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Research Article

A Novel Mechanism for Contention Resolution in Parallel Optical Burst Switching (POBS) Networks

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Abstract: Parallel Optical Burst Switching (POBS) is a variant of Optical Burst Switching (OBS) which is proposed as a new optical switching strategy for Ultra-Dense Wavelength Division Multiplexing (U-DWDM) to support the enormous bandwidth demand of the next generation Internet. As opposed to OBS, POBS transmits bursts in two dimensions: the wavelength dimension and the time dimension. POBS network uses an one-way resource reservation mechanism to set up the resources for each data burst transmission. The use of this mechanism may cause bursts to contend for the same resources at the same time at core (intermediate) nodes of the network. Therefore, the performance of POBS networks depends on the contention resolution policies to reach acceptable levels for bandwidth usage. These policies may increase both the cost and complexities of the core nodes in POBS networks. Most literatures on OBS networks apply contention resolution at the core nodes based on reactive strategies that are activated after contention takes place in core nodes. This study proposes the use of a proactive contention resolution technique at ingress nodes of POBS network as well as reactive contention resolution technique at core nodes for reducing the probability of burst drop in the network in order to increase the performance of the network. The simulation results show that the use of POBS network with the proposed Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT) shows a better performance in terms of reduced data loss rate and increased throughput compared to the performances of both POBS network with Sequential Wavelength Assignment Technique (POBS-SWAT) and OBS network with Burst Segmentation (OBS-BS).

Keywords: Burstification time, OBS networks, POBS networks, Two Dimensions Data Burst (2D-DB), waveband granularity

INTRODUCTION

The Internet has experienced a tremendous growth in terms of usage over the last decade. This growth is a direct consequence of the increasing popularity of Internet services such as Voice-over-IP (VoIP), online video, digital repositories, grid computing, online gaming and other multimedia applications (Berman *et al*., 2003). To address this issue, Wavelength Division Multiplexing (WDM) has been proposed to increase the data rate of fiber optic communication. However, its use is restricted due to current limitations of optical technology such as insufficient optical buffer and lack of proven optical bit-level processing technologies (Detti *et al*., 2002). As a result of these restrictions, Optical Burst Switching (OBS) network is seen as a viable solution as it directly transports IP over WDM (Chen *et al*., 2004). Currently, a variant of OBS, which is known as Parallel Optical Burst Switching (POBS), has taken this concept further by transmitting bursts in a structure of Two-Dimensional Data Bursts (2D-DBs), namely the time dimension and the wavelength dimension (Abdelouahab *et al*., 2011; Huang *et al*., 2007). POBS paradigm is an attractive approach in optical networking technique for it efficiently supports Internet Protocol (IP) data grams, as well as exploits the enormous terahertz bandwidth of single-mode fibers that are presently available in Ultra-Dense Wavelength Division Multiplexing (U-DWDM) technology. Hence, the node architecture of POBS which is based on waveband switching is capable of

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reducing the cost of the whole network through a reduction in the number of required switching elements and wavelength converters.

POBS networks employ one-way resource reservation mechanism (also called "Tell-and-Go") for setting up the resources for each 2D-DB transmission (Abdelouahab *et al*., 2011). This characteristic indicates that 2D-DBs may contend should there be an overlap in the time dimension and wavelength dimension at a core node. This problem of contention can be overcome by delaying, deflecting, or converting one of the contending bursts. These contention resolution techniques are categorized as reactive strategies, which mean they are activated after contention has occurred at the core nodes. The first technique that can be implemented to resolve contention in POBS networks is buffering. Currently, optical buffering can only be implemented using Fiber Delay Lines (FDLs). However, FDL cannot be used widely. They only allow limited and fixed delays to contending burst; hence they have limited buffering capability. Furthermore, the deployment of FDL buffers takes up a bigger switch matrix space (Pedro *et al*., 2008). The second solution for resolving contention in WDM-BS networks is to use deflection routing. One of the setbacks of deflection routing is when the load increases, it may destabilize the network (Wang *et al*., 2000). The third solution to resolve contention is to use wavelength conversion. However, using wavelength converters for all wavelengths at the core nodes can be costly due to the numerous number of wavelengths in one fiber. In POBS networks, waveband conversion (multi-wavelengths conversion) technique, instead of single wavelength conversion, (Huang *et al*., 2007) can be used. This technique converts the waveband into a new set of wavelengths. The advantage of this technique is that it reduces the number of conversions required from the number of wavelengths in a fiber to the number of wavebands in a fiber (Bala *et al*., 1996). Due to this advantage, this study employs the use of waveband conversion to convert the wavelength dimension of contending 2D-DB at the core nodes.

