Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 10, Issue 3, September 2015 , p.p(28-41)
ISSN 1992 – 0849

QoS provisioning for Composite Burst Assembly with Burst Segmentation in Optical Burst Switching (OBS) Networks

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Received date: 10 / 9 / 2014 **Accepted date: 8 / 3 / 2015**

ABSTRACT

Optical Burst Switching (OBS) is one of the suggested that switching paradigms be used in Internet-Protocol over Wavelength Division Multiplexing (IP over WDM) networks along with Optical Circuit Switching (OCS) and Optical Packet Switching (OPS). It combines the advantages of both OCS and OPS and avoids their limitations. Hence, OBS technology is a promising solution for the backbone of next-generation Internet. Since OBS networks are anticipated to be the core for variety of applications, an appropriate Quality of Service (QoS) algorithm is essential to handle the task. One of the major concerns in OBS networks is contention resolution, especially in the case of composite burst assembly. Composite burst assembly scheme suggests the assembling packets of different classes of services into a data burst. In this study, composite burst assembly with a different segmentation size scheme is deployed. Hence, at the ingress (edge) node of OBS network aggregates the arrival low-priority packets into small segments in the data burst while the higher-priority packets are placed into large segments in the data burst. At the core (intermediate) nodes of OBS network, when contention occurs, dropping small segments of burst is deployed. However, the mechanisms are evaluated in terms data loss, and it is observed that the high-priority data have significantly lower losses, when compared to the low-priority data. In addition, based on simulation results, it is shown that an adequate QoS level could be achieved with a simple and easy modification to the OBS with burst segmentation strategy.

Keywords: *OBS networks, IP over WDM networks, Burst Segmentation (BS), Quality of Service (QoS).*

Kirkuk University Journal /Scientific Studies (KUJSS)
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تحسين عامل الجودة لشبكات الـ (OBS) من خلال الدمج بين تجميع وتقسيم الـ (Burst)

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تاريخ استلام البحث: 10 / 9 / 2014 تاريخ قبول البحث: 8 /3 / 2015

الملخص

تعتبر شبكة الـ Optical Burst Switching(OBS) احد النماذج المقترحة لكي تستخدم في بروتوكول الانترنيت على الشبكات الضوئية لمتعددة الاطوال الموجية (IP over WDM) بدلاً من شبكات الـ Optical Circuit Switching (OCS) و شبكات الـOPS (Optical Packet Switching) . شبكة الـ OBS هي مزيج كل من المحاسن الموجودة في الـ OCS والـ OPS وفي نفس الوقت تتجنب كل محدداتهما وبالاضافة الى ذلك تعتبر شبكة الـ OBS العمود الفقري لشبكات الحاسبات العالمية المستقبلية. وهناك عوامل مهمة واساسية تحدد من اداء الشبكة ومن هذه العوامل هو عامل الجودة (QoS) (Quality of Service). يوجد عدد من الخوارزميات المستخدمة لتقليل من الخسائر عند حدوث التصادم بين الـ Burst في عملية الـ Switching. في هذا البحث سندرس خوارزمية جديدة لتقليل من نسبة الخسائر وضمات وصول الـ Packet التي لها افضلية اعلى .حيث سيتم تقسيم الـ Burst الى مجموعة قطع (segments) وهذه القطع ستكون نوعين ، النوع الاول كبيرة الحجم وتتحتوي على الـ Packets التي لها افضلية اعلى واما النوع الثاني حجم صغير وتتحتوي على الـ Packets التي لها افضلية منخفضة . وعند حدوث التصادم سيتم اسقاط الـ segments صغيرة الحجم والسماح للكبيرة بالمرور. ومع ذلك، يتم تقييم هذه السياسة في فقدان البيانات، ويلاحظ أن البيانات ذات الأولوية العالية خسائر أقل من ذلك بكثير، بالمقارنة مع البيانات ذات الأولوية المنخفضة. بالإضافة إلى ذلك، بناء على نتائج المحاكاة، فإنه يظهر أن مستوى جودة الخدمة الكافية يمكن أن يتحقق مع تعديل بسيط وسهل الى OBS مع استراتيجية تجزئة Bursts.

