A Novel Routing Optimization in Optical Burst Switching Networks

Yahaya COULIBALY, Muhammad Shafie ABD LATIFF, Ali SELAMAT
Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia
81310 Skudai, Johor Bahru; Johor, Malaysia
Email: yaya@agetic.gov.my, {shafie, aselamat}@utm.my

Abstract - Among the three optical network technologies being studied for future Internet, namely, Optical Circuit Switching, Optical Packet switching and Optical Burst switching; Optical Burst Switching is, up to now, the most likely to be implemented in the near future. Nevertheless, bursts contention persists and more work need to be done to minimize bursts loss before Optical Burst switching can be implemented.

In this paper, we propose efficient bandwidth utilization and routing optimization scheme aiming at avoiding bursts contention and making better use of the large bandwidth offered by fiber links through Wavelength Division Multiplexing and Dense Wavelength Division Multiplexing. The proposed solution is based on the Hierarchical Optical Burst switching techniques and a modified hybrid algorithm of Ant Colony Optimization and Genetic Algorithm, taking into account the Streamline Effect in Optical Burst switching. Through simulation, we expect low burst loss probability and efficient use of bandwidth.

Keywords – Optical Burst Switching (OBS); bursts loss; routing optimization. Ant Colony Optimization (ACO) Genetic Algorithm (GA); streamline effect (SLE).

I. INTRODUCTION

The rapid growth of large bandwidth multimedia applications development resulted in the search for alternative solution to transport these applications. Optical Burst Switched Networks (OBS) proposed in [1] has proven to be the most feasible and realistic solution in the near future. However, burst contention in the core network, which is a birth-ill in OBS, needs more sophisticated solutions. Burst contention occurs when flows from different input lines are sent to the same output port on the same fiber channel (wavelength) at the same time. In traditional networks (electronic based), contention is resolved using electronic memories (RAM) as buffers. In pure OBS, there is no buffer in the core network. Therefore, it is necessary that, we find ways to avoid burst contention in order to reduce burst loss and increase the overall network performance.

In recent years, various contention avoidance and resolution solutions have been proposed in the literature for OBS, such as load balancing schemes [2], deflection routing [3,4], burst segmentation [5], wavelength conversion [6], and the use of Fiber Line Delay (FDL) [7].

In this paper, we present a solution based on bandwidth and route optimization in order to avoid burst contention and make efficient use of the bandwidth by combining Time Division Multiplexing and Wavelength Division Multiplexing techniques. The rest of this paper is organized as follows: Section II goes through related works. Section III describes the proposed solution. In Section IV we describe the particularities of the proposed solution. Section V describes the simulation scenario is described in Section V. Concluding remarks and future works are found in Section VI.

II. PREVIOUS WORK

To make better use of the large bandwidth offered by fiber optic links through WDM/DWDM, researchers came up with many attractive schemes, such as Slotted Optical Burst Switched (SOBS) [8]. In SOBS, time division multiplexing (TDM) is incorporated into wavelength division multiplexing (WDM), so as to divide the entire λ-bandwidth into smaller bandwidths. This approach is also referred to as the slotted WDM (sWDM), bursts are then transmitted in time domain instead of optical domain as in pure OBS.

Time-Sliced Optical Burst Switching (TSOBS) [9] is another scheme for better use of the bandwidth and at the same control burst contention. In TSOBS, bursts are sliced and spread across multiple frames of fixed-length time slots. A variant of TSOBS is Hierarchical TSOBS (HiTSOBS) proposed in [10]. In HiTOBS, multiple frame sizes are allowed to concurrently co-exist, with slots lower in the hierarchy progressively offering lower rate service. This allows delay sensitive traffic classes to operate at higher levels of the hierarchy while concurrently supporting loss-sensitive traffic at the lower levels.

Routing optimization schemes have also been proposed to resolve and avoid burst contention. In [11], a routing optimization technique using Erlang B formula was used. This solution is not optimal [14] as the researchers did not consider the streamline effect [12] in OBS which, if considered, reduces the Burst Loss Probability (BLP). Other route optimization schemes can be found in [13, 14, 15]. In [13] the researchers adopted a non-linear optimization method where they calculated the partial derivatives and solved the optimal route. In [14], the researchers proposed...
two solutions for route optimization problem. The first solution is applied on non-reduced link load, which they abbreviated as (NR-LL); the second solution is applied on reduced load link abbreviated as (R-LL). NR-LL, they derived exact partial derivatives, while for R-LL they approximate the partial derivatives. Although authors in [13] and [14] solved partial derivatives; the results obtained in [13] are not optimal as they did not consider an important phenomenon in OBS networks known as streamline [12]. The authors in [15] proposed an offline optimization technique to minimize burst loss. However, this solution is not optimal as the authors did not consider the streamline effect. To our best knowledge, the only papers that considered streamline effect while searching for optimized route are [14 and 16]. In [16] the researchers proposed a scheme that optimizes the routes to be followed by burst and thus avoid bursts contention and reduce BLP. They also proposed a solution to find alternative route in case of primary route fails. However, since the authors transmitted bursts in wavelength domain, wavelength converters are needed to implement the solution. Wavelength converters are not yet, technically, mature and are not cost effective as well; so this proposed scheme will have high implementation costs.

