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RESEARCH ARTICLE

Review of contemporary literature on burst assembling and routing strategies in OBS networks

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Abstract In the course of recent years, a lot of research has been directed in the ranges of optical packet switching and optical burst switching (OBS). This examination has been inspired by the requirement for procedures that are equipped for supporting the requesting prerequisites of developing dynamic high-transfer speed applications in an adaptable and effective way. In this paper we have undertaken the critical and mandatory factors of OBS such as (1) assembling the bursts, (2) routing (3) resource (such as transmission channels) scheduling and (4) burst segmenting for optimal transmission). Consequently the current research is focusing on these both of dissimilar variables of OBS and putting endeavors to contribute ideal ways to assemble, route, schedule or segment. This manuscript reviewed the nomenclature of the Optical Burst Switching Networks where fundamental ideas are examined and the aim is to identify the difficulties and strengths for optical packet and burst switching systems. This audit has been inspired by the requirement for methods that are equipped for supporting the future data transmission necessity of cutting edge applications and administrations of Internet Protocol systems. The authors have examined the fundamental ideas of OBS worldview and laid out issues identified with OBS systems. The future challenges that are still limiting the performance of the present contributions are told subsequently evincing the scope for future research.

Keywords Optical burst switching · Blocking probability · Scheduling algorithm · Void filling · Channel utilization · OBS networks · Resources allocation · Burst segmentation

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Introduction

The data transmission in OBS [1] occurs between ingress and egress routers that are connected through optical cross connects (OXC). Unlike optical switching and packet switching, the burst switching aggregates the packets targeted to deliver at same egress node as a burst (this process is known as burst assembling). Prior to transmit the burst that assembled, a control packet will be transmitted through a separate and dedicated control channel to the egress node. The Control packet informs about the transmission properties of the respective burst. After a specific interval the burst triggers towards egress node. Upon receiving the control packet, the egress node schedules the resources to the burst represented by that control packet. Burst delivery at the egress node often fails due to contention, since the burst triggers after a specific interval from the control packet transmission and egress nodes will not entertain any acknowledgement about the egress status after receiving the control packet. Hence burst blocking probability is one scale to assess the OBS performance towards data transmission. Hence, the assembling burst with optimized size, segmenting bursts dynamically to multiple bursts of optimal size, optimal route discovery and optimal resource scheduling to transmit the bursts are equally significant to defuse the burst blocking probability. This paper clarifies the current burst assembling time based schemes. The role of burst assembly schemes, burst routing strategies are described in "Introduction" section. A description of observations and research issues are provided in "Observations and Research Issues" section and finally "Conclusion" section concludes the paper.

Switching strategies in optical fiber networks

The Benchmarking Optical switching strategies are of three types [1] available and they are optical circuit switching (OCS), OPS and OBS. The contemporary literature notified that the OBS is the best among three, since, it has devised in order to overcome the limits (such as scheduling complexity and frequent contention state) observed in other two switching strategies. The OBS paradigm devised with an end goal that it holds the negative marks of the OCS and OPS and nullifies the limits of these two. OBS assembles packets that are to be transmitted to the same target as a burst, henceforth the optimal use of resources with low transmission control overhead is evident. In OBS networks, (1) the ratio of control channels those involved in O–E–O conversion are very few and mostly one control channel per fiber [2], (2) the burst switching is done all-optically (O–O) and (3) data sliding and multiplexing occurs concurrently (Fig. 1).

The prime functionality of Optical Burst Switching is burst formation that occurs at ingress node [3]. This strategy of data transmission observed in OBS leverages to utilize the resources at maximum level with minimal overhead. The OBS retains transmission and switching advantage of fiber optics and processing advantages of electronics. The data transmission optimality in OBS is

