ZeroX Algorithms with Free crosstalk in Optical Multistage Interconnection Network

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Abstract— **Multistage interconnection networks (MINs) have been proposed as interconnecting structures in various types of communication applications ranging from parallel systems, switching architectures, to multicore systems and advances. Optical technologies have drawn the interest for optical implementation in MINs to achieve high bandwidth capacity at the rate of terabits per second. Crosstalk is the major problem with optical interconnections; it not only degrades the performance of network but also disturbs the path of communication signals. To avoid crosstalk in Optical MINs many algorithms have been proposed by many researchers and some of the researchers suppose some solution to improve Zero Algorithm. This paper will be illustrated that is no any crosstalk appears in Zero based algorithms (ZeroX, ZeroY and ZeroXY) in using refine and unique case functions.**

Through simulation modeling, the Zero based algorithm approach yields the best performance in terms of minimal routing time in and number of passes comparison to the previous algorithms tested for comparison in this paper.

Keywords— component; Optical multistage interconnection networks (MINs); ZeroX Algorithm; crosstalk in Omega network.

I. Introduction

Multistage interconnection networks (MINs) have been proposed as interconnecting structures in various types of communication applications ranging from parallel systems [1]

, switching architectures [2], to multicore systems [3]. Advances in optical technologies have drawn the interest for optical implementation in MINs to achieve high bandwidth capacity at the rate of terabits per second. Optical MINs (OMINs) are an attractive solution that offers a combination of high bandwidth, low error probability, and large transmission capacity [4].

However, OMINs introduce optical crosstalk, which results from coupling two signals within a switching element (SE). Optical crosstalk degrades the performance of OMINs in terms of reduced signal-to-noise ratio and limits the size of the network [5]. Limited by the properties of optical signals, it is not possible to route more than one message simultaneously, without optical crosstalk, over a switching element in an OMIN. Reducing the effect of optical crosstalk has been a challenging issue considering trade-offs between aspects i.e. performance, hardware and software complexity.

There are three main approaches for solving optical crosstalk in OMINs namely the space [6], time [7] and wavelength [8][9] dilation approach. In this paper, the interest is on the time dilation approach to solve the optical crosstalk problem in the omega networks, a class of self-routable networks, which is topologically equivalent to the baseline, butterfly, cube networks et[10]. The time dilation approach solves the crosstalk problem by ensuring that only one signal is allowed to pass through each switching element at a given time in the network [11][12]. Typical MINs consist of N inputs, N outputs and n stages with n=log N. Each stage is numbered from 0 to (n-1), from left to right and has N/2 Switching Elements (SE). Each SE has two inputs and two outputs connected in a certain pattern.

The critical challenges with optical multistage interconnections are optical loss, path dependent loss and optical crosstalk [13] [14]. Optical crosstalk is caused by coupling two signals within a switching element.

In this paper, the focus is illustrated that is no any crosstalk in *ZeroX*, *ZeroY* and *ZeroXY* if the refine and unique case apply in the given networks. And illustrate that is *Fast ZeroX* depends for that is some crosstalk still occurs in ZeroX without author used refine and unique case in *ZeroX* [15][16].

II. Related Works

There are various approaches available to reduce the problem of crosstalk like space domain, time domain and wavelength domain approach. In the present paper, our consideration is time domain approach [7]. Crosstalk is considered as a conflict in this approach. It is a good approach because it can make a balance between the electronic processor and Optical MINs [16][17]. It is not possible to send all the source addresses at the same time to their corresponding destination because it will create the switch and link conflict problem. Therefore, to route the data packets, Permutation and Semi-permutation is applied on the message groups. So that a conflict free route can be obtained for each group [4]. The source and destination address is combined to build combination matrix. On the basis of combination matrix message partitioning is performed so that some specific message should get their destination in the first pass and network remains crosstalk free. There are various techniques for message partitioning like Window Method [4][18], Improved Window Method[19] and Heuristic Routing Algorithms [19]. In this paper, the focus is to provide best message partitioning scheme so that a switch and link conflict free network can be obtained. Before describing our algorithms just have a look on the Window Method and Improved Window Method and Heuristic Routing Algorithm.

A. Window Method

This method [4] [20] basically separates the messages, which have the same bit pattern so that crosstalk can be removed. If we consider the network size N x N, it 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. This matrix shows that the optical window size is M-1, where M=log2N and N is the size of the network. The first and last columns of the combination matrix are not considered in this method and all the processing is performed on the remaining columns. If the two messages having the same bit pattern then they will be routed in the different passes.

