Performance Analysis of Continuous Wavelength Optical Burst Switching Networks

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Abstract

Considering the economic and technical aspects of wavelength converters, full wavelength conversion capability will not be available throughout optical networks in the foreseeable future. In this paper we have used balanced static wavelength assignment (BSWA) algorithm. It is a technique to improve the performance of an all-optical network in respect of blocking probability & other parameters to provide cost effective optical communication system. We carried out the performance analysis of wavelength-continuous optical burst switching network-using BSWA for the network topologies namely NSFNET and INTERNET2NET with the initial assumption that there is no wavelength converter or optical buffer in the networks. For simulation we have used a powerful tool MatplanWDM. The performance analysis of burst loss probability v/s traffic load using BSWA algorithm shows that its performance is better than other static wavelength assignment algorithm. We have also explored the performances of NSFNET and INTERNET2NET networks on the basis of channel utilization, message delay, and the ratio of traffic transferred in single hop to total traffic offered against percentage of reused wavelength in the network. It has been observed that channel utilization becomes the maximum for 40% of reused wavelengths per fiber and beyond that cost of network unnecessary increases. By the performance analysis of message propagation delay for both network Topology, it is observed that message propagation delay, is minimum at 40% of reused wavelength per fiber and it becomes constant beyond that. It is therefore recommended that reused wavelengths per fiber should not exceed 40 % of the total available wavelength so as to yield cost effective solution with optimum performance.

Keywords: BSWA: Balanced Static Wavelength Assignment, OBS: Optical Burst Switching, OADM: Optical Add/Drop Multiplexers, OXC: Optical Cross-Connect, TBS: Terabit Burst Switching, PWA: Priority Wavelength Assignment.

1. INTRODUCTION

Due to the introduction of various wide band applications, such as video conferencing, broadband wireless communication [1] etc the demand of transmission capacity is growing exponentially. This has motivated the researcher to device & employ different techniques [2,3] to enhance the existing transmission capacity of optical terrestrial and wireless networks. In order to accommodate this wide capacity requirement, efficient and cost-effective wavelength division multiplexing (WDM) can be used between network nodes [4]. Today up to several Tbit/s traffic can be carried by the optical link over long distances. e.g. in an ultra-dense WDM transmission total capacity of 50 Tbit/s have already been experimentally demonstrated [5]. However, with the introduction of very high capacity WDM optical transmission techniques, the discrepancy between optical transmission capacity and electronic switching capability increases. Moreover, due to cost and complexity aspects, it is advantageous to keep data in the optical domain and to avoid bit-level signal processing. Burst switched WDM optical networks are coming up as suitable network architectures for future Optical Internet backbones [6]. Optical Burst Switching (OBS) has emerged as a new paradigm for an optical Internet [7]. During the past years, there are large efforts to realize OBS. Although the concept of burst switching had already been known since the 1980s, it has never been a big success in electrical networks. The main reason is that its complexity and realization requirements are comparable to that of more flexible electronic packet switching techniques. Optical circuit switching (OCS) does not support fine switching granularity on the packet-level. Only poor bandwidth utilization is obtained due to the absence of statistical multiplexing. On the other hand, Optical Packet Switching (OPS) are still too complex to be realized in the near future. Therefore, a hybrid approach like burst switching seems promising for the WDM-based optical networks. Optical burst switching (OBS) was proposed in the late 1990 [7,8] and it tries to exploit the advantages of both OCS and OPS approaches and avoid a part of their limitations. OBS is considered as one of the most promising approaches to implement IP over WDM [9]. At the moment, due to the fast development of this new approach and the large number of new proposals, OBS is still at its definition phase and no common definition of OBS can be found. However, among several different definitions two main definitions can be found. One is more oriented towards fast wavelength switching. Synonyms like optical flow switching (OFS) [10] and wavelength routed OBS (WR-OBS) [11,12,13] can be found in the literature. Here, an acknowledged two-way reservation is generally used. A burst will be only transmitted after having received a positive acknowledgement of its reservation request. Another most widely used definition for OBS is more packets oriented and was proposed by Qiao and Turner [14,7,8].

To realize an OBS network, a new optical layer is mandatory. Furthermore, an OBS network will be only possible if fast and efficient switching nodes can be built. To constitute the OBS network nodes several key components are needed e.g. optical space switches, tunable filters/lasers, wavelength converters etc. Most of the studies on OBS networks assume that full wavelength conversion is available throughout the network. However, such capability is not at present a realistic assumption. Although use of wavelength converters give better performance with respect to blocking probability but it is quite expensive. So, the absence of (full) wavelength conversion capabilities calls for good and efficient wavelength assignment policies. The Wavelength Assignment Algorithm is a method to improve the performance in respect of blocking probability and to provide cost effective communication system. To solve the above problems there have been developed number of wavelength assignment techniques e.g. Random, FF-TE, BSWA etc. Traditional first-fit or random wavelength assignment algorithm in OCS network is not appropriate for wavelength-continuous OBS networks, since the burst is transmitted without knowledge of the wavelength occupation status of the following links.

