QoS Considerations in OBS Switched Backbone Networks

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Abstract

Optical Burst Switching (OBS) was proposed as a hybrid switching technology solution to handle the multi-Terabit volumes of traffic anticipated to traverse Future Generation backbone Networks. With OBS, incoming data packets are assembled into super-sized packets called data bursts and then assigned an end to end light path. Key challenging areas with regards to OBS Networks implementation are data bursts assembling and scheduling at the network ingress and core nodes respectively as they are key to minimizing subsequent losses due to contention among themselves in the core nodes. These losses are significant contributories to serious degradation in renderable QoS. The paper overviews existing methods of enhancing it at both burst and transport levels. A distributed resources control architecture is proposed together with a proposed wavelength assignment algorithm.

Index terms— data bursts, quality of service, distributed control architecture, drop ratio, random routing, shortest path routing.

1 Introduction

ptical burst switching (OBS) has become a perspective solution towards narrowing the gap be-tween switching and transmission speeds in future generation backbone networks. At transmission level, data packets sourced from edge nodes are aggregated and assembled into optical burst units generally re-ferred to as bursts. A burst control packet is transmitted for each assembled burst in a dedicated control channel and delivered with a small relative offsettime prior to the actual data burst's arrival. This offset timing allows for electronic processing of the control packet by a controller at an intermediate node thus creating an allowance for a wavelength reservation on its output link and switch matrix reconfiguring usually for the duration time of the incoming burst. The burst will then shortly fly by and immediately afterwards the reserved wavelength can now be freed /released and made available for other connections. This effectively alleviates the need for optical buffering at intermediate nodes which otherwise would escalate network design and operational costs. Further more, such a temporary usage of wavelengths promotes higher resource networks. OBS architectures with limited buffering capabilities would still be susceptible to congestion states. The existence of a few highly congested links may seriously aggravate the network throughput [1]. The congestion itself can be reduced either by appropriate network dimensioning or by a proper routing in the network. The dimensioning approach fits the node and link capacities according to the matrix of actual traffic load demands and after such optimization it needs only either a simple shortest path algorithm or a similar mechanism [2]. Some parts of such a network, may however, encounter the congestion problem if the traffic demands change. On the contrary, the routing approach in-troduces some operational complexity since it often requires advanced mechanisms with signaling pro-tocols involved. Nevertheless, the advantage is that it adapts to the changes in the traffic demands. A great part of the research on routing in OBS networks ad-dresses the problem of deflection routing, [3], [4] in which in the event of contention or its imminence, one of the contending bursts is deflected to an alternative route. However, the deflection routing approach can partially improve network performance under rela-tively low traffic loads and gradual degrade it as the traffic intensity increases [4]. Overall in OBS networks burst loss probability and delay jittery are the main primary performance metrics of interest which adequately represent the congestion state of the entire network and at the same time dictating renderable QoS. Its provisioning consistently for the various diverse applications with varying handling demands remains a problematic task. The current lack or inadequacy of optical buffering facilities further posses a real challenge in the operation of OBS net-works in this regard, especially, in a scenario where it is desirable to guarantee a certain level of QoS con-sistency. Stringent QoS demanding traffic types such as real-time voice or interactive video transmissions require additional QoS differentiation mechanisms in order to preserve them from low priority data traffic especially when the network is near to resource con-strained. In this context burst assembling/contention resolution mechanisms that facilitate minimal low burst blocking probabilities, latency as well as jitter metrics will be very vital in the operation of OBS networks that are consistent QoS capable. Various approaches to QoS differentiation and utilization as well as better adaptation to highly variable input traffic in comparison to optical circuit-switching implementation schemes have been discussed extensively in various literatures e.g. [5], [6], [7].

2 Networks

Basically two kinds of QoS differentiation models have been defined: relative versus absolute differentiation [7].

