Optimization Technique in Optical Interconnection Network

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ABSTRACT

The future of digital technology will be based on power efficient communication. Bandwidth improvement is based on latency and more power consumption by electronic circuitry. so there is dramatic growth in alternate technology like optics and optoelectronics in the digital world. The photonic switching is the first step towards low latency and low power consumption in the digital world. Here our approach is to optimize the number of switches in the optical interconnection network by using the wavelength division multiplexing (WDM).In this paper we have proposed an optical interconnection network where the numbers of switches are significantly reduced as compared to the existing interconnection networks. This reduction in switches in turn helps in reducing the hardware complexity, power consumption and latency in the transmission system. particularly in case where input communication lines are significantly large. This is verified analytically. Further, we have discussed the control mechanism of the purposed network in details.

Keyword: Optical Switching, Interconnection Network, Optical, Multiplexing, Clos Network, Benes Network.

1. Introduction:

Optical interconnection networks provides basic solutions to many of the problems associated with scaling the performance of the microprocessor from single-chip multiprocessors, and multiprocessor to board-scale processor–memory systems, to large -scale high-performance computing systems and data centers. Optical transmission systems offer bandwidth transparency that does not depend on signal frequencies. Optical components do not consume much power, in contrast with traditional electrical systems. Optical interconnection networks enable immense bandwidth scalability offered by wavelength-division multiplexing, where the multiple wavelength-parallel optical data streams may be transmitted in a single optical fiber. Also the networks simultaneously leverage time-division multiplexing, where optical data streams are combined serially on the same wavelength channel to form higher aggregate bandwidths.

These techniques increase the bandwidth densities far beyond what is possible with conventional electrical transmission systems.

Large scale high-performance computing systems, which have processor - processor and processor-memory communication, require high bandwidth and low latency. Optical interconnections are capable of transmitting Terabits of data per second and have recently been considered as possible solution to the electronic communication bottleneck in interconnection network [1-3].

In this paper we have proposed an optical interconnection network in order to reduce the number of switches as used in the traditional non-blocking interconnection networks such as Clos [4], Benes [5] and Cross Bar [6].

The proposed network consists of two stages and four blocks. The First stage is meant for input and the second stage is for output. The Input and output stages are further divided into two blocks. These blocks have equal number of lines that is if total number of input lines in the network are N then total number of lines in a block will be n=N/2. The header information H1 controls the switches of stage 1 whereas the header information H2 controls the switches of stage 2. The control information in both the headers must be different for all the input which is explained in the Reservation Table 1&2. The input line consists of an optical demultiplexer to separate the header and data from incoming packets. After getting separated, headers from all input lines reaches at optical multiplexer. And output of it reaches at optical demultiplexer to divide the header into H1 and H2. Now H1 reaches at splitter 1 and splitter 1 sends these signals to all the switches of stage 1. Similarly H2 reaches at splitter 2 and splitter 2 sends these signals to all the switches of stage 2. Headers activate the corresponding switches therefore input data reaches at their desired output line. Input data remains in the loop until the switches are not getting connected.

Figure 1 : Packet format

As shown in figure 2. There are six (N=6) input line. And all the working of this network is as described in the above paragraph.

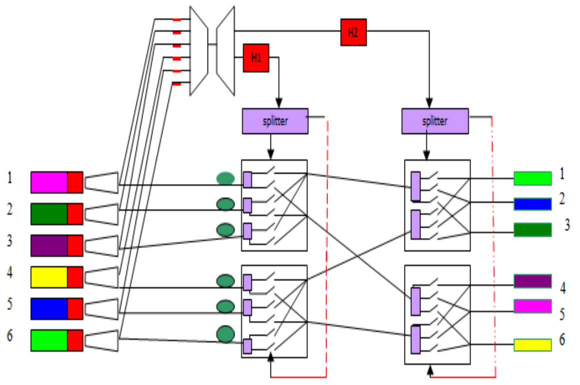

Figure 2 : Optical Interconnection Network

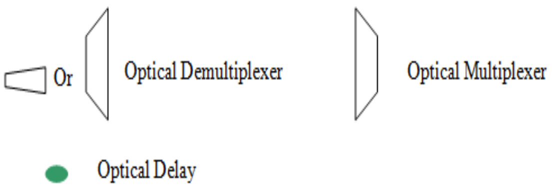

Figure 3 : Optical Interconnection Network Components

2. Wavelength assignment to different switches:

Since each switch will be controlled by a particular wavelength so we have assigned different wavelength to each switch as shown in reservation tables.

