# Effective Implementation of Burst Segmentation Techniques in OBS Networks

A. Abid, F. M. Abbou, and H. T. Ewe



***Abstract*—**Optical Bursts Switching (OBS) is a relatively new optical switching paradigm. Contention and burst loss in OBS networks are major concerns. To resolve contentions, an interesting alternative to discarding the entire data burst is to partially drop the burst. Partial burst dropping is based on burst segmentation concept that its implementation is constrained by some technical challenges, besides the complexity added to the algorithms and protocols on both edge and core nodes. In this paper, the burst segmentation concept is investigated, and an implementation scheme is proposed and evaluated. An appropriate dropping policy that effectively manages the size of the segmented data bursts is presented. The dropping policy is further supported by a new control packet format that provides constant transmission overhead.

***Keywords*—**Burst length, Burst Segmentation, Optical Burst Switching.

## I. Introduction

ALL-OPTICAL networks are the solution to sustain the exponential growth of the Internet traffic and the ever-increasing demands for higher throughput. Particularly, with the implementation of Wavelength Division Multiplexing (WDM) technology in the network backbone, many optical switching paradigms have emerged, such as Optical Circuit Switching (OCS) a wavelength-routed network [1]–[3], Optical Packet Switching (OPS) [4, 5], and Optical Burst Switching (OBS) [6, 7]. Wavelength-routed optical networks (currently deployed) represent a promising technology for optical networks. However, wavelength-routed optical networks, which employ circuit switching, may not be the optimal choice and the most appropriate switching paradigm to support the Internet traffic requirements. Alternatively, optical packet switching paradigm appears to be the optimum option. Unfortunately, OPS is not mature enough to provide a viable solution. Therefore, a switching technique that provides granularity in between wavelengths and packets was devised, thus, occupying the middle of the spectrum between circuit switching and packet switching paradigms. Optical burst switching is a switching technique where the benefits of both packet-switching networks and circuit-switching networks are combined; OBS borrows ideas from both to deliver a completely new functionality.

Manuscript received December 29, 2005.

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OBS appears to be an appropriate data transfer technique for all-optical networks, which takes into consideration the limitation of the existing all-optical technology (i.e. limited processing power, the lack of efficient buffering techniques, and the limited number of wavelengths per physical fiber coupled with the high cost of wavelength conversion) [8]. In OBS networks, the ingress nodes generate control packets that are sent into the network an offset time ahead of macro-packets. The macro-packets named Data Bursts (DB) are made up of various upper layers' packets (e.g. IP packets, ATM cells, Frame Relay frames…). The control packets configure the fabric switch of the core nodes and reserve the necessary network resources to accommodate the upcoming data bursts.

For various reasons the control packet may fail to reserve the full/part of the resources needed to establish an all-optical transmission path for its corresponding DB. Consequently the burst is blocked and discarded in an intermediate node. In order to reduce the burst loss probability, many approaches were considered based on different techniques, such as the use of deflection routing to resolve contention presented by Hsu et al. [9] and Kim et al. [10]. Other promising techniques for partial burst dropping (that reduces the packet loss probability) were introduced, based on the concept of burst segmentation. Optical Composite Burst Switching (OCBS) proposed by Detti et al. [11], suggests that if all the resources are occupied at the time of the burst arrival, then only the initial part of the burst is dropped. The final part of the burst is transmitted once the needed recourses become available. Similarly, based on the concept of burst segmentation another technique was proposed by Vokkarane et al. [12] to reduce the packet loss probability. In this technique designed upon Just-Enough-Time (JET) architecture [13], the data burst is broken into multiple segments that consist of a single packet or multiple packets. Combined with deflection routing, the authors showed that their approach performed better than the "entire-burst-dropping" policy used by the standard OBS. In this paper, a new control packet format is proposed. Furthermore, an implementation scheme based on burst segmentation concept is developed for OBS to resolve burst contention. With this scheme the dropped segments are selected evenly from both contending bursts. The scheme ensures optimal link utilization and avoids congestion in the control channels by allowing only the bursts with the proper size to be switched and transmitted. The performance of the technique is evaluated using a simple queuing model. The rest of the paper is organized as follows: In the next section, a general description of the OBS framework is presented. In section 3, the existing contention resolution techniques that are based on partial burst dropping strategy are briefly reviewed. The control packet format and the proposed scheme are discussed in section 4. In section 5, the analytical model and the performance evaluation results are given. Finally, section 6 concludes the paper.

