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Fast Routing Algorithm in Optical Multistage Interconnection Networks using Fast Window Method

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Abstract- ***A major problem in parallel computing systems which are based on optical interconnection networks is the optical crosstalk that limits the performance of the network, and its size. Crosstalk free routing algorithms are used to rout data packet from a source to destination through switches without crosstalk. This paper discusses the implementation of fast scheduling methods (fast window methods) to the traditional routing algorithm (zero algorithms) in terms of algorithm running time and network size. The proposed routing algorithm minimizes the running time and gives the ability to maximize the network size up to 2^{13} computing units.***

***Index Terms**— optical interconnection networks, fast window method, crosstalk free routing algorithms, parallel computing.*

I. INTRODUCTION

In parallel computing systems, an optical multistage interconnection network (OMIN) organizes a reliable communication between the sources and destinations in parallel computing systems [1].OMIN are a class of dynamic interconnection network that connects input devices to output devices through a number of switch stages, each stage consists of a set of Switching Elements (SE) arranged in cascaded order, where each switch is a crossbar network [2]. Now, opt-electrical modulators made optical communication a good solution to face the needs of high speed computing and there communication applications. Low communication latency, high channel bandwidth and parallel processing are the main advantages of optical communication [3].

Optical multi stage interconnection network (OMIN) offers large transition capacity, wide bandwidth, and low error probability [4]. Optical Omega network (OON) is an example of OMINs Fig 1 which connects N inputs with N outputs using n stages, where n $=\log_2 N$ and each stage consist of 2^{n-1} switching elements [5] which offer the probability of optical crosstalk problem.

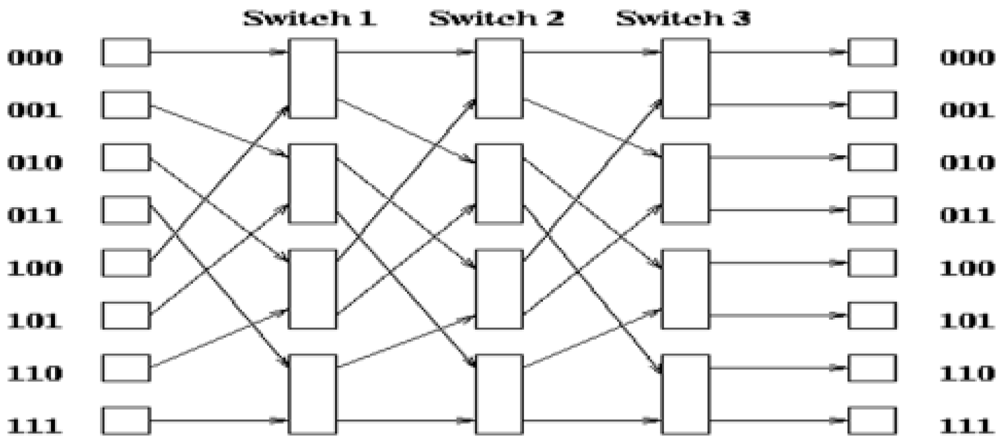


Fig. 1 Optical omega network (OON)

Optical crosstalk problem occurs in OMINs when two signals interact within the same switching element (SE), this problem degrades the performance of the optical multistage interconnection network as it limits the size of the network and reduces signal-to-noise ratio [6]. The challenging issue of reducing the optical crosstalk effect includes tradeoff between several aspects like Hardwar and Software complexity, and performance of the system. There are three common approaches used to reduce the effect of crosstalk either in the space domain, the wavelength domain or the time domain [7, 8].

Time domain approach lets only one input link to be active on the same switch at a time. This action is applied on every switching element in the network, to transact with crosstalk problem. A set of alternative connections are allocated in several groups, and within each group there are crosstalk free routable connections [9].

