Segmentation-based On-Demand Burst Rescheduling Algorithm for Optical Burst Switched Networks

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Abstract—Optical Burst Switching (OBS) is a type of switching technology capable of harnessing the Wavelength Division Multiplexing (WDM) capability by aggregating different client packets into larger packets known as bursts. OBS is a promising candidate for near-future all-optical networks. However, large burst loss at the core node due to contention is a key issue and it is caused by the bufferless nature of OBS architecture. This paper focuses on scheduling as a means to reduce contention and improve the overall network performance in terms of loss and throughput. Two important design criteria for scheduling algorithms are speed and link utilization. These criteria are not supported in current scheduling algorithms due to the trade-off between control packet processing speed and efficient utilization of the bandwidth resource. In this paper, a Segmentation-based On-Demand Burst Rescheduling Algorithm (SODBRA) is proposed and evaluated. In SODBRA, the aforementioned trade-off is balanced by hybridizing First-Fit Unscheduled Channel (FFUC) with void filling scheme. The proposed scheduling algorithm was evaluated using the NCTUns 6.0 event driven simulator and emulator. The results obtained shows that SODBRA does reduce burst loss ratio, increase network throughput and outperforms most of the existing scheduling schemes especially as the load and the number of wavelength increases.

Keywords—Scheduling; Signalling; Optical Burst Switching; Burst Loss Ratio; On-demand burst segmentation

1 Introduction

As the information and communication technology (ICT) continues to evolve, it brings about the continuous emergence of new technologies as well as new bandwidth hungry applications such as the uncompressed high-definition television (HDTV) signals, zero-jittery supercomputing applications, etc. [1]. These bandwidth hungry applications are on the increase on the Internet and they require an efficient and effective technology that is capable of providing the required bandwidth as well as efficient services delivery. Optical Burst Switching (OBS) has emerged as one of the technologies capable of supporting bandwidth hungry applications and efficient services delivery. It is an optical switching technology which utilizes the full bandwidth potentials of the optical fiber cable through Dense Wavelength Division Multiplexing (DWDM) to transmit large amounts of data [2]. It draws its features from Optical Circuit Switching (OCS) and Optical Packet Switching (OPS) [3], [4]. In OBS, the packets of data to be transmitted are first assembled into a unit called burst at the ingress (edge) node and a special packet known as a control packet is generated and transmitted into the network at an appropriate time prior to transmitting the burst [2]. The control packet is processed using a signalling technique to establish a connection for the announced burst. When the control packet succeeds in establishing a connection, its burst simply cuts-through the intermediate nodes without any optical-electrical-optical (O-E-O) conversion in the core node [2], [5]. For a burst to be transported in an OBS network, a signalling technique must be implemented in order to configure the optical switches and allocate necessary resources for the burst at each intermediate node [6]. OBS uses out-of-band signalling in which one or more wavelengths are reserved for control packet transmission [7]. By using this method of signalling, the control packet and the data burst are more loosely coupled than in packet switching [2]. In OBS, signalling can be classified as one-way or two-way. In one-way signalling schemes, a burst is transmitted after a predefined amount of time known as the offset time. It neither waits for nor receives any acknowledgement before transmitting the burst. Examples of such techniques are Tell-And-Go (TAG) [8], Just-Enough-Time (JET) [[9], Horizon [10], Just-In-Time (JIT) [11], and their variants e.g. JIT+, pJET, Jumpstart [12], etc. In two-way signalling, an acknowledgement message must be received in response to a control packet sent before a burst can be transmitted [13]. The well known two-way signalling technique is the Tell-And-Wait (TAW) [14] technique. All the signalling techniques in an OBS network must employ a type of scheduling scheme [13]. The performance of the overall OBS network partly depends on the performance of the core nodes whose

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performance is further affected by the type of scheduling scheme used. Most of the existing scheduling schemes in OBS networks have a varying degree of complexity and none of them have the unique feature of low complexity, low burst drop ratio, and high bandwidth utilization.