With the rela-tive QoS differentiation model, traffic is segre-gated according to classes. The performance of each class is not defined quantitatively in absolute terms based on loss, delay and bandwidth. Instead, the QoS of one class is defined relatively to other classes. The absolute QoS model aims to provide worst-case guarantees on the loss, delay and band-width to applications. This type of hard guarantee is considered essential for the classes of delay and loss sensitive applications, which include multimedia and missioncritical applications. Generally QoS differentiation can be provided either with respect to forwarding performance (e.g., the burst loss rate), or with respect to service availability. In the former case, a pre-defined quality guarantees are expected during a normal, fault-free operation while the latter case concerns QoS-enhanced protection mechanisms in the resilience problem. Effective QoS provisioning in OBS engages both the definition of specific QoS classes to be given for higher level applications and some dedicated mechanisms in order to provide such classes, [8]. Each class will be classified by pre-setting upper limit bounds on known QoS parameters such as end-to-end latency, jitter and burst loss probability. The delays arise mostly due to the propagation delay in fiber links, the introduced offset time, edge node processing (i.e., burst assembly) and optical fiber delay lines (FDL) buffering. The first two factors can be easily limited by properly setting up the maximum hop distance allowed for the routing algorithm. Also the delay produced in the edge node can be imposed by a proper timer-based burst assembly strategy. Finally the optical buffering, which in fact has limited application in OBS, introduces relatively small delays. Since there are many factors that influence the end-to-end data delays, the problem of jitter is more complicated and needs more focus. Overall it is clear that the key to successful implementation of affective QoS mechanisms in OBS networks is Burst Assembly and Scheduling techniques. The rest of this review paper is presented as follows; Section 2 gives an overview of burst assembling algorithms including burst reservation protocols, whilst burst reservation, scheduling and contention methods are discussed in section 3. The two sections are discussed with regards to QoS support. In section 4 we briefly describe a framework model for QoS provisioning based on both advance and immediate reservation of resources depending on application in a decentralized resources control and management network, and finally we conclude the paper.

3 II.

Burst Assembling settable QoS. The strategy implemented will de-termine the end to end performance of the network. The primary focus of any burst assembly strat-egy/mechanism is to minimise the packet burstification delays thus ensure that the end to end delays fall within acceptable bounds.

It should also reduce the rate of control packets generation by maximising the burst sizes, otherwise overhead processing loads at the intermediate /core nodes may increase drastically and eventually lead to congestion. On the other hand, in-creasing the burst sizes leads to burstification delays especially in low traffic scenarios. Hence a trade-off between the two is thus desirable. To date several burst assembly schemes have been proposed and are all geared towards improving QoS, [8]- [13]. Generally these are broadly classified into different schemes such as; time based, volume-based, as well as hybrid schemes. An example of a time based scheme is the Fixed Time-based scheme [9].With this scheme, also denoted as max T in the literatures i.e., [10] a time counter starts any time a packet arrives and when the timer reaches a time threshold max T , a burst under assembly is dispatched. The timer is reset again and only re-initiated upon next packet arrival at the burstification queue. Hence, the ingress router generates bursts with a duration max T , independently of the yielding burst size. The pre-setting a fixed interval time will create drawbacks such as increasing the loss rate in case of high traffic or reaching the interval time max T before aggregation of enough packets in the burst. (In this case padding may be necessary if the resultant burst is below a minimum threshold min L . In contrast to time-based schemes, a volumebased scheme, which is non-adaptive, sets a minimum burst size value min B before the burst can be dispatched. Alternatively to that is whereby a threshold max B is used to determine the end of the assembly process. As soon as that value is reached, the assembling is dispatched. A minimum burst size min B scheme will favor real time applications during relative low traffic loads, as low delays will be experienced whereas a maximum threshold max B scheme will reduce the frequency of control packets especially whenmin max B B »

. This however will attract delays for real time applications during low traffic conditions. A hybrid scheme is proposed and analyzed in [11], [12]. That is, the burst is created either by reaching a maximum value of the timer max T or by reaching the minimum/ or maximum burst size. Since this scheme combines the benefits of the time-based burst assembly scheme and the minimum /maximum volume-based scheme, it is considered to be the default burst assembly scheme.