Out of the number of wavelength assignment techniques we have selected Balanced Static wavelength assignment (BSWA) algorithm. The BSWA algorithm is new and improved wavelength assignment policy [15] In BSWA wavelength order lists are carefully designed during the network-planning phase, and no extra information exchange or signaling is needed. The BSWA improves the performance of blocking probability vs. traffic load than other existing static wavelength assignment policies. The BSWA also reduces the cost of communication system because it reduces the number of wavelength converters, which is too costly. The BSWA has improved the performance in respect of blocking probability as compared to other static approaches. Numerical results show that BSWA reduces the burst loss probability in comparison with existing static approaches, and almost achieves the same performance as PWA (Priority Wavelength Assignment) with the advantage that no extra dynamic information is needed. In this work performance analysis for NSFNET and INTERNET2NET networks have been carried out for various crucial parameters like burst loss probability, message propagation delay and channel utilization.

1.1 Optical Burst Switching (OBS)

The main characteristics of OBS can be summarized as follows:

- Client layer data (IP-Packet) is aggregated and assembled into variable length optical bursts in edge nodes. OBS assumes more extensive burst aggregation, to realize bursts with payloads typically carrying tens of Kbytes.
- There is a separation between control information (header) and user information (data) in space and in time. Control header packets are sent on a separate wavelength (out-of-band) and processed electronically in all OBS core nodes to set up the switch matrix before the data bursts arrive.
- Data bursts are asynchronously switched in core nodes and stay in the optical domain until they reach their destination edge node. Only wavelength conversion and/or some degree of regeneration are applied to the signal.
- Resources are allocated by using one-pass reservation, i.e., burst transmission is not delayed until an acknowledgment of successful end- to-end path setup is received but is initiated after the burst was assembled and the control packet was sent out.
- Burst switching does not require buffering inside the core network.

2. BSWA ALGORITHM & IMPLEMENTATION

To reduce the blocking probability, wavelength assignment techniques play an important role in OBS Network, which are not having full wavelength conversion capability. To address the burning problem of network congestion along with low cost, various wavelength assignment algorithms have been developed like First-Fit, Random, First-Fit-TE, etc. In this paper we have carried out the performance analysis of newly developed wavelength assignment algorithm, Balanced Static Wavelength Assignment algorithm. BSWA is capable of reducing the burning problem of network congestion to a substantial amount in comparison to other traditional wavelength assignment algorithm.

2.1 BSWA Algorithm

BSWA algorithm is static approach, which does not require the exchange of any information among network routers. Thus, the assignment rules are determined during the network-planning phase, depending on certain properties of the network like topology, routing paths, and traffic. In this work we used traffic information for wavelength assignment. In this BSWA tries to fully balance the traffic that shares common links between different source-destination pairs among wavelength on those links.

An OBS network is represented by a graph G (V, E), where V = $\{V_1, V_2,...,V_N\}$ is the set of nodes, and E=$\{E_1, E_2,\ldots,E_M\}$ is the set of unidirectional fiber links. The link $E(V_s, V_d)$ connects V_s to V_d and contains W different wavelengths labeled arbitrarily, say, , $\lambda_1, \lambda_2, \ldots\ldots, \lambda_w$. By $P\{V_s, V_d\}$, we denote the routing path from V_s to V_d, and $\rho(V_s, V_d)$ is the given traffic load from V_s to V_d. We define virtual_wl_cost(V_i, V_j, λ_k) to be the virtual cost of wavelength λ_k on link $E(V_i, V_j)$, and path_cost(V_s, V_d, λ_k) to be the cost of the the path on λ_k along which the source V_s sends bursts to the destination V_d. Thus , path_cost(V_s, V_d, λ_k) is calculated as

$$\text{path\_cost}(V_s, V_d, \lambda_k) = \sum_{E(V_i, V_j) \in P(V_s, V_d)} \text{virtual\_wl\_cost}(V_i, V_j, \lambda_k) \quad (1)$$

Balanced static wavelength assignment (BSWA) algorithm:

Input: $G(V,E)$, $P(V_s, V_d)$, $\rho(V_s, V_d)$ for all $s,d \in \{1,2,\ldots,n\}$

Output: $WA(V_s, V_d, t)$ for all $s,d \in \{1,2,\ldots,n\}$, $t \in \{1,2,\ldots,w\}$

Initialization: virtual_wl_cost $(V_i, V_j, \lambda_k) = 0$ for all $i, j \in \{1,2, \ldots ,N\}$, $t \in \{1,2, \ldots ,W\}$

FOR t← from 1 to W

FOR s← from 1 to N

FOR d← from 1 to N

Step 1: Compute the path_cost for each wavelength that has not been assigned before for this s-d pair.