الكلمات الدالة: : شبكات الـ OBS ، بروتوكول الانترنيت على الشبكات الضوئية لمتعددة الاطوال الموجية ، تجزئة الـ Bursts ، عامل الجودة.

Kirkuk University Journal /Scientific Studies (KUJSS)
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1.INTRODUCTION

Currently the significant increase of network traffic and the tremendous growth of a variety of Internet Protocol (IP) services have brought about the bandwidth demand per user to be on the rise. These services that demand large bandwidth such as Voice-over-IP (VoIP), online video, online gaming, dynamic navigation systems, telemedicine, e-Science, e-Astronomy. Hence, the Internet hosts are still increasing in number by 30 percent a year; this will result in a 70% increase in the number of connections [1]. This has driven the providers to design Internet infrastructure to be capable of providing high-capacity with applied of QoS guarantee such as delay constraints and low packet loss [2].

The OBS paradigm [3] has attracted characteristics as an optical networking architecture is seen as a promising solution as it directly transports Internet Protocol over Wavelength Division Multiplexing (IP over WDM), while exploiting the enormous transmission capacity already available today with WDM technology [4]. In OBS networks, at the ingress nodes, the incoming IP packets that have same egress node (destination) are assembled into bursts, whereas at the OBS core nodes, each data burst are allocated wavelength and pass through in cut through manner along the transmission bursts' bath to the destination. Consequently, the OBS network is able to minimize the switching overheads; because at each core node along the burst path, the resources for data burst transmission is reserved using a control packet, which is sent in advance of the data burst and out-of-band.

In this paper, new QoS mechanisms are introduced for OBS networks. For the new QoS mechanisms to be realizable and efficient in the OBS networks, the simplicity principle was one of the most important design considerations. The rest of this paper is organized as follows: Section 2 presents a brief overview on the OBS networks. In Section 3, the Quality of Service mechanisms in OBS networks are introduced. The proposed technique of Segment Drop Based Priority Scheme (SDBPS) are introduced and discussed in Section 4. Section 5 presents simulation setup of OBS networks to evaluate the SDBPS, while Section 6 presents the simulation results. Finally, this paper is concluded in last section.

2.OPTICAL BURST SWITCHING (OBS) FRAMEWORK

OBS is relatively a new optical switching technique and still at its description phase, which is clearly suggested by the number of research groups and their publications, specially, on new

Kirkuk University Journal /Scientific Studies (KUJSS)
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OBS architectures [5,6], prototypes[7], reservation mechanisms[8], and assembly mechanisms [9]. On the other hand, even though the truth that there is no standard architecture or a general definition of optical burst switching, OBS networks suppose the following general attributes: Granularity: Each burst should have a short duration, and long sufficient to be efficiently switched optically and multiplexed statistically, i.e., a granularity between the one of optical circuit switching and optical packet switching.

Separation of Control and Data: Each of control information and data payload are propagated in individual channel (wavelengths).

One-Way Reservation: control information packets are transmitted before the bursts (data) transmitting to confirm switch resources reservation without receiving or waiting for any acknowledgements from the destination.

Variable Burst Length: The burst duration may be variable and should be long enough to switching efficiently.

Optical Buffering/Wavelength conversion: In the traditional application of OBS networks, optical buffers /wavelength converters are not compulsory in the intermediate nodes. Therefore, there is no delay (buffering) in optical switching of data bursts from source to destination in same wavelength.

2.1.OBS Network Architecture

Typically, an Optical Burst Switching (OBS) network consists of optical core nodes (routers) and electronic edge nodes (routers) that are interconnected via WDM fiber links. Figure (1) shows the main components of OBS networks.

In OBS networks, the data payload is retained in the optical domain, whereas the control information can move through optical-electrical-optical conversions to be efficiently processed in the electrical domain. OBS presents exactly that, by splitting the control and the data in the physical space, i.e., the control information and the data spread individually in different designated channels, and maybe with different data rates. OBS also separates the control and the data in time, i.e., the control packet is transmitted an offset time prior to its corresponding data. In the buffer-less core nodes, the offset time is gradually consumed to compensate for both processing and configuration time, needed respectively by the control unit to process the control information and the switching-fabric to be configured. Figure (1) shows some of the main components of an OBS network.

