Crosstalk Free Routing Algorithm for High Speed Optical Multistage Interconnection Network

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(Received: 5 Feb. 2018 – Accepted: 20 May 2018)

Abstract

High speed optical interconnection networks are further more integrated for modern computing systems and parallel computing. Optical multistage interconnection network (OMIN) is a popular dynamic network schemes that are used in switching and communication of high speed optical interconnection network applications. However, OMINs introduce crosstalk which results from coupling two signals within one Switching Element. This paper highlights the breakthroughs in the area of scheduling methods and crosstalk free routing in optical interconnection networks, and proposes new timely conflict free routing algorithms.

Key words: optical interconnection networks, crosstalk free routing algorithms, optical switches, integration optical devices.

1. Introduction

Optical interconnection networks for computer systems have been an important research topic since the 80's when the bandwidth capacity advantage of the optical domain became evident. Supported by, research in the field of high speed optical interconnection networks, high-performance parallel computing systems could achieve low-latency and high-throughput interconnectivity between processing elements [1]. Requirements of new high band width applications such as medical imaging, video services, and distributed central processing units interconnections require modern solutions with high throughputs to emulate the needs of the modern communication systems which reach the limits of terabits per second [2].

Popular classes of dynamic networks are Multistage Interconnection Networks (MIN) Fig. 1, which are used for interconnecting in parallel computing systems and multiprocessor systems [3]. Multistage interconnection networks have various architectures like, banyan, crossbar, baseline, clos, delta and the Omega network [4]. These networks are type of shuffle exchange MINs that have the ability of simple routing technique with leading scalabilities [5]. OMIN connects N inputs or sources to N outputs or destinations using S stages, where $S=\log_2 N$ and each stage consist of 2^{S-1} 2x2 switching elements (SE) [6]. The switching elements offer the prospect of optical crosstalk specifically when two sources try to rout their data through one SE at the same time.

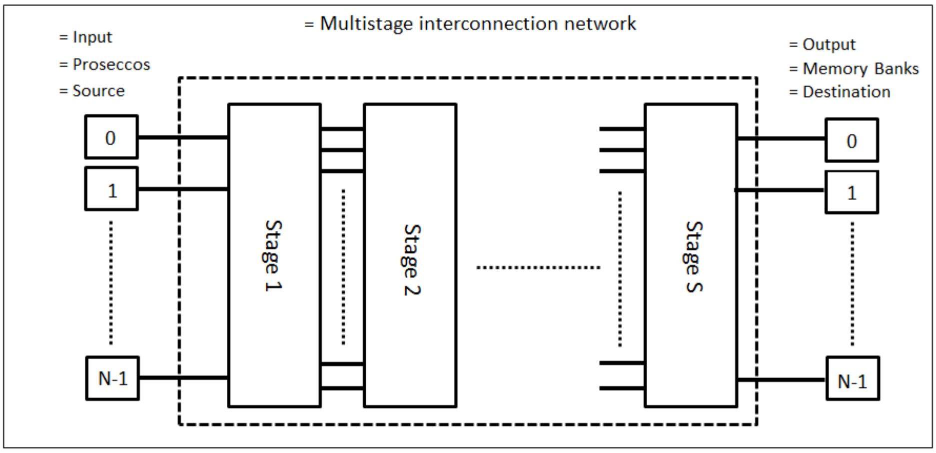

Fig. 1 Multistage interconnection networks

Various approaches are developed to minimize the crosstalk effect; space domain, time domain and wavelength domain approach [7]. This article presents our consideration in time domain approach. The time domain approach considers crosstalk as a conflict, and has the advantage making balance between the electronic processor and Optical MINs [8, 9]. Broad cast communication is not available in this network because it inspires the crosstalk conflict. Therefore, Permutation and Semi-permutation is applied to route the data packets on groups. So that a conflict free routable way is obtained for each group [10]. The source and destination address is combined to build combination matrix. Basis a combination matrix with size 8x8 the message are performed in two passes so that specific group of message should get their destination in the first pass and the second passes for the rest of the network, so network remains crosstalk free. There are various techniques used to separate messages in several groups in several network sizes like, Simulated Annealing (SA) algorithm, Genetic algorithm (GA) , Ant Colony Optimization (ACO),Zero and four heuristic algorithms[10-12].This paper aims to obtains a better scheme for timely message partitioning, so that a switch and link conflict free network is achieved. Before describing our algorithms just have a look on the window method types compared with various scheduling and routing algorithms in [13, 14].

