with current optical routers. The comparison between the 6-

port and 7-port routers introduced so far is summarized in terms of performance in Table 4.

Table 4. Maximum, Minimum Insertion Loss and Number of Component switching Comparisons with different routers.

Router	Number of Mach-Zehnder Interferometer	Number of waveguide crossing	Max Insertion Loss (dB)	Min Insertion Loss (dB)
6×6 Optical Router in [26]	12	11	8.7	2.48
6×6 Optical Router in [31]	12	2	7.8	2.2
7×7 Optical Router in [26]	22	24	12.47	2.48
Proposed 7×7 Optical Router	18	0	7.9	1.2

The maximum and minimum insertion loss for the proposed router and the router in [26] are represented in Fig. 9. The change in network size due to the minimum path length of both nodes does not affect the minimum insertion loss in this proposed router. It should be mentioned that the insertion loss varies slightly along the maximum path.

4.2. Q-Factor and BER and Eye Diagram

The amount of insertion loss and the eye diagram calculated for each of the 42 seven-port optical router paths are indicated in Fig. 10. As is known, the maximum and minimum insertion loss rates are 7.9 and 1.2, respectively. In these two routers, the eye diagram has the highest amount of noise and the lowest amount of noise, respectively, which can be because of the larger number of Mach-Zehnder switches in this router in the bar mode, which causes more insertion loss than other input-output routers.

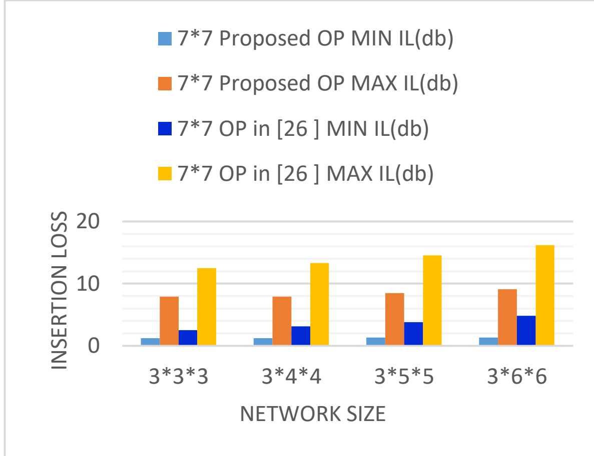


Fig. 9. Maximum and Minimum possible insertion loss of various mesh network sizes for the proposed 7-port optical router and 7-port optical router in [26]

Table 5. Q-Factor Parameter Results for the 42 possible input-output routings through the seven-port optical router.

	O1	O2	O3	O4	O5	O6	O7
I 1	---	6.9833	6.8921	6.5812	6.8921	6.6905	7.2443
I 2	6.9833	---	6.5812	6.5194	6.6905	6.5194	6.6905
I 3	6.8921	6.5194	---	6.5812	6.8921	6.6905	7.2443
I 4	7.2845	6.8921	6.5194	---	6.9833	6.8921	6.3093
I 5	7.7423	7.2845	6.6176	6.6905	---	6.5194	6.8921
I 6	7.9803	7.7423	7.2845	6.8921	6.5812	---	6.9833
I 7	8.0604	7.9803	7.7423	7.2845	6.8921	6.9833	---

Table 5 shows the Q-factor and Table 6 represents the bit error rates for the proposed router with 20Gbps optical signal at 1525-1565nm at 42 input-output paths. The data in Table 5 and Table 6 are proper for both proposed 7-port routers parameters for use in the optical network on chip especially the 3-D mesh architecture.

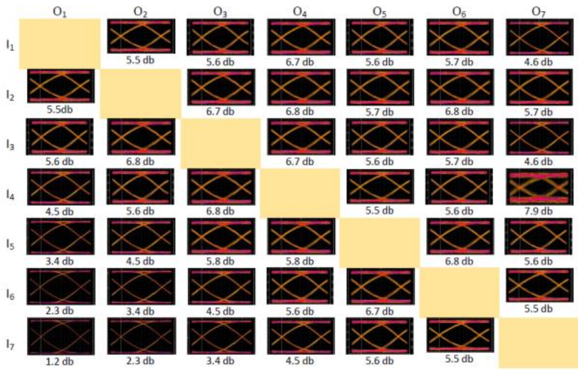


Fig. 10. Eye diagram and insertion loss for the 42 possible input-output routings through the seven-port optical router

Table 6. BER results for the 42 possible input-output routings through the seven-port optical router

