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Wavelength Division Multiplexing for Optical Burst Switched Networks

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ABSTRACT

Optical Burst Switching (OBS) is one of the important fast growing technologies in the next-generation Internet. The burst scheduling is one of the challenging issues in OBS networks. Existing scheduling algorithms consider unscheduled time and time gap between two successive scheduled bursts on a channel. In this paper, we propose a wavelength division multiplexing (WDM) algorithm for the OBS networks. This algorithm is implemented in two stages as switching and scheduling. Switching takes care of wavelength routing and optical switching. The scheduler performs the link and traffic scheduling. The channel selection is based on wavelength grouping for both real time and non real time data bursts. The channel utilization is improved and the data burst loss is reduced. The simulation results show that the proposed WDM algorithm performs better when compared with the existing algorithms.

Keywords: Optical Burst Switching, Wavelength Division Multiplexing

1. INTRODUCTION

Nowadays all the enterprise networking solutions are in need of reliable and high speed network. The network in general relied on the circuit switching and packet switching technologies. As the optical fiber offers higher transmission capacity than the conventional copper-wire network, the optical networking is highly preferred. Optical Packet Switching (OPS) and Optical Circuit Switching are not efficient for better data transmission. The Optical Burst Switching (OBS) allocates the wavelength dynamically with the separate control packet. OBS combines optical circuit switching and optical packet switching for efficient usage of the bandwidth. Wavelength routing and packet switching in OBS networks are very challenging.

Designing of an efficient algorithm for scheduling the bursts is the key problem. A good scheduling algorithm should capable of processing the control packets fast enough before the burst arrives and finding a suitable interval for the burst. In this paper, Wavelength Division Multiplexing (WDM) algorithm for OBS networks is proposed. WDM facilitates to utilize the full bandwidth of the optical fiber. Channel allocation is done by assigning different wavelengths to each channel. The main objective of this algorithm is to reduce the burst loss and improve the channel utilization. The channel selection is done by wavelength grouping for both real time and non real time data bursts. Based on the data bursts, static wavelength grouping or dynamic wavelength is applied.

2. RELATED WORK

A partially preemptive scheduling technique combined with proportional service model is suggested to provide QoS. The data bursts are handled in parts and preemption is used due to the priorities of data bursts in a multi-service Optical Burst Switching (OBS) network environment. The service performance differentiation among defined service classes are predicted and controlled in this model [1]. A competitive analysis of a large set of online scheduling algorithms has been carried out to find out the best worst-case

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performance. It is suggested that all bursts should have the same length and should be scheduled according to their arrival time. The worst-case performance of online scheduling algorithms is improved by the channel reservation protocol Virtual Fixed Offset Time (VFO) [2].

A wavelength grouping approach for core nodes in OBS is proposed to control byte drop rates for different classes of traffic. Channel scheduling in OBS is implemented by the Preemptive Channel Scheduling Algorithm (PCSA). Regulative Wavelength Grouping (RWG) and priority based scheduling is applied to meet the QoS requirements [3]. The channel utilization is done in a limited time window by setting the criteria to select out the optimal channel in the Max-CU-VF channel scheduling algorithm. A hardware implementation is done with the combinational logic circuits to set up the 16 channel Max-CU-VF based scheduler. The complexity comparison is done between the MAX-CU-VF and Index-based scheduler and it is found that MAX-CU-VF algorithm works better [4]. Pre-Estimate Burst Scheduling (PEBS) algorithm is implemented for OBS burst scheduling to reduce the complexity of scheduling modules by precalculating parts of the scheduling decisions [5]. The unfairness among connections with different numbers of hop counts in the network is resolved by the new wavelength scheduling algorithm.

This algorithm reduces the blocking probability with burst duration weighting [6]. The data burst scheduling is mapped with the combinatorial optimization problem and the graph theory is applied to schedule the non-overlapping intervals. The group scheduling concept makes the scheduling of the bursts delayed so that a better decision can be made from all bursts. This improves channel utilization and reduces the burst loss probability [7].