This paper is organized as follow.in section II.1 types of fast window methods are introduced. Section II.2 introduces routing algorithm that are used to solve crosstalk problem in optical multistage interconnection network, focused on algorithms that apply window method as a main step as a conflict detecting technique. Section III illustrates the proposed modified routing algorithms after applying the conflict detecting technique. Section IV shows the MATLAB simulation result, followed by conclusions in Section V.

2. Data Analysis:

2.1. Scheduling Methods:

Window method is a scheduling technique that 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 sources and N destinations. 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 the 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 [15]. Compared to the standard window method (WM), the execution time is reduced approximately by 1/S, where S is the number of stages [16]. In the bitwise window method, each binary bit optical window of the standard WM is transformed into its equivalent decimal figuration using bitwise functionality [17].

The last update to the window method is the Fast window method, which minimizes the running time of 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 [18]. Table 1 compares between the different window methods through their window size, time consumption, number of windows used, Pattern and Similarity checking techniques.

Table 1. Comparison between 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	Log_2N	(Log_2N)-1	Log_2N	Log_2N
Pattern check	Binary	Binary	decimal	Binary
Similarity check	Randomly sorted	Randomly sorted	Randomly sorted	Sorted Increasing or decreasing order

2.1 Routing Algorithms

The aim of the 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. Genetic Algorithms (GAs) are a part of evolutionary computing [11, 12]. A GA is initialized with a set of solutions, which are represented by chromosomes. Those solutions are called the population. Solutions from the initial population are taken and used to form a new population. The Genetic algorithm improves the performance in terms of the average number of passes. It saves one or two passes [8] than the remaining algorithms, but Genetic algorithm was time consuming. It even took hours to calculate the number of passes for large network sizes. Zero algorithm strategy is based on taking zero values in row N+1(X axis) in conflict matrix and putting it in a group [19]. 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. 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 [20,21]. Other routing algorithms used to solve crosstalk problem in optical multistage interconnection network with different strategies like, ant colony optimization algorithm [22] simulated annealing algorithm [23]. Based on the comparative analysis in [20], it was concluded that four heuristic algorithm and the zero algorithm consume minimum execution time with minimum number of passes from source to its cross bonding destination through several stages and switches in the OMIN, on the other hand they are based on the window method as a conflict checking step[24]. There for our work proposes a new updates for the four heuristic algorithms.

3. Proposed Fast WM-Heuristic Routing Algorithms

Four heuristic algorithms are the Sequential (increasing), Sequential (decreasing), Degree Increasing and Degree Descending [19]. The purpose of these routing algorithms is to schedule the messages in different passes in order to avoid the path conflicts in the network [20]. The more efficient the algorithm is, the less passes it will generate. The goal is to design efficient algorithm to minimize the number of the time slots (passes) for sending all the messages. This would mean that the messages will be sent out in less time. The order of the messages to be picked for scheduling is an essential cause for generating the different results. There are many ways to decide the order of the scheduling. The four heuristic algorithms select the message in the following way:

1. Select a message sequentially in increasing order of the message source address,
2. Select a message sequentially in decreasing order of the message source address
3. Select a message based on the order of increasing degrees in the conflict graph
4. Select a message based on the order of decreasing degrees in the conflict graph