	O1	O2	O3	O4	O5	O6	O7
I1	---	**55.68**	**56.85**	**60.47**	**56.08**	**56.46**	**52.08**
I2	**55.68**	---	**60.47**	**60.87**	**56.46**	**60.87**	**56.46**
I3	**56.08**	**60.87**	---	**60.47**	**56.08**	**56.46**	**52.08**
I4	**51.6**	**56.08**	**60.87**	---	**55.68**	**56.08**	**65.25**
I5	**47.2**	**51.6**	**56.87**	**56.87**	---	**60.87**	**56.08**
I6	**42.88**	**47.2**	**51.6**	**56.08**	**60.47**	---	**55.68**
I7	**38.48**	**42.88**	**47.2**	**51.6**	**56.08**	**55.68**	---

4.3. Bandwidth Density

An important parameter for designing network connections is the optical power budget because it determines the performance of the network bandwidth as well as the acceptable insertion loss. If the lower and upper limits of the optical power budget are named S and P, a value higher than P will result in nonlinear effects [32, 34-35]. This causes insertion loss and undesirable changes. If the optical power budget is lower than the sensitivity of the detector (S), then the receiver loses the ability to photo detector. The difference between P and S determines the optical power budget.

$$P - S \geq IL_{max} + 10log_{10}^{n} \quad (2)$$

According to formula (2), n is the allowed number of wavelength channels and IL_{max} is the maximum insertion loss [32, 34- 35]. Fig. 11 depicts the chart for the allowed number of wavelength channels in various mesh network sizes for different routers.

4.4. Power Consumption

The other parameter considered in this paper is power consumption. The output power consumption is measured and calculated separately for each of the 42 proposed routers routes.

Table 7 shows the power consumption of the 42 proposed routers routes. The maximum power consumption is 65.25 mw, which is related to the route I4 to O7, this is when all the optical switches are set to the state with the most energy consumption and the highest insertion loss is achieved. The lowest power consumption is 38.48 mw, which relates to the route I7 to O1, this is when all the optical switches are set in a state with less energy consumption and with the least amount of insertion loss.

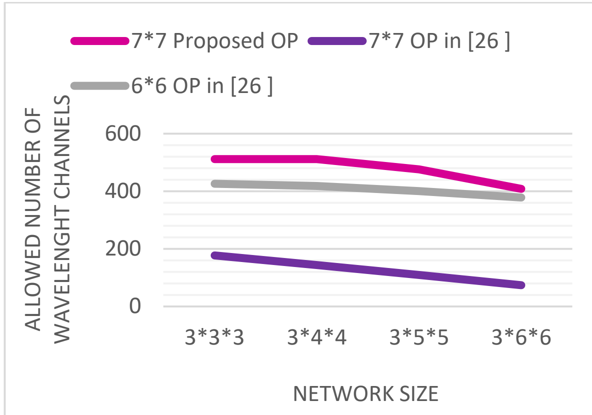


Fig. 11. Allowed number of wavelength channels in various mesh network sizes for different routers.

Table 7. Power Consumption Results for the 42 possible input-output routings through the seven-port optical router.

	O1	O2	O3	O4	O5	O6	O7
I1	---	**55.68**	**56.85**	**60.47**	**56.08**	**56.46**	**52.08**
I2	**55.68**	---	**60.47**	**60.87**	**56.46**	**60.87**	**56.46**
I3	**56.08**	**60.87**	---	**60.47**	**56.08**	**56.46**	**52.08**
I4	**51.6**	**56.08**	**60.87**	---	**55.68**	**56.08**	**65.25**
I5	**47.2**	**51.6**	**56.87**	**56.87**	---	**60.87**	**56.08**
I6	**42.88**	**47.2**	**51.6**	**56.08**	**60.47**	---	**55.68**
I7	**38.48**	**42.88**	**47.2**	**51.6**	**56.08**	**55.68**	---

5. CONCLUSION

In this article, a multi-wavelength seven-port non-block optical router is proposed that is appropriate for optical connections with high throughput in a photonic network on chip based on 3-D mesh. This router consists of 18 Mach-Zehnder optical switches. Optical router routing function is simulated by transferring 4 optical wavelengths simultaneously at any time for each desired port of 42 possible physical connections by OptiSystem simulator. The proposed router is evaluated in terms of insertion loss, Q factor, Bit Error Rate (BER) and power consumption. The simulation results indicate that this router decreases the insertion loss and improves the use of wavelength channels as much as possible comparing with the currently considered routers. So it delays reduction and the impact on energy levels.

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