The framework of the time domain approach includes two stages; permutation decomposition, and message scheduling. Permutation decomposition is responsible for generating source and destination address, and building the conflict matrix. The message scheduling aim is to sorting and selecting messages to be scheduled into crosstalk-free groups based on the conflict matrix. Messages are selected for scheduling according to some order unique of a scheduling algorithm [3]. Then, each group of sources is routed to their corresponding destinations in different time slots. Omega network is an example for this perfect shuffled interconnection networks. Source and destination addresses of the permutation are randomly generated [10]. Source and its cross ponding destination addresses construct the combination matrix which is useful when identifying conflicts in OON [11], and then window method is applied on this matrix to find out which messages should be in the different group with different time slots. The result of the window method is represented in an N x N matrix called conflict matrix where N is the network size [9]. The routing algorithm consists of some steps applied on the conflict matrix to select and schedule the message from source to its cross bonding destination without conflict [12].

This paper is organized as follow.in section II.1 types of window methods are introduced and, in section II.2 routing algorithm are introduced used to solve crosstalk problem in optical multistage interconnection network (OON as example) with different strategies and the strategy that consumes minimum execution time is modified in Section III. The proposed coded routing algorithm and its flow chart are represented in this section. Section IV shows the programing simulation result, followed by conclusions in Section V.

II. Data Analysis

II.1 Window Method

Window method is a scheduling technique and is used to find out which messages should not be sent in the same group. Network size N x N, shows that there are N source and N destination address. To get a combination matrix, it is required to combine the corresponding source and destination address. A window of size (M-1) where M= $\log_2 N$ is applied to the combination matrix from the left hand side to the right hand side with the elimination of first and last column of the matrix. When two messages in the same window have the same bit pattern, they will cause a crosstalk conflict in the network. Therefore, they must be routed in different time slots, in other words, they should be routed in different groups [11]. Improved window method was proposed as it does not check for conflicts in the first window, because the resultant conflicts are rebated in the next windows [12]. Compared to the standard window method (WM), the execution time is reduced approximately by 1/S where S is the number of stages [13]. In the bitwise window method each binary bit optical window of the standard WM is transformed into its equivalent decimal figuration using bitwise functionality [1].

The last update to the window method is Fast window method, which minimize the running time of the several WM's types by arranging each window before checking the conflict and generating the conflict matrix. This fast search method is applied to the WM, improved window method (IWM) and bitwise window method (BWM) to produce fast WM, fast IWM, and fast BWM [14].table 1showes the difference between the window methods in terms of Running time of the routing algorithm represents the time taken to rout the message from source to its destination, window size, number of windows, pattern check, and the similarity check.

Table 1. Comparison between da different window methods and their developments

	Window method [11]	**Improved window method [12]**	**Bitwise window method [1]**	**Fast window method [14]**
Window size	M-1	M-1	M-1	M-1
Running time	High	Less approximately by 1/S	Less than IWM	minimum
Number of windows	$\mathrm{Log}_2 N$	$(\mathrm{Log}_2 N)$-1	$\mathrm{Log}_2 N$	$\mathrm{Log}_2 N$
Pattern check	binary	binary	decimal	binary
Similarity check	Randomly sorted	Randomly sorted	Randomly sorted	Sorted Increasing or decreasing order

II.2 Routing algorithms and related work:

The aim of routing algorithm is to schedule the messages in different independent subsets in order to avoid the conflicts in the network. There are many types of routing algorithms depending on their strategies of selecting the message. Heuristic algorithms use four strategies for selecting the message; first one is selecting the messages sequentially in increasing order of the message source address, which is called sequential increasing strategy, the second strategy is selecting the message sequentially in a decreasing order of the message source address which is called sequential decreasing strategy. Third and Fourth strategies are selecting the message based on the number of conflicts of each message that has other messages in the conflict graph which are called degree ascending and degree descending strategies [15, 16]. Zero algorithm strategy is based on taking zero values in row N+1(X axis) in conflict matrix and putting it in a group [17]. Row N+1 result from summing the columns of the matrix. The selected addresses of this group are considered as having zero value in the row N+1. After that, a new summation for the other entries of the matrix will be done and collecting the zero values on row N+1 as a new group. These steps are to be repeated until the whole matrix becomes zero. Other routing algorithms used to solve crosstalk problem in optical multistage interconnection network with different strategies like genetic algorithm [18], ant colony optimization algorithm [17] simulated annealing algorithm [19] and zero algorithms [15]. Based on the comparative analysis in [15], it was concluded that zero algorithm consumes minimum execution and minimum number of passes from source to its cross bonding destination through several stages and switches in the OMIN, there for the proposed algorithm is an upgrade of the zero routing algorithm.