The process of using 2D-DB in POBS network is straightforward. First, construct a 2D-DB. Next, select appropriate wavelengths to transmit the burst. Finally, inject the burst into the network. Abdelouahab *et al*. (2011) proposed for the selection of intelligent choices in assigning wavelengths to data bursts at the ingress node of POBS networks (Abdelouahab *et al*., 2011). They named this method the Sequential Wavelengths Assignment Technique (SWAT), which aims to utilize the unused wavelengths between the boundaries of 2D-DB in a specific waveband for the purpose of decreasing the probability of unresolved contention at the core nodes.

This study proposes the use of a technique which is a combination of a proactive contention resolution technique at the ingress (edge) nodes of POBS network as well as a reactive contention resolution technique at the core nodes of POBS network to decrease the probability of burst drop in the network. This proposed technique is known as POBS network with Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT).

POBS network: Pobs network consists of an optical edge with core nodes that are interconnected through u-dwdm fiber links. Legacy systems are connected to the pobs network through edge nodes as shown in fig. 1.

In POBS networks, the transmission of U-DWDM link is carried out in multiple wavelengths with each wavelength being represented in a separate channel. Therefore, data and control traffics are transmitted on different and separate wavelengths (channels) over the same fiber link. Nevertheless, the structure of each burst is two-dimensional, with time and wavelength