In this paper, we propose a hybrid void filling algorithm which is based on the First-Fit unscheduled channel with Void Filling (FFUC-VF), On-Demand Burst Rescheduling (ODBR) and burst segmentation named: SODBRA. The aim is to reduce the burst loss ratio at the core nodes, such that the overall network throughput is improved.

The organisation of this paper is as follows: Section 2 describes the existing scheduling and rescheduling algorithms. Section 3 describes the proposed hybrid void filling algorithm. Simulation results are discussed in Section 4 and Section 5 concludes the paper.

2 Related Works

In OBS, scheduling is the process of allocating or reserving resources for a burst based on its requirements at an appropriate time. The main objective of scheduling is to minimize the idle spaces that exist between scheduled bursts which are scheduled for transmission over the same output channel [3], [4]. Scheduling in OBS networks differs from the normal internet protocol scheduling; this is due to lack of buffers in the core network to temporarily store and forward the burst in the event of contention [13]. Therefore, a burst should be forwarded immediately to the next node along its destination otherwise it will be dropped. [1] states that an ideal scheduling algorithm should be fast in processing control packets as well as utilize suitable voids efficiently. A void is the unused or idle space between two scheduled bursts on the same output channel. According to [15], channel scheduling algorithms can be classified into two main types; void filling and non-void filling. The major differences between these two categories are the types and amount of information they maintain for every channel on each node. Void filling algorithms keep track of latest unused resources on every channel while non-void filling algorithms keep track of the latest unscheduled resources on every channel [16].

First-Fit Unscheduled Channel (FFUC) is a simple scheduling algorithm which does not support void filling. FFUC scheduling is done in a fixed order so as to get the first available unscheduled channel satisfying the requirements of the burst [15]. It only needs to maintain the latest available unused time (LAUT) for every channel. FFUC has a time complexity of $O(logW)$, where W is the number of data channels on each optical fibre [4], [15], [17], [18]. Although FFUC is simple, it has the following setbacks: It is unable to utilize voids between scheduled bursts and it stops searching for an optimal channel after getting the first one that satisfies its requirements. As a result, FFUC has high-burst loss ratio. The Latest Available Unscheduled Channel (LAUC) scheme is similar to the FFUC except that it is not restricted to the searching and assignment of channels in a fixed order. It assigns the burst to the channel with the minimum LAUT. It has a time complexity of $O(W)$, where W is the number of data channels on each optical fibre. It is reported in [15] that LAUC has better resource utilization than FFUC and this is attributed to the ability of LAUC to assign channels based on a minimum time requirement.

The FFUC-VF scheduling algorithm is an improvement of the FFUC scheme and its main goal is to utilize the voids existing between scheduled bursts on the same output channel [15]. This scheme maintains a record of the starting and finishing times of each burst that is scheduled on every channel of the fibre link. This makes it more complex than the FFUC. Thus, the time complexity of the FFUC-VF algorithm with N burst scheduled on every data channel is $O(WlogN)$, where W is the number of channels on the fibre link. LAUC-VF is the void filling version of the LAUC scheduling scheme. It also maintains information similar to FFUC-VF but still assigns the burst to the channel with minimum LAUT. This enables it to have better bandwidth utilization when compared with FFUC and LAUC. Although it has a better bandwidth utilization capability, its implementation is complex and this leads to a slow performance of the scheme [17]. Its time complexity is given as $O(WlogN)$, where N is the number of burst scheduled on every data channel and W is the number of channels on the fibre link.

The researchers in [4] have proposed a non preemptive Minimum Overlapping Channel (NP-MOC) with and without void filling. The NP-MOC is based on the LAUC scheduling algorithm and in its case, it maintains information about the minimum overlap of all contending bursts on all channels in addition to the information used by the LAUC scheduling scheme. The channel with the minimum overlap is selected to transmit the burst. Their argument here is that, instead of dropping the entire burst, only the overlapping part of the affected burst should be dropped. This helps to reduce packet loss. This algorithm has a worst case time complexity of $O(W)$, where W is the maximum number of outgoing channels. NP-MOC-VF is similar to NP-MOC algorithm but it incorporates void filling. This scheme does not only utilize the voids between scheduled burst on the same output channel, it also selects the void that minimizes the gap between them [4]. In the worst case, the time complexity of the technique is $O(WlogN)$, where W is the maximum number of outgoing channels and N is the maximum number of bursts scheduled on a channel.