Computational Geometry based burst scheduling algorithms (Min-SV, Min-EV, Max-SV, Max-EV, Batching FL and Best Fit) for OBS networks with and without fiber delay lines (FDLs) has been proposed. These algorithms have a short scheduling time for each incoming burst and maintain a low loss rate [8]. BERN/CRN typed routing is adapted to slotted OBS that achieves the improvement of the optical networks. The burst contention problems like enforced waiting control and scheduling are improved by this technique [9]. Buffer scheduling problem in bufferless, burst switched WDM networks is addressed in [10]. A scheduling algorithm with delayed scheduling solves this problem and minimizes the overall number of blocked bursts in the system. An online scheduler called delayed scheduling is designed to achieve minimal burst blocking in core nodes of WDN burst-switched networks.

Reduction in blocking probability depends on the input traffic. Batch scheduling in OBS networks is done with different optimization criteria based algorithms that will result in reduced data loss rate [11]. An index-based parallel scheduler for OBS networks achieves a high channel utilization and high processing speed at the same time. This algorithm also finds the feasible voids on different channels in parallel with O (1) time complexity. The channel scheduler is implemented in two phases [12]. OBS networks with linear computational complexity are applied with batch scheduling algorithm. The batch scheduling problem is modeled as a job scheduling with similar machines problem. This will lead to the design of an algorithm with linear computational complexity [13].

The analysis of the performance of horizon and void filling scheduling algorithms is done to find out the limitations. A reverse scheduling algorithm is designed by considering the first voids and then search horizons [14].

The effective void utilization and less data burst loss are achieved by the Best Fit Void Filling (BFVF) algorithm. This algorithm maximizes the channel utilization and minimizes the burst loss by selecting the channel which has the maximum void utilization factor [15]. The horizon scheduling algorithms results in low bandwidth utilization without utilizing the voids created by previously scheduled bursts. A modified Horizon scheduling algorithm with minimum effects (MHS-MOE) is alternate that suits for high speed network applications [16].

3. PROPOSED ALGORITHM

The proposed wavelength division multiplexing algorithm is implemented in two main stages namely Switching and Scheduling. Switching is the process of selecting the best optimal link and performing packet routing in the selected link. Switching stage is sub-divided into two task named as wavelength routing, optical switching. The wavelength routing is the route the packet in best available link and optical switching is the model to change the select link during route unavailability. Scheduling is the model of enable/access the link/channel to perform the switching process. Scheduling also divided into two sub-stages which are named as link scheduling, wavelength decision which is performed after switching process. Each packet contains two main entities which are packet header and burst traffic. Packet header which contains the meta information about the data.Burst traffic is the data (which includes both real time and non-real-time data).

Switching is implemented with the aid of Packet classifier, Scheduler and Spatial separation. Packet classifier classifies the real-time and nonreal-time data separately. Scheduler performs the priority ordering operation as link scheduling. Spatial separation of header and data (divided in each channel) is., dividing the data and header fields separately

3.1. Scheduler

The Scheduler is designed to perform the operation of both Traffic scheduler and link scheduler. It assigns which packet to be transmitted in which connected link. Burst traffic is divided into two main types as overlapping burst and non-overlapping burst. The overlapping burst is differentiated into minimum overlapping burst and normal overlapping burst and the non overlapping burst is separately handled without any sub types.

Burst allocation is performed based on channel availability which is modeled in 4 steps

1. traffic depends on free channel availability
2. already allocated (minimum usage)
3. remaining available channel
4. wavelength grouping

The components of the proposed algorithm are depicted in Figure 1.

WAVELENGTH DIVISION MULTIPLEXING

Switching
Wavelength routing
Optical Switching

Scheduling

Packet classifier

Scheduler
- **Traffic scheduler**
- **Link Scheduler**

Spatial Separation

Figure 1: Components of proposed WDM algorithm

Packets are buffers based on channel information which is included in packet, and it is decided, when to perform the departure process of the packet and order of departure. In wavelength grouping, Regulative wavelength grouping is used to decide which channel to select for transmission operation.

There are two types of wavelength grouping, which are static grouping and dynamic grouping. Static grouping is applied for delay in-sensitive packets and dynamic grouping is applied for delay sensitive (remaining all types).

Maximum channel utilization is executed by the scheduler by applying the stages below.