## II. Optical Burst Switching (Basic Concept)

OBS is an adaptation of a stander known as ATM Block Transfer (ABT) developed by the telecommunication standardization sector of the International Telecommunication Union (ITU-T) for burst switching in Asynchronous Transfer Mode (ATM) networks. OBS consists of core nodes – built from optical and electronic components – and edge (Ingress/ Egress) nodes connected by WDM links. OBS differs from optical packet switching and the original burst switching concept introduced in the 80s [14]-[15] in that it separates the control and the data, both in time (i.e. the control packet is transmitted an offset time prior to its corresponding data) and physical space (i.e. the control packets and the data propagate in different chosen channels).

In OBS system, a generated control packet at the network ingress is sent into the network on a separate wavelength(s)/channel(s) over a WDM link to the OBS core nodes to announce and reserve the needed network resources for an upcoming set (burst) of packets assembled into a macro-packet, called Data Burst (DB). In order to establish an all-optical transmission path through the network backbone, the control packets are sent an offset time ahead of the data. The time difference is utilized to electronically process the control packet as it passes through O/E/O conversion at the core nodes, and to configure the switching fabric before the arrival of the DB. The control packets named Burst Control Packets (BCP) usually contain the offset time, the routing information, and the data burst length (duration). The data bursts are disassembled back into the original packets at the network edge (egress node).

Currently, there are various OBS schemes with different tradeoffs [13], [16], [17]. Those schemes may differ in the resource allocation and contention resolution methods, however, they all share two characteristics, first the separation of the control and the user data in time and space; second is the use of the burst (aggregation of packets) as the transmission data unit, which is assembled and disassembled only at the edge nodes.

## III. Contention Resolution Techniques

The motivation behind developing OBS was mainly building a bufferless network, where the data are transmitted and switched all-optically. Therefore, the data in the core nodes is either forwarded if there are enough resources, or dropped in case of contention. Thus, burst-dropping probability is a critical factor in OBS systems' efficiency measurement and performance evaluation. In order to reduce the burst loss probability, many methods and schemes were introduced. In this section we will present an overview of the main contention resolution techniques based on partial burst dropping strategy.

### *A. Optical Composite Burst Switching (OCBS)*

Proposed by Detti et al. [11], the Optical Composite Burst Switching (OCBS) technique introduces the idea of dropping only the initial part of the burst if all the resources are occupied at the time of the burst arrival. The final part of the burst is transmitted as soon as the needed recourses become free.

Though that this technique allows the packet loss probability to be reduced therefore improving the performance of the network compared to the traditional OBS architecture where the entire burst is dropped, OCBS suffers from the need for Fiber Delay Lines (FDLs). FDLs (optical buffer) are needed to delay the data bursts while the control packet is being electronically updated with the new burst size, which is considered as a problem itself, as it increases the electronic processing time needed before forwarding the control packet to the next node.

### *B. Burst Segmentation*

Burst Segmentation was proposed by Vokkarane et al. [12] to reduce packet loss in optical burst switched networks. Burst segmentation is designed upon OBS-JET architecture and it assumes fixed upper-layer packet size. This approach is comparable to OCBS in that it uses burst segmentation concept. In this technique the data burst is broken into multiple segments that may contain a single packet or multiple packets. Combined with deflection routing, the authors showed that their approach performed better than the "entire-burst-dropping" policy. Two ways were proposed to implement this scheme:

*Segment-first.* The remaining length of the original burst (i.e. the segments of the burst yet to be transmitted when the contending burst arrive) is compared to the contending burst. The contending burst is deflected in case it is the shorter one otherwise the original burst is segmented and its tail is deflected or dropped if the alternate port is busy.

*Deflection-first.* The contending burst is deflected if the alternate port is free. If the alternate port is busy then a similar process to segment-first takes place and the lengths of both original and contending bursts are compared and the tail of the shorter one is dropped, as the alternate port is busy.

Albeit their demonstrated efficiency, the contention resolution techniques based on burst segmentation concept are associated with a number of challenges and practical issues. Thus, the implementation of the burst segmentation strategies is not a straightforward implementation. Accordingly, the following aspects are identified to be considered for an efficient and viable implementation.

*Switching time (ST):* ST is the time needed to reconfigure the switching fabric. ST depends on the design and implementation of the core node, and it may differ from a core node to another.

