A New Model of Cost Effective Clos Network

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***Abstract*—In this paper, a new cost effective model of clos symmetrical optical network is constructed and it is proved that the hardware implementation cost for the constructed network is lesser than the previous clos multistage optical networks.**

Keywords- cost effective, clos symmetrical network, optical, multistage..

I. Introduction

Owing to information explosion, the expansion of the Internet has always been running out of network capacity, which yields a continuously-growing demand on bandwidth from emerging bandwidth-intensive applications, such as video-on-demand services, video conferencing, and Ecommerce. Optical network, which features providing high bandwidth with low latency, has become an available option for networking.

Currently, there exists an enormous demand for bandwidth from many emerging networking and computing applications, such as data-browsing in the worldwide web, video conferencing, video on demand, E-commerce and image distributing. Optical networking is a promising solution to this problem because of the huge bandwidth of optics. As we know, a single optical fiber can potentially provide a bandwidth of nearly 50 terabits per second, which is about four orders of magnitude higher than electronic data rates of a few gigabits per second accessed by the attached electronic devices such as network processors or gateways.

Advances in this area have made optical communication a promising networking choice to meet the increasing demands of high performance computing/communication applications for high channel bandwidth and low communication latency. Fiber optic communications offer a combination of high bandwidth, low error probability, and gigabit transmission capacity. Multistage optical networks have also been extensively accepted as an interconnecting scheme for parallel computing systems. As optical technology advances, there is considerable interest in using optical technology to implement interconnection networks and switches. Depending on the interconnection scheme employed between two adjacent stages and the number of stages, various MINs has been proposed. Multistage interconnection networks:

- Attempt to reduce cost
- Attempt to decrease the path length

There are many types of multistage optical networks but clos network has gained wide attention due to its regular topology and low latency. It is be widely used for parallel and distributed networks.

A major problem in optical multistage network is the hardware implementation cost. In the following sections, the cost effective multistage clos symmetrical optical network is discussed which offers very low implementation cost in comparison with other models of clos symmetrical optical networks.

II. Clos Symmetrical Multistage optical Network

The traditional electronic three-stage Clos network, first proposed by Clos [1], is a type of multistage network and has been widely used in parallel and distributed systems due to its regular topology and low latency. The Clos network has three stages: the input stage, middle stage, and the output stage. Each stage is a stack of crossbar switches. In the $N_1 \times N_2$ three-stage Clos network $C(m, n_1, r_1, n_2, r_2)$ shown in Fig 1, there are r_1 input switches, m middle switches, and r_2 output switches, where $N_1 = r_1 \times n_1$, $N_2 = r_2 \times n_2$, and any crossbar switch is interconnected with any other crossbar switch in the adjacent stage by a unique link. Hence, the dimension of each crossbar switch in the input, middle and output stages are $n_1 \times m$, $r_1 \times r_2$ and $m \times n_2$, respectively. If $n_1 = n_2 = n$ and $r_1 = r_2 = r$, $m = n$ then the Clos network is symmetric and denoted as C (m, n, r).

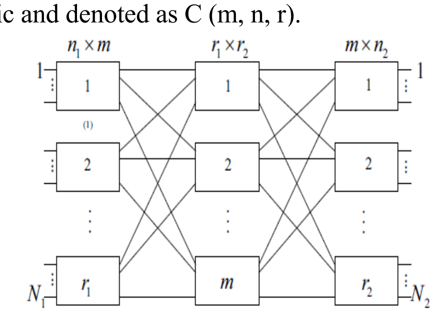

Fig 1 3-stage Clos Symmetrical MIN

The Clos networks can be classified according to route assignment algorithms of input calls as; strictly non-blocking (SNB), Wide-sense non-blocking (WSNB) and Rearrangeably non-blocking (RNB). A Clos network is strictly non-blocking (SNB) if there is always an available path for an input call request, and if there are more than one choice of middle switches, one of them is arbitrarily chosen without consideration of future call requests. A wide-sense non-blocking (WSNB) network can always provide a connection path for an incoming call without rearranging current connections, but each connection path is selected according to some predetermined rules that guarantee future requests will not be blocked. A Rearrangeably non-blocking (RNB) network allows rearrangements of existing connections to accommodate a new call request.

III. Cost Effeective Clos Symmetrical Multistage Network

It can be seen in [1] that using a single stage crossbar network to implement an N × N Optical Multistage network requires N^2 cross-points/switches, which can be very expensive for a typical Optical Multistage network with hundreds of fibers and wavelengths. To reduce the hardware complexity, a Clos multistage optical network [1], which consists of smaller crossbars (switches) at each stage, can be adopted. It has been shown in [2] that the hardware implementation cost can be reduced by using 3-stage (N x N) Clos Optical Multistage symmetrical network up to $O(N^{3/2})$. To reduce the hardware implementation cost of a (N x N) Clos Optical Multistage symmetrical network further, 3-stage Clos Optical MIN is extended to 5-stage, which consists of smaller crossbars (switches) at each stage. A 5-stage Clos symmetrical Optical network is constructed using a 3-stage symmetrical Clos Optical network.