- Formation of switching matrix (contains wavelength details)
- Optimal channel selection
- Judgment engine
- Weight assignment (which depend the oncoming packet rate)
- Channel reservation

3.2. Packet Classifier

Packet classifier is used to separate the packet based on the data type. It is applied for both incoming, outgoing packet. It classifies the packet into real-time and non-real-time packet. Packet header contains the information about the data which is currently transmitting. The field of the common header that contains the Hop to hop information is depicted in Table 1.

Table 1
Fields of the Common Header

Packet type
Packet size
Interface ID
Addr type (unicast or broadcast)
Direction (from upper layer or from lower layer)
Previous hop ID
Next hop ID
Error Field
num_forwards (hop count information)

The Packet handling procedure is done as below. Whenever packet is handled by source node, then it performs following three tasks. These tasks are applied for the first packet number and the remaining packets are following the same route.

- wavelength conversion
- wavelength assignment
- wavelength routing

Two fields are newly added to the packet routing header, viz, packet indication field, packet type. Indication field denotes the operation to be performed indication field marked in routing header based on the route direction and number of hops (known packet classifier information) and the Packet type depend the value of the packet type in common header, the type is finalized and it is also attached in routing header.

3.3. Priority assignment

It is executed based on information contains in routing header information. This model performs wavelength conversion, wavelength assignment and routing for first packet.For the remaining packet routing only performed. It is performed based on the packet type. The priority assignment is depicted in Table 2.

Table 2
Priority Assignment

Priority	*Packet Type*
High	real time for real-time with streaming
Medium	remaining real time traffic
Low	non real time (cbr, cbr, ftp)

The real-time packets include the packets used in Streaming, Video, Voice and Audio. The non real-time packets are the packets used by the applications like FTP, Telnet, VBR and CBR. Totally it is combined process for the traffic for assigning priority. This information is attached to routing header which has three fields namely task indication field, packet type and packet priority information. Wavelength grouping is done by using this information.

3.4. Link scheduling

Second main stage to be performed is link scheduling. It is process of performing spatial separation. Here Data and header separated and we add a packet indication field to both to identify the packet. It performs disjoint separation in source and intermediate node. And it executes join process in destination node.

A —————— B —————— C

A->B

A->C

pktid-4 3 2 1 (B)   PI-8 3 2 1 (B)

pktid-4 3 2 1 (C)   PI-7 6 5 4 (C)

Pkt indication field is differing with pkt id.

Packet is separated into data and header. Instead of pkt id, pkt indication field is added in both sides. The packet id in the packet is removed and the packet indication field is attached.

Traffic scheduling:

It is executed based on packet priority and channel availability. The data packet is divided into overlapping burst and non-overlapping burst. The header field is processed as burst header packet.

DP->4 3 2 1

6 6 5 5

Priority 8 7 6 5 4 3 2 1

8 3 7 7 6 5 5 5

It is begins with packet grouping. And packet grouping is done depend on the priority

OB 12 (55) 34 (66)

OB 321 (555) 4 (6) 56 (77)

OB 7 3

OB 8 8

NOB 4 8 6 8

NOB 4 8 6 8 7 3

Wavelength is defined as channel. Channel availability checks the available channels and imitates the channel selection process. Channel usage is measured by a timer which is included in all channels. Timer is executed periodically for observation interval (1 sec). It monitors the number of incoming and outgoing packets and Channel ideal time which is calculated as current time-last used time.

Depends on the ideal time value channel availability is estimated with utilization

1. If Channel ideal time > observation interval, the Channel is free
2. If Channel ideal time == observation interval, the Channel is minimal used
3. All the other channel are remaining channel

The channel utilization ratio (UR) can be calculated as

UR = sum of incoming and outgoing packet / (current_time * channel_capacity)

UR is sorted ascending order and overlapping burst with high priority burst is selected and transmitted and un-utilized free channel is also assigned. Burst with next priority burst is selected and transmitted and minimal usage channel is assigned.

For Non-overlapping burst (NOB), the average priority is calculated. Depends on the value, the burst in free un-utilized channel is selected and transmitted.

3.5. Wavelength grouping

Channel selection is based on the Wavelength grouping. For all real-time packets, dynamic wavelength grouping is performed (DWG). For delay sensitive (telnet) non real time packets, dynamic wavelength grouping is performed (DWG). For all remaining other packets static wavelength grouping is performed (SWG).