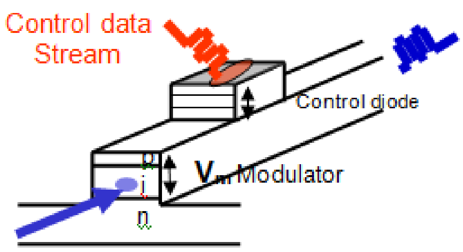

Figure 4 : Optical Switch

Switches at stage one will be controlled by the wavelengths assigned in reservation table 1. All of these wavelengths will be a part of first header (H1).

Switch No. / Line No.	1	2	3	4	5	6	7	8	9	10	11	12
1	$\lambda 1$	$\lambda 2$										
2			$\lambda 3$	$\lambda 4$								
3					$\lambda 5$	$\lambda 6$						
4							$\lambda 7$	$\lambda 8$				
5									$\lambda 9$	$\lambda 10$		
6											$\lambda 11$	$\lambda 12$

Table 1 : Reservation table for Stage 1

Switches at stage two will be controlled by the wavelengths assigned in reservation table 2. All of these wavelengths will be a part of first header (H2).

Switch No. / Line No.	1	2	3	4	5	6	7	8	9	10	11	12
1	$\lambda'1$	$\lambda'2$	$\lambda'3$									
2				$\lambda'4$	$\lambda'5$	$\lambda'6$						
3							$\lambda'7$	$\lambda'8$	$\lambda'9$			
4										$\lambda'10$	$\lambda'11$	$\lambda'12$

Table 2 : Reservation table for Stage 2

3. Technical Analysis of optical Interconnection network:

In ideal case, this optical interconnection network has two stages and each stage consists of two blocks for N input /output lines. And each block will have N switches. It implies that total numbers of switches in the network are 4N.

If each stage consists of three blocks (m=3) then total number of switches in entire network will be 6N. Similarly if a network consists of four blocks (m=4) at each stage then total number of switches in the entire network will be 8 N.

If we have m blocks at each stage and n input lines in a block then number of input lines for particular block is given by

$n=N/m$ (1)

Each block has N switches. And each stage consists of m blocks so total number of blocks in entire network is 2m.

Total number of switches = $2mN$ (2)

From (1) and (2) we get the

Total number of switches $=2N^2/n$ (3)

From (3) we concluded that if the number of lines n in a block increases, then total number of switches in the network will decrease.

So in ideal case we take m=2 blocks and n=N/2 number of lines respectively.

From above we get the total number of switches

$S = 2N^2/(N/2) = 4N$ (4)

If m=1 it means there is one block in input stage and one block in output stage. Input stage is now irrelevant. We only need switching at output stage and output stage is like a cross bar were we have the N^2 switches.

For best performance m should be equal to 2.

If m greater than two performances will decrease.

4. Comparison with other Non-blocking interconnection Networks:

From Table. 3 and graph given below it is clear that in the proposed optical interconnection networks by increasing the number of input lines the requirements for the numbers of switches will be minimum as compared to other interconnection networks.