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Volume XIV Issue V Version I Burst assembling at edge nodes is key in the de-sign and implementation of OBS networks with pre-Nonetheless, the low traffic load problem remains unsolved since the packets still have to wait for reaching the maximum value which affects the real time traffic delay requirements. A Learning-based Burst Assembly (LBA) is adaptive scheme was proposed to reduce burst losses [13]. With this algorithm, the burst assembly process is adapted according to the loss pattern experienced in the network itself. By the learning automata algorithm used in this scheme, the loss is checked periodically in order to adapt the assembly time at the ingress node accordingly. Therefore, this scheme may be effective in reducing the loss but it is unsuitable to use in real time traffic since end-to-end delay is not considered. A timer based Burst-assembly algorithm with service differentiation scheme was also proposed [13] and it uses a single timer that is set to a maximum threshold value not exceeding tolerable delays by any of the traffic. Its main drawback is that the preset timer value out T cannot be determined precisely as the overall end to-end delays in an OBS network is dependent on a variety of factors. Moreover, the performance of this algorithm is affected due to the small size bursts created.

5 III.

6 Reservation, Scheduling and Contention a) Reservation

A resources reservation process in the core node concerns the allocation of resources necessary for the smooth switching and transmission of data bursts from a given source to a desired destination (output port). Separation of bursts and control channels together with offset-time provisioning enables the implementation of a variety of differing resources reservation schemes. One way, two way and hybrid resources reservation approaches have been studied extensively e.g. [14]. Broadly these can either be explicit or estimated.

In explicit setup, a wavelength is reserved, and the switch fabric is configured immediately upon proc-actual burst arrives. The allocated resources can be released after the burst has come through using either explicit release or estimated release. In explicit release, the source sends an explicit trailing control packet to signify the end of a burst transmission, whereas in estimated release, an OBS node knows exactly the end of the burst transmission from the burst length, and therefore can precisely estimate when to release the occupied resources. Based on this classification, the following four possibilities exist: explicit setup/explicit release, explicit setup/estimated release, estimated setup/explicit release, and estimated setup/estimated release, see e.g. [15], [16], [17]. Several light paths (resources) reservation algorithms have been proposed in adherence to some or all of these fundamental rules. Examples include, immediate reservation (JIT, E-JIT), delayed reservation with void filling (JET), delayed reservation without void filling (Horizon), and modified immediate reservation (JIT+). An extensive performance comparisons of the JIT, JIT+, JET and Horizon protocols can be found in [24]. Overall delayed schemes promote better and efficient utilization of available resources, especially when void filling is applied, and perform better in terms of burst loss probability. However, the sophisticated scheduling algorithms that they require increase the processing times of BCPs at intermediate nodes. Thus, given the scenario, the simplicity of JIT may balance its relative poor performance.

Overall from a QoS perspective, the absence of acknowledgement in one-way reservation algorithms will suit delay sensitive applications, more than two-way based reservation protocols as the latter has to incur acknowledgement delays. However two way reservation will enhance reliability in the sense that there is provision for, retransmission should the initial burst not succeed. As such hybrid schemes generally inherit the better features of both to enhance QoS support.

For an example, proposed in [21], is a Dualheader Optical Burst Switching (DOBS) signalling scheme that decouples the resource reservation process from the service request process in core nodes and allows for delayed scheduling to be implemented. This relaxes the constraints on burst reservation operations and allows the offset sizes of bursts to be precisely controlled in core nodes without the use of fiber delay line buffers, thus allowing for increased flexibility, control, and performance. A variant of the scheme called the constant-reservation/schedulingoffset (CSO-DOBS) in which the offset size of every burst on a core link is set to a constant value is evaluated, with the result that it realizes lower ingress delay, higher throughput, and better fairness in comparison to the conventional sin-gle-header OBS