3.6. SWG

For all non real time (prior value lies from 10 to 16). It is arranged in descending order. Very low priority has the preferred to select the maximal utilized remaining channel. If there is unavailability of channel, then we have to choose the maximal utilized minimum available channel

3.7. Order

1. Maximal utilized remaining (10 to 16) (low, medium, high)
2. Maximal utilized minimal available Class is assigned I, II, III for both packet and channel

Class of packet is I-low II-med III-hi

Class of channel I-MaxUtil, MinFree

II-MinUtil, MinFree

III-UnUtil/RemainingUtil, MinFree

3.8. Switching matrix

It contains row as packet priority and column as channel class as subclass (c1, c2, c3) as (123,456,789). This matrix is a binary matrix. If there is any difference in current usage and previous usage then 0, 1,-1 (0-no change, 1-current assigned, 2-previously assigned).

	C1	C2	C3
	123	456	789
9			
8			
7			
...			

Cj = sum i=1to6 (Pi) / 16

In order to assign the weight, consider max as 2, min as 1, cant as 0, and then the weight value of the switching matrix will be

-1-last used value 0

0-no change value 1

1-previous used value 2

Normalized weight of each channel Cj = sum i=1to16 Pi / (16*2)

To get the actual weight of the channel, just multiply the normalized weight of the channel with channel utilization

$$Wj = Cj * C\_util\_j$$

3.9. Judgment engine

Wj value of all channel is arranged in descending order.

Based on sorted wj classes are classified,

C-I, C-II, C-III

wj = recent switching * overall utilization

3.10. Wavelength conversion

lambda->freq calculation to transmit the data over optical fiber

Demux performs following operations,

- Combining data and header by matching packet indication field
- Order based on packet indication field
- Sort it based on traffic priority
- Forward the packet to packet classifier

4. PERFORMANCE EVALUATION

The performance evaluation of the proposed WDM algorithm is done with the following metrics.

1. Goodput
2. Throughput
3. Delay
4. Packet Delivery Ratio
5. Received Signal
6. Link Utilization

Figure 4.1 represents the goodput of the proposed algorithm which is high when compared to the existing algorithms. This results in the improved performance of the network.

Signals received in different intervals are depicted in Figure 4.2. The signal strength is high in the proposed algorithm because the channel selection is based on the wave length grouping.