Step 2: Choose the λ_k that has the least path_cost, and make it the wavelength assigned in this loop.That is, $WA(V_s, V_d, t)= \lambda_k$.

Step 3: Update virtual_wl_cost(V_i, V_j, λ_k) for all $E(V_i, V_j) \in P\{V_s, V_d\}$ by virtual_wl_cost(V_i, V_j, λ_k) = virtual_wl_cost$(V_i, V_j, \lambda_k) + \rho(V_s, V_d)$ (2)

The process of BSWA is stated as follows. First the cost of each wavelength on all links, virtual_wl_cost(V_i, V_j, λ_k) is initialized to 0. Then we begin to assign wavelengths for s-d pairs one by one. The value of path_cost(V_s, V_d, λ_k), $k \in \{1, 2, \ldots,w\}$, is calculated for each (V_s, V_d) pair, and λ_k that has the least path_cost is chosen as the wavelength assigned for the (V_s, V_d) pair.Every time we assign a wavelength (e.g. λ_k) for an s-d pair, we increase virtual_wl_cost(V_i, V_j, λ_k) on all the passing links of $P\{V_s, V_d\}$ by $\rho(V_s, V_d)$ so that the wavelength is less likely to be chosen by other s-d pairs if it is already heavily loaded. We continue to do this for all s-d pairs, so that each pair is assigned a wavelength. The process described is called searching loop W times, we can get a list of the wavelength assignment order for each s-d pair.

2.2 Implementation of BSWA Algorithm

To reduce the data congestion with low cost, we have used balanced static wavelength assignment algorithm to assign the wavelength for each source-destination pair (s-d pair). The programming of the BSWA algorithm has been coded in Matlab. We have used a very powerful tool named as Matplan-wdm to implement the coded algorithm. This works on the platform of Matlab7.0 or above version. The optimization in this tool will be done with the help of Tomlab, which is also a powerful tool for optimization. The algorithm has been implemented in two network topology namely NSFNET & INTERNET2NET as shown in Figure 1 & Figure 2 respectively. The NSFNET consist of 14 nodes and 21 bi-directional fiber links, where as INTERNET2NET consist of 9 nodes and 13 bi-directional fiber links. The traffic loads have been taken in erlangs per wavelength. The NSFNET have 40 maximum wavelengths per fiber where as INTERNET2NET have 32 maximum wavelengths per fiber. It is assumed that there are not available wavelengths converters and optical buffers in both networks. We have used the Dijkastra's shortest-path algorithm to calculate the route for each s-d pair [15]. In this algorithm each s-d pair will select shortest path in network to transfer the data. This algorithm has been also coded in Matlab. We have analyzed the burst loss probability by varying the traffic load in erlangs per wavelength. Similarly we have done performance analysis of channel utilization, traffic transferred in single hop, message propagation delay by varying the number of wavelengths per fiber. The channel utilization has been calculated as how many wavelengths channels are being used to transfer the data out of total wavelengths channels available in the network. The traffic transferred in single hop has been calculated as ratio of traffic transferred in single hop to total traffic offered in percentage. The message propagation delay has been calculated as the difference between the time that message being transmitted at transmitter and that is being received at receiver. It is assumed that burst dropped at transmitter have negligible propagation delay. The number of wavelengths per fiber varied as percentage of maximum wavelengths used per fiber in the particular network. For example in NSFNET maximum wavelengths per fiber is 40 and in INTERNET2NET that is 32.

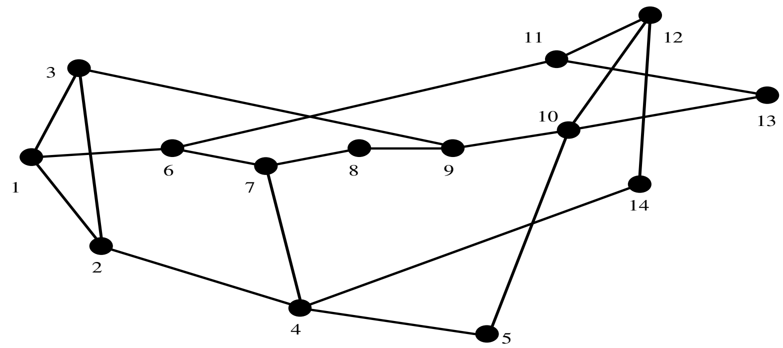

FIGURE 1: NSFNET (14 Nodes, 21 Bi-directional Link)