7 b) Burst Scheduling

The principal aim of a burst scheduling algorithm is to obtain the right switching configuration matrix for efficiently transferring received bursts to the desired output port. Several algorithms in this regard have been suggested broadly categorized as either without void filling or with void filling. Without void algorithms do not aim to maximize the use of resources but rather to generate low processing times. Examples include the latest available unused channel (LAUC) and the first fit unscheduled channel (FFUC) [17].More advanced scheduling algorithms belong to the void filling category. These are designed to achieve efficient use of resources coupled with minimal blocking probabilities. However, void filling algorithms are more complex, hence difficult in implementation and sluggish. Examples of algorithms that are void filling include latest available unused channel with void filling (LAUC-VF) and first fit unscheduled channel with void filling (FFUC-VF).

Modified versions of these include the minimum starting void (Min-SV) and the minimum ending void (Min-EV) scheduling algorithms, [18], which significantly improve processing time in comparisons with the LAUC-VF. It appears however that Min-SV/EV algorithms involve time-consuming memory accesses and hence generally considered too sluggish to provide a viable solution to the problem. Table **??** summarizes the comparison between the algorithms based on the study in [17]. In the table, (w) is the number of wavelengths at each output port; N is the number of bursts currently scheduled.

8 c) Contention resolution

When two or more bursts contend for the same re-sources then contention will result. There are four principal approaches to solving contentions. These include, wavelength conversion, fibre delay lines (FDLs), deflection routing and burst segmentation. Contention and consequently partial or total data burst losses may be reduced by implementing contention resolution policies. Clearly, a combination of such techniques can be very effective. Using buffering in the core switches may not be viable, since the hardware complexity and high cost of such devices make them less attractive and limits their practicality.

Deflection routing can potentially result in inefficient routing and a high number of collisions. Furthermore, it results in high end-to-end delay and possible packet reordering, neither of which may be acceptable for many applications, thus a compromise to QoS.

9 Figure 2 : Contention resolution

Wavelength conversion on output ports is a very efficient approach for resolving contention and adds an additional dimension (in addition to time and space) to contention resolution. When a contention cannot be resolved by any one of these techniques, one or more bursts must be dropped. The policy for selecting which bursts to drop is referred to as the soft contention resolution policy. A soft contention resolution algorithm may be utilized in conjunction with a scheduling algo-rithm to reduce the overall burst loss rate (BLR) and consequently, enhancing link utilization. Thus, the contention resolution algorithm is invoked only when no available unscheduled channel can be found for a burst header packet (BCP) request. A contention scheme based on combining deflection, retransmission and delaying bursts to improve overall OBS performance called the Dynamic Contention Resolution scheme was proposed. see [20]. The scheme basically combines deflection routing, retransmission or delay of bursts dynamically. Based on current network conditions a decision is made to select whether to use either of the three. This is further coupled with offset time adaptation by using an adaptive decision threshold. With this al-gorithm ACKs and NACKs are exchanged by all par-ticipating nodes such that they always update each other with statistics about network conditions. As illustrated in figure 3, when no contention occurs, the primary path is used (a). However when contention occurs, the scheme chooses between the best contention resolution strategy among deflection routing, re-transmission and delay (b). When the control packet reaches the destination, an ACK is sent back to the sources. However if it is dropped, a NACK is instead sent to notify the source for burst retransmission. In such situations, it would seem appropriate to work out a mechanism for promoting fairness in burst dropping and effectively not over compromising QoS.