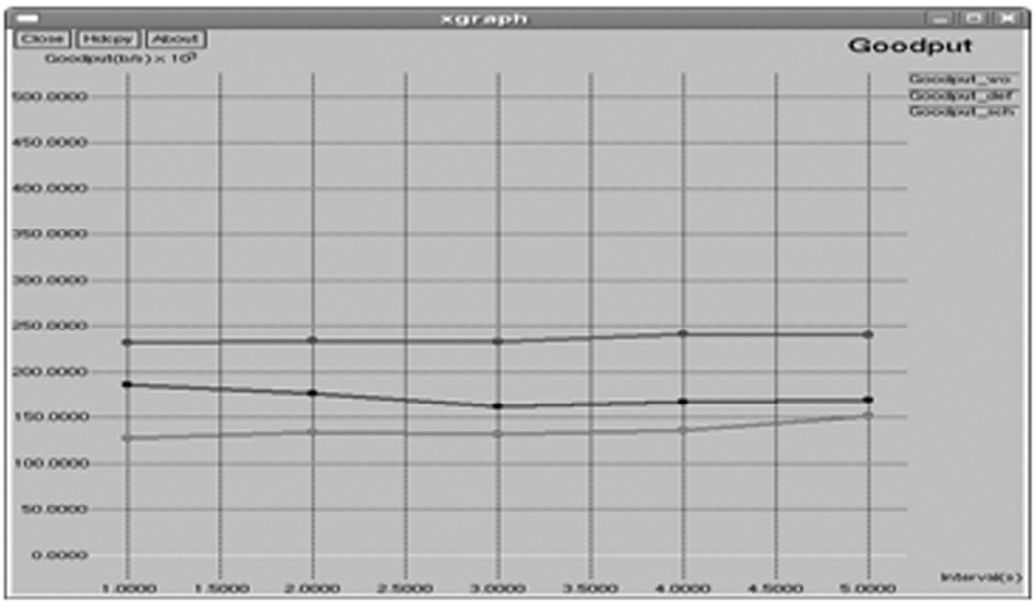

Figure 4.1: Goodput

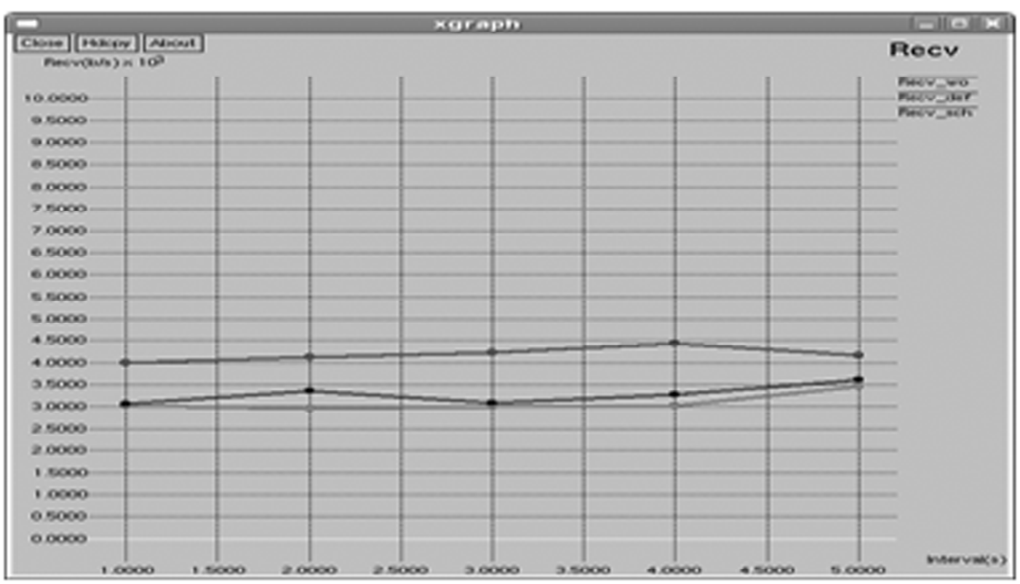

Figure 4.2: Signals Received

Figure 4.3 represents the throughput in the OBS networks when the WDM algorithm is applied. The throughput of WDM algorithm keeps rising when compared with the existing algorithms.

The delay of the network is measured and depicted in the Figure 4.4. The delay is 40s for all the time intervals whereas it is approximately 55s in the other algorithms.

The Packet Delivery Ratio is evaluated and depicted in Figure 4.5. The packet delivery ratio of the proposed WDM algorithm is almost 100% whereas the other algorithms have around 70% to 75%. The performance of the network is improved.