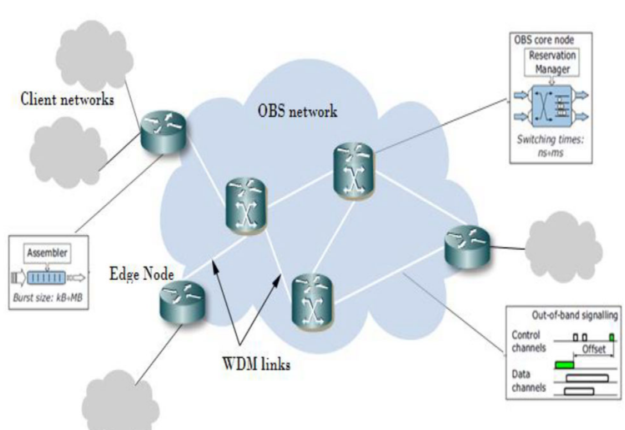

Fig. 1 OBS network architecture [3]

centric to the process of assembling bursts, since the size and transmission time of the burst are critical factors. The burst segmenting, routing and resource scheduling also plays a vital role along the burst assembling process, which is in order to achieve optimality in data transmission over OBS networks. Hence the contribution of optimal models for burst assembling, segmenting, routing and scheduling are vigorous in the field of research (Table 1).

Review of routing, burst scheduling and contention resolution strategies of optical burst switching networks

Burst assembling strategies

Numerous solutions have been proposed in addressing the assembly process. In some of the solutions, adaptive approach is presented, while in some of the cases non-adaptive schemes are gathered. Time-based scheme [4] that relies on non-adaptive strategy majorly depends on the interval time T for creating the data bursts. As soon as the packets arrive in the interval time, T, solutions are usually aggregated into the burst. The queues are set according to the destination and every queue has to focus on its own timer with base 0. As per the set time T, all the packets shall be assembled into a burst and is sent. Though such system works effectively, due to the emphasis on setting an interval time, certain implications like the loss rate in case of high traffic or the reaching of interval time T before aggregating enough packets into the burst turns to be a critical outcome.

The other model of size-based scheme is a non-adaptive process using the burst minimum size Bmin [5] as a parameter. In the process, irrelevant to time bound nature, burst is created once the minimum size is attained. Though this could be a right option, one disadvantage is about the burst assembly time. For instance, if the load time is less it could lead to more time for completing the burst and the delay could take place. Hence, in the real time traffic conditions, such process might not yield results to the requirements.

In the Hybrid model [6, 7], both the time based and size based schemes are combined for non-adaptive scheme, and the burst is usually created while any one of the values like time or size set and whichever is attained first. Considering the effectiveness of the hybrid system, it is accepted as default burst assembly scheme, but during the times of low traffic, even the hybrid model results in delays.

In addressing the burst loss, Learning- based burst assembly [8] is proposed, in which the burst assembly is managed according the learning on the loss pattern in the network. The learning automat algorithm used in the

Table 1 Comparison of switching technologies

Switching	Bandwidth utilization	Latency	Adaptively	Overhead	Optical buffering
Circuit	Low	High	Low	Low	Not required
Packet	High	Low	High	High	Required
OBS	High	Low	High	Low	Not required

solution focus on checking the loss periodically to understand the pattern and also to change the assembly time in order to ensure more suitable ones are created. Certainly this model reduces the loss but may not be an effective model for real-time traffic as end-to-end delays are not taken into account.

The other method proposed with the service differentiation scheme is developed on the basis of time-based method [9]. However, one of the drawbacks identified with the system is about the approach in terms of considering Tout as the only end-to-end delay.

In the other model of Burst assembly algorithm that is based on burst size and assembly is the other adaptive algorithm which uses the hybrid threshold for identifying the alternation in traffic load [10]. Both the size and time makes a significant impact for prediction probability and the traffic load is usually detected using the investigation of hybrid threshold and hence the burst size shall vary according to the traffic load. The tendency of offset time being high is envisaged despite of eliminating the bandwidth wastage, as there is some elapsed time in terms of sending burst control packet and sending data burst.

The other solution [11] showed significant improvement in terms of quality of service (QoS) parameters that are adapted in terms of burst delay and the kind of delivery ratio that could be envisaged in the process. The redundant burst segmentation (RBS) is adapted in the assembly phase, but that contains redundant data for the other bursts, which leads to a reduction in the burst loss. Using the scheduling algorithm, switching of burst payload to the target output fiber, by managing the output wavelength; in terms of fiber delay lines is evaluated. Despite that the RBS technique shall have depicted improved results [12], still the new solution has resulted in 18.8% lesser scope of burst delay, yielding in terms of QoS parameters.