The On-Demand Burst Rescheduling (ODBR) scheme proposed by Tan et al. in [19] is a single-level rescheduling scheme and it is based on LAUC. The technique relies on its ability to change the channel already assigned to a burst before the burst arrives. This is in order to provide the unscheduled burst with the channel relinquished by the rescheduled burst. It consists of two phases: the base phase (LAUC) and the on-demand phase (ODBR). Phases one and two have a worst case time complexity of $O(W)$ and $O(W^2)$ respectively. Where W, is the total number of wavelengths per fibre. According to [19], since phase II is only invoked a few times (less than 10% probability) it still has a lower complexity than LAUC-VF. Aggressive Burst Rescheduling (ABR) scheme is another single-level rescheduling scheme also proposed by [19]. The ABR has two phases like the ODBR but it differs from it in the sense that, it is only invoked when phase one succeeds instead of when it fails. It is used as a preventive mechanism to forestall contention by rescheduling all bursts that have been scheduled successfully, thereby given a higher probability to accommodate new burst requests. The worst case complexity for both phases is $O(W)$ where W, is the total number of wavelengths per fibre.

In [20], a Pre-emptive Channel Scheduling Algorithm (PCSA) was proposed. The algorithm is based on On-Demand Burst Rescheduling with Void Filling (ODBR-VF) and ODBR-VF with burst segmentation. These schemes were designed with focus on quality of service (QoS) in OBS networks. The researchers claim that: by using the appropriate scheduling mechanism, guaranteed service is provided for bursts assembled using priority queues. Because the schemes are based on the LAUC-VF scheduling technique, they inherit its time complexity. Although scheduling is the focus of this paper, it is worth noting that there exist many other approaches to address the issue of burst loss in OBS. For instance, [21] have proposed routing optimization technique as an approach to reduce burst loss ratio in OBS networks. Furthermore, Yahaya et al., in [22] have proposed an ant-based route optimization algorithm which aims at reducing burst loss ratio and make better use of the large bandwidth provided by DWDM technology. In another approach, wavelength conversion was used to resolve contention. In such techniques, contending bursts are sent to a different out going wavelength in order to avoid burst loss at the core node. Contention-based limited deflection routing pro-posed in [23] is also another way of reducing burst loss due to contention at the core nodes. Burst loss ratio can also be reduced via signalling schemes. The TAW signalling technique proposed in [14] requires a connection to be established in order to transmit burst and with this feature it helps to reduce burst loss in the network. However, the high delay and non-efficient use of the bandwidth are the drawbacks of TAW based contention resolution mechanisms.

3 The Proposed Scheduling Algorithm: SODBRA

In this section, a description of the proposed scheduling scheme is given. This new algorithm is based on FFUC-VF, burst rescheduling [19] and burst segmentation techniques [24]. When a control packet (CP) arrives at a core node, the requested wavelength, arrival time and duration of the burst are extracted from the CP by the scheduler in order to reserve the resources for the incoming burst. Upon arrival, the CP is passed to the SODBRA scheduler which is composed of the FFUC-VF, ODBR and the ODBS Techniques. These techniques are then invoked in sequence depending on the success or failure of the previous technique. The information extracted from the CP is passed to the FFUC-VF scheme inside the SODBRA which then attempts to reserve the resources for the burst. If it succeeds, it schedules the burst and exits the SODBRA otherwise it invokes the ODBR technique which also attempts to reschedule an already scheduled burst to another wavelength in order to provide the newly requesting burst with the wavelength just freed by the rescheduled burst. If the ODBR succeeds at this stage then it reserves the resources for the newly arriving burst and at the same time it generates and sends an update CP to the subsequent nodes in order to notify them about the change in wavelength channel for the rescheduled burst. The process of updating the next node is adopted from the methods used in the original ODBR technique.

