An Insight into Optical Multistage Interconnection Networks: A Qualitative Perspective

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Abstract- Optical communication is considered as one of the fastest communication in present scenario. It provides quality oriented, reliable services than the wired communication. Due to the Advancement in the communication, it has made optical communication a reliable networking choice to meet the increasing demands for high bandwidth for the high performance applications. So, optical networks give high performance in terms of bandwidth. Although optical MINs hold great promise and have advantages over their electronic networks, they also hold their own challenges. In this paper the reason of why the optical communication is better for communication applications is given. Also it includes the Comparison of different interconnection Networking techniques.

Key Words: Network, Multistage, Crosstalk.

1. INTRODUCTION

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. 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.

Multistage interconnection networks MINs) have been an attractive interconnecting structure for high performance parallel computing systems. Available optical MINs were built mainly on banyan or its equivalent (e.g. baseline, omega) networks because they are fast in switch setting (self-routing) and also have a small number of switches between an input output pair. Banyan networks have a unique path between an input-output pair, and this makes them blocking networks. Non blocking networks can be constructed by either appending some extra stages to the back of a regular banyan network. To transfer messages from a source address to a destination address on an optical network without crosstalk, we need 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 (TDM). In each group, the paths of the messages going through the network should be crosstalk free.

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.

2. MULTISTAGE INTERCONNECTION NETWORKS

Multistage interconnection networks (MINs) consist of more than one stages of small interconnection elements called switching elements and links interconnecting them. Multistage interconnection networks (MINs) are used in multiprocessor interconnections networks. Multistage interconnection networks (MINs) are normally built on banyan or its equivalent networks such as baseline, omega, etc. A MIN normally connects N inputs to N outputs and is referred as an N × N MIN. The parameter N is called the size of the network. There are several different multistage interconnection networks proposed and studied in the literature. Figure 1 illustrates a structure of multistage interconnection network, which are representatives of a general class of networks. This figure shows the connection between p inputs and b outputs, and connection between these is via number of stages. Multistage interconnection network is actually a compromise between crossbar and shared bus networks of various types of multiprocessor interconnections networks. Multistage interconnection networks are:

- Attempt to reduce cost.
3. 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.

Switching in optical networks:

In optical networks, circuit switching is used. Packet switching is not possible with Optical Multistage Interconnection Networks. If packet switching is used, the address information in each packet must be decoded in order to determine the switch state. In a hybrid MIN, it means it require conversions from optical signals to electronic ones, which could be very costly. For this reason, circuit switching is usually preferred in optical MINs. So we assume that circuit switching is used.

Figure 1: A Multistage Network

Table 1: Properties of different Networks

<table>
<thead>
<tr>
<th>Property</th>
<th>Bus</th>
<th>Crossbar</th>
<th>Multistage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Reliability</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Configurability</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Complexity</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

4. PROBLEMS IN OPTICAL NETWORKS

Due to the difference in speeds of the electronic and optical switching elements and the nature of optical signals, optical MINs also hold their own challenges.

A. Path Dependent Loss:

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.

Figure 2: Types of Multistage Networks

There are lots of benefits of optical networks over the electronic ones. The main benefit of the optical networks over the electronic network is the high speed of the Optical signals. In the Optical networks light is transmitted which has a very good speed but in the electronic Multistage interconnection networks electricity is used which has very slow speed. The second advantage is the Bandwidth. These days applications in communication require high bandwidth. The optical networks give combination of very high bandwidth and low latency. That is why they have been used in the parallel processing applications. Optical MIN’s are also used in wide area networks which require less error probability and very high bandwidth. Fibre optic transmission distance is significantly greater than the electronic ones. The signal needs not to be regenerated in optical networks. Optical fiber has very less weight in comparison to electronic MIN’s. Thus Optical networks give the combination of high bandwidth and low latency.
B. Optical Crosstalk:

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. Alternatively, two paths sharing a switch could experience some undesired coupling from one path to another within a switch. For example, assume that the two inputs are y and z, respectively, the two outputs will have y_1 + l_1x and z_1 + l_1x respectively, where l is path loss and x is signal crosstalk in a switch. Using the best device x=35 dB and l=0.25 dB. For more practically available devices, it is more likely that x=20 dB and l=1 dB [1-5]. Hence, when a signal passes many switches, the input signal will be distorted at the output due to the loss and crosstalk introduced on the path.

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 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.

5. WAYS TO SOLVE CROSSTALK PROBLEM

A. Space Domain Approach:

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, we can say the no of switches will be double. Thus host 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 cross talk 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.

Figure 3: Ways to Avoid Crosstalk in the Network using Space Domain Approach.

B. Time Domain Approach:

Another way to solve the problem of crosstalk is the time domain approach. With the time domain approach, the same objective is achieved by treating crosstalk as a conflict; that is, two connections will be established at different times if they use the same SE. Whereas we want to distribute the messages to be sent to the network into several groups, a method is used to find out which messages should not be in the same group because they will cause crosstalk in the network. A set of connections is partitioned into several subsets such that the connections in each subset can be established simultaneously in a network. There is no crosstalk in these subsections. This approach makes importance in optical MINs for various reasons [5-9]. First, most of the multiprocessors use electronic processors and optical MINs.

There is a big mismatch between the slow processing speed in processors and the high communication speed in networks carrying optical signals. Second, there is a mismatch between the routing control and the fast signal transmission speed. To avoid crosstalk, we use the TDM approach, which is to partition the set of messages into several groups such that the messages in each group can be sent simultaneously through the network without any crosstalk. If we don’t allow crosstalk in the network that is if the crosstalk in the network is zero the performance of the optical networks will be less. But if we allow limited crosstalk in the network that is if we allow crosstalk in the earlier stages the performance of the networks improves. The performance of the optical networks will be very less than the non-optical networks if the crosstalk is zero. But the performance starts increasing if we allow limited crosstalk in the earlier stages of the networks. The bandwidth of a non-optical network is much more than optical networks.

6. CONCLUSION

In this, we analyzed the difference between Optical networks and Electronic Networks. We studied the 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.
REFERENCES