*Data burst size:* since the transmission of DBs depends on the transmission of their BCPs. The DB length should agree with minimum and maximum length requirements, to avoid congestion in the control channels. The same is true for the truncated burst (i.e. DB that lost some of its packets).

*Segment Delineation:* since the data burst are transmitted all-optically the segments' boundaries are transparent to the core nodes, and their sizes are not reflected in the BCP.

*Fiber Delay Lines (FDLs):* as in Optical Composite Burst Switching (OCBS), FDLs are needed to delay the data bursts while their control packets are being electronically updated with the new burst size, which increases the electronic processing time needed before forwarding the control packet to the next node.

*Trail-control messages:* generated by the node where the DB is being truncated. The trailing control message is needed to indicate the burst's new size to the downstream nodes, to avoid unnecessarily resource reservation or needlessly contention resolution actions.

## IV. Burst Segmentation Implementation Scheme

To effectively implement a burst segmentation strategy, it is noted that dividing each data burst into data segments (DSs) will not be sufficient, and representing each DS's control information in the BCP is not feasible (which is traditionally done). In this paper, it is proposed that all the data segments should be equal (for simplicity), and they should exhibit the same attributes as the DBs, i.e., each segment may range from one to several packets, and its length should agree with a minimum and maximum length requirements (for efficiency). Additionally, the length of each DS should be explicitly reflected in the BCP. Therefore, a suitable BCP format is proposed.

### A. Burst Control Packet Format

The proposed BCP's format provides constant transmission overhead and makes the BCP scalable to higher speeds, as it uses the *Flow Control and Reservation Bits* (FCRB) as the segments' length indicator instead of flags [2]. A brief description of the BCP in Fig. 1, is provided here:

*FCRB field:* FCRB is created by the ingress-node to reflect the permitted segmentations. In the core-nodes, the SRS-length is multiplied by the number of $1_2$ in FCRB to obtain the actual size of the corresponding DB. For example $0111_2$ is an indication that the length of the DB (or truncated DB) is (3 * SRS-length), and it might be segmented into three segments. The size of *FCRB* is dynamic that may vary from one DB to another, and the burst assembly algorithm controls it.

*Flag field:* is a sequence of bits with a recognizable pattern that identifies the end of the FCRB field (as its size is not fixed), and the beginning of the DS-length field.

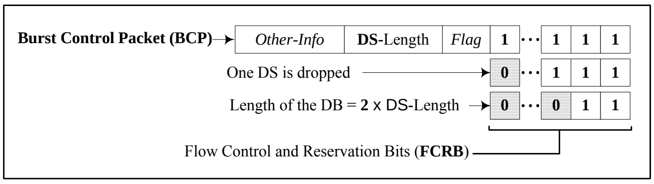


Fig. 1 The Burst Control Packet (BCP) format

*DS-length field:* contains the length of one data segment. However, the *DS-length* combined with FCRB provides sufficient information about the DB's length and segmentation. To avoid congestion in OBS control-channel, *DS-length* should comply with a minimum length [2], which is the minimum permitted data burst length transmitted over the optical links. The *DS-length* may vary from one DB to another.

*Other-Info field:* contains routing information (e.g. Burst destination Address), offset time, etc…

### B. Data Segments Dropping Policy

A key parameter in the design of an OBS network is the maximum and minimum burst size, which is managed by the edge nodes using the assembly algorithms. During the burst segmentation process in the core nodes, this key parameter is entirely overlooked by the resource allocation schemes based on the burst segmentation concept, since no policies related to the size of the truncated burst (i.e. shortened data burst) are implemented. Furthermore, there is no fairness in allocating the network resources to the contending data bursts, as all the segments are simply discarded from only one burst to resolve the contention.

A better solution would be selecting evenly the segments to be dropped from both contending data bursts. Likewise, the truncated burst size should be monitored at the core nodes, and guaranteed to be larger than the Minimum Burst Length (MBL), which is the minimum length allowed into the network to avoid congestion in the control channels.

Additionally, the technique proposed in this paper is designed to deal with the Switching Time (ST), which is the time needed to configure the switching fabric. To understand what follows, the following definition are provided and illustrated in Fig. 2.