A. *Steps to construct a 5-stage Clos symmetrical Optical network*

- Assume an (N x N) single stage network as shown in fig 2

Fig 2 single stage network

- Replace the (N x N) single stage network with a 3-stage network (with N inlets and outlets) which consists of n_0- number of switches of (n_1 x m_1) with n_1-number of inputs to each switch of first stage and m_1-number of outputs of each switch, where $n_0=n_1=m_1=\sqrt{N}$ as $N=n_0n_1$ and $m_1=n_0=n_1$ for symmetrical 3-stage Clos multistage network [3]. The second stage consists of m_1-switches of (n_0 x n_0) and the third stage being a mirror image of first stage consists of n_0-switches of (n_1 x m_1). A 3-stage Clos symmetrical network is shown in fig 3

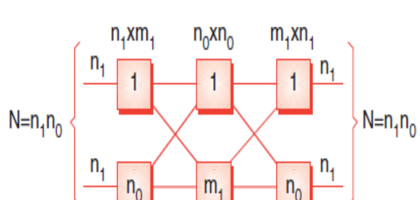

Fig 3 3-stage Clos symmetrical network

- Now replace each of the middle stage switches with a 3-stage Clos symmetrical network, having same number of inputs and outputs as the switch has. As shown in fig 4, a 3-stage Clos network has $N=n_1n_0$ as input and output, so each of the middle stage network will have the same value as input and output, shown in fig 4. Thus, in 5-stage Clos symmetrical network, the first stage consists of ($n_2n_1n_0$)-number of switches of (n_2 x m_2), the second stage will be the first stage of each middle stage network which is being replaced by a 3-stage Clos symmetrical network and the third stage would be the middle stage of 3-stage Clos network, fourth stage would be the third stage of 3-stage Clos symmetrical network and final(fifth) stage would be the mirror image of the first stage with ($n_2n_1n_0$)-number of switches of (m_2 x n_2).

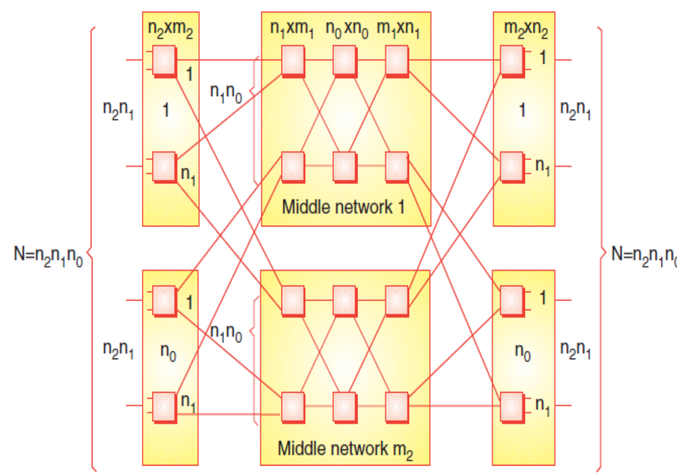

Fig 4 5-stage Clos symmetrical network

IV. Cost Analysis of Clos Symmetrical Multistage Optical Networks

In general, the hardware cost of a crossbar network is characterized by the number of crossbar switches (or cross-points), because these components are expensive, active devices and thus, play a major role in measuring the network cost. The following conditions should be taken into account to compute the number of crossbar switches for a 5-stage Clos symmetrical network;

- The middle stage switches is replaced by 3-stage Clos symmetrical network
- $N = n_2 x n_1 x n_0$, $n_2 = n_1 = n_0 = n$, so $n = (N)^{1/3}$
- For symmetrical network, $m_2 = n = (N)^{1/3}$

Therefore using all these conditions the cost of 5-stage Clos symmetrical network is given by;

$$C(5) = 2n_0n_1m_2m_1 + 2n_0n_1n_2m_2 + n_0^2m_1m_2$$

$$C(5) = O(N)^{4/3}$$

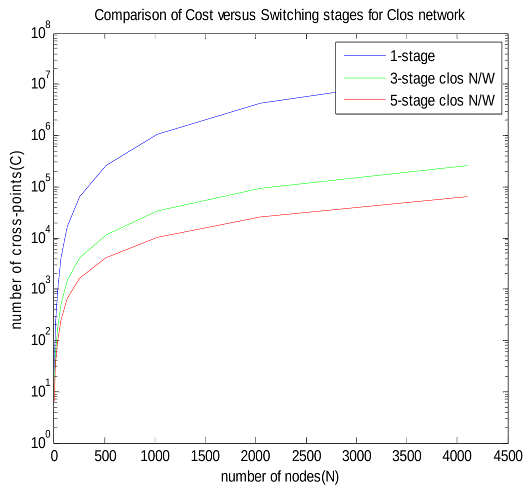

Fig 5 Comparison of Cost versus Switching stages for Clos network

Therefore it is clear from the experimental results that our 5-stage Clos symmetrical network constructed is cost effective than previous models of Clos symmetrical network.

V. CONCLUSION

The cost analysis is done using 8X8 5-stage Clos symmetrical optical network and the results obtained shows that the implementation cost of this network is lesser than other multistage Clos symmetrical networks.

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