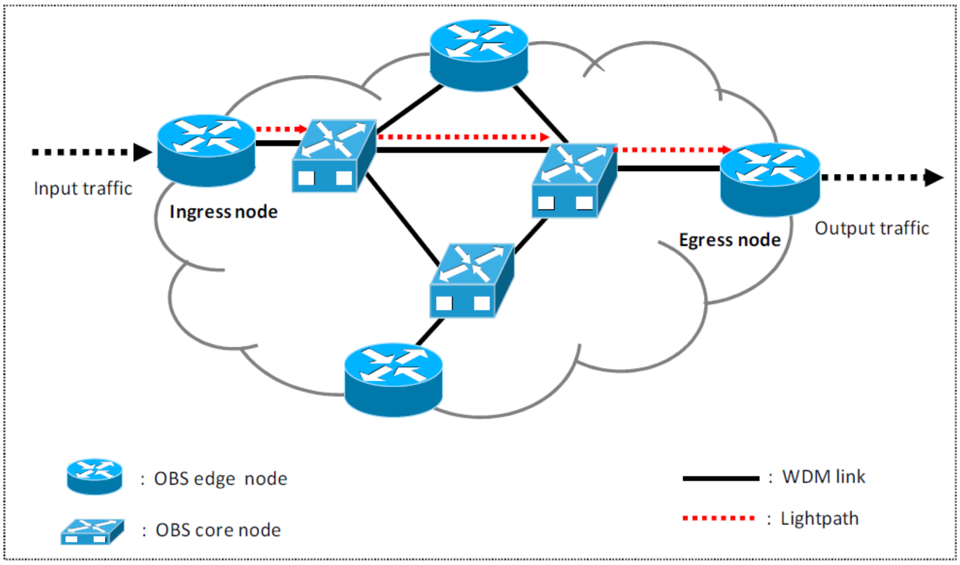

Figure (1): Main components of OBS networks

2.2.Edge Node Architecture

OBS network includes two types of nodes, edge (ingress/egress) nodes and core nodes. In the edge nodes, network traffic is collected from access networks and assembled into macro data units called data bursts (DBs). Edge nodes (Ingress/Egress) provide an interface between the OBS network (optical domain) and legacy access networks. Generally the ingress node which is illustrated in Figure (2) should be capable of performing bursts assembly, BCPs generation, burst/channel scheduling, and routing. The Egress node contains bursts disassembler, BCPs processor/terminator, and optical receivers. The edge node should have the functionalities of both the ingress and the egress nodes.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 10, Issue 3, September 2015 , p.p(28-41)
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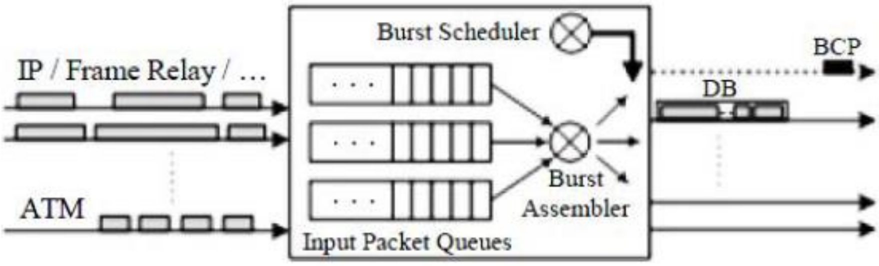

Figure (2): OBS edge node

2.3.Core Node Architecture

Core nodes serve as transit nodes at the core network. Their main task is to switch bursts (data) all-optically without any conversion or processing. The switching fabrics are configured according to the control information contained in the Burst Control Packets (BCPs), which are transmitted as reservation requests an offset time ahead of their corresponding data bursts. Hence, core nodes is an intermediate node between the edge nodes which located inside the OBS bursts switching (optically), and BCPs processing (electronically). The capabilities of a core node may be farther extended to provide optical data buffering and wavelengths conversion. A generic core node contains the following:

- **Optical receivers/transmitters:** Reception/Transmission of the control information and data bursts.

- **Optical multiplexer and de-multiplexers:** responsible for optical channels multiplexing and de-multiplexing.