The purpose of these routing algorithms is to schedule the message in different passes in order to avoid the path conflicts in the network. The degree of each message in the conflict graph is the number of conflicts to other messages it has in the conflict graph. Based on Ref. [25] work, scheduling the messages in Decreasing Degrees of the message conflicts will result in the best performance among these four algorithms. Working on this conclusion the present work modified the heuristic algorithms to reduce the running time by replacing the traditional scheduling method (window method) with fast window method. Figure 2 represents the pseud code of four heuristic algorithms steps after implementing the fast scheduling 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
Algorithm Message_Routing()
begin
 while (not end of messages list)
begin
 Select one of the left messages; // from the conflict matrix
Schedule the message in a time slot with no conflict withother messages that have been already scheduled;
 end while;
end;
----------------------------------------------------------------------------------
```

Fig.2: Pseud code of four heuristic algorithms with fast scheduling method

4. Results and Discussion

This section gives a quick review about the comparison between different types of fast window method (FWM) and discus the implementation of the timeliest FWM to the fore heuristic algorithms. Figure 3 compares between the different types of the Fast Window Method; fast bitwise window method

(FBWM), fast improved window method (FIWM) and fast window method (FWM) in term of time in seconds, concluding that FIWM and FBWM are mostly close in their time consumption and less than the FWM, and Fig. 4 shows a Comparison of number of columns in windows use to find out conflicts in FWM, FIWM, FBWM, which indicates the complexity of each the window methods scheduling types.

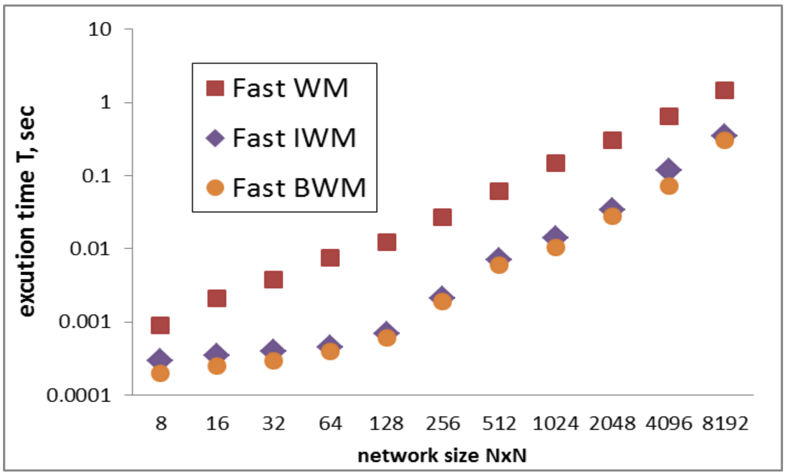

Fig 3: comparison between the three types of the Fast Window Method