Timer algorithm and the Threshold based algorithms are two predominant burst assembly algorithms [13]. In the timer algorithm, the timer is used for burst assembly and in the threshold algorithm, the number of packets is used for burst generation, and both the models are simple to be implemented. There is high end-to-end delay reported in threshold-based assembly algorithm due to the low loads of packets in the burst, and in the instances of high loads too, only fixed size of bursts are injected into network. Even in the timer based model, the burst assembly generates average size bursts in lower load factors, while in the higher loads, the outcome in terms of variable size bursts creeps up. It can be stated that under higher loads, both the algorithm lack efficacy essential for burst management.

In the threshold oriented mixed algorithm [14], the packets of varied classes are classified into same burst, and usually higher priority packets are stored at the head and the ones with low priority packets are handled at the tail bust. Using the segmentation policy adapted for contention management tail dropping is employed for managing contending burst. Despite of supporting only two classes in a burst, it still gets impacted with the drawbacks of length threshold algorithm.

Zhang et al. [14, 15] proposes a similar kind of solution in exception to process of high priority packets being stored in the tail of burst. In turn the impact is high on out-of-order packet delivery, thus resulting in increased delay in [15].

In [16], the authors have proposed a new algorithm that adjusts the timer and threshold size values for the assembler, in relation to an adaptation of congestion information. When the algorithm was used for analyzing the performance of core scheduling under varied types of traffic, additional delay is envisaged due to large burst sizes that are generated.

Mixed-Threshold burst assembly is a traffic prediction based algorithm (MBTA) [17], which uses the traffic prediction as the pattern towards evaluating the expected length for a burst and then such length is added to burst control packet (BCP). And following such addition, BCP is transmitted to the network in order to have early reservation before the burst is generated. In this process, the focus is on end-to-end delay performance pertaining to high priority bursts in the OBS network as it does not look forward for burst generation process before sending the BCP. But the challenge is about the poor resource utilization which might lead to more impact on the burst size in terms of predicted length.

In another study [18], the authors proposed a different model of Fast Reservation Protocol (FRP) using the traffic prediction techniques, and the assembly schemes that are essential for reducing the queuing delay in the FRP shall support in reducing the end-to-end delay. The results that are predicted are used for deciding assemble burst. The other filter process used in FRP is to calculate the expected burst length and assembly duration to ensure an early reservation by sending BCP. Hence, in such conditions the assembly process need not wait for the burst to be assembled whilst of sending the BCP.

Such approaches reduce the quantum of burst assembly and also the reservation times towards improving packet end-to-end delay, but the crux envisaged in the process is that it could be inaccurate and shall lead to poor resource utilization conditions.

The fuzzy adaptive algorithm (FAT) [19] relies on the length of the threshold for adjusting the length of the threshold for assembler, and despite of having such ability, still the bursts that are generated using the FAT shall experience many delays pertinent to low loads. In the case of high loads, the FAT generates a wide range of bursts that could lead to complexities in terms of blocking the probability. The inputs clearly reflect that the process of assembly algorithms shall have impact of end-to-end delay.

Routing strategies

Static routing strategies

Shortest path, Dijkstra, FAR, Extended Dijkstra routing, travel agency based algorithm are some of the key factors that impact the OBS static routing [20]. In [21], authors have quoted that the usage of linear programming approach for dealing with the route optimization in OBS can be resourceful in burst loss reduction. The process that is adapted is to ensure that source routing and predefined multipath are used for the process.

In order to evaluate a burst loss probability (BLP) in link, two models have been considered: non-reduced link load and the reduced link load. In the non-reduced model, the traffic ordered to a link is the accumulation of the sum of the traffic to all the paths that has the connect by link, but in the reduced link load model, the traffic link in the path is deducted from the sum of traffic. The study signifies that from the test of two models that outperformed both OSPF and bypass routing techniques. But the crux is that the streamline effect on the loss calculations are not estimated in the process and it could lead to misleading results of optimization.