- **Input/output interface for BCP:** Control reception/transmission and O/E/O conversions.

- **Control packet processing unit:** For BCPs interpretation, channels scheduling, collision resolution; routing, and optical switching-fabric control.

- **Optical switching fabric:** To optically switch data bursts. And possibly wavelength converters and Fiber Delay Lines (FDLs).

A general architecture of OBS core node is shown in Figure (3). The OBS core node (switch) should be equipped with the capabilities of routing,

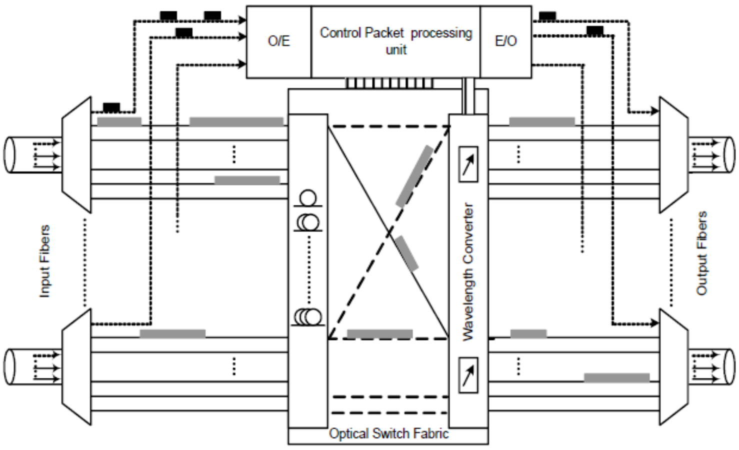

Figure (3): Architecture of an OBS core node

3.OBS QUALITY OF SERVICE MECHANISMS

A great effort has been made to make the optical layer a layer of convergence with respect to the QoS provisioning, in the context of IP over WDM. For OBS networks, many QoS mechanisms were designed and reported in the literature. Unlike traditional QoS mechanisms that, usually, make use of buffers, the OBS-QoS mechanisms differentiate between critical and noncritical traffic by varying some of the OBS parameters, e.g. offset time, assembly threshold, and/or control packet scheduling. In OBS, service differentiation may be obtained using FDLs to reduce the burst loss probability of the critical data [10], or through deflection routing [11]. However, the main OBS-QoS mechanisms can be classified in three categories: Offset-based [12], Segmentation-based [13], and Active Dropping-based mechanisms [14].

FDL-based QoS mechanisms are limited by the inflexibility and the immaturity of the optical buffering technology. Similarly, if deflection routing is used as service differentiation mechanism, then the network may experience increases in the end-to-end packet delay jitter, resulting in more out-of-order packet delivery events, which is unsuitable particularly for real time multimedia applications. Likewise, the three main OBS-QoS mechanisms suffer from many problems, and their deployment often comes at the expense of increased control complexity, and additional resources requirements and network cost.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 10, Issue 3, September 2015 , p.p(28-41)
ISSN 1992 – 0849

4.Proposed Technique

Segment Drop Based Priority Scheme (SDBPS) is developed to streamline the implementation of the burst segmentation concept with provisioning QoS, bringing it closer to the realization in OBS networks. In SDBPS each burst consists of a number of segments that may be discarded when they overlap (contend) with other segments from other bursts. SDBPS is based on Just-Enough-Time (JET) signaling scheme and uses a segments dropping policy that discard the low priority segments from one contending bursts. To provide QoS, the ingress nodes assemble the upper layer packets (access networks traffic) into data segments according to their priority. Whenever possible, the data segments that contain high priority data are then placed at the large segment of the bursts, while the data segments that contain lower priority data are placed at the small segment of the bursts. Therefore and according to the characteristics of the access networks traffic, composite bursts that carry the high priority packets are large segments and low priority packets are small segments which are generated by the ingress nodes. The following algorithm illustrates the steps taken to construct the Data Burst (DB):

Algorithm (1): Construct the data burst based segments priority

Input: The threshold time in μs (burst_time) , the size of higher-priority segment (hp_s), the size of low-priority segment (lp_s) and the input packet to edge node *(pkt).*

Output: Constructed the data burst with segments of different QoS classes and sizes.