On the other hand, if the ODBR fails then the last part of the SODBRA is invoked; that is, the segmentation part. The segmentation technique will be invoked to segment the burst based on the type of segmentation setting (head or tail) of the SODBRA. After segmenting the burst, the segments are scheduled on the available wavelengths to forward them to the next node. Finally, if the segmentation fails then the burst will be dropped. The pseudo code of the algorithm is given in Fig.1

The major differences between the newly proposed scheduling algorithm and ODBR are described below.

Firstly, FFUC-VF is used as the base scheduling algorithm. The FFUC-VF scheme was chosen based on the fact that, it schedules a burst immediately upon getting the first wavelength that satisfies the burst reservation requirements; thus, FFUC-VF schedules faster than LAUC-VF. In LAUC-VF, all the available wavelengths are scanned first before choosing a suitable one. This makes LAUC-VF non-scalable and time consuming. Therefore, as the number of wavelengths increases its performance decreases. Therefore, the time taken by LAUC-VF to scan the entire wavelengths of a given fibre link can be used by FFUC-VF to schedule a burst.

Secondly, burst rescheduling in the existing ODBR algorithms is carried out only on the last burst of the selected wavelength. That is, if a reservation needs to be made and the burst that needs to be rescheduled is not the last burst on the selected wavelength, the ODBR will fail. In the proposed SODBRA, any bursts can be re-scheduled regardless of its position along the wavelength.

Thirdly, burst segmentation is also used in the proposed algorithm. It is only used when both FFUC-VF and ODBR fail to schedule a burst. This feature is not

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SODBRA(CP for burst b) based on FFUC-VF.

Let b_j and b_j+1 be two successive burst which are already scheduled on
wavelength n.
Let s_j and s_j+1 be the start time of burst b_j and b_j+1 respectively.
Let e_j and e_j+1 be the end times of burst b_j and b_j+1 respectively.
Let b, be a new unscheduled burst with start time s and end time e
Let n be any wavelength and N be the max number of wavelength in a
link.

SODBRA (CP for burst b){
FFUC_VF(){          //Phase One: FFUC-VF
    Starting at the wavelength requested by the new burst b, say
    channel n and continuing in that fixed order up to wavelength N,

    IF (channel n is free of any burst)
        Schedule new burst b, and exit SODBRA;
    ELSE IF (s>= e_j) {
        IF ((s <s_j+1) AND (e<= s_j+1))
            Schedule new burst b and exit SODBRA;  //Void filling
        ELSE
            Call ODBR();
    }
    ELSE IF (s <e_j)
            Call ODBR();     // Overlap exist
    ELSE IF(s >= e_j+1)
            Schedule new burst b; //No burst after burst bj+1.
    ELSE
            Exit SODBRA();
    }       //End of FFUC-VF

ODBR(){//Phase 2:  Modified ODBR

Step 1:   For every wavelength n, Determine if out-wavelength V_i is
          valid. Out-wavelength is valid,
          IF (The contending burst on wavelength n can be moved to
          wavelength V_i) AND (The new burst can be scheduled to n)
          THEN Out-wavelength V_i is valid;
Otherwise
          Out-wavelength is said to be invalid for n.
Step 2:   If no valid out-wavelength V_i exists,
             Call ODBS(); //Rescheduling failed,call ODBS()
          Otherwise,
             Choose wavelength n_p such that V_p is valid.
Step 3:   Reschedule contending burst on n_p to V_p.
                   Assign new burst to n_p.
Step 4:   Send a special NOTIFY control packet to notify the next
          node about the change in wavelength of the rescheduled
          burst.
                   Exit SODBRA();
       }  //End of ODBR

ODBS(){  //Phase 3:  ODBS

Step 1:   Determine the type of segmentation method used;
Step 2:   IF (Segmentation method is Tail Dropping)
          Segment the affected burst, generate and send control packet
          to inform the  subsequent nodes about the changes for the
          affected burst;
             Exit ODBS;
          ELSE
             Segment Burst;
             Exit SODBRA ();
      }   //End of ODBS