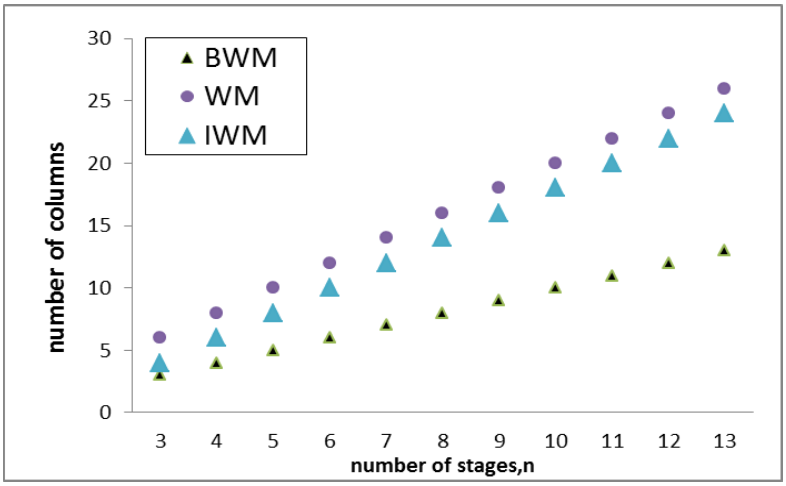

Fig 4: Comparisons between the three types of the Fast Window Method in term of number of columns in windows use to find out conflicts.

Figure 5 shows a comparison between the average time achieved by the fast window method and the average time of the routing algorithms, which indicates that the execution time of the scheduling method represent 20% of time taken to rout the message from source to destination, and this percentage increases to achieve 50% for large network size.

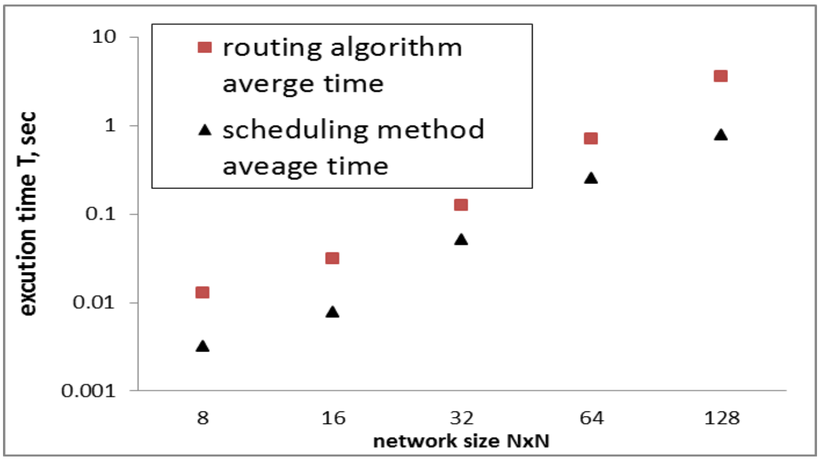

Fig 5: comparison between the time consumption of the scheduling method a

Figure 6-9 illustrates the effect of implementing the fast scheduling method; FBWM to the different types of traditional four heuristic algorithms through the comparison between; sequential ascending, sequential descending, degree ascends, degree descending and the fast window method heuristic algorithm (Fast WM-Heuristic); fast sequential ascending, fast sequential descending, fast degree ascends, fast degree descending. The indication is that Fast WM-Heuristic types minimized the time taken for routing messages, spatially with extended network sizes.

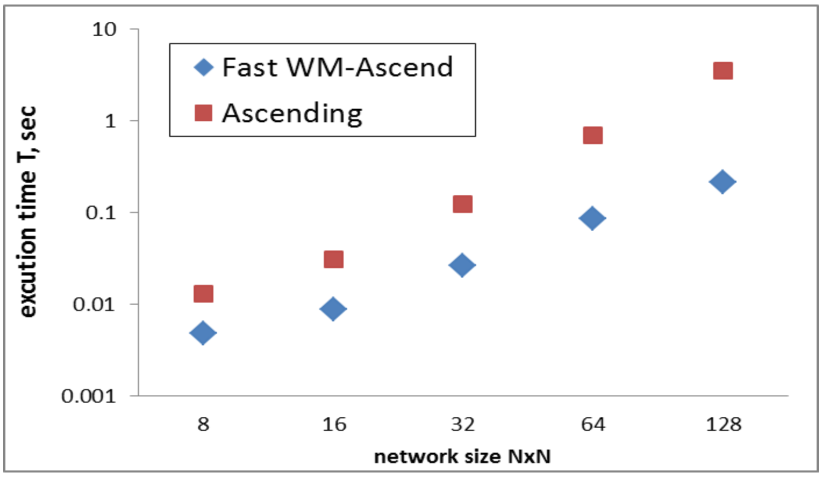

Fig 6: comparison between ascending and Fast WM-ascending algorithm in term of time

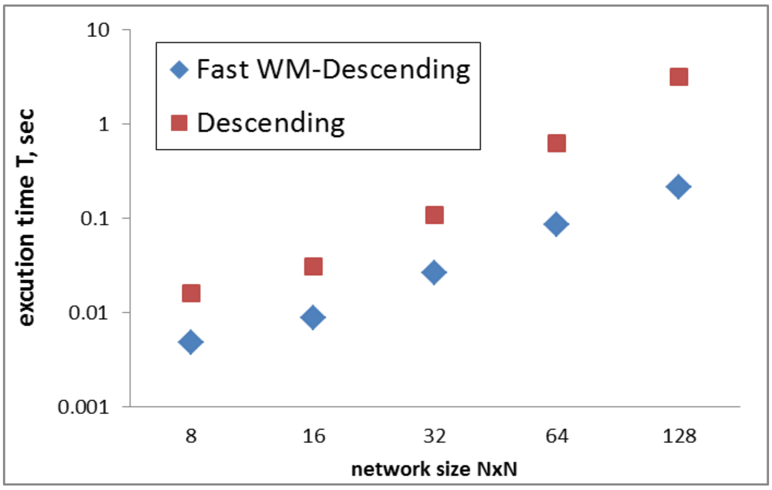

Fig 7: comparison between descending and Fast WM-descending algorithm

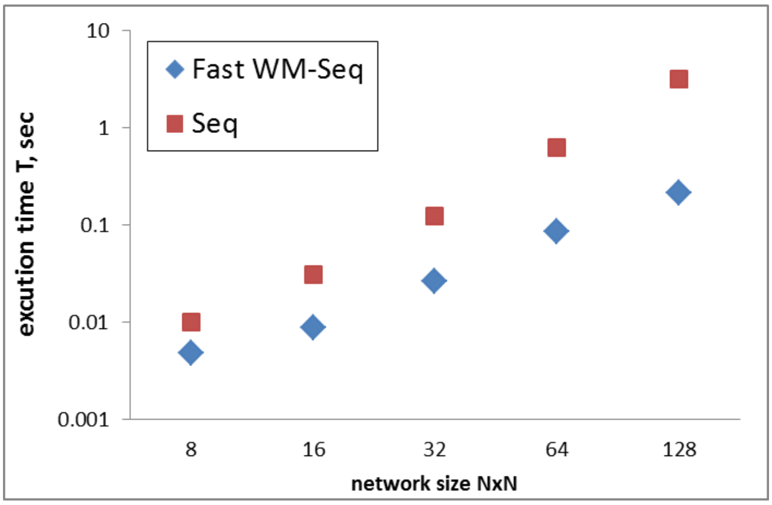

Fig 8: comparison between sequential and Fast WM-sequential algorithm in term of time

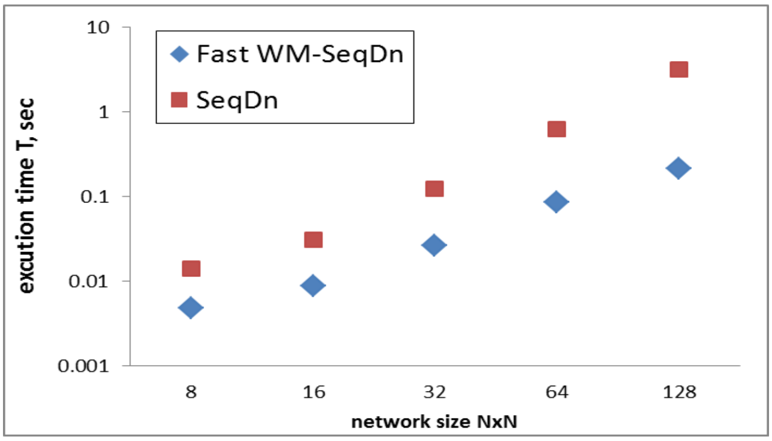

Fig 8: comparison between sequential and Fast WM-sequential algorithm in term of time

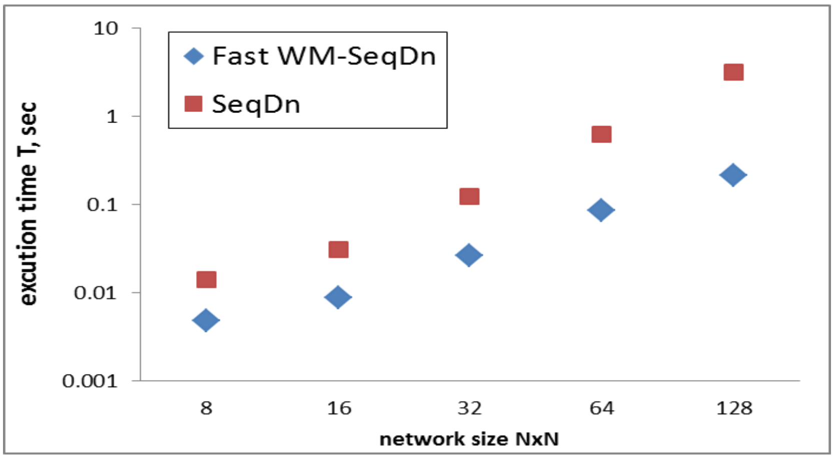

Fig 9: comparison between sequential down and Fast WM-sequential down algorithm in term of time

Figure 10 shows a comparison between times achieved by the four different types of the four heuristic algorithms after implementing the FBWM as the scheduling step.