In another study [22] proposed on the route optimization, the authors have considered two key scenarios, firstly a scenario in which the normal working situation is taken into account and in the second scenario works on network failure state, where the links are not working. Mixed integer linear programming (MILP) formulations have been developed to solve the problems, and using the heuristic algorithm towards the actual evaluation of the proposed solution, the outcome has been tested for full wavelength conversion and considered streamline effect for the BLP. Among very few papers that have focused upon streamline effect in computing BLP, the result produced in the solution is near to optimal. In the solution full wavelength conversion and fixed routing are adapted and despite that the solution is not scalable and shall make the wavelength converters to be impractical.

Barradas and Medeiros [23] have tackled contention in OBS using the traffic engineering approach for path selection. Two streamline-based pre-planned routing strategies (SBPR) have been adapted. The first technique that is used in the K predetermined paths for the pair of nodes as SBPR-PP, and the second method of not requiring pre-determined path requirement SBPR-nPP.

The focus area in the study is about balancing the traffic across the network in order to prevent any kind of congestion in the core network. The major benefit of the process is that the solutions can work either with or without converters, and the test results indicate better performance compared to shortest path (SP). These techniques are not much scalable and are usually depending on the linear programming approach. In the work proposed in [24], which is similar to [23], the process suffers from similar kind of limitations.

Many of the above routing techniques are static and are certainly based on the shortest path routing algorithms, and the derivatives and extensions pertaining to fixed alternative routing are feasible in most of the cases by using MILP. As routing and wavelength assignment (RWA) in OBS is turning out to be a hard NP problem, the case of MILP solutions turns to be more complex and also non-scalable. In the other dimension, static routing algorithms are usually less efficient in bandwidth utilization and also result high BLP, and also they are not scalable. Hence, there are more of routing algorithms that are proposed for handling high BLP in the OBS.

Researchers are now considering the varied ways of using the swarm intelligent algorithms [25, 26] for solving the problem. Ant colony optimization (ACO) [27, 28] and the related derivatives for communication networks, such as AntNet [29] shall be used for the purpose as the process is more about adaptive, multipath, proactive and scalable.

Dynamic routing algorithms

In [30] Yang and Rouskas has proposed a range of dynamic routing algorithms based on the varied range of route selection metrics: weighted bottleneck link utilization strategy (WBLU), end-to-end path priority-based (EPP) strategy and weighted link congestion (WLC) strategy.

In WBLU, routes are ranked using the link utilization information. In this predominantly the focus is on avoiding contention in terms of routing bursts with less utilized links. In the second scheme, routes focus on bursts along the path that has a probability of successful transmission. To ensure that goal is achieved, BLR on each path, with link-state protocol has been used for ranking different paths that are available.

In the last technique adapted, EPP, despite of using BLR as selection metric, the technique does not rely on individual link congestion information as in the way of WLC. But the inputs are received from the ingress node, depending on the feedback messages that could be received from the network. Among the three routing strategies that are compared with SP, many of them performed better. From the results that are generated, it is imperative that three path switching strategies are always similar in performance, but it is concluded that WBLU has produced better outcome at lower loads, whilst EPP is better in high loads. Whereas, WLC has been moderate compared to the other values, and the outstanding performance of WBLU is attributed to how the model uses link utilization as route selection metric.

In low network loads, majorly the links have low utilization and avoids few highly utilized links towards improving the burst drop probability. EPP performs better than other models as path priorities are updated immediately after getting feedback from network unlike WBLU and WLC in which they are done periodically. However the WBLU and WLC have to be independent of the network load.

In [20], Garcia, proposed a better method of dynamic routing as Next Available Neighbor (NAN) routing algorithm, which works on regular sharing of information on traffic intensity. The level of fluctuations that take place in the network requires effective transporting of routing algorithms. In NAN, during the occurrence of burst or packet drops, rather than dropping the burst, the packet is forwarded to close the node towards the destination node, and such solution is possible as the existing routing strategies can be used for managing burst or packet loss. In OBS environment, rather than receiving the negative acknowledgement (NAK), BCP focus on NAN-BCP destined to NAN node.

As and how the burst arrives at that node, it shall be routed to a NAN node and the burst shall be Optical to Electrical (O/E) converted, and later added to the network.