III. Proposed Routing Algorithm

Comparative analysis performed in [13], found that the time taken for identifying conflicts in an optical omega network OON is very high compared to routing the messages. Working on this conclusion the present work modified the zero algorithms to reduce the running time by replacing the traditional scheduling method (window method) with fast window method. The following flow chart Fig. 2 represents the zero algorithm steps after implementing the fast scheduling method.

Algorithm 1.The pseudo code of fast window method

```
M=log2(N);                      //M is number of windows, M-1 window size
comb=[tx_add rx_add];           //combination matrix
conf=zeros(N,N);                //initialization conflict matrix NxN
for i=1:M                       //loop for window
 w=c(:,i+1:i+M-1);
 [indx,nw]=sort(w);
   for j=1:2:n-1
     conf(nw(j),nw(j+1))=1;
   end
```

Fig 2. Flow chart of the proposed algorithm based on zero algorithm

IV. Results and Comparative Analysis

This section discusses the implementation of fast scheduling method such as fast BWM, fast IWM, and fast WM of the zero routing algorithms. As mentioned that the Source and its cross ponding destination addresses construct the combination matrix which is used to identify the crosstalk conflict and scheduling the messages in OON, and the time taken for identifying the conflict is much higher than the time taken for routing the messages. Therefor fast bitwise window method, fast improved window method and fast window method take minimum time for searching the matched patterns within the same window. Hence, the total execution time of routing the message is decreased, which gives the ability to increase the network size. Based on the programming analysis, the obtained results include running time, are shown in Figs. 3-8 and Table 2 comparing between the traditional method and our proposed zero algorithms in terms of running time versus the network size.

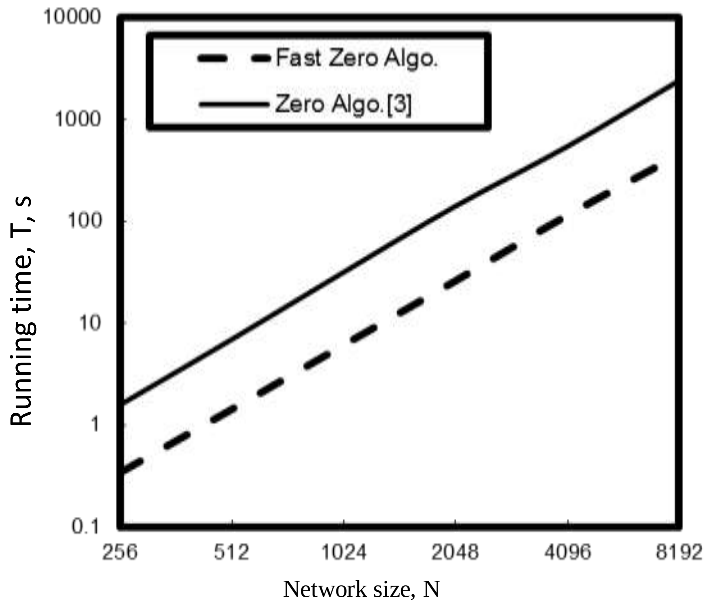


Fig. 3. zero algorithm and fast zero algorithm is term of running time for large network size