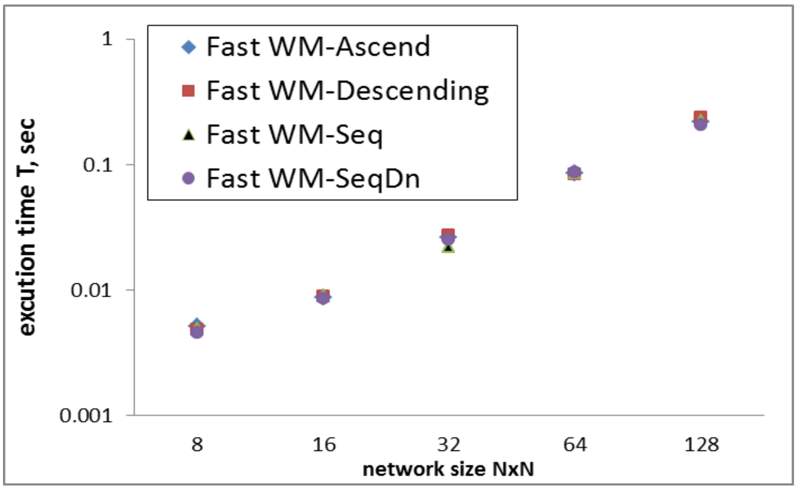

Fig 10: Figure shows a comparison between Fast Window Method, Fast WM Zero and Fast WM Heuristic

Tables 2: Comparison between the fast window method types and the traditional window methods

Network size	no. of stages	WM	Fast WM	IWM	Fast IWM	BWM	Fast BWM
8	3	0.0035	0.0009	0.0018	0.0003	0.0012	0.0002
16	4	0.0104	0.0021	0.0058	0.00035	0.003	0.00025
32	5	0.0205	0.0038	0.0187	0.0004	0.0126	0.0003
64	6	0.0404	0.0075	0.0688	0.00045	0.0198	0.0004
128	7	0.1814	0.0124	0.3035	0.0007	0.0771	0.0006
256	8	0.7394	0.0272	1.4049	0.0021	0.3409	0.0019
512	9	3.1381	0.0616	6.425	0.007	1.6549	0.006
1024	10	13.9201	0.1485	28.2648	0.0142	7.0331	0.0106
2048	11	60.2443	0.3051	125.5096	0.0337	31.2922	0.028
4096	12	277.089	0.6398	705.7785	0.1167	143.7656	0.0725
8192	13	1205.445	1.493	2804.8	0.351	605.8877	0.3052

Tables 3: no of columns resulting in window method types.

Network size	No. of stages	FBWM	FWM	FIWM
8	3	3	6	4
16	4	4	8	6
32	5	5	10	8
64	6	6	12	10
128	7	7	14	12
256	8	8	16	14
512	9	9	18	16
1024	10	10	20	18
2048	11	11	22	20
4096	12	12	24	22
8192	13	13	26	24

Tables 4: shows the results and compares between the proposed routing algorithm

network size	Fast WM-Ascend	Ascending	Fast WM-Descending	Descending	Fast WM-Seq	Seq	Fast WM-SeqDn	SeqDn
8	0.00520	0.013	0.00490028	0.016	0.00500028	0.01	0.00460028	0.014
16	0.00884198	0.031	0.00894198	0.031	0.00914198	0.031	0.00854198	0.031
32	0.026187894	0.125	0.02718789	0.109	0.02187894	0.125	0.025187894	0.125
64	0.085401047	0.703	0.08401047	0.625	0.08560105	0.625	0.087227778	0.625
128	0.217553734	3.547	0.23733882	3.172	0.22553734	3.172	0.207553734	3.172

Table 2, 3 gives a quick review about the results achieved and compares between the different types of fast window method (FWM) in term of running time and number of columns resulting in window method types, which indicates the complexity of each the window methods scheduling types. Results indicated that and Fast BWM is less complex and minimum running time. Table 4 shows the results after the implementing of the FWM to the fore heuristic algorithms. The advantages of applying the new fast BWM on the four heuristic algorithms are reducing time taken in routing the message.