Yoshikawa et al. [31] proposed a solution as centralized routing and wavelength assignment algorithm towards OBS networks. Modus of the system is to estimate the expected total blocking time in the network, and use the iterative local optimization for minimizing the estimated blocking time. The study claims that the algorithm attains considerably smaller blocking probability rather than the conventional distributed control algorithms.

It also states that the introduction of optical buffers and burst retransmission works on low burst loss rates that are acceptable with many applications, but the key limitation in the system is about the use of fiber delay lines (FDL).

In [32] the study has focused on the behavior of varied, many-casting over OBS using the QoS constraints. Also, mathematical model is developed using the lattice algebra for the multi-constraint problems. For minimizing the request blocking, multi-constrained many-cast (MCM) issues, two routing algorithms MCM-shortest path tree (MCM-SPT) and MCM dynamic membership (MCM-DM) are adapted using the distributed routing techniques, in which each node maintains the network state information individually, and implements the algorithm.

Gao et al. in their studies has presented an effective model of routing scheme which adapts link congestion for reducing the negative impact of certain constraints. In order to reduce the negative impact in OBS caused by cascaded wavelength.

To focus on optical wavelength-division multiplexing (WDM) networks that has irregular topology, Ngo et al. [33] has discussed about ant-based dynamic RWA algorithm which shall help in updating the routing table on each of the nodes, in a pattern where the current network state is depicted in the routing tables and it leads to much faster determination of path and also the probability of blocking is also much lower. But the model does not have much emphasis on continuity or FDL.

In the RWA algorithm which is fault-tolerant and is developed on ACO framework [34], the emphasis is on dynamic ant-based reliable routing algorithm which minimizes the BLP. Ant colony algorithm is used in dynamic determination protection cycle and also works on establishing dependable lightpath, and is defined as NP-Complete.

In order to ensure that the algorithm performs better, the methods of using routing table and pheromone table is suggested by the authors. As the routing model comprises certain feasible protection cycles of sources and destination modes, pheromone table constitutes intensity status, and such a model is found to be resulting better in terms of survivability than the ones that are mentioned in the other model proposed in [35]. Still in terms of veracity, there is need for more intensive tests using varied other metrics as the number of agents and the pheromone parameters have to be evaluated.

Triay and Cervello-Pastor in [12] in their study, discuss adapting ant colony optimization (ACO) algorithm for supporting the routing and wavelength in OBS. As per the test results claimed by the authors, the new protocol responds to the congestion in an effective manner, when compared to the shortest path routing with random wavelength. The key difference that has been identified in the system is about the continuity constraint. In evaluating the contention, FDL though, is adapted as a temporal store for contending bursts, still as the process is on evolutionary stage, the accuracy of the results is always subjective.

Pedro et al. [36] discussed distributed framework with the routing path optimization OBS depending on ACO algorithm. The proposed model constitutes additional data structures at the nodes and also special control packets which leads the network towards the right path and updates the data structures accordingly. Results of simulation indicate the improvement in OBS network performance in terms of reduced data loss and optimum performance than other centralized models. Also, it is imperative that the framework is ready for any kind of changes to its parameters. In the study, the unique feature is about implementing the algorithm towards both egress and ingress of the networks, and it could lead to more effective ways of load balancing at the routing tables.

MILP is usually adapted in mathematical oriented routing algorithms for solving optimization function in terms of searching for best paths which could minimize congestion and avoid contention. In the other way, heuristic algorithms adapt process oriented approach for routing the burst whilst focusing on reducing congestion, leading to minimum contention and maximum throughput.

In [37], RWA problems are classified in terms of static path establishment (SLE) and dynamic path establishment (DLE). In SLE, the routes are fixed hence traffic connections requests are known in advance. In DLE, without the knowledge of future lightpath events, lightpaths are established in real time dynamically. Again SLE and DLE have two sub problems, namely routing and wavelength assignment. Bijoy and Nityananda [37], in their study discussed the four types of routing, namely fixed routing (FR), fixed alternate routing(FAR), adaptive routing(AR), and least congested routing(LCR) and stated that the calculation unpredictability of LCR is very high compared to the other routing techniques.