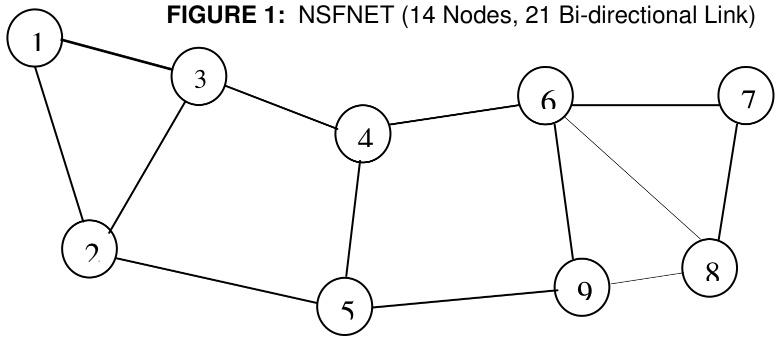

FIGURE 2:INTERNET2NET (9 Nodes, 13 Bi-directional Link)

2.3 Validation of BSWA

We have validated our simulated results generated through our code with the previously published results [15] as reported by Chunlei Zhu, Wenda Ni at all in their paper titled "New and Improved Approaches for Wavelength Assignment in Wavelength-Continuous Optical Burst Switching Network," By The tabular comparison of the two shows that the simulated result is in reasonably good agreement with the reported result [15]. The comparison of result is for NSFNET with 14 nodes and 21 bidirectional fiber links. The load is taken in erlangs per wavelength.

Table: 2.1 Result Validations

LOAD (Erlang)	Published Result (1)	Simulated
0.1	0.0015	0.002
0.2	0.009	0.009
0.3	0.026	0.03
0.4	0.05	0.06
0.5	0.08	0.08
0.6	0.12	0.12
0.7	0.15	0.15
0.8	0.2	0.19
0.9	0.25	0.26
1.0	0.30	0.30

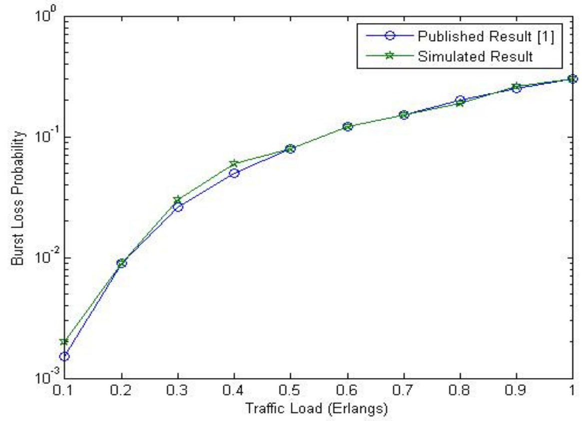

FIGURE 3: Result validation

The Figure 3 shows that there is small variation of simulated result from that with published result [15] up to 0.5 erlangs of traffic load and after 0.5 erlangs of traffic load the simulated result and published result [15] are almost coincident. Hence this shows that simulated results are in good agreement reasonably with that of published reported results [15]. Once the validation has been done, it is ensured that the simulated code is free from logical & other errors. Hence we can apply our code to other networks and applications.

2.4 Comparison of Various Wavelength Assignments

The comparision of various wavelength assignment policies with respect to burst loss probability have been shown in the Figure. 4. In this we can see at low load, burst loss probability is minimum for BSWA.This comparision is demonstrated for NSFNET network with 14 nodes, 21 bidirectional link.The load is in *erlangs per wavelength*. At high load burst loss probability is almost same as PWA which is dynamic wavelength assignment algorithm. Thus BSWA is giving optimum performance because it is giving almost the same result as PWA with the advantage that no extra dynamic information is needed.

The Figure 4 shows that up to 0.2 erlangs, the BSWA is giving optimum performance. After 0.2 erlangs load BSWA shows the same performance as PWA with small variation in burst loss probability and after 0.9 erlang it shows almost same performance as PWA. The advantage of BSWA is that it shows almost same performance as PWA without incorporating any extra dynamic information exchange.

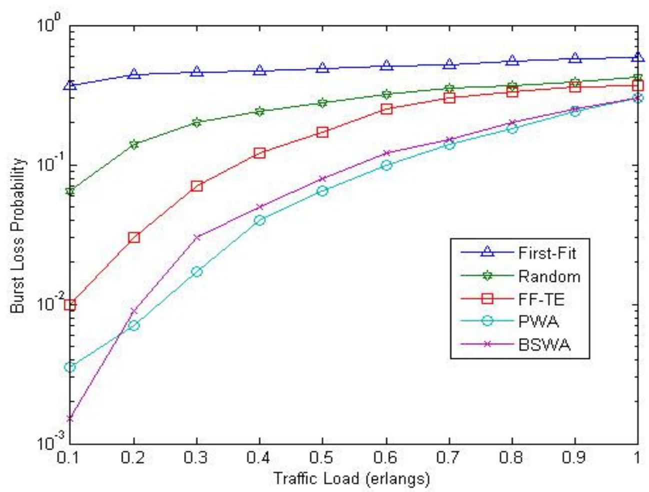

FIGURE 4: Traffic Load vs. Burst Loss Probability for Various Wavelengths Assignments Policies (NSFNET, 14 Nodes, 21 Bi-directional Link)