1: Initialization: The index variable of Data Burst (DB) $(i \leftarrow 1)$ *and the* index variable of Segment (S) $(j \leftarrow 1)$.

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 *DB [i]* **then**

7: **if** *(assembly timer* $<$ *burst_time of DB [i])* and **then**

8: **if** priority of segment is high and current size of *S[j]* $<$ *hp_s* **then**

9: add the pkt to the *S [j]*

10: **else if** priority of segment is low and current size of *S[j]* $<$ *lp_s* **then**

```
11:             add the pkt to the S [j]
12:         else
13:             increment j
14:             go to 7
15:         end if
16:      else
17:         generate BCP
18:         increment i
19:         trigger the timer of new DB [i] to ON
20:      end if
21:   else
22:      increment i
23:      trigger the timer of new DB [i] to ON
24:      go to 7
25:   end if
```

The SDBPS signaling is a distributed one-way ingress-initiated signaling technique, which is based on staged delayed reservation and implicit release strategies as shown in the Figure (4). In the following we present the SDBPS signaling technique main parameters.

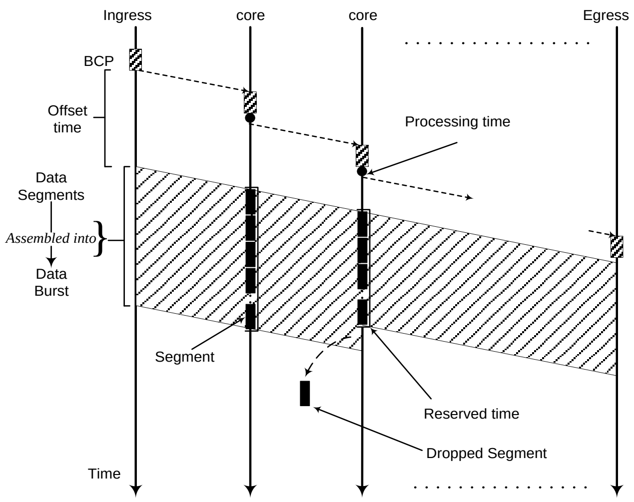

Figure (4): SDBPS signaling scheme

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 10, Issue 3, September 2015 , p.p(28-41)
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The segments susceptibility for dropping is mainly affected by their priority of segments. However, at the core (intermediate) nodes of OBS network, when contention occurs, dropping small segments of burst is deployed. The following algorithm illustrates the implementation of SDBPS at the core nodes:

Algorithm (2): Dropping policy of SDBPS at the core nodes

Input: The Burst Control Packet *BCP[i*], and the Data Burst *DB[i]*.

Output: Send the received *DB to* next hop.

1: **if** received data is *BCP[i]* **then**
2:   **update** reservation table
3:   **if** *DB[i]* reservation is not permitted **then** //*The contention occur*//
4:   **if** priority of segment *s[j]* is low **then**
5:   **drop** segment *s[j]*
6:   **end if**
7:   **end if**
8:   **update** *BCP[i]* header
9:   **send** *BCP[i]* to next-hop
10:   **forward** *2D-DB[i]* to the next hop
11:   **go to** 1
12: **end if**

5.SIMULATION SETUP

In order to evaluate the proposed Segment Drop Based Priority Scheme (SDBPS) performance, simulation is used. The data loss rate is a metric used for measuring the network performance. To simulate the SDBPS, a simulation model is developed based on NCTUns-6.0 simulator [15].

We consider the National Science Foundation Network (NSFNET) topology in the simulation Figure (5). The topology of the network consists of bi-directional links, 14 switches (core nodes), 10 routers (edge nodes) and 10 personal computers (PC). Each fiber has 12 wavelengths, and the bandwidth of each wavelength is 100 Mbps.