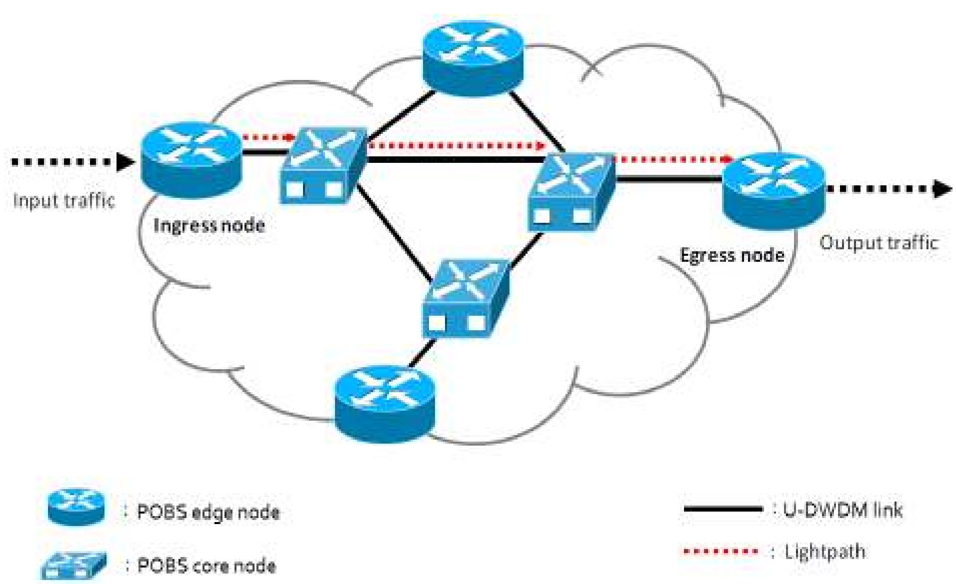

Fig. 1: The POBS network main components

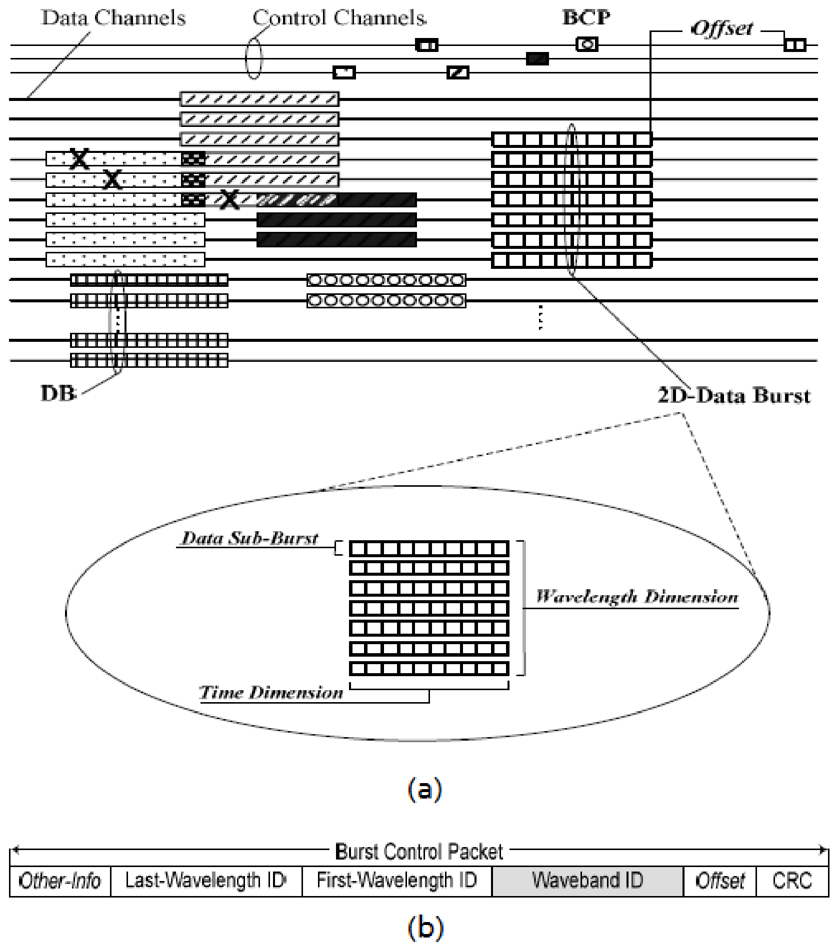

Fig. 2: General illustration of POBS

dimensions. Figure 2a illustrates the dimensions of each burst. When the incoming packets such as IP packets, Frame Relay or ATM cells arrive from access networks, they are classified according to their destinations and Quality-of-Service (QoS). Then they are assembled to become Data Sub-Bursts (DSBs), which are relatively small, fixed-size data units. Subsequently, the 2D-DBs are created from the assembled DSBs with the same destination. Thus, the 2D-DBs are fixed in the time dimension, but vary in wavelength dimension. This structure is shown in Fig. 2a. Moreover, this structure maintains the flexibility of creating varied-sized 2D-DBs. One of which is the Burst Control Packets (BCPs) illustrated in Fig. 2b where the IDs of the first and last wavelengths from the boundaries that indicate the size of each 2D-DB in the wavelength dimension. At the core nodes, the switching fabrics are configured according to the information relayed in the BCPs. These BCPs are sent an offset time ahead of their corresponding 2D-DBs. The BCP is used for reserving the required transmission and switching resources for the corresponding burst along the path of the burst using a one-way reservation mechanism. In fact, a number of one-way reservation mechanisms have been proposed for OBS networks, including the Just In Time (JIT) and Just Enough Time (JET) reservation mechanisms (Jue and Vokkarane, 2005). The 2D-DBs are disassembled into packets at the egress network. Subsequently, they are forwarded to their final destinations (Abdelouahab *et al*., 2011). POBS provides the transportation of data burst along optical paths that are transparent end-to-end in a purely optical domain, while the control packet is converted and processed in the electrical domain.

In POBS networks, contention occurs when two or more bursts overlap in both time and wavelength dimensions. The contention in POBS can be resolved by reactive and proactive strategies described above. However, in POBS, the simplest contention resolution technique is to drop the entire DSB which yields better results than OBS with the Burst Segmentation (OBS-BS) technique (Abdelouahab *et al*., 2011). That means, contention in POBS network can be solved easily by dropping contending DSBs from each 2D-DB (from the upper and/or lower parts of the burst). Figure 2a illustrates the contention in POBS network where the dropped DSBs are denoted by “X”.

LITERATURE REVIEW

In connectionless datagram networks, contention occurs when two or more datagrams from different input ports need to use the same output port at the same time. Contention can be resolved easily in electronic networks using electronic Random-Access Memory (RAM) to store and queue the datagrams, which are transmitted as soon as an output port is available. Currently, there is no equivalent optical RAM available. Therefore, Burst Segmentation (BS) strategy is introduced to reduce packet loss during bursts contention and to provide an alternative dropping policy to the traditional OBS dropping policy, which is done by dropping the entire contending burst. In this policy, some segments of a contending burst may be dropped, buffered, deflected, or converted to a different channel when contention occurs. It has been revealed in literature that contention resolution mechanisms based on burst segmentation are the most efficient in solving the contention problem, to the extent of outperforming the traditional OBS which uses the entire-burst dropping policy (Detti and Listanti, 2002; Vokkarane and Jue, 2002). Wavelength conversion is used to support the objective of burst segmentation in order to resolve contention in the network. However, the use of wavelength converters for all wavelengths at the core nodes can be costly due to the large number of wavelengths in one fiber. In addition, the implementation of this scheme requires an increase in the size of the BCP as well as an increase in the complexity of the algorithms and protocols both at the core and edge nodes (Garg and Kaler, 2010).