2.5 Performance Analysis

The performance analysis of wavelength-continuous optical burst switching network [17 has been carried out, by evaluating the performance of following parameters: -

2.5.1 Burst loss probability

Burst loss probability [17 is given by,

$$P_b = \frac{(\text{Numer of burst dropped})}{(\text{Total number of arrivals})} \quad (3)$$

Here we have assumed that if any route is blocked then coming burst through this rote will be dropped. Hence the burst loss probability has been calculated as the average blocking probability P_b for the network and is defined as average of the blocking probabilities on all the routes and is given by,

$$P_b = \frac{\sum_{r=1}^{R} Br}{R} \quad (4)$$

Where R is the total number of routes in the network.

Br is the blocking probability of a route r, which involves multiple links (say n links), is given by,

$$Br = 1 - \prod_{i=1}^{n}(1-Pi) \quad (5)$$

Where P_i is the blocking probability of a link i with capacity C (number of wavelengths on link) and is given by

$$P_i = R(L(i), C) = \frac{L(i)^C}{C!}\left[\sum_{n=0}^{C}\frac{L(i)^n}{n}\right]^{-1} \quad (6)$$

Where L (i) is carried traffic on link i which has frequency of usage, F_i and is given by,

$$L(i) = \sum_{j=1}^{F_i} L_r = \frac{L \times F_i}{R} \quad (7)$$

Where L_r is the load on any route r and is given by,

$$L_r = \frac{L}{R} \quad (8)$$

Where L is the total load (erlangs) on the network and is given by,

$$L = l \times N \quad (9)$$

and R is the total number of bi-directional routes and is given by,

$$R = \frac{N \times (N-1)}{2} \quad (10)$$

2.5.2 Channel Utilization

Channel Utilization [17] s given by,

$$U = \frac{\text{Average value of occupied channels in the network}}{\text{Total available channels in the network}} \quad (11)$$

$$= \frac{\sum_{i=1}^{J}\sum_{m=0}^{C-1}(C-m)P_i(C-m)}{C * J} \quad (12)$$

Total Available Channels = C × J (13)

Here Occupied channels = $\sum_{i=1}^{J}\sum_{m=0}^{C-1}(C-m)P_i(C-m)$; where $\sum_{m=0}^{C} P_i(m) = 1$ (14)

Where $P_i(C-m) = q_i(m)$ (15)

≅ Probability of finding C-m wavelengths occupied in link i

≅ Probability of finding m wavelengths free on link i

Where $q_i(m)$ is the probability of finding m idle or free wavelengths on link i and from the Birth-death model, $q_i(m)$ is given as,

$$q_i(m) = \frac{C(C-1)......(C-m+1)}{L_{eff}(i)^m} q_i(0);\ m = 1,2,.....C \quad (16)$$

Where

$$q_i(0) = \left[1 + \sum_{m=1}^{C} \frac{C(C-1)......(C-m+1)}{L_{eff}(i)^m}\right] \quad (17)$$

and $L_{eff}(i)$ is the effective carried traffic on link I and is given by,

$$L_{eff}(i) = \sum_{r=1}^{F_i} L_r(1+P_i-B_r) = L_r\left[F_i + F_i \times P_i - \sum_{r=1}^{F_i} B_r\right] \quad (18)$$

Since in the formula of channel utilization given, channel utilization mainly depends on value of occupied channels so we have simulated the result for average Occupied Channel used against total channel available.

2.5.3 Message propagation delay

This is the difference between the times of Message being transmitted from source and message being received at receiver. The assumption has been taken that dropped burst have no transmission delay.

2.5.4 Ratio of single hop traffic to total traffic offered

It is the ratio of traffic being transmitted in single hop to total traffic offered to network. In our simulation traffic is being transmitted through Dijkastra's shortest path [15].

2.6 Burst loss calculation for OBS Network using full wavelength converter capability

The objective of calculation of burst loss probability for full wavelength conversion capability network is to show that wavelength converters have very important roll to reduce the burst loss probability. The disadvantage of wavelength converter is, it is too costly. So to reduce the cost wavelength assignment policies is being used. Let in the OBS Network, there are (M+1) wavelengths per fiber link. In (M+1) wavelengths one wavelength is used as reservation channel for signaling and other M wavelengths channel carry data bursts. The bursts loss probability B on each fiber link is the same and is given by using the well known Erlang loss formula [16,17] with

$$B(A,M) = (A^M / M!) \,/\, \left(\sum_{i=0}^{M} A^i / i! \right), \quad (19)$$

Where A is the offered traffic load and M the number of wavelengths (which will carry data bursts) per out put fiber. Therefore A/M is the normalized offered traffic, which corresponds to utilization of output fiber of the node.