10 i. Burst Drop Policies for contention res-olution

In the presence of congestion or its imminence, Burst dropping is generally considered as a last resort contention resolving measure [21] as it potentially readily compromises QoS. At burst level, several burst drop policies that take into account fairness have been proposed. Such is the Latest arrival drop policy (LP) which in its basic form, will always attempt to search for an available unscheduled channel on the desired route and if no such channel is found, the next incom-ing data burst will be discarded. Its poor performance can be attributed to lack of buffering and hence inca-pabilities of differentiated QoS support. In order to accommodate differentiated QoS support, the Look-ahead window contention resolution (LCR) was proposed. By receiving BCPs one offset time (o t ?) prior to their corresponding data bursts, it is possible to construct a look-ahead window (LAW) with a size of W time units. After the LCR process is completed for the look-ahead window, the starting time of the window is advanced to the next slot and may include new BCPs. Already existing scheduled re will be processed unimpeded and irreversibly and cannot be superseded by future requests. In this way multiple class services can be supported without necessarily provisioning extra offset time. Both absolute proportional differentiation QoS support is possible with this scheme. In particular it is noted that the possibility of a high-priority burst being blocked by any lower priority burst is eliminated. A further enhancement of this scheme is by way of the Shortest burst drop policy (SBP) which regionalizes each window and the bursts with the shortest duration and latest arrival time in each region will preferentially be dropped. As reported in [21], in order to reduce the endto-end data-burst delays, the LCR with shortest drop algorithm can be modified such that the window size is reduced to a single slot and the contending burst with the shortest duration in each slot is selectively discarded. In terms of supporting class differentiation, SBP can support multi-priority levels and requires no extra offsetting for bursts with relative higher QoS demands. It also guarantees complete class isolation. In addition, SBP offers proportional QoS differentiation. Given that a single burst accommodates gigabits of data, a single burst loss will potentially have adverse QoS compromises on one or many connections at the time. As such assembling bursts in segmented form will enable discarding sections of an individual burst rather that an integral whole.

The Segmentation drop policy (SP) implementable in situations whereby the original burst was assembled in segment form where the individual segments are independent, hence facilitating their selective discard-ing when contention occurs on a priority basis. The obvious drawback with this policy is the complexity in hardware implementation especially with regards to burst generation and disassembling, as well as overhead insertion and extraction.

Further, a burst dropping policy with even selection of burst (BDPES) was proposed [20] in which the QoS requirements of the traffic are defined based on their class. Packets of the same class and destination are assembled into the same data chunks called segments which will be priority tagged accordingly. As such a data burst may contain data chunks of the same or different priorities. The segments are assembled into data bursts, in such a way that the lower priority data segments envelop the higher priority ones. With this scheme, the dropped segments are selected evenly from both contending bursts but such that the residual (truncated) data bursts still retain a minimum threshold length allowed by the network.

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Volume XIV Issue V Version I This results in even loss of data for all sources who contributed to the burst rather than an individual source suffering data losses as is the case with most existing burst dropping schemes. It is further noted that both the edge nodes and core nodes must co-operate in the fully implementing of such a scheme. Overall it is note that with this scheme, the data chunks 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.

12 IV. Resources Allocation Framework

The heterogeneous nature of NGN backbones in terms of traffic types makes guaranteed QoS provisioning quite complex as the various traffic types differ i.e., in terms of performance parameters such as loss, delay, delay jitter etc. Traffic diversities range from unicast, anycast, broadcast, multicast as well as delay/loss sensitive and insensitive traffics applica-tions. In each case the request can be for one or more channels, where each channel can be routed independently of others using a different route and wavelength. Multicast requests would generally accommodate delivery of data bursts to multiple destinations but from a single original source. For example broad-casting multiple video streams to several locations at the same time, or near to live IP traffic data up-dating// backups to several locations would require an optical multicast. Furthermore, requests may be bidi-rectional, where the same route and wavelength is used in both directions, or unidirectional. For better QoS guarantees it is hereby proposed that a distributed control plane architectural framework which supports both advance and immediate resource reservations be implemented [23]. As is known, with immediate res-ervation (IR) data transmission starts immediately upon arrival of the request, save only for burst assem-bling and control delays, and the holding time is typi-cally unknown. Advance reservation (AR) in contrast typically specifies a data transmission start time that is sometime in the future and also specifies a finite holding time, e.g. grid applications. It is herein pro-posed that the entire backbone network be re-organized into smaller multiple cluster networks (subnets) each with a cluster header controller (CHC) node. Controllers that perform core routing functions are distributed throughout the network. Each CHC node manages key network routing related information, such as e.g., static nodes and link information within each cluster, whereas a dedicated controller (C) takes care of candidate routes for all destinations, resources state in the core network (available wavelengths) for each outgoing/output link(s), and exchanged link resource information from other controllers (figure5). ,) is blocked/aborted in the event that all fibres of the assigned wavelengths are not available and at the same time burst size/offset time adjusting will not help accommodate the connection. In cases where the contended node is equipped with wavelength converters, then the wavelength of the optical path is can be converted to another available one and the reservation is continued. Should the wavelength reservation succeed, the destination node echoes an acknowledgement (ACK) message to the source node. The source node will immediately start transmitting upon receiving the ACK message.