In [38], under two conditions, blocking and non-blocking, the authors proposed a priority based dispersion reduced wavelength assignment(PDRWA), which leads to better quality in high speed optical networks. It is observed that, in PDRWA scheme, as the channel speed increases, the total dispersion in the network also increases.

In [39], the authors addressed call blocking in optical networks as one of the challenging issues, hence proposed a priority based routing and wavelength assignment with traffic grooming mechanism (PRWATG) and compared with a similar non- priority based routing and wavelength assignment (NPRWATG), henceforth inferred that under increased connection requests on the network, PRWATG is better than NRWATG.

Sahu in [40] proposed restricted shared protection (RSP) scheme that gives limitation on the sharing of a portion of lightpaths to increase the unwavering quality of the security in an optical system. To decrease blocking probability, it is observed that alternate path routing protection schemes are utilized and hence blocking probability reduction in case of RSP is more than that of shared protection (SP; Table 2).

Observations and research issues

Burst assembly

As large fixed times could lead to increased time delays at the edge, effective consideration is necessary. Also, if the value is less, many bursts might be generated, thus leading to the high control overhead for the core nodes.

In terms of limitations for the Burst Length, the dependency on traffic is high, and it might need more time for burst to reach to the node, and hence, in the conditions of high traffic and low burst lengths, the scope of high control overhead is inevitable.

The hybrid approaches also has some constraints in terms of both time based and also length based assembly models.

Traffic self-similarity is one of the factors upon which many researchers were keen on. Sahinoglu and Tekinay in [41] stated that the model is associated with fractals, for which the appearances are changed regardless the scale at which the inputs are viewed. And also the model could be very implicating if not handled with utmost care.

It can also result in high traffic loss for small buffered systems and also shall lead to undesirable queuing delay in the large buffered systems [42]. From the studies in [43] and [44], it is imperative that burst assembly reduces the traffic self-similarity, but the traffic prediction is another significant challenge in the burst assembly models.

Routing

FDL or Wavelength Converters are predominantly adapted in the route optimization techniques adapted for OBS, despite the fact that both are still in infancy stage and even are not cost effective [45].

In the OBS networks, for RWA the heuristic algorithms turn out to be a right model because of their ability for avoiding contention, which is a more preferred solution than the contention resolution, considering the cost effectiveness. Some of the categorical issues in OBS networks are: Issues of QoS Provisioning, Performance Issues, Traffic Grooming, Monitoring of Faults, Loss Rates Estimation, Issues pertaining to designs of the system.

Table 2 Comparison of different contention resolution techniques

Contention resolution	Advantages	Disadvantages
Wavelength conversion	The most efficient solution	Immature and expensive
FDL buffering	Simple	Increasing end-to-end delay
Deflection routing	No extra hardware requirement	Out of order arrival
Burst segmentation	Lower packet loss ratio	Complicated control handling requirement

Conclusion

This paper exhibited general ideas of OBS. High speed internet networks for the next generation will be required to help an expansive scope of rising applications which may require huge date transfer capacity as well as QoS requirements. For such large traffic, instead of fixed bandwidth circuits, OBS is a promising technique which endeavors to address the issues of allocating the resources efficiently for bursty traffic.

In the study, the methods, solutions and algorithms pertaining to Burst Assembling, routing, contention handling in OBS networks and other such factors are reviewed. From the intrinsic analysis that is carried out, it is imperative that there are many contemporary solutions that are defined in the process of burst assembling, segmenting, scheduling, contention handling and burst transmission factors in the Optical Burst Switching Networks.

In terms of observations that are developed from the contemporary models reviewed in the literature, it is imperative that varied factors of scheduling, segmenting and assembling of bursts, are interdependent in order to achieve QoS in burst transmission. Also, it is evident that there is significant scope for devising novel and cooperative approaches for the aforesaid factors, to improve the Optical Burst Switching Networks

Research issues associated with the improvement of OBS systems are examined and ways to deal with giving QoS in OBS systems are exhibited. The review findings of burst assembly algorithms illustrate that most of the present techniques are based on QoS and are concerned about end-to-end delay. In terms of futuristic studies, it is clear that there is a genuine requirement for more satisfactory solutions to address burst assembly in OBS.

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