}         //End of SODBRA.
```

Fig. 1. Pseudocode of SODBRA

TABLE 1
Simulation Parameters

No.	Simulation Parameter	Value
1	Network topology	NSFNET
2	Bandwidth per wavelength	1 Gbps
3	Control packet processing time	2 micro seconds
4	Burst size or length	16 kilobytes
5	Number of wavelengths per link	9 (8 data , 1 control), 5 (4 data , 1 control), 3 (2 data , 1 control)
6	Burst Segmentation	On
7	Wavelength Conversion	On
8	Fiber Delay Lines	Off
9	Scheduling Schemes	FFUC, LAUC, FFUC-VF, LAUC-VF, ODBR, ODBR-VF and SODBRA
10	Simulation tool	NCTUns 6.0
11	Load Intensity	High , Low

available in most of the scheduling algorithms and it is a unique feature of this new algorithm.

4 Results and Discussion

This section elaborates and discusses the results of the proposed scheduling algorithm which was developed to overcome the shortcomings of the basic scheduling techniques. Simulation parameters are listed in Table 1. Fig. 2 depicts the burst loss ratios for the basic types of scheduling techniques; that is LAUC and FFUC. From this figure, it can be seen that the performance of these algorithms are similar for the network loads between Erlang 0.1 to 0.4, that is, when the load is less than 50%. As the network load increased, a difference between the two techniques was noticed. This is attributed to the ability of the LAUC technique to utilize its inherent resource utilization mechanism to schedule burst optimally as the load increased. As for the FFUC technique, its burst loss ratio increased steadily as the load became very heavy. This phenomenon can be observed between the 0.6 and 0.8 load marks. This high burst loss is due to poor utilization of the resource.

Fig. 3 shows the loss results of different scheduling and rescheduling techniques. From this figure, a significant improvement in terms of burst loss performance for the void filling techniques is observed. This improvement can be attributed to the ability of the schemes to utilize voids on all out going data channels. However, the LAUC-VF still performs better than the FFUC-VF because of its efficient utilization of the network resources (wavelengths).

Furthermore, from Fig. 3, it is obvious that ODBR out-performs its competitors. The high performance of ODBR compared to others is achieved by scheduling more bursts as quickly as possible. Also, the FFUC-VF variant of the ODBR technique outperforms its LAUC-VF counterpart. This is because; the ODBR combines the concept of scheduling burst as quickly as possible (a unique feature of FFUC-VF) with the ability to move

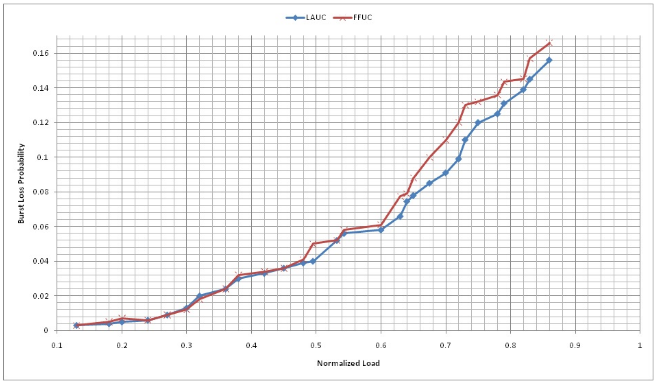

Fig. 2. Burst Loss Ratio against Load for FFUC and LAUC

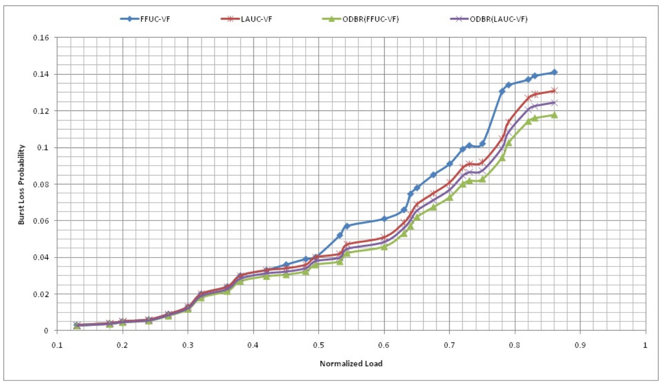

Fig. 3. Burst Loss Ratio against Load for Void Filling and Rescheduling Techniques