3. Results and Discussion

The typical network topologies we have used in this simulation are NSFNET (14 nodes, 21 bi-directional fiber links) and INTERNET2NET (9 nodes, 13 bi-directional fiber links) as shown in Figure 1 and Figure 2 respectively. We initially assume wavelength converters are not available. Dijkstra's shortest-path algorithm is used to calculate the route for each **s-d pair**. The performance of BSWA has been investigated by evaluating the performance of following parameters:

1. Burst loss probability vs. traffic load in Erlangs with BSWA.
2. Number of used wavelength channels v/s. % of wavelengths used per fiber.
3. Message propagation Delay v/s % of wavelengths used per fiber.

Further we have also calculated the blocking probability of OBS Network with full wavelength conversion capability using Erlangs Loss formula for NSFNET.

3.1 Burst Loss Probability with BSWA Algorithm

3.1.1 NSFNET Topology

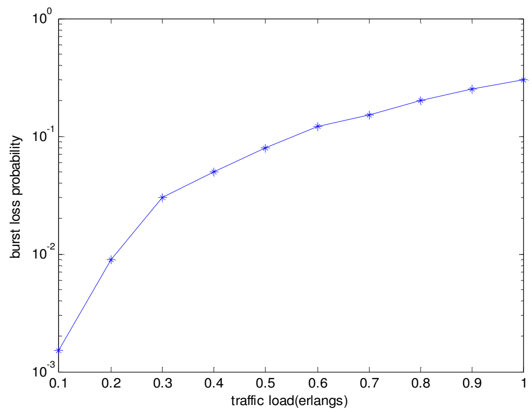

FIGURE 5: for NSFNET Topology

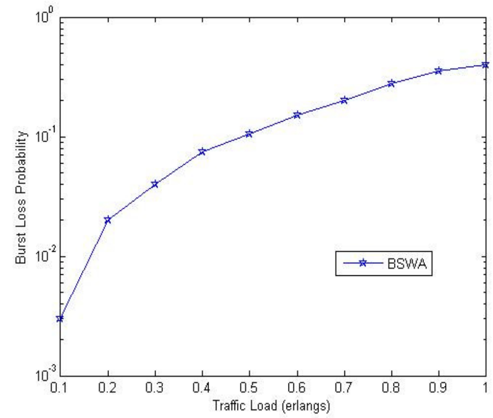

FIGURE 6:for INTERNET2NET Topology

The results of burst loss probability vs traffic load with BSWA algorithm have been shown in Figure 5 for NSFNET. We observe that as the load increases burst loss probability also increases. From Figure 5 it is evident that up to 0.3 erlangs traffic load, burst loss probability increases rapidly and at 0.3 erlangs it is approximately $3{\times}10^{-2}$.beyond 0.3 erlangs of traffic load, burst loss probability increases at aslower pace and after 0.8 erlangs it becomes nearly uniform (burst loss probability is approximately 0.2 to 0.3 as traffic load ranges between 0.8 erlangs to 1.0 erlangs) .

3.1.2 INTERNET2NET Topology

The results of burst loss probability vs traffic load with BSWA algorithm have been shown in Figure 6 for INTERNET2NET. We observe from Figure 6 as load increases burst loss probability also increases. From Figure 6 it is clear that up to 0.2 erlangs of traffic load, burst loss probability increases rapidly and between 0.2 erlangs to 0.5 erlangs of traffic load, burst loss probability increases but at a slower rate. At 0.1 erlangs burst loss probability is approximately $3{\times}10^{-3}$ and at 0.2 erlangs of traffic load it is approximately $2{\times}10^{-2}$. Beyond 0.5 erlangs of load, burst loss probability increases at a much slower rate while after 0.8 erlangs it becomes almost uniform, so no need was felt to simulate for more than 1.0 erlags of traffic load.

3.2 Number of Used Wavelength Channels vs. % of Wavelengths Used per Fiber

3.2.1 NSFNET Topology

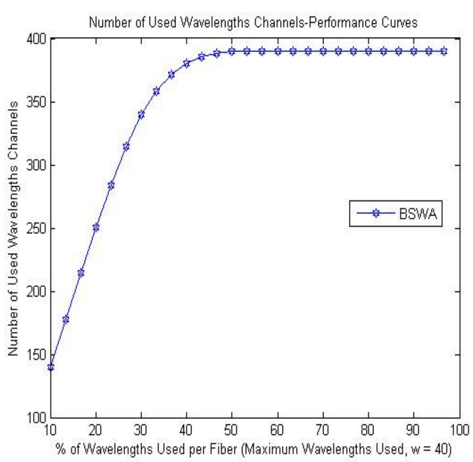

FIGURE 7: for NSFNET Topology.