However should contention occur and there are no wavelength converters available, the intermediate node echoes a negative ACK (NACK) message to the source node. After receiving the NACK message, the source node may now change the wavelength/route reservation request to (j H). In this case during the re-reservation, similar procedures for routing and wavelength assignment are followed only that the contended wavelength and route are excluded. If the network resources are optimally dimensioned, then there is always an excellent probability that the wavelength rereservation would succeed. The distributed control architecture is proposed as it is more robust, scalable and resilient to "a single point of failure" compared to a centralized control architecture. The proposed wavelength assignment algorithm (figure 6), is necessary in that the entire network resources state cannot be communicated in real time due to the unavoidable propagation delays We also propose that the candidate routing path be computed according to the Dijksra shortest path algo-rithm (spr) with collision avoidance and that both one and two way (immediate and advance) reservation be supported. This is because of the heterogeneous nature of connections which inevitably have varying QoS demands. To evaluate the performance of this distri-buted control architecture, we modified the simulation approach used in [23] in which we set the number of clusters varying from 4 to 10, each comprising a set of 3 ingress (subsidiary) nodes and a CHC/C.

In-ter-linkages between CHC/Cs are 32 wavelengths and supports 10Mbps speed per wavelength. This evaluation focuses on a two-way reservation, in which the connection request packets inter arrival times are exponential distributed, and have a service time at each CHC/C. The bursts themselves have a maximum fixed s, and so is the offset time static and equal to 0.6ms. Performance metrics of interest are defined as follows: Connections requests drop ratio; The impact of the number of wavelength per fiber on the connections requests drop ratio is shown in figure 7. In this case we fixed the network resource information updating interval to 10 milliseconds, otherwise setting it long degrades the proposed wavelength assignment/routing method.

V.

13 Conclusions

In this paper we reviewed various existing methods of enhancing a consistent QoS in OBS networks. Burst assembling and scheduling algorithms were discussed in view of enhancing QoS.

A wavelength reservation algorithm with burst size/offset time adjusting is also discussed A distributed resources control architecture is briefly explored. [1] [2] [3]

Figure 1:

[2] © 2014 Global Journals Inc. (US) QoS Considerations in OBS Switched Backbone Networks

[3] © 2014 Global Journals Inc. (US) equidistant. Each link is a bundle of 16 fibers, each with

1

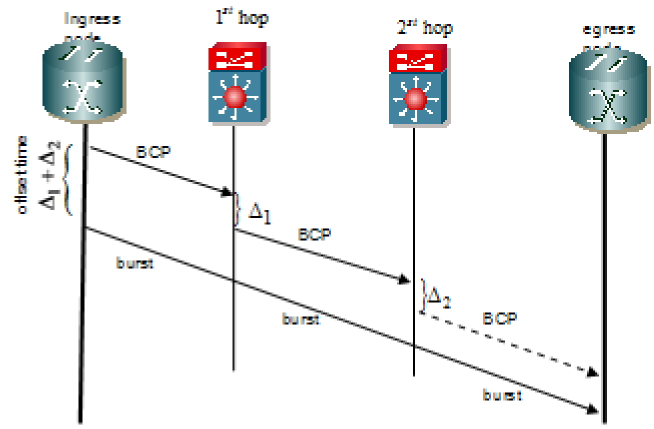

Figure 2: Figure 1 :