Abdelouahab *et al*. (2011) proposed the Sequential Wavelength Assignment Technique (SWAT) which is a proactive contention resolution approach to mitigate the problem of burst dropping. In this technique, gaps (unused wavelengths) are inserted between the boundaries of the 2D-DB, as illustrated in Fig. 3. When a constructed 2D-DB is ready to be injected into the network at the ingress node, the appropriate wavelength(s) is selected for the transmission of the burst. The process in SWAT begins with a random selection of the first wavelength in a specified waveband of the optical link which will be assigned to the first DSB of the 2D-DB. The next wavelength(s) will subsequently carry the remaining DSBs of the 2D-DB until the end of the final wavelength. The subsequent DSB (if any) is then directed to the first wavelength of the specified waveband. This process continues for the remaining DSBs. The findings point out that the accumulated data loss due to the problem of early arrival is greater for the OBS-BS compared to POBS with SWAT (POBS-SWAT), particularly for high loads. Waveband conversion is also used to support the objective of SWAT to resolve contention in the network. Unfortunately, the waveband conversion with SWAT cannot be implemented in POBS network

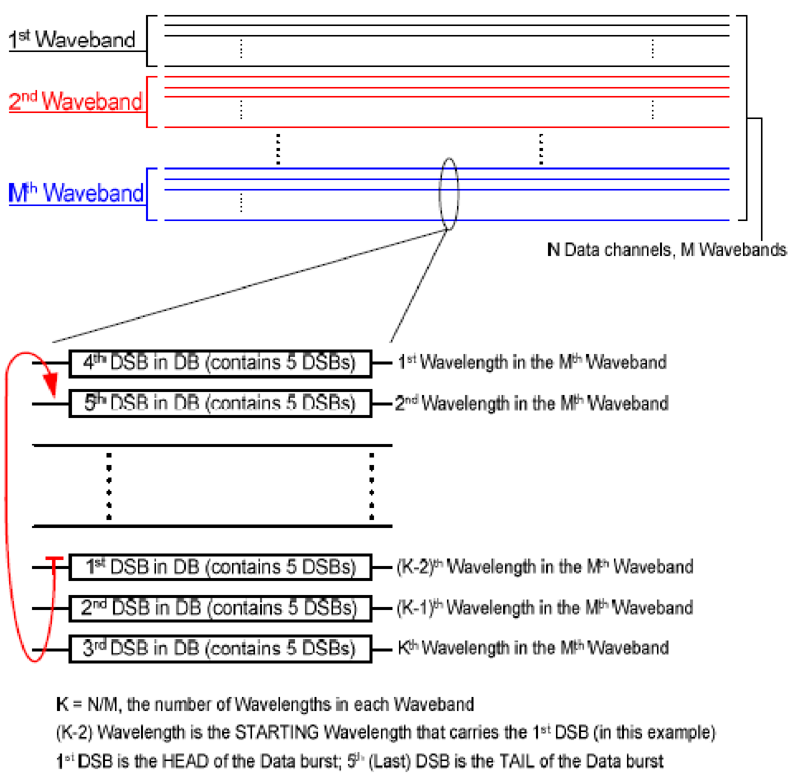

Fig. 3: The wavebands, DSBs and DB in POBS with SWAT (Abdelouahab *et al.*, 2011)

to convert the wavelength dimension of 2D-DB to new set of wavelengths in the same specified waveband because the wavelength dimension of 2D-DB is unlimited and it exceeds the number of half of waveband size (M).

PROPOSED METHODOLOGY

This study proposed the use of Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT) at the (edge and core) nodes of POBS networks for the purpose of reducing the blocking probability of data bursts in the network. The underlying principle of this technique is the allocation of sequences (even or odd) of wavelengths in a specified waveband for Data Sub-Bursts (DSBs) of the 2D-DB, which is based on ingress node ID, can act as a balance to the scheduling of the bursts that will ultimately reduce the number of cases of overlapping data bursts which are destined to the same output fibre of a core node. In this algorithm, the size of 2D-DB which is controlled by the condition of threshold length, aims to limit the number of wavelengths dimension so that it does not exceed the number of half of waveband size (M). The burst assembly is based on a hybrid (time-length) threshold to trigger the release of a 2D-DB. The 2D-DBs are shaped in two dimensions; time and wavelength dimensions. Each DSB in 2D-DB is assembled based on a threshold length. Since the size DSBs is fixed, the 2D-DB is therefore, fixed in time dimension, but vary in wavelength dimension, where DSBs are assembled from IP packets that have the same destination and grouped in parallel (wavelength dimension). The maximum number of allowable wavelength dimension for use in this algorithm is (M/2). Thus, the maximum size of 2D-DB is equal to the size of DSB multiplied by half of the waveband size. The following algorithm illustrates the steps taken to construct the 2D-DB.

Algorithm 1: Construct the 2D-DB:
Input: The waveband size (granularity) (*M*), the burstification time in *μs* (burst_time), the size of DSB of 2D-DB in KByte (*DSB*_size) and the input packet to edge node (*pkt*).

Output: Constructed the Two Dimension Data Burst 2*D-DB*.

