Effect of Crosstalk on Permutation in Optical Multistage Interconnection Networks

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Abstract — Optical MINs hold great promise and have advantages over their electronic networks. They also hold their own challenges. More research has been done on Electronic Multistage Interconnection Networks (EMINs) but these days optical communication is a good networking choice to meet the increasing demands of high-performance computing communication applications for high bandwidth applications. The electronic Multistage Interconnection Networks (EMINs) and the Optical Multistage Interconnection Networks (OMINs) have many similarities, but there are some fundamental differences between them such as the optical-loss during switching and the crosstalk problem in the optical switches. To reduce the negative effect of crosstalk, various approaches which apply the concept of dilation in either the space or time domain have been proposed. With the space domain approach, extra SES are used to ensure that at most one input and one output of every SE will be used at any given time. For an Optical network without crosstalk, it is needed to divide the messages into several groups, and then deliver the messages using one time slot (pass) for each group, which is called the time division multiplexing. This paper discusses the permutation passability behavior of optical MINs. The bandwidth of optical MINs with or without crosstalk has also been explained. The results thus obtained show that the performance of the networks improves by allowing crosstalk to some extent.

Index Terms—Optical, Multistage, Permutation, Interconnection.

1 INTRODUCTION

Optical communication is necessary for achieving reliable, quick and flexible communication. Advances in optical technologies have made optical communication a reliable networking choice to meet the demands for high bandwidth and low communication latency of high-performance computing/communication applications. So optical networks give high performance as well as low latency. Although optical MINs hold great promise and have advantages over their electronic networks, they also hold their own challenges. Advances in electro-optic technologies have made optical communication a good networking choice for the increasing demands of high channel bandwidth and low communication latency of high-performance computing/communication applications. Fiber optic communications offer a combination of high bandwidth, low error probability, and gigabit transmission capacity. Multistage Interconnection Networks (MINs) are very popular in switching and communication applications and have been used in telecommunication and parallel computing systems. But these days with growing demand for bandwidth, optical technology is used to implement interconnection networks and switches. In electronic MINs electricity is used, where as in Optical MINs (OMIN) light is used to transmit the messages [21]. The electronic MINs and the optical MINs have many similarities, but there are some fundamental differences between them such as the optical-loss during switching and the crosstalk problem in the optical switches. Optical interconnections have the potential of becoming an appealing alternative to electrical interconnections. For long and medium range distances (e.g., local area networks and telecommunication), optical technology (fibers) is the technology of choice, offering better performance and lower costs than electrical wires [21]. There is a trend for optics to replace electronics for shorter distances and larger connectivity applications. Optical interconnections are insensitive to radio wave interference effects, are free from transmission line capacitive loading, do not have geometrical planar constraints, and can be reconfigurable (circuit-switched)[6,7]. Crosstalk in optical networks is one of the major shortcomings in optical switching networks, and avoiding crosstalk is an important for making optical communication properly. To avoid a crosstalk, many approaches have been used such as time domain and space domain approaches [22]. Because the messages should be partitioned into several groups to send to the network, some methods are used to find conflicts between the messages.

2 OPTICAL MULTISTAGE INTERCONNECTION NETWORKS

An optical MIN can be implemented with either free-space optics or guided wave technology. It uses the Time Division Multiplexing. To exploit the huge optical bandwidth of fiber, the Wavelength Division Multiplexing (WDM) technique can also be used. With WDM, the optical spectrum is divided into many different logical
channels, and each channel corresponds to a unique wavelength. Optical switching, involves the switching of optical signals, rather than electronic signals as in conventional electronic systems. Two types of guided wave optical switching systems can be used. The first is a hybrid approach in which optical signals are switched, but the switches are electronically controlled. With this approach, the use of electronic control signals means that the routing will be carried out electronically. As such, the speed of the electronic switch control signals can be much less than the bit rate of the optical signals being switched. So, with this approach there is a big speed mismatch occurs due to the high speed of optical signals. The second approach is all-optical switching. This has removed the problem that occurred with the hybrid approach. But, such systems will not become practical in the future and hence only hybrid optical MINs are considered. In hybrid optical MINs, the electronically controlled optical switches, such as lithium neonate directional couplers, can have switching speeds from hundreds of picoseconds to tens of nanoseconds.

3 PROBLEMS
Path dependent loss means that optical signals become weak after passing through an optical path. In a large MIN, a big part of the path-dependent loss is directly proportional to the number of couplers that the optical path passes through. Hence, it depends on the architecture used and its network size. Hence, if the optical signal has to pass through more no of stages or switches, the path dependent loss will be more.

Optical crosstalk occurs when two signal channels interact with each other. There are two ways in which optical paths can interact in a switching network. The channels carrying the signals could cross each other. The second way is when two paths sharing a switch could experience some undesired coupling from one path to another within a switch.

4 SOLVE CROSSTALK
One way to solve the crosstalk problem is a space domain approach, where a MIN is duplicated and combined to avoid crosstalk. The number of switches required for the same connectivity in a network with space domain approach is slightly larger than twice that for the regular network. This approach uses more than double the original network hardware to achieve the same. Thus for the same permutation the hardware or we can say the no of switches will be double. Thus cost will be more with the networks using space domain approach. In the entire four cases only one input and only one output is active at a given time so that no crosstalk occurs. With the space domain approach, extra switching elements (SEs) (and links) are used to ensure that at most one input and one output of every SE will be used at any given time.