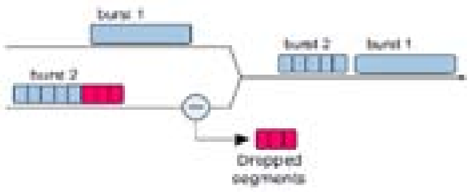

Figure 3:

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Figure 4: Table 2 :

Figure 5:

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Figure 6: Figure 3 :

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Figure 7: Figure 4 :

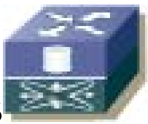
5 

Figure 8: Figure 5 :

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Figure 9: Figure 6 :

Figure 10:

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Figure 11: Figure 7 :

8 

Figure 12: Figure 8 :

1

	t ?	o ?	fairness
CSO-DOBS	very lowest	highest	excellent
JIT	low	lowest	excellent
JET w/ (Void Filling)	high	high	burst length and path unfairness
JET w/o Void Filling	highest	low	path length unfairness

Figure 13: Table 1 :

3

mechanism	pros	cons
Wavelength conversion	Most effective solution	Immature and expensive
FDL buffering	simple	Increased end to end delays
Deflection routing	No extra h/w requirement	Out of sequence arrivals
Burst segmentation	Reduced packet loss ratio	Complicate control handling req irements

Figure 14: Table 3 :

[Photonic Network Communications] , *Photonic Network Communications* 14 (1) p. .

[Christodoulopoulos et al.] 'A Comparison of Centralized and distributed meta-scheduling architectures for computation and communication tasks in Grid networks'. K V Christodoulopoulos , M Sourlas , E Mpakolas , Varvarigos . *Computer Communications*

[Venkatesh et al. ()] 'A novel burst assembly algorithm for optical burst switched networks based on learning automata. Optical Network Design and Modeling'. T Venkatesh , T L Sujatha , C S R Murthy . *Proceedings* 2007. 4534 p. .

[Adgaonkar and Sharma (2011)] 'A Review of Burst Scheduling Algorithm in WDM Optical Burst Switching Network'. R Adgaonkar , S Sharma . *IJCSI International Journal of Computer Science Issues* November 2011. 8 (3) p. .

[Iioannis and Evagelos] *A survey of Reservation Schemes for Optical Burst Switching (OBS) Department of Information and Communication Systems University of the Aegean*, Karamitsos Iioannis , Varthis Evagelos . Samos; GREECE. 83200.

[Zhang and Vokkarane (2003)] 'Absolute QoS Differentiation in Optical Burst-Switched Networks'. Qiong Zhang , Vinod M Vokkarane . *IEEE HPSR'03*, (Torino, Italy) June 2003.

[Kantarci and Oktug ()] 'Adaptive Threshold based Burst Assembly in OBS Networks. Electrical and Computer Engineering, 2006. CCECE '06'. B Kantarci , S Oktug . *Canadian Conference on Ottawa* 2006. p. .

[Charbonneau et al. (2011)] 'Advance Reservation Frame works in Hybrid IP-WDM Networks'. V Charbonneau , Vokkarane , Inder D C Guok , Monga . *IEEE Communications Magazine* May 2011.

[Garg ()] 'Analysis of burst/packet assembly techniques in high-speed optical switching networks'. A Garg . *Op tik-International Journal for Light and Electron Optics* 2011. 122 (7) p. .

[Kumargarga and Kaler ()] 'Burst dropping policies in optical burst switched network'. Amit Kumargarga , R S Kaler . *Optik* 2010. 121 p. .

[Yayah et al. ()] 'Comparative study of offset timing schemes over OBS'. A A Yayah , A Ismail , M A Alshargabi , S M Idrus . *Jurnal Teknologu* 2011.