1: **Initialization:** The index variable of 2D-DB (*i*←1) and the index variable of DSB (*j*←1).
2: arrive pkt at edge node //* Where *pkt* is packet*//
3: if *pkt* direction is receive then
4: send *pkt* to the upper layer //*The packet at egress node forward to access network *//
5: else if *pkt* direction is send //*The packet from access networks assembly at ingress node*//
6: if *pkt* with same destination as *2D-DB* [*i*] then
7: if *(assembly timer < burst_time)* and (*j* < *M/*2) then
8: if current size of *DSB*[*j*] < *DSB_size* then
9: add the pkt to the *DSB* [*j*]
10: else
11: increment *j*
12: add the *pkt* to the *DSB* [*j*]
13: end if
14: else
15: generate *BCP*
16: increment *i*
17: trigger the timer of new 2*D-DB* [*i*] to ON
18: end if
19: else
20: increment *i*
21: trigger the timer of new 2*D-DB* [*i*] to ON
22: end if

When the constructed 2D-DB is ready for injection into the network, appropriate wavelengths are chosen for the transmission of 2D-DB. The process starts with the random selection of the first wavelength in a specified waveband that is based on the ID of the ingress node (even or odd). The selected wavelength will carry the first DSB. For instance, if the ID ingress node equals 3, the way of allocation of sequences (even or odd) of wavelengths in a specified waveband is labeled as odd. This allows for the selection of the first wavelength for the first DSB of the 2D-DB from any odd sequence in the specified waveband of the optical link. The subsequent wavelengths of the odd sequence will carry the remaining DSBs until the arrival of the final wavelength of the selected waveband. Then the following DSB (if any) is directed to the first odd sequence of the wavelength of the specified waveband, followed by odd sequences for the remaining DSBs. The details of the Odd/Even Node ID Wavelength Assignment Technique (POBS-OENIDWAT) algorithm are given as follows.

Algorithm 2: POBS-OENIDWAT:
Input: The constructed Two Dimension Data Burst (2*D-DB*[*i*]) where the size of *DSB* is time dimension and *N* is wavelength dimension, the waveband size (*M*) and the edge *ID* (*SQ*).

Output: Wavelength assignment of constructed 2D-DB.

1: **Initialization:** The index variable of DSB (*j*←1).
2: if *SQ* is odd number then
3: go to 8 //*Call Odd Wavelength Assignment Algorithm*//
4: end if
5: if *SQ* is even number then

6: go to 21 //*Call Even Wavelength Assignment Algorithm*//
7: end if //*end Algorithm*//
8: //* Odd Wavelength Assignment Algorithm*//
9: select *x* as a random integer number in range of 1 to *M*
10: if x%2 = = 0 then
11: go to 8
12: end if
13: for $j \leftarrow 1$ to N do
14: assignment the wavelength *x* for *DSB*[*j*]
15: set bit of *x* sequence in Bit-Mask to 1
16: $x \leftarrow x+2$
17: if *x*>*M* then
18: $x \leftarrow 1$ //*Allocation the first odd sequence of the wavelength in the specified waveband*//
19: end if
20: end for
21: // *Even Wavelength Assignment Algorithm*//
22: select *x* as a random integer number in range of 1 to *M*
23: if not x%2 = = 0 then
24: go to: 21
25: end if
26: for $j \leftarrow 1$ to N do
27: assignment the wavelength *x* for *DSB[j]*
28: set bit of *x* sequence in Bit-Mask to 1
29: $x \leftarrow x+2$
30: if *x*>*M* then
31: $x \leftarrow 2$ //*Allocation the first even sequence of the wavelength in the specified waveband*//
32: end if
33: end for

The first technique proposed is the proactive OENIDWAT algorithm which decreases the probabilities of unresolved contention at the core nodes and increases the throughput of the optical core nodes. The second technique is the reactive contention resolution technique that support the function of OENIDWAT algorithm. This reactive technique converts the wavelengths of contending burst into a new set of wavelengths using waveband conversion (Bala *et al*., 1996). However, it is only activated at the core nodes when contention occurs. This wavelength conversion takes place easily as changes only occur to the sequences of allocated wavelengths (even/odd) for contending 2D-DB which are specified by OENIDWAT algorithm according to ingress node ID. These two techniques are called Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT) are based on DSB of 2D-DB allocation in odd or even sequences in wavelength dimension in order to reduce the probability of burst drop in the network. The following algorithm illustrates the implementation of reactive contention resolution technique at the core nodes.

Algorithm 3: Reactive contention resolution technique:
Input: The Burst Control Packet *BCP*[*i*] and the Two Dimension Data Burst 2*D-DB*[*i*].

Output: Send the received 2*D-DB* to next hop.