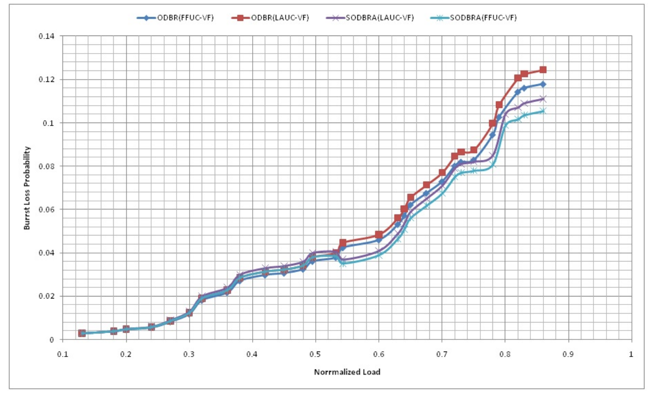

Fig. 4. Burst Loss Ratio against Load (8 Wavelengths)

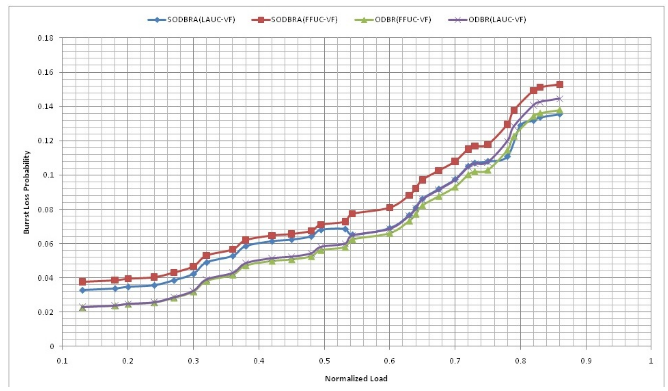

Fig. 5. Burst Loss Ratio against Load (4 Wavelengths)

a contending burst to another channel without having to drop the new burst. These results demonstrate that the ODBR techniques, in general, have better burst loss performance than the conventional techniques.Furthermore, the ODBR technique which is based on FFUC-VF outperforms its LAUC-VF counterpart. Fig. 4 depicts the burst loss ratios of all the rescheduling techniques. Their loss ratios are tested on fibre links having eight data wavelengths with ODBS enabled. It is noticed that the techniques implementing ODBS which in this case is our SODBRA algorithm, have better loss ratios when compared to the non-ODBS schemes. This is attributed to the burst segmentation capability incorporated into the rescheduling technique which gives it the ability to segment a burst and schedule these segments by utilizing the available voids on the channels. Only those segments which could not be scheduled are dropped. For this reason, the burst loss performance of SODBRA is better than those techniques implementing ODBR alone.

Referring back to Fig. 4 again, it can be observed that, at light loads less than 0.2 Erlang, the performance of the SODBRA is similar to the normal ODBR but as the load increased from medium, 0.5 to high, 0.8; its performance becomes visible. The performances of the hybrid techniques are similar at high loads irrespective of the type of base scheduling techniques used. Even with this similarity, the FFUC-VF variant of the SODBRA performs better because it schedules the burst as quickly as possible and in the event of resource scarcity; it segments the burst and schedules the segments to the available voids. This is another advantage of the FFUC-VF. As for the others, their loss ratios are high because they do not provide burst segmentation when contention occurs. Fig. 5 shows the burst loss ratio performances of the various rescheduling techniques with the number of data channels reduced from 8 to 4.

In this case, the ODBR techniques almost have the same pattern of burst loss. However, their performances are better than those of the SODBRA in the same situation. This low performance can be attributed to the late scheduling of the bursts. Fig. 6 displays the burst loss ratio of the rescheduling schemes with the number of data channels set to two. The figure shows the performance of the schemes to be almost similar when the number of wavelengths was set to 4. This is due to the shortage of wavelength re-sources which are mostly occupied at the time when new request are made. Hence more bursts are dropped. The second performance metrics used in this paper is the network throughput. The results show the through-put of the network under varying load intensity. Fig. 7 depicts the network throughput performance for the various scheduling techniques with the number of wavelengths set to 8. It can be observed that, at low load intensity