The work proposed in [17] used a hybrid algorithm based on Ant Colony Optimization [19] and Genetic Algorithm [20] to generate dynamic routes and find optimal route in WDM optical networks without focus on OBS. Although the obtained results are attractive, this scheme needs some modification in order to adapt to OBS architecture. Also, in [18], the authors proposed an Ant-based contention resolution scheme for Optical Packet Switching focusing only on FDLs selection. To our best knowledge, none has used this technique in OBS, and since the algorithm performed well in OPS, packet loss rate was improved by 10% to 40%, there is no reason that, with some modifications and enhancement it cannot be adapted to OBS architecture, which will be our contribution.

In the following section we describe a solution that combines the positive points of Slotted Optical Burst Switched (SOBS), Hierarchical Time-Sliced Optical Burst Switched (HiTSOBS) [8, 10] and that of the route optimization scheme proposed in [16, 18] to avoid burst contention while making efficient utilization of the bandwidth, by combining TDM and WDM techniques.

III. PROPOSED SCHEME

Bandwidth greedy multimedia applications are being developed continuously [22], such as e-health, e-education, e-administration, IPTV, video conference, and others. OBS is the promising technology to meet these high demands. However, OBS still suffers from performance problems. Therefore, in this paper, we propose a novel routing optimization in OBS. The scheme does not use wavelength converters, because they are not yet matured technologically [21]. We rarely use FDLs. The use of many FDLs is also not practical as mentioned in Section II. Blocked bursts are retransmitted.

As in pure OBS, control packet is sent before the data burst to reserve network resources.

Figure 1 depicts the flowchart of the proposed solution and it is briefly described as flows:

- Bursts from the ingress nodes are classified according to their type (QoS considerations);
- At the core node, a route optimization technique is applied (the route optimization being developed is based on techniques used in [16, 17 and 18]);
- Time Division Multiplexing (TDM) is applied on the optimized route where the routes are divided into levels and time slots similar to what is used in [10];
- The core node then looks in the Burst Control Packet (BCP) to allocate the requested resources;
- If the requested resources are available, bursts are sent to the selected output port, otherwise, the algorithm checks for an adjacent level and allocate it to the burst after delaying it for sometimes;
- If the there is no adjacent level with the required time slot and the burst is of high priority, new level is generated (provided that there is free wavelength); if the burst is of low priority or there is no wavelength, the burst is dropped and retransmitted later;
- Network performance is measured by calculating Burst loss Probability, Average delay and throughput.

The difference between the proposed scheme and those proposed in [8, 10] and [16, 18] is that we have tried to combine the good points of these schemes in one algorithm; for example, shortest path algorithm is not being used to find the first path for a burst as was proposed in [16], and we are not planning to append FDLs to each link as proposed in [8] instead, FDLs are used selectively; this is to minimize the cost of the network implementation while keeping the network performance at an acceptable level.

Also in [10], the maximum number of levels tested is 2. Since more levels means low burst loss probability, in the proposed scheme, more levels is being generated, dynamically, according to the state of the network to keep BLP as low as possible. The maximum number of levels is fixed at 4 to keep burst delivery latency at an acceptable level.

The loss model proposed in [10] is:

$$L = \rho \left( \frac{1 - \sum_{i} \lambda_i}{\sqrt{\sum_{i} \lambda_i \left( \lambda_i - \lambda_j \right)}} \right)$$  \hspace{1cm} (1)

While the mean delay for flow $i$ is given by:
\[
\frac{1}{\lambda_i} = \frac{1}{f_i \cdot B} - \frac{\lambda}{N} \cdot \frac{1}{B} = \frac{1}{f_i - \lambda},
\]

(2)

Where \( \lambda \) is the burst arrival rate, \( N \) number of flows multiplexed at the core node, \( D \) the average delay of flow \( i \), \( B \) average burst size and \( f_i \) is fraction of link capacity available to flow \( i \) and is given by \( f_i = \frac{r_i}{r} \), \( r \) denotes the radix of the frame (number of slots per frame) \( k_i \) denotes the level of frame.