In our example, the window size will be two and the number of window will be three W0, W1 and W2 as shown in Figure 1.

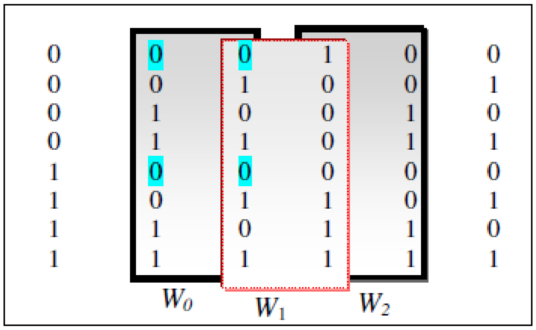

Fig. 1. Three Optical Windows in an 8×8 OON

Then, we take the second and third columns as a matrix, where example messages 000 and 100 in this window have the same bit pattern of 00 inside the window and have a conflict. The bit patterns can be any of the four combinations of 00, 01, 10, and 11.

B. Conflict Matrix

A conflict matrix is the new proposed method proposed in this research, it is a square matrix with $N \times N$ entry, where N is the size of the network, it consist of the output of the window method , the propose definition of Conflict Matrix is the matrix *Mij* with size $N \times N$ where N is the size of network,

$$M_{ij} = \begin{cases} 1 & \text{if conflict} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where *Mij* is the entries of the Conflict Matrix.

Conflict matrix can be formed by assigning the value 1 when there is a conflict between the source and destination; otherwise the value 0 is assigned [4][20].

III. ZERO BASED ALGORITHMS

To avoid the crosstalk problem in omega network a new algorithm called Zero Based Algorithm is proposed and named it ZeroX algorithm, ZeroY algorithm and ZeroXY algorithm.

The following sections explain these algorithms.

A. ZeroX algorithm

This algorithm depends on taking the zero values from the row *N+1*(axis X) in conflict matrix and putting it in a new group. Then, the entries of this group are considered as having zero value in the matrix. After that, anew summation for the other entries of the matrix it 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. That means, all the entries of matrix are found to be in separate groups. Figure 2 illustrates the general flowchart of ZeroX algorithm [4] [20].

Initialization
A: Matrix $N*N$,
N: no. of the nodes, *S*: current node
A_R: Reduced matrix contains the currently rows r_i and columns, $i \in G[k]$
r_i ,c_j are the i^{th} row and j^{th} column where $0 \le i \le N\text{-}1$, $0 \le j \le N\text{-}1$
G: List of groups; k: group index
Input : conflict matrix A with size $N*N$
Output: (*K* and *G[k]*), k is the color number and *G[k]* is nodes at the color k
Begin
K: = 0; *S*: = 0 $A_R := A$;
While $S < N$ do
Begin
For $i = 1$ to *N* do
For $j = 1$ to *N* do
Sum [i] = Sum [i] + A_R [i,j];
// Sum [i] *is* the sum for all columns in matrix A_R
For $j: = 0$ to $N\text{-}1$ do
// this loop to clustered the entries element in Current group called G[k]
Begin
If *Sum[j] = 0* Then
Begin
Color[j]:= k; G[k]:= G[k] +j; S: = S+1;
End if
End for
If $S = 1$ then
// s =1 this mean the current group G[k] have only one entry equal zero
Call Unique_Case (A_R, *j, G[k], S*) // function for Unique case
Call Refine (A_R, *G [k], S*) // function for enhance the group
$A_R := A_R$ with rows r_j and columns c_j where $j \notin G[k]$
$K: = k+1$
End While
Return (*k, G[k]*)

Fig. 2. Pseudo Code of ZeroX Algorithm

To avoiding the crosstalk the algorithm must implement the refine Function and Unique Case Function. The refine function illustrated in Figure 3 is used to enhance the current groups by adding one or more entries in Matrix M the intersection with current group G equal to zero.

The unique function illustrated in figure 4 is only used to check whether the current group G consists of only one entry equals zero in order for the successor entry equals to zero to be added in the same row of the G and return for the main algorithm[4][20].