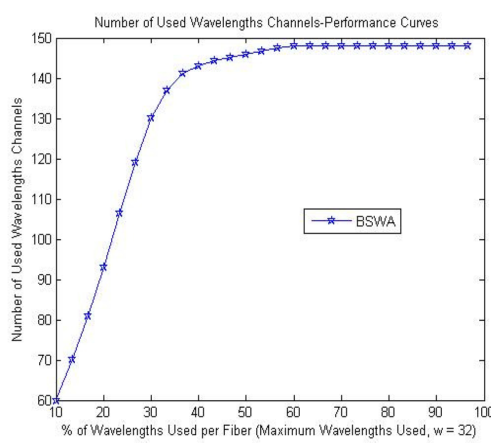

FIGURE 8:for INTERNET2NET Topology

For simulation we have taken number of wavelengths per fiber equal to 40 for NSFNET network. The simulation results are shown in Fig. **7** for traffic load of 0.2 erlangs. In Figure 7 at 10% of wavelengths used per fiber, number of used wavelengths channels are 140 and it increases with the % of wavelengths used per fiber. Again at 40% of wavelengths used per fiber (i.e. number of wavelengths per fiber w =16), the number of used wavelengths channels is 360 and that is almost constant after 40% of wavelengths used per fiber. Hence beyond 40 % , wavelengths reused per fiber more than 40% are unnecessary going to augment overall cost of the network.

3.2.2 INTERNET2NET Topology

Here for simulation we have taken maximum number of wavelengths per fiber = 32 . The simulation results are shown in Figure 8 for traffic load of 0.2 erlangs. As shown in Figure **8**, for 10% of wavelengths used per fiber, number of used wavelengths channels are 60 and it increases with the % of wavelengths used per fiber. Again at 40% of wavelengths used per fiber (i.e. number of wavelengths per fiber w = 12), the number of used wavelengths channels is 145 and thereafter it is almost constant. Hence here also the % of wavelength reused per fiber should not be allowed to exceed 40 %.

3.3 Message Propagation Delay vs. % of Wavelengths Used Per Fiber

3.3.1 NSFNET Topology

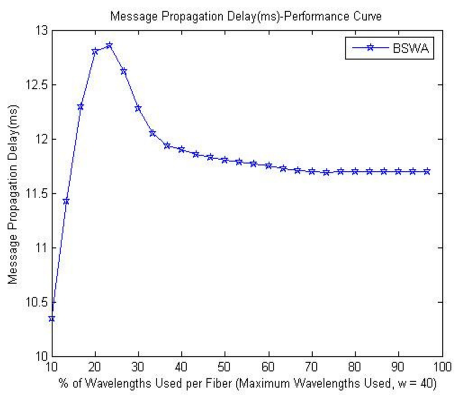

FIGURE 9: for NSFNET Topology.

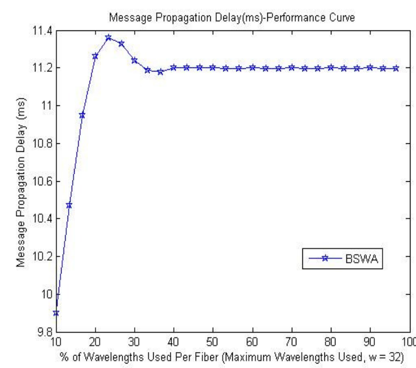

FIGURE10: for INTERNET2NET.Topology

we have assumed maximum number of wavelength per fiber W = 40 . The simulation results are shown in Figure 9 for traffic load of 0.2 erlangs. From Figure 9 we noticed that message propogation delay increases upto 25 % of wavelengths used per fiber and then it suddenly decreases. It become nearlyuniform 40 % of wavelength used per fibr. As % of wavelengths used per fiber increases up to 25%, message reaches from source to destination with significant delay and therefore initially the message propagation delay also increases.

However after 25% of wavelengths used per fiber, number of available wavelength channels also increases and more message are being propagated through single hop which led to decrease in delay up to 40% of wavelengths used per fiber. Thereafter it becomes saturated because all traffic is being propagated through the single hop. This investigation also reveals that wavelength used per fiber should be confined within 40 %.

3.3.2 INTERNET2NET Topology

For simulation we have taken maximum number of wavelength per fiber = 32 .The simulation result are demonstrated in Figure 10 for traffic load of 0.2 erlangs. Here also up to 25% of wavelengths per fiber, message propagation delay increases with a further decreases till 40 % and thereafter becomes nearly uniform . As % of wavelengths used per fiber increases up to 25%, message reaches from source to destination with a significant delay,thereby resulting in increase of message propogation delay.