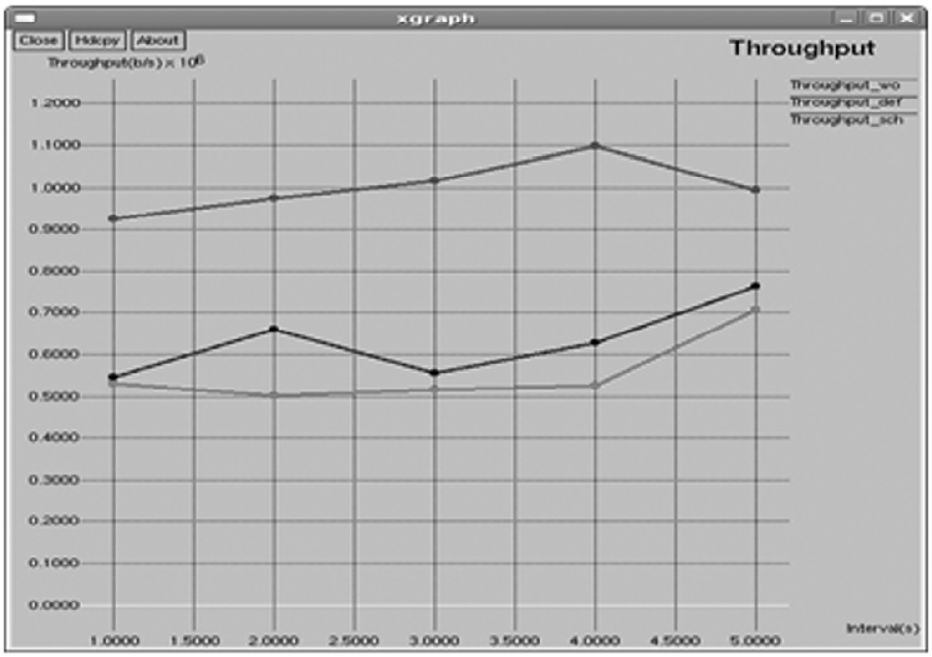

Figure 4.3: Throughput

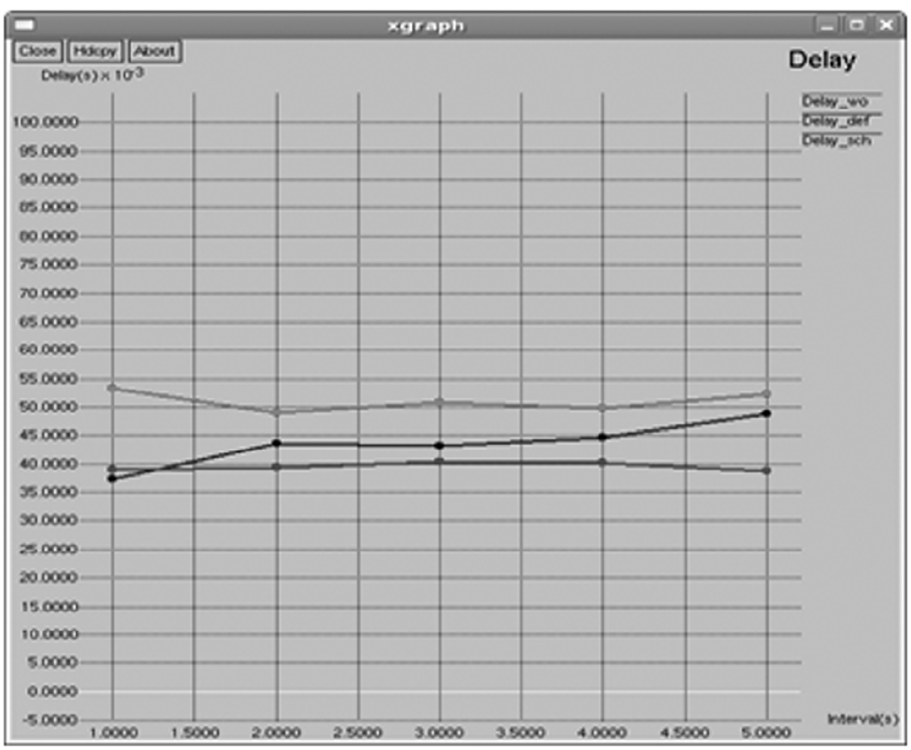

Figure 4.4: Delay

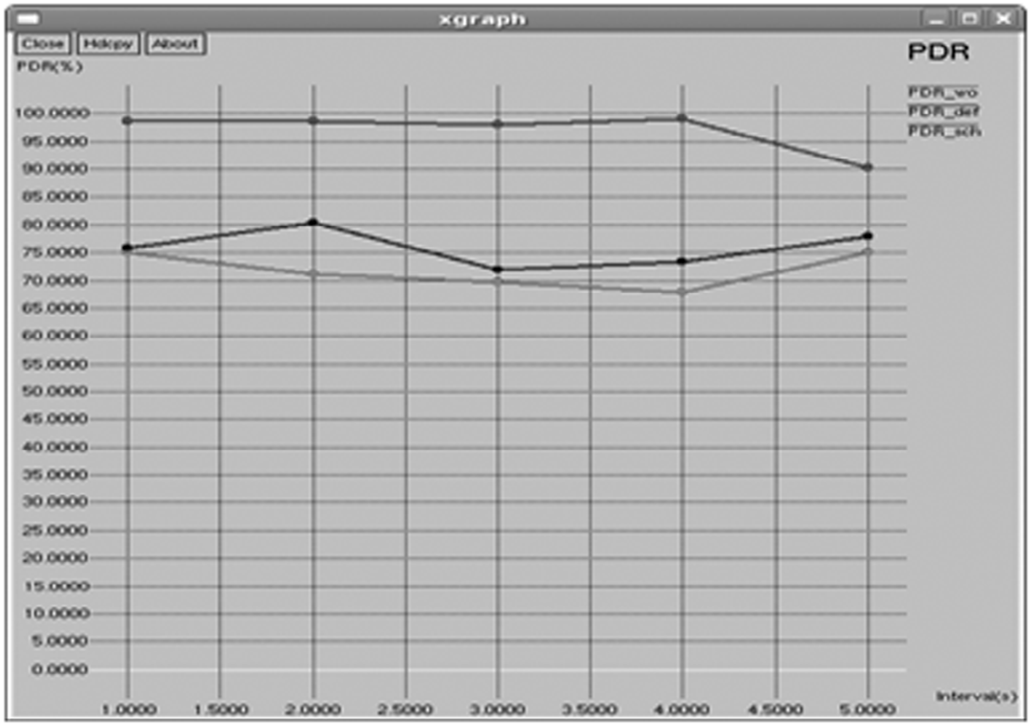

Figure 4.5: Packet Delivery Ratio

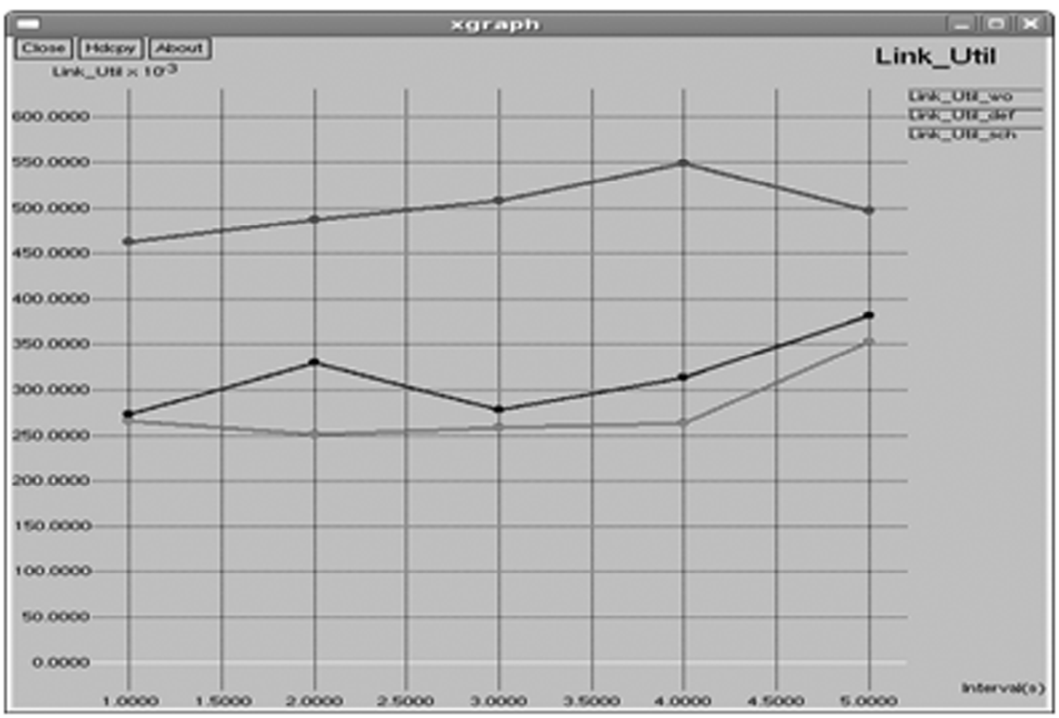

Figure 4.6: Link Utilization

The link utilization is depicted in Figure 4.6. Link utilization is the ratio of the traffic load on the link to the links capacity. The link scheduling is performed by separating the packets. This leads to the effective utilization of the channel link. The proposed WDM algorithm outperforms the other algorithms.

5. CONCLUSION

In this paper Wavelength Division Multiplexing (WDM) algorithm for OBS networks is proposed. Switching and scheduling are the two main tasks of this algorithm. The channel allocation is done based on wavelength grouping for both the real time and non real time data bursts. Static wavelength grouping or dynamic wavelength grouping is applied based on the type of the data bursts. The channel utilization is improved and the data burst loss is reduced when compared with the existing algorithms.

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