Authors' are use ZeroX algorithm without apply refine function and Unique case Function and decided that are some crosstalk still occur in ZeroX algorithm in papers [12][15] [16] [18].

```
Function Refine (A_R ,G[k],S)        // rows of A_R which only in G[k]
Begin //The Function Refine is used to add new elements to the current group.
 For i = 1 to N do
 For j = 1 to N do
 Sum [i] = Sum [i]+ A_R [i,j];
 // Sum [i] is the summation for all columns in matrix A_R
    For j: = 0 to N-1 do
         Begin
          If Sum[j] =0 and (j ∉ G[k] ) Then
            Begin
              Color[j]:= k;
              G[k]:= G[k] +m;
               S: = S+1;
            End if
         End For
    Return (G[k], S)
  End Refine
```

Fig. 3. Refine Function in *ZeroX* Algorithm

```
Function Unique_Case (A_R , j, G[k], S)        // function for Unique
case
  Begin
    For m: = j+1 to N-1 do
     Begin
        If A_R [j, m] = 0 then
        Begin
           G[k]:= G[k] +m;
            S: = S+1;
           Exit For
          End if
     End For
  Return (G[k], S);
  End Unique_Case
```

Fig. 4. Unique Case in *ZeroX* Algorithm

B. *ZeroY Algorithm*

ZeroY algorithm is another new algorithm proposed to avoid the crosstalk problem in Omega Network. It has the same steps of ZeroX algorithm, but with a difference in the first step where it considers the summation of rows instead of columns. The rest of the algorithm operates in the same way ZeroX algorithm does. In addition, the columns will be changed to rows an vice versa [4][20].

C. *ZeroXY Algorithm*

The ZeroXY algorithm is another new algorithm proposed to avoid the crosstalk problem in Omega network. The minimum number of passes between *ZeroX* and *ZeroY* algorithms is the output of the *ZeroXY* algorithm [20].

IV. UNIQUE CASE FUNCTION TO AVOIDING CROSSTALK IN ZEROX

The unique case is only used to check whether the current group consists of only one entry equal zero in *ZeroY* algorithm then the previous entry equal to zero is added in the same column of the current group and the next step of the algorithm is continued. That also happened in *ZeroX* for the same reason, but in *ZeroX* the successor entry equal to zero is added in the same row of current group and the next steps of the algorithm is continued. This section provides an illustrate example that show how the unique case happens and explain that no any crosstalk occur *in ZeroX* or *ZeroY* algorithms.

Assuming that the source and the destination are randomly generated and the size of the network is 8×8, the shuffle exchange in Omega network for the unique case would be as shown in Table I.

TABLE I. SHUFFLE EXCHANGE IN OMEGA NETWORK FOR UNIQUE CASE

Node No.	Source	Destination
0	000	011
1	001	001
2	010	010
3	011	000
4	100	100
5	101	101
6	110	110
7	111	111

The first column in Table 1 shows the node number of the network while, the second and third columns present the sources and the destinations. Using the Window method, the generated conflict matrix would be as it is shown in Table II.

TABLE II. THE CONFLICT MATRIX IN UNIQUE CASE

Message	000	001	010	011	100	101	110	111
000	0	0	1	0	1	0	0	0
001	0	0	0	1	0	1	0	0
010	0	0	0	0	0	0	1	0
011	0	0	0	0	0	0	0	1
100	0	0	0	0	0	1	1	0
101	0	0	0	0	0	0	0	1
110	0	0	0	0	0	0	0	1
111	0	0	0	0	0	0	0	0

From Table II, upon completing the first step of the ZeroY algorithm, the results would be as it is presented in Table III.

TABLE III. THE SUMMATION STEP IN ZEROY ALGORITHM

Message	000	001	010	011	100	101	110	11 1	Sum
000	0	0	1	0	1	0	0	0	2
001	0	0	0	1	0	1	0	0	2
010	0	0	0	0	0	0	1	0	1
011	0	0	0	0	0	0	0	1	1
100	0	0	0	0	0	1	1	0	2
101	0	0	0	0	0	0	0	1	1
110	0	0	0	0	0	0	0	1	1
111	0	0	0	0	0	0	0	0	0

Table III shows that only one summation appears to be zero, which is the row (message) 111. If this unique case happened, the solution would be adding the previous entry equal to zero in the same column of the current group and then continuing the next step of the algorithm. As observed from this example, the only one entry which satisfies this condition is entry 100. By adding this entry to the current group, the group will be including 2 entries 100, and 111, and then continue with the normal steps to get the rest of the nodes in the first group. Figure 5 illustrates the two passes (colors), acquired from the example after finishing the implementation of the whole ZeroY algorithm steps. The first color includes the nodes 000, 101, 011, and 110, and the second color includes the nodes 010, 001, 100 and 111.