Since after 25% of wavelengths used per fiber, number of available wavelength channels increases and more message are being propagated through the single hop which ultimately results in decrease of delay up to 40% of wavelengths used per fiber. Thereafter delay becomes saturated because all traffic is being propagated through the single hop. Hence the above investigation also reveals that % of wavelength used per fiber should be confined to 40 % as far as message delay is concerned.

3.4 Burst Loss Probability with full wavelength converter Capability with 8,16,24,32 wavelengths per fiber

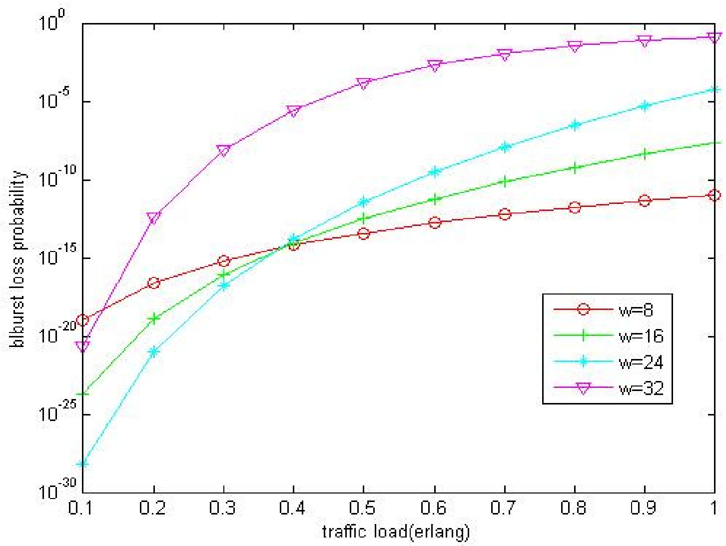

FIGURE 11: Burst Loss Probability vs.Traffic Load for full wavelength converters OBS Network

In FIGURE 11 burst loss probability vs traffic load per wavelength in erlangs have been shown for different number of wavelength per optical fiber. We can see at high traffic load beyond 0.4 erlags, number of wavelengths per fiber w = 8 is giving minimum blocking probability. The decreasing performance order is w = 8, 16, 24, 32 for traffic load per wavelength more than 0.4 erlangs. The decreasing performance order is w=24, 16, 8, 32 for traffic load per wavelength between 0.15 and 0.4 erlags. The decreasing order is w =24, 16, 32, 8 for traffic load per wavelength for traffic load less than 0.15 erlangs. Therefore from the above study we conclude that wavelength factor w=16,24 are giving better performance for different traffic loads as compared to 8 & 32.

4. CONCLUSION

In this paper we have discussed a novel static wavelength assignment approach, called BSWA, which can greatly reduce the burst loss probability by balancing the traffic that shares common links among wavelengths on those links. We have compared also the burst loss probability of various wavelength assignment policies and observed that at the starting of traffic load BSWA is giving relatively better performance among others. It has been also observed that without incorporating extra dynamic information and signaling cost, BSWA can achieve almost the same performance as dynamic techniques like PWA. The performance of BSWA algorithm with NSFNET and INTERNET2NET network has also been studied and it is observed that approximately 40% of wavelengths used per fiber give reasonably good results with respect to the parameters: message propagation delay and channel utilization. The performance with respect to various parameters can be individually summarized as follows: -

A. The performance analysis of burst loss probability vs. traffic load for both networks shows that it has been improved by BSWA algorithm as compared to other static wavelength assignment algorithm and it is almost same as PWA (dynamic wavelength assignment algorithm).

B. The performance analysis of number of used wavelengths channels vs. % of wavelengths Used per fiber shows that after approximately 40% of wavelengths used per fiber (i.e. for NSFNET 16 & INTERNET2NET 12 wavelengths per fiber), number of used wavelengths Channels become uniform. Hence it is recommended that beyond 40% of wavelengths reused per fiber the cost of network will increase without improvement in the overall performance.

C. The performance analysis of message propagation delay vs. % of wavelengths used per fiber shows that after approximately 40% of wavelengths used per fiber (i.e. for NSFNET 16 and INTERNET2NET 12 wavelengths per fiber), message propagation delay is minimum and nearly uniform. Here again it is observed that % of wavelengths used per fiber must be confined to 40 %, as there is no significant improvement in the performance beyond that.
Further we have also analyzed the performance with wavelength converters for different number of wavelengths per fiber and it is observed that wavelengths factor w = 16 and 24 reduces the blocking probability more efficiently in comparison with w= 8 & 32.

The above investigations ultimately conclude that % of wavelengths reused per fiber should not be allowed to exceed 40% as otherwise it augments the overall network cost without any further significant improvement in the performance of the network. The Performance analysis of Optical Burst Switching Networks for INTERNET2NET and NSFNET can also be carried out in future by using dynamic wavelength techniques. The possibility of optimizing an arbitrary network topologies to yield better network performance can also be explored in future.

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