[Elbiaze et al. ()] *Deflection Routing Strategies in Optical, Burst-Switched Networks*, Halima Elbiaze , Brigitte Jaumard , Ammar Metnani . EJM_OBS_August_2004.

[Hu et al. (2003)] *Does Burst Assembly Really Reduce the Self-Similarity? Optical Fiber Communication Conference (OFC)*, G Hu , K Dolzer , C M Gauger . 2003. March 24. Atlanta, Georgia. p. .

[Christodoulopoulos et al. ()] *Efficient burst reservation protocol: A hybrid signalling protocol for efficient burst-level res-ervations and Quality-of-Service differentiation in optical burst switching networks*, Kostas Christodoulopoulos , Kyriakos Vlachos , Emmanouel Varvarigos . 2006. 2006. America JON 8303 March: Optical Society. 5.

[Lee and Sriram (2005)] 'HyunSook Kim Joo Seok Song. Contention-Based Limited Deflection Routing Protocol in Optical Burst-Switched Networks'. Sukyoung Kotikalapudi Lee , Sriram . *IEEE Journal On Selected Areas In Communications* August 2005. 23 (8) .

[Yoo and Qiao ()] 'Just-enough-time (jet): a high speed protocol for bursty traffic in optical networks'. M Yoo , C Qiao . *Pro-ceedings of IEEE/ LEOS Technologies for a Global In formation Infrastructure*, 1997. IEEE.

[Wei and Mcfarland (2000)] 'Just-in-time signalling for WDM optical burst switching networks'. J Wei , R Mcfarland . *J.Lightwave Technology* Dec. 2000. 18 (12) p. .

[Hernandez et al. ()] *On the analysis of burstassembly delay in OBS networks and applications in delay-based service differentiation*, J A Hernandez , J Aracil , V Lopez , J L Vergara . 2007.

[Garcia] *On the Performance of Shortest Path Routing Algorithms for Modeling and Simulation of Static Source Routed Networks–an Extension to the Dijkstra Algorithm*, Nuno Garcia . `http://ulusofona.academia.edu/`

[Chen et al. ()] 'Optical Burst Switching (OBS): A New Area in Optical Networking Research'. Y Chen , C Qiao , X Yu . *Network* 2004 -ieeexplore.org. IEEE.

[Garg (2012)] 'Performance Analysis of Scheduling Algorithms In Optical Burst Switching Networks'. Rohit Lamba Dr.Amit Kumar Garg . *International Journal of Advanced Research in Computer Science and Software Engineering* 2277 128X. January 2012. 2 (1) .

[Phuritatkul ()] *Quality Of Service Provisioning In WDM, Optical Burst Switching Networks*, Jumpot Phuritatkul . 2005. (Ph.D Thesis)

[Emmanouel ()] 'Routing and Scheduling Connections in Networks that Support Advance Res ervations'. Emmanouel . *Computer Networks* 2008. 52 p. . (Manos) Varvarigos, Vasileios Sourlas and Konstantinos Christodoulopoulos)

[Barakat and Sargent (2006)] 'Service Requests to Improve the Performance of Optical Burst-Switching Networks'. Neil Barakat , Edward H Sargent . *IEEE Journal on Selected Areas in Communications* April, 2006. 24 (4) .

[Vokkarane et al.] *Threshold-Based Burst Assembly Policies for QoS Support in Optical Burst-Switched Networks. Centre for Advanced Telecommunications Systems and Services. The University of Texas at Dallas*, M Vokkarane , Karthik Haridoss , Jason P Jue . Richardson, TX. p. .

[Nail Akar A, Ezhan Karasan A and Kyriakos ()] *Vlachos b, Emmanouel A. Varvarigos b, Davide Careglio c, Miroslaw Klinkowski c,d, Josep Solé-Pareta . A survey of quality of service differentiation mechanisms for Optical Burst Switching Networks*, _Nail Akar A, Ezhan Karasan A , G Kyriakos . 2010. Elservier.