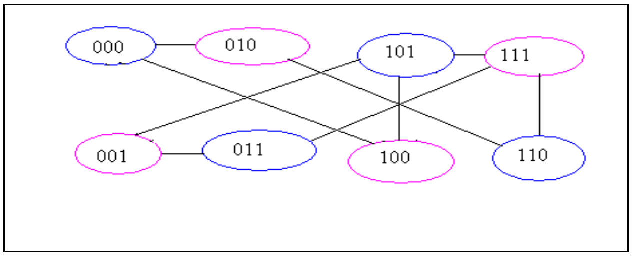

Fig. 5. Two Colors in Unique Case

The Figure 5 illustrate that is no any crosstalk in this network like the authors says in papers [12] [15] [16][18].

V. COMPARATIVE ANALYSIS AND DISCUSSION

The comparison in this section is between the ZeroX algorithm with include refine and Unique Case functions and the routing algorithms, which includes the four heuristic algorithms namely; the Sequential up (Seq), the Sequential down (SeqDn), the Degree Ascending (Ascend), the Degree Descend (Descend), and the SA algorithm. The comparison depends on two parameters which are the average number of passes parameter and the execution time parameter using different values of the network size.

The average number of passes is shown in figures 6, and execution time shown in figures 7 respectively.

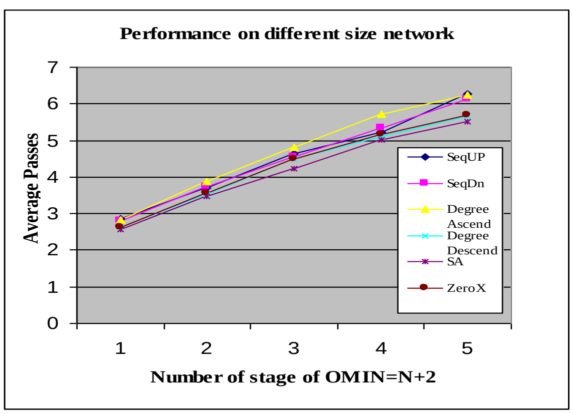

Fig. 6. Average number of Passes

From the results elaborated in figure 6 it is observed that the Degree-Ascending algorithm performs the worst in terms of the average number of passes. However, the Descend algorithm and ZeroX algorithm have the better performance. Seq algorithm and SeqDn algorithm perform better than Ascend algorithm and poorer than Descend. The Figure 6 illustrate that the SA Algorithm has been the best. The results obtained by ZeroX algorithms match closely those obtained by the Degree-Descending Algorithm. Therefore, the simulated annealing is still considered to be more appropriate for finding the average number of passes for a given network.

In the execution time terms, the results of the different heuristic algorithms, SA algorithm and ZeroX algorithm are shown figure 7.

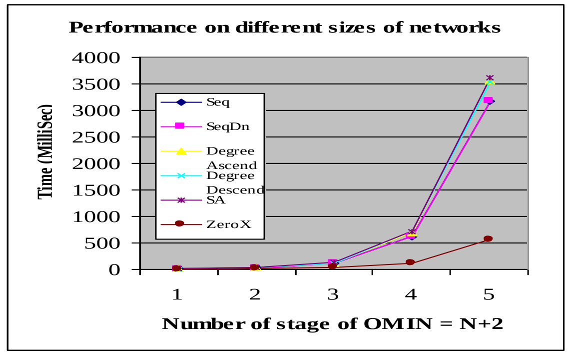

Fig. 7. Execution Time for ZeroX and Routing Algorithms

It is illustrated in figures 7 that the algorithms SA, Degree Ascend and Degree Descend perform the worst in terms of the execution time. Sequential and Sequential algorithm Down SeqDn algorithm perform better than SA, Ascend and Descend algorithms, but poorer than ZeroX algorithm. In addition, all the five routing algorithm in Figure 7 take the longest time to compute a solution compared the ZeroX algorithm in terms of the execution time. Therefore, the ZeroX algorithm can be considered more appropriate for finding the execution time for a given network. And finally the ZeroX algorithm includes refine and unique case function is free crosstalk for any given network.

REFERENCES

[1] Y. Yang, J. Wang and Y. Pan, "Routing Permutations with Link-Disjoint and Node-Disjoint Paths in a Class of Self-Routable Interconnects". IEEE Transactions on Parallel and Distributed Systems, Vol. 14, No. 4, pp. 383-393, 2003.