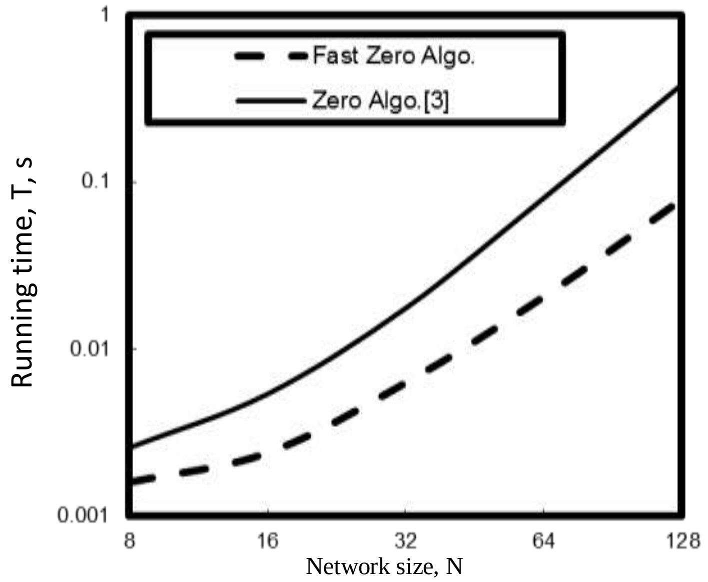


Fig. 4. zero algorithm and fast zero algorithm is term of running time for traditional network size

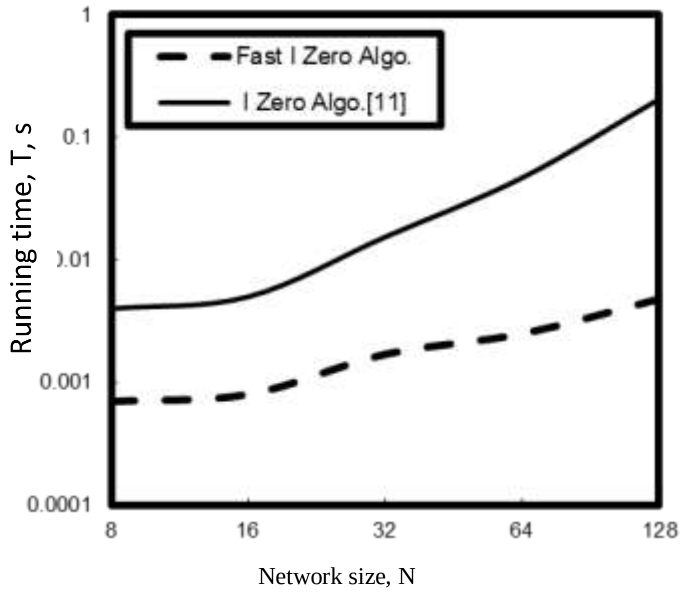


Fig. 5. Improved zero and fast improved zero algorithms in term of time for traditional network size.

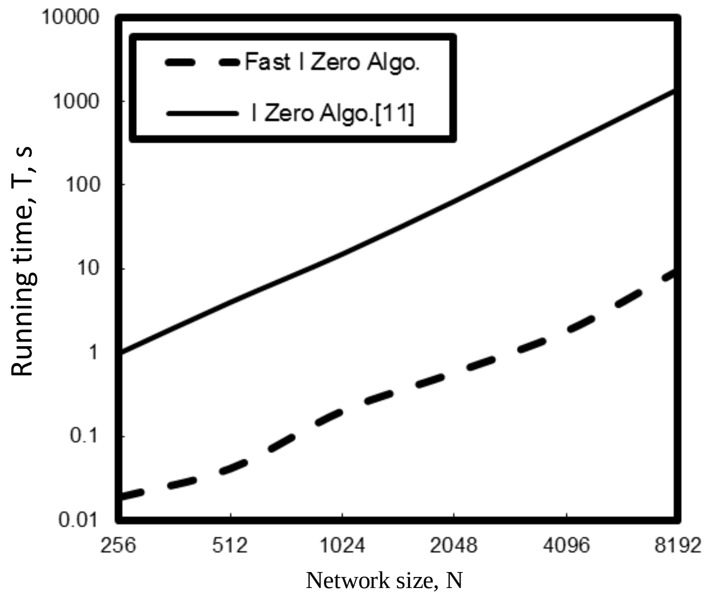


Fig. 6. Improved zero and fast improved zero algorithms in term of time for large network size.