- $DB_O$: Original DB with Arrival time $T_{OA}$ and leaving time $T_{OL}$
- $DB_C$ : Contending DB with Arrival time $T_{CA}$ and leaving time $T_{CL}$ .
- *TDB*: Truncated DB (i.e. a DB with dropped segments).
- $N$, $M$: are respectively the number of segments in $DB_O$, $DB_C$ .
- *DS*: Data segment with length *DSL*.
- Original DB length: $\boldsymbol{DBL_O = T_{OL} - T_{OA} = N * DSL}$
- Contending DB length: $\boldsymbol{DBL_C = T_{CL} - T_{CA} = M * DSL}$
- $R$: the expected number of segments to be dropped from each

data burst in case of contention, $R = \left\lceil \frac{|T_{CA} - T_{OL}|}{2DSL} \right\rceil$

-Length to be dropped from each data burst: ***LTD = R * DSL***

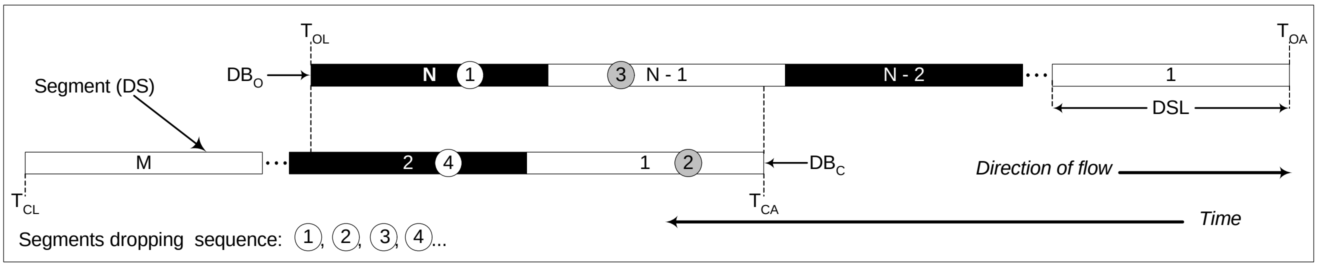


Fig. 2 Illustration of data burst contention, and segments dropping process

Before the DBs are sent to the downstream nodes the technique performs three functions arranged in three main events. Starting with *Contention_Detection* event, if a contention is detected then *R* (number of segments to be dropped from the contending data bursts) is calculated, then the second event is executed.

```
Event :: Contention_Detection

/* There is a contention if the condition is true */
    IF ((T_CA - T_OL) < ST) THEN
          R = ⌈ |T_CA - T_OL| / 2DSL ⌉   /* calculate R. */
          Execute: Length _of _Truncated_Burst
    END IF
End of Event
```

Through *Contention_Detection* event, the second event named *Length_of_Truncated_Burst* is executed to guarantee that whatever is left from the data bursts after dropping some of their segments is good for transmission over the OBS network.

```
Event :: Length _of _Truncated_Burst

/* The truncated burst will be less than the allowed
   burst length if the condition is true */
  IF ((DBL_O - LTD < MBL) || (DBL_C - LTD < MBL)) THEN
       IF (DBL_C < DBL_O) THEN
       /* DB_C is the smallest, therefore, dropped */
           Drop DB_C
       ELSE
       /* DB_O is the smallest, therefore, dropped */
           Drop DB_O
       END IF
  ELSE
       Execute: Even_Resource_Allocation
  END IF
End of Event
```

In this event, if one of the truncated data bursts does not meet the MBL requirements, then the contention is simply resolved by dropping the shortest data burst in its entirety. However, the third event is executed if the truncated data bursts are larger then MBL. The *Even_Resource_Allocation* is used to resolve the burst contention by discarding the overlapping segments *alternatively,* starting from the tail of the original burst, and then the head of the contending burst as shown in Fig. 2.

```
Event :: Even_Resource_Allocation
/* Initialize counter */
i = 1
   DO
     {
      IF (i % 2 = 0) THEN
   /* DB_C is reduced by one DS from the burst head*/
         T_CA = T_CA + DSL
      ELSE
   /* DB_O is reduced by one DS from the burst tail*/
         T_OL = T_OL - DSL
      END IF
   /* Increase the counter i by 1 */
       i++
     }
   WHILE ((T_CA - T_OL) < ST)
End of Event
```

As a summary, by adopting this scheme, if a contention is detected in the core-nodes, the resources allocation process will not be aborted, i.e., BCP is dropped and later the corresponding DB is entirely discarded. Conversely, the FCRB fields in the corresponding BCPs are updated according to the resources that the core-node can provide. Hence, only the overlapping segments are dropped, allowing part of the DB to be transmitted. Since the BCPs are updated before forwarding them to the downstream nodes, to reflect the new DBs' length, the need for trailing messages is eliminated, and the contention is resolved at the BCPs level rather than at the DBs level.