No. of input lines (N)	Cross Network=N^2	Clos Network $=3.N^{1.5}$	Benes Network $=NLog_2N-N/2$	Optical Network =4N
2	4	8	2	8
4	16	24	14	16
8	64	68	50	32
16	256	192	145	64
32	1024	543	380	128
64	4096	1536	937	256
128	16384	4345	2229	512
256	65536	12288	5167	1024

Table 3 : No. of Switches requirements for different interconnection networks

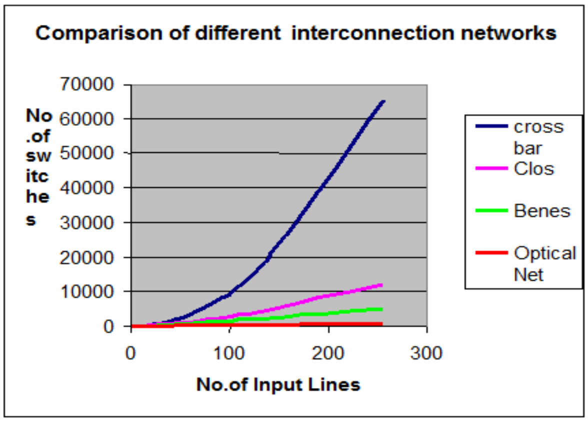

Figure 5 : Comparison of different interconnection networks

4.1. The variation of number of switches (S) with input lines (N) for constant m, where m is the number of blocks:

Here the switch complexity is given by

S= 2N m for $m \geq 2$ (5)

S= N (N+1) for m=1 (6)

For m=1 the switch complexity is different because output stage is just like a cross bar, whose switching complexity is N^2.

N	m=1	m=2	m=4	m=8
2	6	8	16	32
4	20	16	32	64
8	72	32	64	128
16	272	64	128	256
32	1056	128	256	512
64	4160	256	512	1024

Table 4: No. Of switches for given m, N.

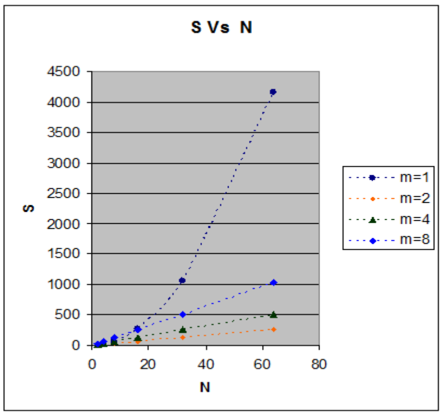

Figure 6 : Graph for the number of switches (S) vs input lines (N) for constant m.

4.2. The variation of number of switches (S) with no. of blocks (m) for constant N.

As the switch complexity is given by

S= 2N m for $m \geq 2$

S=N (N+1) for m=1

m	N=2	N=4	N=8	N=16	N=32
1	6	20	72	272	1056
2	8	16	32	64	128
4	16	32	64	128	256
8	32	64	128	256	512

Table 5: The variation of number of switches (S) with no. of blocks (m) at constant N

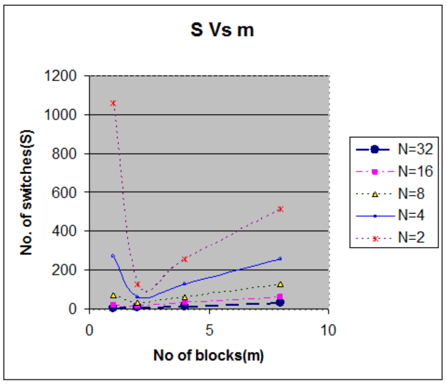

Figure 7 : Graph for the number of switches (S) vs no. of blocks (m) for constant N

It is clear from the above graphs that if we take two blocks in a stage then the numbers of switches required are minimum. So in the final structure we will be take m=2 in our optical interconnection network. As shown in figure 2.

5. Conclusions and Future Work:

In this paper we have presented that by using optical communication and switching technologies sufficient number of switches could be reduced in the interconnection networks.it is extremely beneficial when the number of input line increases. Although we have reduced the number of switches up to 4N but we hope in the future it could be reduced further .one of the limitation in our network is that the structure of the network could not be implemented in the electrical environment. But few other network structures can be used in both the environments. This will not affect much as the world is moving toward the optical technology..

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