5 PERMUTATION PASSABILITY
Permutation passability means how many input requests occurring simultaneously at the input are able to pass through a given network and how many of them will successfully mature i.e. will reach their destination [21]. The request always pass from the most suitable path available (generally, the minimum length path), if such path is busy or faulty then the request is pass through an alternate path. If no alternate path is available then the request has to be simply dropped or said to be having clash. So some of the requests will pass through the most favorable path, others have to be routed through an available alternative path. If no alternative paths are available then some requests cannot be served at all. Crosstalk in optical networks is one of the major shortcomings in optical switching networks, and avoiding crosstalk is an important for making optical communication properly. To avoid a crosstalk, many approaches have been used such as time domain and space domain approaches. Because the messages should be partitioned into several groups to send to the network, some methods are used to find conflicts between the messages. If we allow the limited crosstalk in the optical networks the permutation passibility of the optical networks will be increased [21].

6 CALCULATION AND DISCUSSION
6.1 No of passes of Banyan Network
To avoid Crosstalk only one input is allowed to pass through one switch. For example, in Banyan network if all the 8 inputs get active only 4 inputs would be allowed to pass through the network towards its output to avoid the problem of crosstalk.

| Inputs  | 0 1 2 3 4 5 6 7 |
|---------|----------------|
| Output  | 7 0 5 2 3 6 1 4 |

It is decomposed into two permutations in the first Pass.

| Inputs  | 0 1 2 3 4 5 6 7 |
|---------|----------------|
| Output  | 7 0 5 2 3 6 1 4 |

These two passes would solve the crosstalk problem at the first and last stage, the Intermediate stage would still be having the problem of crosstalk. Thus the permutations again has to break to avoid the crosstalk.
problem. This can be done with the decomposition again. It can be possible with the bipartite graph. Crosstalk is the dangerous problem for the banyan Network. This should be removed.

Figure 1(a): Crosstalk at the Middle stage in Pass 1

Figure 1(b): Crosstalk at the Middle stage in Pass 1

To avoid this problem (crosstalk at the intermediate stage), we divide the permutations into semi permutations. Semi permutation of pass 1 in the given example is

| Input | 0 1 | 2 3 |
|-------|-----|-----|
| Output| 7 0 | 5 2 |

Second pass permutation will be

| Input | 4 5 | 6 7 |
|-------|-----|-----|
| Output| 3 6 | 1 4 |

Figure 1(c): Crosstalk at the Middle stage in Pass 2

Figure 1(d): Crosstalk at the Middle stage in Pass 2

6.2 Bandwidth Comparison

The bandwidth of stage banyan network \( N = 2^n \) is the network size is given by:

\[
BW = P(n) \times \text{Size of Network} [45]
\]

The value of \( P(n) \) can be obtained from the probabilistic Equations In this the effect of Crosstalk is studied on the Permutation of Optical MINS. Optical multistage interconnection networks (OMINS), which interconnect their inputs and outputs via several stages of switching elements using optical guided waves or free space, is studied. Although optical MINS hold great promises and have demonstrated advantages over their electronic counterparts, they also introduce new challenges and problems of avoiding cross-talks in the switching elements [45].

In this the effect of limited Crosstalk is studied on the Permutation of Optical MINS. Optical multistage interconnection networks (OMINS), which interconnect their inputs and outputs via several stages of switching elements using optical guided waves or free space, is studied. Although optical MINS hold great promises and have demonstrated advantages over their electronic counterparts, they also introduce new challenges and problems of avoiding cross-talks in the switching elements. Interact with each other. There are two ways in which optical paths can interact in a switching network. The channels carrying the signals could cross each other and When the two paths sharing a switch could experience some undesired coupling from one path to another within a switch. Crosstalk problem is more dangerous than the path-dependent loss problem with current optical technology. Thus, switch crosstalk is the most significant factor that reduces the signal-to-noise ratio and limits the size of a network. Luckily, first-order crosstalk can be eliminated by ensuring that a switch is not used by two input signals simultaneously. Once the major source of crosstalk disappears, crosstalk in an optical MIN will have a very small effect on the signal-to-noise ratio and
thus a large optical MIN can be built and effectively used in parallel computing systems. Initially it is checked that bandwidth of Optical Networks with crosstalk is greater than without crosstalk networks for Banyan and Baseline network. The bandwidth is calculated in terms of probability of whether the switch is active or not using the probability equations. The bandwidth without crosstalk and with crosstalk is calculated.

| Table 1: Banyan Network Bandwidth |
| Size | Bandwidth |
|------|-----------|
| 4    | 1.9       |
| 8    | 3.81      |
| 16   | 6.2       |
| 32   | 12.1      |
| 64   | 22        |

| Table 2: Bandwidth with allowing crosstalk to some extent |
| Size | Bandwidth |
|------|-----------|
| 4    | 1.9       |
| 8    | 6         |
| 16   | 10        |
| 32   | 16        |
| 64   | 54        |

7 CONCLUSION

In this, we analyzed various advantages of Optical Networks over the Electronic Networks. So, we conclude that for today's applications such as in WAN'S Optical networks are the promising choice to meet the high demand of Speed and Bandwidth. We concluded that optical loss can be removed by using the space and time-space approach. Bandwidths of OMINs have been analyzed with and without crosstalk. It has been observed that OMINs provide higher bandwidth with some crosstalk than without crosstalk.

8 FUTURE WORK

Bandwidth can be calculated under Traffic and Bursty conditions. Performance can be calculated for OMINs that do not have self-routing capabilities. Permutations Capability of more networks with or without faults can be checked.

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