Kirkuk University Journal /Scientific Studies (KUJSS)
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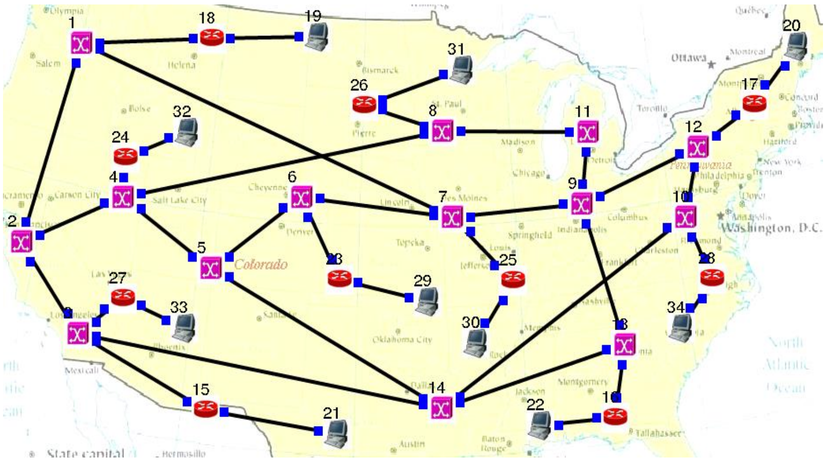

Figure (5): Network topology of the OBS network

The high-priority segment length is 15360 bytes while the low-priority segment is 7500 bytes and threshold time of data burst is 2μs. In addition, we assume that there is no wavelength conversion and regeneration capability for the network. The simulation parameters setup is summarized in the following Table (1).

Table (1): Simulation parameters

Parameter	Value
Threshold Time	2 μs
BCP Processing time	2 ns
high-priority length	15360 KB
low-priority length	7500 KB
Bandwidth/channel	100 Mbps
Reservation Protocol	JET
Number of channels/fiber	12

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 10, Issue 3, September 2015 , p.p(28-41)
ISSN 1992 – 0849

6.RESULTS AND DISCUSSION

Figure (6) depicts the results of a simulation performed using the network topology in Figure (5) with the same main parameters and a scenario where the fractions of the high-priority and the low-priority traffic are respectively 30% and 70%. The following results can be achieved as a points:

1. It can be observed that the low priority data (small segments) experience more loss compared to the high priority data (large segments).

2. It is worth noting that this mechanism does not cause the starvation of low priority traffic.

3. The justification of SDBPS superior results in high-priority traffic, because it adopting burst segmentation strategy with deploying of small segments dropping policy for contented segments.

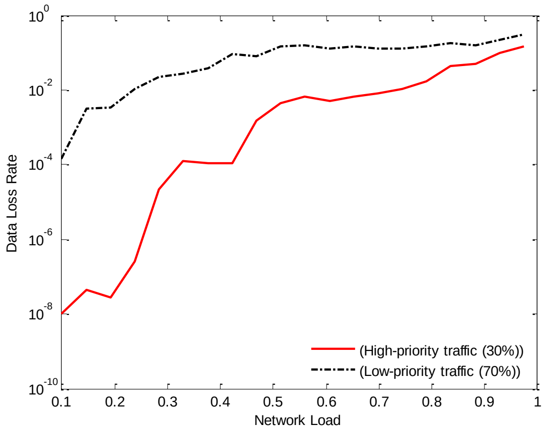

Figure (6): Data loss rate vs. Network load for SDBPS QoS mechanism

7.CONCLUSIONS

In this paper, new QoS mechanisms are introduced for OBS networks that deploy the Segment Drop Based Priority Scheme (SDBPS). The new QoS mechanisms allow the core nodes to simply and efficiently provide service differentiation to different traffic flows. Hence, assembling composite bursts, varying the lengths of data segments in SDBPS based on priority of traffic load. The SDBPS mechanisms are not evaluated in terms of delay as they can be deployed without using additional offset time and without any modification to the general assembly framework of OBS network. However, the mechanisms are evaluated in terms data loss, and it is observed that the high-priority data have significantly lower losses, when compared to the low-priority data. In addition, the simulation results have shown that the SDBPS maintain does not only reduce the burst loss of high-priority traffic due to unresolved contention at the core nodes, but also can be deployed without requiring any additional complex operations or processing at the core nodes.

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Volume 10, Issue 3, September 2015 , p.p(28-41)
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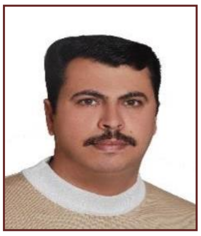

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