1: if received data is *BCP*[*i*] then
2: update reservation table
3: if 2*D-DB*[*i*] reservation is not permitted then //*The contention occur*//
4: RIGHT-SHIFT Bit-Mask of *BCP*[*i*] //* Change the sequences of allocation of wavelengths (even/odd) for contending 2D-DB*//
5: if new wavelengths according to Bit-Mask of *BCP*[*i*] are not available in reservation table then
6: drop *BCP*[*i*]
7: go to 13
8: end if
9: end if
10: update *BCP*[*i*] header
11: send *BCP*[*i*] to next-hop
12: end if
13: if received data is 2*D-DB*[*i*] then
14: if *BCP*[*i*] was dropped then
15: drop 2*D-DB*[*i*]
16: go to 1
17: end if
18: if Bit-Mask of *BCP*[*i*] was updated then
19: convert the wavelengths of *2D-DB*[*i*] according to Bit-Mask of *BCP*[*i*]
20: end if
21: forward *2D-DB*[*i*] to the next hop
21: go to 1
22: end if

Figure 4 shows the 2D-DB in POBS link with Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT). The 2D-DB in the first waveband is scheduled by an even allocation, while the second 2D-DB is scheduled by an odd allocation. The Bit-Mask field consists of an array of bits where each bit is linked to a wavelength in a specified waveband. When the value of the bit is one, it means the wavelength is transmitting DSB. On the other hand, when the value of the bit is zero, it means that the wavelength is not occupied by any DSB of 2D-DB. The objective of using POBS-ROENIDWAT strategy is to reduce the probability of DSBs dropping of 2D-DB. This reduction in probability is possible because the unused wavelengths (Gap) are left in the odd or even sequence between the DSBs of 2D-DBs based on the ID of the ingress nodes. In addition, at the core nodes, when contention occurs, simply changing the sequences of allocated wavelengths (even/odd) for contending 2D-DB can also reduce the probability of burst drop in the network.

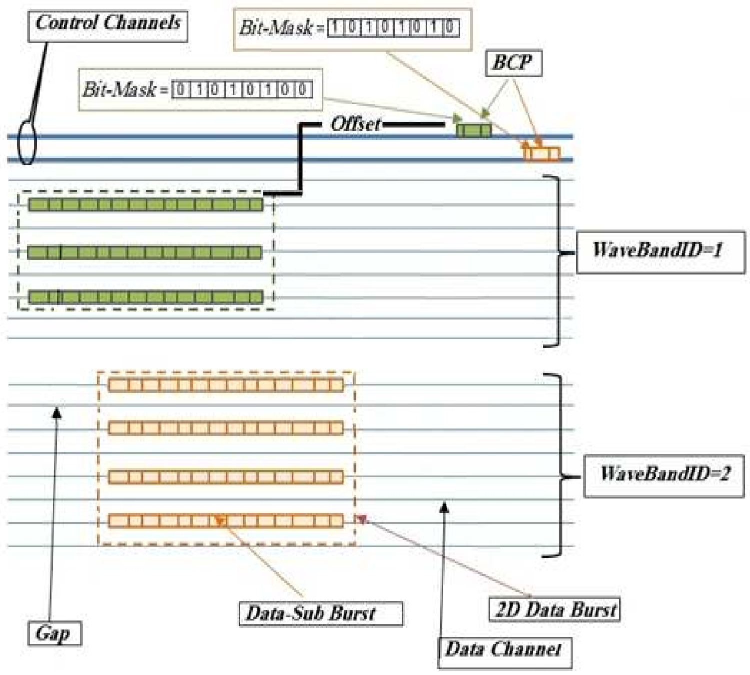

Fig. 4: POBS link with ROENIDWAT

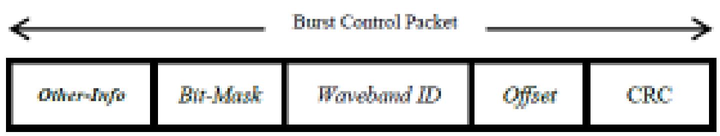

Fig. 5: BCP in POBS with ROENIDWAT

As shown in Fig. 5, the information in all fields of Burst Control Packet (BCP) for ROENIDWAT is the same as the information of BCP for SWAT that was shown in Fig. 2b, except that the ID fields for the first and last wavelengths in the BCP for SWAT are replaced with the Bit-Mask field.