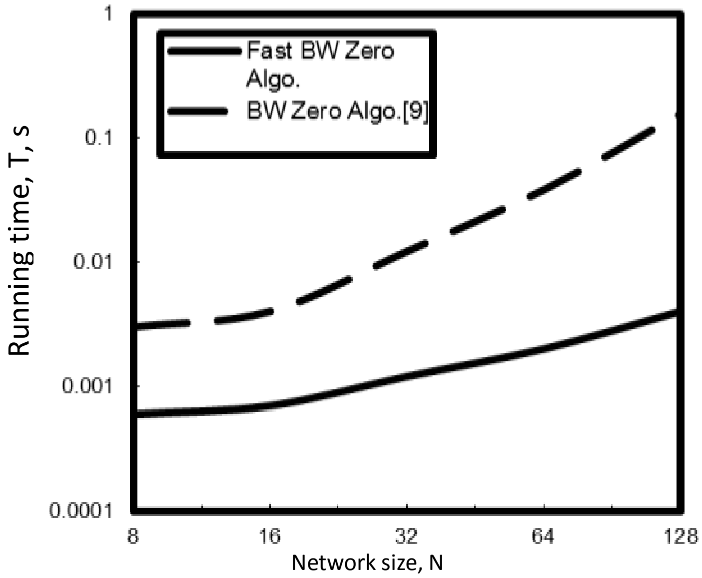


Fig 7. Traditional bitwise Zero algorithms and, fast bitwise window method, in term of time for traditional network.

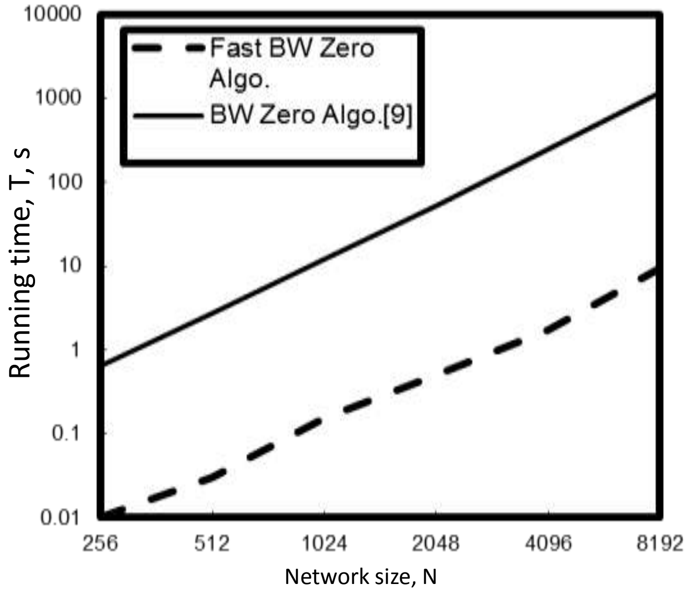
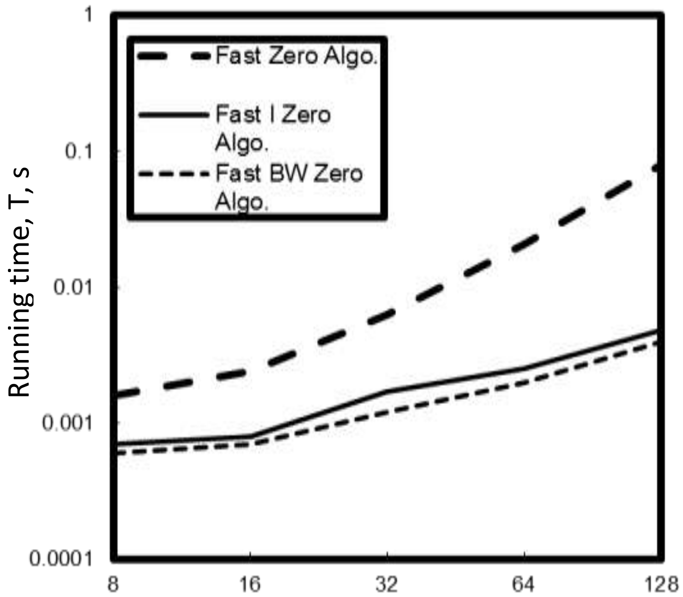


Fig. 8 Traditional bitwise Zero algorithms and, fast bitwise window method, in term of time for large network.

Figure (9, 10) shows the difference between the proposed routing algorithms in term of running time.