[2] D. Tustch and G. Hommel, "MLMIN: A Multicore Processor and Parallel Computer Network Topology for Multicast". Computers and Operations Research Journal, Elsevier, Vol. 35, No. 12, pp. 3807-3821, 2008.

[3] M. A. Al-Shabi and M. Othman, "A New Algorithm for Routing and Scheduling in Optical Omega Network". International Journal of the Computer, The Internet and Management, Vol. 16, No. 1, pp. 26-31, 2008.

[4] E. Lu and S. Q. Zheng, "High-Speed Crosstalk-Free Routing for Optical Multistage Interconnection Networks". Proceedings of the 12th International Conference on Computer Communications and Networks, pp. 249-254, 2003.

[5] S. C. Chau, T. Xiao and A. W. C. Fu, "Routing and Scheduling for a Novel Optical Multistage Interconnection Networks". Euro-Par 2005 Parallel Processing, Lecture Notes in Computer Science, Vol. 3648, pp. 984-993, 2005.

[6] Y. Pan, C. Qiao, and Y. Yang, Optical Multistage Interconnection Networks: New Challenges and Approaches, IEEE Communications Magazine, Feature Topic on Optical Networks, Communication Systems and Devices, Vol 37, No. 2, 1999, pp: 50-56.

[7] C. Qiao and R. Melhem, A Time Domain Approach for Avoiding Crosstalk in Optical Blocking Multistage Interconnection Networks, Journal of Lightwave Technology, Vol. 12. No. 10, 1994, pp. 1854-1862.

[8] Enyue Lu and S. Q. Zheng, Parallel Routing and Wavelength Assignment for Optical Multistage Interconnection Networks,

Proceedings of the 2004 International Conference on Parallel Processing (ICPP 04), 2004.

[9] C. L. Wu, and T. Y. Feng, "On a Class of Multistage Interconnection Networks". IEEE Transactions on Computers, Vol. 29, No. 8, pp. 694-702, 1980.

[10] T.T. Lee and P. P. To, Non-blocking routing properties of Clos networks, in Advances in switching networks (Princeton, NJ, 1997), Amer. Math. Soc., Providence, RI, 1998, pp. 181–195.

[11] X. Shen, F. Yang, and Y. Pan, Equivalent Permutation Capabilities Between Time Division Optical Omega Networks and Non-Optical Extra-Stage Omega Networks, IEEE/ACM Transactions on Networking, Vol. 9. No. 4, 2001, pp: 518-524.

[12] T. D. Shahida, M. Othman, M. Khazani, Routing Algorithms in Optical Multistage Interconnection Networks: Revisited, World Engineering Congress 2007 (WEC 2007), August 2007.

[13] V.P. Bhardwaj, Nitin and V. Tyagi, An Algorithmic Approach to Minimize the Conflicts in an Optical Multistage Interconnection Network, Proceedings of the 1st International Conference on Advances in Computing and Communications (ACC), Lecture Notes in Computer Science (LNCS), Springer, Kerala, 2011.

[14] V.P. Bhardwaj, Nitin and V. Tyagi, Minimizing the Switch and Link Conflicts in an Optical Multi–stage Interconnection Network, International Journal of Computer Science Issues, 8 (4) 1, ISSN: 1694–0814, 2011

[15] T. Shahida, M. Othman, M. Khazani, " A Fast and Efficient Crosstalk-Free Algorithm for Routing in Optical Multistage Interconnection Networks", IEEE,2008.

[16] T. D. Shahida, M. Othman and M. K. Abdullah, Fast Zerox algorithm for routing in optical Multistage interconnection networks, IIUM Engineering Journal, 11(1), pp. 28-39, 2010.

[17] A.K. Katangur, S. Akkaladevi and Y. Pan, Analyzing the performance of optical multistage interconnection networks with limited crosstalk, Cluster Computing, 10, pp. 241-250.

[18] F. Abed and M. Othman, Fast method to find conflicts in optical multistage interconnection networks, International Journal of The Computer, The Internet and Management, 16(1), pp. 18-25, 2008.

[19] M. Abdullah, M. Othman and R. Johari, An efficient approach for message routing in optical omega network, International Journal of The Computer, the Internet and Management, 14(1), pp. 50- 60, 2006.

[20] M. A. Al-Shabi, "Zero Algorithms to avoid Crosstalk in Optical Multistage Interconnection Networks". PhD Thesis, Universiti Putra Malaysia, 2005.

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