RESULTS AND PERFORMANCE COMPARISON

The aim of this evaluation is to investigate the performance of POBS networks with the proposed ROENIDWAT. The data loss rate and throughput are the two metrics used for measuring the network performance. The National Science Foundation Network (NSFNET) topology depicted in Fig. 6 is used for our simulations. The findings are then compared with both POBS-SWAT and OBS-BS networks with common parameters that include WDM bi-directional links where each link between core nodes carries 12 wavelengths (channels) at the transmission rate of 100 Mb/s, through 2 control channels based on JET signaling technique with the Last Available Unscheduled Channel (LAUC) scheduling algorithm. However, the core nodes do not support burst buffering, deflection routing or wavelength converter. Furthermore, the shortest path is predetermined for each source destination pair. The processing time of BCP is set to 2ns with the assumption that the data segment length in OBS equals to the DSB length in POBS which is set to 15360 bytes, while burstification time is set to 2 µs for two switching techniques. In POBS, two wavebands are selected, each of which comprises of six wavelengths (M = 6). The POBS simulator is developed by extending the open-source NCTUns-6.0 network simulator for the purpose of simulating POBS network, while OBS network is already supported by the NCTUns-6.0 simulator (Wang *et al*., 2010; Yu *et al*., 2004). Each experiment uses User Datagram Protocol (UDP) of ten source-destination node pairs, where each node is represented with a Personal Computer (PC).

Figure 7 shows the simulation results that are obtained by comparing the data loss rate for the proposed POBS-ROENIDWAT method with both POBS-SWAT and OBS-BS methods. The simulation results of data loss rate show that the performance of POBS-ROENIDWAT network outperforms both POBS-SWAT and OBS-BS networks for all network load. In addition, the results show that OBS-BS network experiences a higher data loss rate than POBS-ROENIDWAT and POBS-SWAT networks with increasing network load.

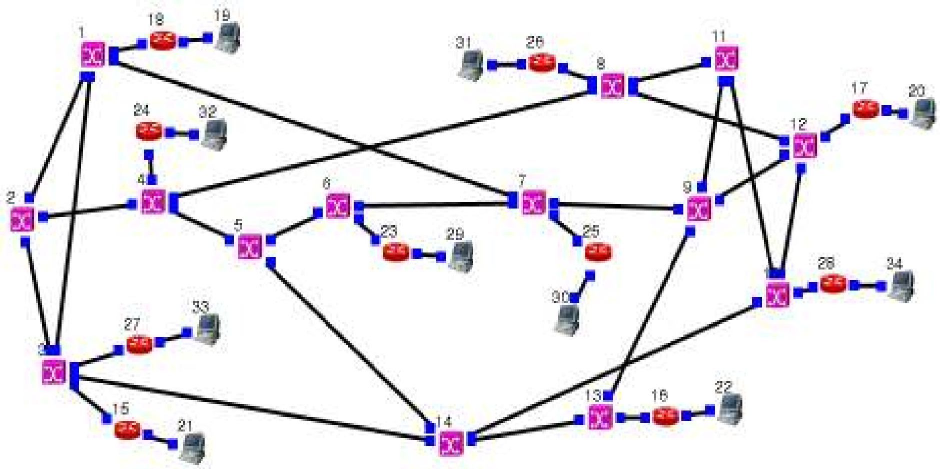

Fig. 6: NSFNET with 14 core nodes to simulate POBS network (NCTUns 0.6 screenshot)

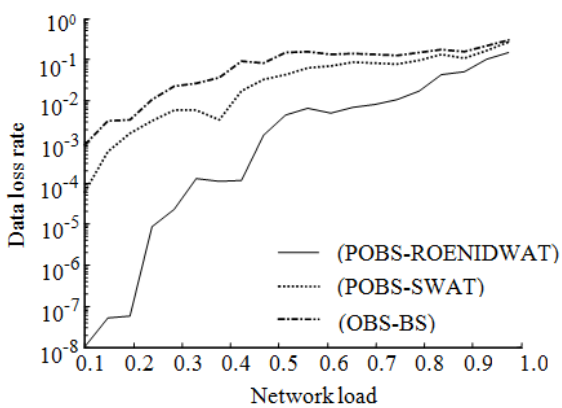

Fig. 7: Data loss rate versus network load

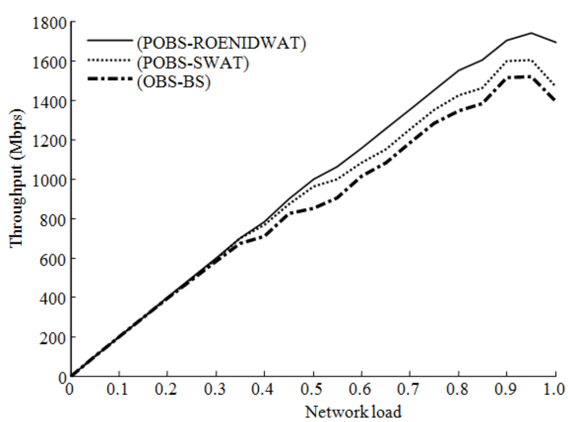

Fig. 8: Throughput of the network versus network load

Next, comparisons between POBS-ROENIDWAT, POBS-SWAT and OBS-BS are made based on throughput. Throughput is defined as the amount of data received at the destination per unit of time. Figure 8, shows that the throughput of POBS network is higher than the throughput of OBS network for all traffic loads. In addition, it is shown that in low traffic load, the throughput of POBS-ROENIDWAT is only slightly better than the throughput of POBS-SWAT. However, as the traffic load increases, the throughput of POBS-ROENIDWAT becomes increasingly higher as compared to that of POBS-SWAT.