Network size, N

Fig. 9. Comparison in term of time for traditional network size for three different algorithms

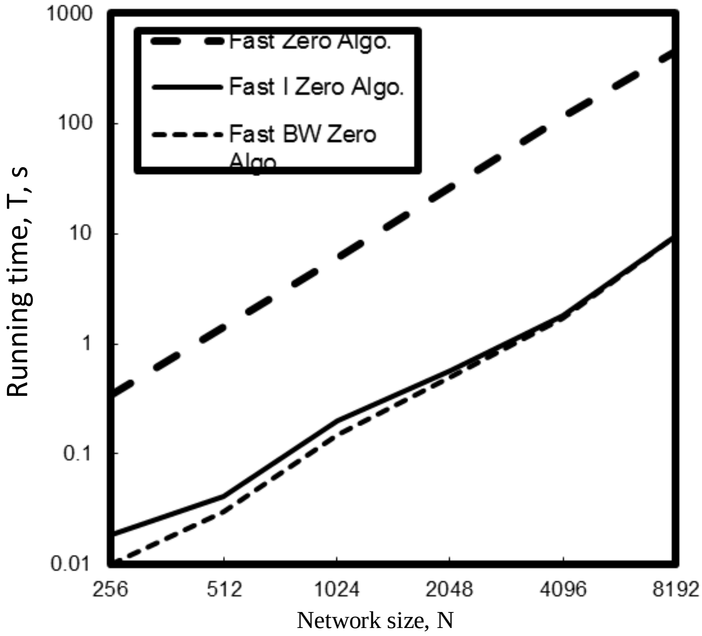


Fig. 10.Comparisson for large network size for three different algorithms

Network size	no. of stages	Execution time (sec)					
		fast Zero Algo.	Zero Algo.	fast I Zero Algo.	I Zero Algo.	BW Zero Algo.	fast BW Zero Algo.
8	3	0.0016	0.0048	0.0007	0.004	0.003	0.0006
16	4	0.0024	0.0054	0.0008	0.005	0.004	0.0007
32	5	0.0063	0.0176	0.0017	0.0154	0.0122	0.0016
64	6	0.0206	0.0803	0.0022	0.0469	0.0383	0.00215
128	7	0.0788	0.3834	0.0048	0.2055	0.156	0.0047
256	8	0.3397	1.5717	0.0186	0.9707	0.6407	0.0184
512	9	1.4233	6.9354	0.0412	3.9783	2.7611	0.0402
1024	10	6.097	31.6336	0.1294	14.9647	12.096	0.258
2048	11	26.0273	141.107	0.5737	63.8881	52.881	0.568
4096	12	114.657	544.449	1.7936	298.4405	244.504	1.7494
8192	13	450.476	2413.24	9.5081	1390.202	1157.639	9.4623

Table 2. Running time for various types of zero algorithm before and after implementing the fast scheduling methods

V. CONCLUSION

This paper shows that the proposed fast matching detection function provide a lot of time to create the conflict matrix, and scheduling messages. Scheduling the message forms major time in routing the messages in the (MIN). The advantages of applying the new fast WM, fast IWM, and fast BWM on the Zero routing algorithm are reducing time taken in routing the message, and gives the ability to enlarge the network size up to 2^{13} processing unit.

The time spent in routing the message is reduced approximate by 20% to 30% spatially when increasing the network size. For example, the time taken for routing the messages in network with size 128 were 0.38 sec before implementing the fast WM and is 0.09 after using fast WM as the first step in the zero routing algorithm. Table 2 shows the difference in time taken for routing the messages for different network sizes and different types of zero algorithm after applying the fast WM, fast IWM, and fast BWM as the scheduling step (first step) of the algorithm. The difference more obvious with this running time it make sense to increase the network size to 2^{12} processing unit

The results show that the fast zero achieves the worst time compared to fast improved zero and fast bitwise zero which achieve better time in routing the message from source to destination, but fast improved zero algorithms is recommended because it does not need to convert the binary bits to decimal numbers which can represent complexity in the programming, at the same time its running time is too close to fast BW zero algorithm specially when we increase the network size.

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