5. Conclusion

Results indicated that the execution time of the scheduling method represent about 20% of time taken to rout the message from source to destination, and this percentage increases to 40% for large network size, which shows the importance of developing the scheduling methods. Results indicated that number of columns in windows use to find out conflicts in FBWM is less than FWM, FIWM, which means that applying the FBWM is less complex than the two other types of the conflict searching methods.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 four heuristic algorithms are reducing time taken in routing the message, and give the ability to enlarge the network size up to 2^7 processing unit. The time spent in routing the message is reduced approximate by 20% to 30% spatially when increasing the network size.

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الملخص باللغة العربية

تعتبر الشبكات البصريه متعدده المراحل من اهم الشبكات المستخدمه في تطبيق الاتصالات الحديثه, على الرغم من ظهورعيوب التداخل بين البيانات عند توجيه اكثر من اشاره من خلال نفس عنصر التحويل اوعبر كابل الالياف الضوئيه. وقد تم استخدام طرق خوارزمية سابقه لتقليل زمن تنفيذ عمليه التشغيل مبنيه على اساس طريقه النافذه, وطريقه النافذه المتقدمه وطريقه النافذه العشريه في عمليه تنظيم ارسال البيانات و قد تم تطوير تلك الطرق الي طريقه النافذه السريعه, وطريقه النافذه المتقدمه السريعه وطريقه النافذه العشريه السريعه, لتقليل زمن عمليه جدوله او تنظيم البيانات قبل التوجيه والارسال. خلال تلك الدراسه تم تطبيق طريقه النافذه المتقدمه السريعه وطريقه النافذه العشريه السريعه على الخوارزم الارشادي لتقيل الزمن الكلي لعمليه توجيه البيانات بين المرسل و المستقبل بدون تداخل حيث ثبت بعمل مقارنه بين الطرق المقدمه المقترحه و الطرق السابقه, نجاح الطرق المقترحه في تقليل زمن تنفيذ عمليه التشغيل.