Clearly, in terms of performance, the POBS network outperforms the OBS network. This is because the POBS strategy adopts a Two-Dimensional representation for the Data Burst (2D-DB), so each DSB scheduling is performed in different wavelengths, while all the segments of the OBS-BS scheduling are performed in the same wavelength. The simulation results also show that the performance of the proposed POBS- ROENIDWAT method is better than the performance of POBS-SWAT. This is because the allocation of wavelengths to DSBs of the 2D-DB in POBS-ROENIDWAT is based on node ID (even or odd sequence) which is applied evenly among all the ingress nodes, while the allocation of wavelengths to DSBs in SWAT-POBS is based on sequential strategy with a random start. The other reason is the POBS-ROENIDWAT strategy at the core nodes performs wavelength conversion on the contending 2D-DBs.

CONCLUSION

This study proposed the use of a Reactive Odd/Even Node ID Wavelength Assignment Technique (POBS-ROENIDWAT) in POBS networks in order to exploit the big number of wavelengths in single-mode fibers that are available with Ultra-Dense Wavelength Division Multiplexing (U-DWDM) technology. The objective of ROENIDWAT strategy is to improve the performance of POBS networks by reducing the probability of burst drop in the network. Furthermore, this ROENIDWAT strategy is based on the principle of simplicity, where the complexity is transferred from the network core to the network edge. Thus, this technique does not only provide intelligent network edge for robustness, but also maintains a simple network core for scalability. The simulation results have shown that the POBS-ROENIDWAT strategy does not only reduce the burst loss due to unresolved contention at the core nodes, but also provide a higher throughput than POBS-SWAT and OBS-BS strategies.

REFERENCES

Abdelouahab, A., F. Abbou and H. Ewe, 2011. Parallel Optical Burst Switching (POBS) for ultra-dense WDM (U-DWDM) systems. Proceeding of the International Conference on Information Technology and Multimedia (ICIM).

Bala, K., S. Yoo, N. Antoniades and G. Ellinas, 1996. Parametric wavelength interchanging cross-connect architecture. Proceeding of the Optical Fiber Communications (OFC'96), pp: 261-262.

Berman, F., G. Fox and A.J. Hey, 2003. Grid Computing: Making the Global Infrastructure a Reality. Vol. 2, John Wiley and Sons, NY.

Chen, Y., C. Qiao and X. Yu, 2004. Optical burst switching: A new area in optical networking research. IEEE Network, 18(3): 16-23.

Detti, A. and M. Listanti, 2002. Impact of segments aggregation on TCP Reno flows in optical burst switching networks. Proceeding of the 21st Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2002), pp: 1803-1812.

Detti, A., V. Eramo and M. Listanti, 2002. Performance evaluation of a new technique for IP support in a WDM optical network: Optical composite burst switching (OCBS). J. Lightwave Technol., 20(2): 154-165.

Garg, A.K. and R. Kaler, 2010. Burst dropping policies in optical burst switched network. Int. J. Light Electron. Opt., 121(15): 1355-1362.

Huang, Y., J.P. Heritage and B. Mukherjee, 2007. A new node architecture employing waveband-selective switching for optical burst-switched networks. IEEE Commun. Lett., 11(9): 756-758.

Jue, J.P. and V.M. Vokkarane, 2005. Optical Burst Switched Networks. Springer, Heidelberg.

Pedro, J., P. Monteiro and J. Pires, 2008. Performance study of OBS networks using traffic engineering in the wavelength domain and delayed ingress burst scheduling. Proceeding of the Global Telecommunications Conference (IEEE GLOBECOM).

Vokkarane, V.M. and J.P. Jue, 2002. Prioritized routing and burst segmentation for QoS in optical burst-switched networks. Proceeding of the Optical Fiber Communication Conference and Exhibit (OFC 2002).

Wang, X., H. Morikawa and T. Aoyama, 2000. Burst optical deflection routing protocol for wavelength routing WDM networks. Proceeding of the SPIE OptiComm, pp: 257-266.

Wang, S.Y., C.L. Chou, C.C. Lin and C.H. Huang, 2010. The Protocol Developer Manual for the NCTUns 6.0 Network Simulator and Emulator. National Chiao Tung University, Taiwan.

Yu, M., H. Tsai, C. Huang and S. Wang, 2004. Supporting optical network simulations (OBS) on the NCTUns network simulator and emulator. NCTU Technical Report, National Chiao Tung University, Taiwan.