## V. Performance Evaluation

OBS system was modeled as M/M/k/k, M/M/k/D or M/G/n loss system, in [18]-[22]. The well-known Erlang B formula (1) was used to obtain the burst loss probability.

$$P(k, A) = \frac{\frac{A^k}{k!}}{\sum_{m=0}^{k} \frac{A^m}{m!}}, \tag{1}$$

Where *A* is the traffic load, and *k* is the number of wavelengths available at each output port.

M/G/k/k queuing system was extended in the literature [18] to an M/G/∞ queue with an unlimited number of pseudo-servers (channels). This model was used to study the performance enhancement in OCBS. With the assumption that the segment length is fixed and equivalent to one packet [12], we could straightforwardly use the queuing model M/G/∞ to evaluate the performance of the proposed technique implemented upon the burst segmentation model proposed in [12].

With no buffering and seeing that the ST is contained in the dropped DSs, the technique can then be modeled as M/G/∞ queue system with infinity of imaginary servers besides the available n servers (i.e. number of wavelengths). With the number of busy servers equal to *(n + k)*, two cases emerge:

- k ≤ 0: no contention (number of busy servers is ≤ n).
- k > 0: all the n servers are busy, and there are k imaginary active servers for k upcoming DBs attempting to be switched.

Under the second case, there are k DSs lost for every n DSs transmitted (for every *n* DSs on the n servers (wavelengths), k DSs are dropped to resolve the contention). As soon as the contention is resolved, the contending burst is moved from the imaginary server to be served by an original server. The packet loss probability can be obtained by:

$$P = A^{-1}\sum_{k=1}^{\infty} i.P(n + k) \qquad (2)$$

Where *A* and *P (n+ k)* are respectively the traffic load and the probability that *(n + k)* servers are busy. Since the number of busy servers in M/G/∞ model has a Poisson distribution [23], *P(n + k)* can be obtained as follows:

$$P(n+k)=A^{n+k}\frac{e^{-A}}{(n+k)!},k=1,2,3,... \qquad (3)$$

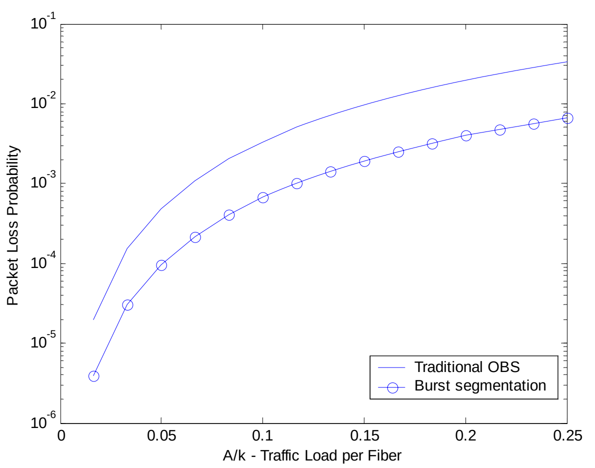


Fig. 3 Packet loss probability versus normalized Traffic load

The results in Fig. 3, show significant performance improvement in the burst segmentation model over the traditional OBS. Further improvement is expected if the OBS system is designed to support deflection routing, with fiber delay lines, or with wavelength conversion capabilities.

## VI. Conclusion

In this paper, an overview of the optical burst switching network and its current contention resolution techniques based on burst segmentation concept is provided. A new and effective implementation scheme is presented. With this scheme, the dropped segments are evenly distributed between the contending bursts to achieve some kind of fairness between traffic flows and to minimize the number of short data bursts. Furthermore, the scheme enables the core nodes to monitor and manage the size (length) of the data bursts traveling within the network backbone. The scheme is simple, practical, and its implementation does not lead to any compromises on one of the main motivational reasons behind the emergence of the OBS paradigm, witch is simplicity.

Additionally, a new format for the burst control packet is proposed. With the new format, the length of the data burst and data segments can be shown, as well as, the number of the dropped segments and the forwarded segments using only a limited number of bits (Flow Control and Reservation Bits). As a result, It is clear that the functionality of FCRB field can be extended to provide flow and congestion control capabilities in the optical domain.

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