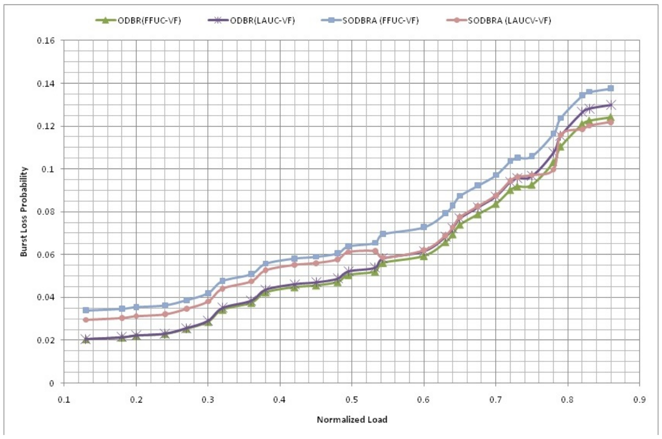

Fig. 6. Burst Loss Ratio against Load (2 Wavelengths)

almost all the scheduling techniques performances are the same. This is due to network resources availability; hence, no contention occurred at low load. But as the load intensity increases and becomes heavy, each of the techniques took a different path in the graph. The FFUC-VF has the lowest performance. Despite this low performance, it is still better than its FFUC parent which does not support void filling. The LAUC-VF is better than the FFUC-VF but its performance is lower than the ODBR variants. The ODBR variants exhibit good performance among all the techniques. It can be seen that the SODBRA (FFUC-VF) technique performs better than the others. This is attributed to its ability to schedule more bursts as quickly as possible; reschedule a burst or finally segment a burst in order to avoid losing it entirely. Also another reason for the superiority of SODBRA (FFUC-VF) over SODBRA (LAUC-VF) is because it does not spend much time searching for an optimal channel to schedule a burst as it is done by LAUC-VF. From Fig. 8, it is observed that the scheduling technique with the best throughput is the SODBRA (LAUC-VF) technique. As for the LAUC-VF and FFUC-VF techniques, their throughput patterns are similar; nevertheless, LAUC-VF has the best overall performance. The SODBRA technique has the lowest throughput and this is attributed to the limited number of data wave-length channels which are mostly in use at the time of new burst scheduling request.

Even though ODBR is used in the SODBRA (FFUC-VF) scheme, in the event of contention, wavelengths may still not be available for the already scheduled burst to be rescheduled. In such situations, ODBS is invoked and this is the final part of the new scheduling technique. ODBS attempts to divide the contending burst into segments and fill in any available voids with these segments; only parts of a burst may be dropped. Limited resources in the network are the major cause of the poor throughput. Another reason for its poor performance is due to the type of segmentation technique used. SODBRA (LAUC-VF) performs better than the SODBRA (FFUC-VF) because of its ability to optimally schedule

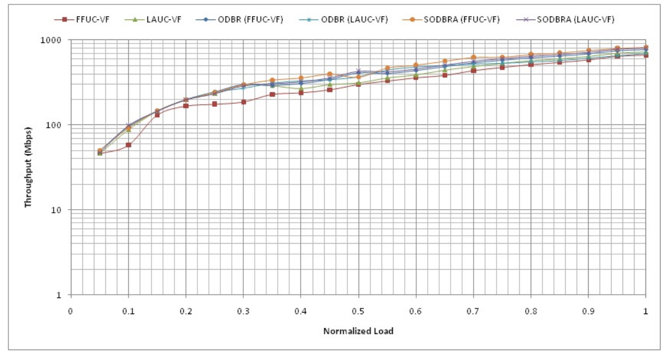

Fig. 7. Throughput against Load for various scheduling and rescheduling techniques with 8 wavelengths

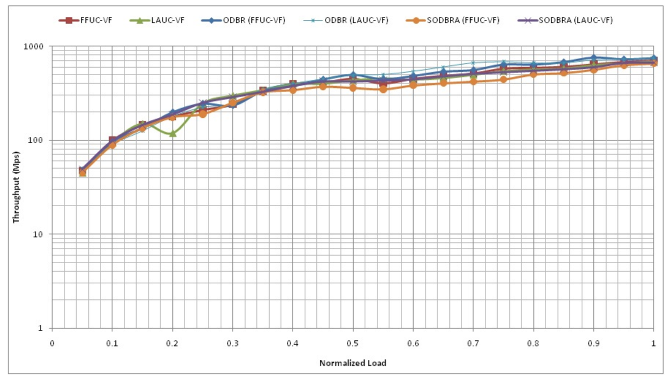

Fig. 8. Throughput against Load (4 wavelengths)