The above loss model does not make any assumption about burst arrivals process, therefore it does not accurately calculate the loss in an OBS network. Streamline effect is not being taken into consideration, which states that: “bursts traversing the same link (shared link) will not experience any contention (no burst drop)” [12]. In [16], the researchers developed a loss equation considering streamline effect. However, they have assumed wavelength conversion that is wavelength continuity is not being considered. Because wavelength converters are not yet commercially economic; this solution may not be applicable in the near future. Thus, the proposed scheme in this paper is an intermediate solution before the maturity of optical equipments. OBS itself is an intermediate solution for all optical networks for the same reasons (non-maturity of optical equipments).

IV. PARTICULARITIES OF THE PROPOSED SOLUTION

The proposed solution has the following particularities, enhancing the solutions proposed in [10, 16, 18].

- The first contention avoidance/resolution solution that applies routing optimization techniques while combining TDM and WDM techniques, and considering streamline effect in burst loss calculations;
- Less use of FDLs;
- The solution does not require wavelength converters.

These particularities are the novelty of the proposed solution. To combine WDM and TDM while considering streamline and not using wavelength converters is really a challenge. Given wavelength \( \lambda \), we should make sure that \( \lambda \) is available through the network with the requested levels and slots. We also have to strive to make bursts come out from the same input line. Doing that, will minimize burst loss and improve network performance. As mentioned earlier, FDLs are used selectively. This constraint is hard to implement with TDM and therefore we are taking the challenge. The use of many FDLs in optical networks is not practical, so the less the better.

However, we are aware that, these characteristics could make the solution, somehow, complex in terms of optimal routes selection and wavelength assignment, which is normal. We believe that, the expected results justify our choice. We have chosen moderate complexity to avoid contention and minimize the burst loss probability, which is the ultimate objective of all contention avoidance and resolution solutions in OBS networks, rather than a simple solution with high burst loss and non efficient use of bandwidth.

![Flowchart of the proposed Scheme](image)

Figure 1: Flowchart of the proposed Scheme.

Number of bursts dropped across the network \( B_d \), burst loss probability \( P_{bl} \), burst delivery latency \( B_l \) and throughput \( \eta \) are the four metric that will be used in the simulation for evaluating the proposed solution. Since we are proposing dynamic generation of frame levels in the hierarchy, we are sure to achieve high throughput with low burst loss probability while considering the streamline effect.

V. SIMULATION SCENARIO

To evaluate the proposed scheme, ns-OBS simulator is being used where our constraints and parameters are to be integrated. The network to be simulated is depicted in Figure 2. This network, which we are proposing to
interconnect the district of Bamako and the capital cities (Kayes, Koulikoro, Sikasso, Segou, Mopti, Tombouctou, Gao and Kidal) of the 8 regions of the Republic of Mali by fiber optic, has 11 nodes, 13 links; we assume that, each link consists of 16 wavelengths operating at 10Gbps. Poison arrival rate is assumed and is given by \( \lambda = \frac{\rho N}{B} \); \( \rho \) represents network load. For simplicity, we keep the number of flows \( N \) at 50. Frames are dynamically generated but limited to 4 so as to reduce resource reservation process while keeping the performance at an acceptable level. Each frame level consists of \( r \) slots and it is equal to 15 which may be increased or decreased according to the performance testing. The higher the number of slots, the lower the buffer size is. Time is measured in units of timeslots; in this case 1 \( \mu s \), which is consistent with the switching speeds of solid-sate optical switching technologies available today [23] while service is measured in units of slices (number of data that can be transported by the system in one timeslot). The operation rate of the core optical links is one slice per time slot. Buffer capacity \( B_c = 6.67 \approx 7 \) slices; this is because level-1 frames transport bursts at a rate of 0.067 given by \( 1/r' \).

VI. CONCLUSION AND FUTURE WORKS

In this paper, we have proposed a scheme that not only optimizes the route to be followed by bursts, but it also makes better use of the bandwidth.

This is a work in progress, and currently, we are working on the link cost and loss model parameters to be used in the simulation so as to show that the proposed solution can effectively avoid burst contention, make better use of the bandwidth, assure Quality of Service and reduce Burst Loss Probability (BLP). All these together contribute to the enhancement of the overall network performance. NS-2 is being used for simulation. Expected results are to be compared with those obtained in [10, 16, 17].

The proposed solution does not assume wavelength converters for the reasons mentioned in Section II. Therefore, as optical technology matures, the scheme can further be improved by considering wavelength converters.

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