burst on the wavelengths channels efficiently. Fig. 5 above supports these arguments. In that figure, it is observed that, SODBRA (FFUC-VF) has the lowest burst loss ratio compared to other scheduling schemes studied in this paper. In order to further investigate the performance of the newly proposed scheduling algorithm, the number of wavelengths was reduced to 2. Fig. 9 depicts that not only the SODBRA (FFUC-VF) scheme performs poorly under fewer wavelengths but also all the ODBR derivatives with void filling capability behave similarly. This poor performance is due to the complexity of the void filling schemes used to build the ODBR and also due to the complexity of the ODBR scheme itself.

The time complexity of ODBR depends on the time complexity of the base scheduling technique used to implement it [19]. It follows that, the time complexity of the SODBRA (FFUC-VF) is also $O(WlogN)$. This is because, in the event of contention, other parts of SODBRA are called only when either a burst needs to be dropped or when a scheduled burst could not be rescheduled. Also, according to [19], the probability that ODBR is called is usually less than 10% of the total scheduling done in the OBS core node.

5 Conclusion and Future Work

This paper has proposed and evaluated a new rescheduling scheme called SODBRA for OBS. The algorithm was

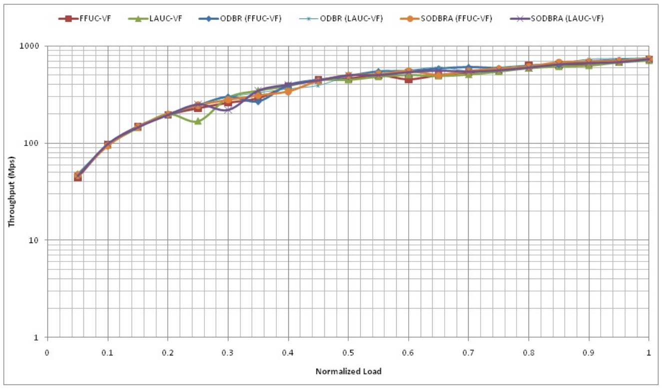

Fig. 9. Throughput against Load (2 wavelengths)

evaluated using NCTUns 6.0 Simulator and Emulator [25] and was compared in terms of burst loss ratio and throughput with ODBR (LAUC-VF). Simulation results showed that SODBRA performs better than its competitor especially at high load. Moreover, SODBRA outperforms ODBR (LAUC-VF) as the number of wavelength increases. However, its performance is close to that of FFUC-VF under fewer numbers of wavelengths.

The time complexity of SODBRA is similar to that of the FFUC-VF and LAUC-VF. This puts it on the same complexity level with the other void filling techniques. Based on the obtained results, one can conclude that the number of wavelengths used in an OBS network significantly affects the overall performance of the network. Additionally, these results confirm that void filling techniques have better performance in terms of burst loss ratio when compared with non-void filling techniques. The results also prove that ODBR scheduling techniques supporting void filling have better performance in terms of burst loss ratios and network through-put. But, non-void filling algorithms have less time complexity and execute faster than void filling schemes.

The authors are currently extending this work to support QoS provisioning so as to meet the requirements of real time traffics.

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