Pre-planned Optical Burst Switching Routing Strategies

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ABSTRACT
This paper addresses the problem of pre-planned Optical Burst Switching (OBS) routing strategies. Pre-planned OBS routing strategies can be applied as static routes in normal network operation without the need for resource-update signalling messages, combined with dynamic contention resolution schemes, or when the network tries to recover from a congestion state. In this paper, we discuss the applicability and performance improvement, when compared with shortest path routing, of two path selection strategies, taking into account different network topologies and strategy parameters.

Keywords: Optical Burst Switching (OBS), path selection strategies, routing algorithms, burst loss.

1. INTRODUCTION
Optical burst switching (OBS) has been proposed as a cost-effective paradigm to support high-bandwidth, bursty data traffic in the next-generation optical Internet[1]. OBS is a photonic network technology which overcomes the inefficient resource utilization of Optical Circuit Switching at the same time that avoids the requirements of buffers, optical logic processing and synchronization problems of Optical Packet Switching.

In OBS the basic transport unit is the data burst, an aggregate of IP packets grouped by destination address criteria and assembled at the ingress node. The transmission of each data burst is preceded by a control message, whose purpose is to reserve switching resources along the path from source to destination for the upcoming data burst. Several resource reservation schemes have been proposed for OBS networks, which can be classified into one-way reservation, also called Tell-and-Go (TAG-OBS), such as Just In Time (JIT) and Just Enough Time (JET) [2], and two-way reservation, also termed Tell-and-Wait (TAW-OBS), such as wavelength routed optical burst switching (WR-OBS) [3]. Although, Tell-and-Wait signaling protocols provide a more reliable solution when compared with Tell-and-Go protocols, they are characterized by longer end-to-end delays.

In this paper we focus on one-way reservation protocols. Under this scenario the ingress node, does not wait for confirmation that an end-to-end connection has been set-up before it starts sending the data burst. Therefore bursts may contend for the same transmission resources leading to burst drop.

Considerable effort has been devoted to the study of different methods to handle contention, including, burst scheduling, optical buffering, burst segmentation, wavelength conversion, and deflection routing [4], [5]. These are mainly reactive mechanisms driven by burst contention and requiring extra hardware and/or software components at each core-node, significantly increasing their cost and complexity, leading to scalability impairments. A simple and cost efficient solution is to deploy contention mechanisms at the edge nodes. This approach has been followed by using burst assembly mechanisms [6]-[8], by path selection and wavelength assignment [9][10], or by balancing the traffic load between alternate paths [11]-[13].

If no path selection mechanism is employed at the edge router, the common approach is to use shortest path routing, i.e. the edge router upon receiving a request chooses randomly one of the shortest paths between the source and destination. In this strategy, each edge router only needs to have a table containing the set of shortest paths from it to any node of the network. Contention, in OBS networks, can be reduced to some extend if a suitable path selection criteria is employed by the ingress node. In [11] a path selection for source routing was obtained using a traffic engineering approach aimed at the balance of the traffic load across the network.

Recently, alternate path selection mechanisms at the ingress node have being the topic of some research work [12]. In this approach each ingress node maintains a list of alternate paths to each destination ranked according to their congestion status. The authors present a suite of path selection strategies, each utilizing a different type of information regarding the link congestion status. This adaptive and dynamic path selection schemes require a link state signaling protocol and the efficiency of the solution, characterized in terms of burst blocking probability, depends on both the ability of the scheme to provide good performance for a

The work reported in this paper was supported in part by the Foundation for Science and Technology (Portugal) within project POSC/EEA-CPS/59556/2004 and PTDC/EEA-TEL/7168/2006.
given traffic scenario characterized by a well known statistics, and, the convergence time of the link state advertisement protocol. Since the convergence of the link state advertisement protocol is difficult to achieve for bursty traffic scenarios, such as OBS networks, it is important to have efficient path selection strategies, for routing, which do not require link state protocols [13]. We note that, the routes obtained in [13] can be used as static routes to provide load balancing without the need for resource-update signaling messages, or combined with other dynamic contention resolution schemes. In the latter scenario, static routing can be used occasionally as a default routing option whenever the network needs to recover from instability.

In this paper, we focus on static edge-node deployed routing strategies based on load balancing approaches. In particular, our scope is to discuss two strategies: (a) path selection based on the minimization of the maximum congested link (MCL), (b) path selection based on the minimization of the maximum end-to-end congested path (MEC). The rest of the paper is structured as follows. Section 2 gives an overview of OBS routing and contention resolution strategies. In section 3, the MCL and MEC path selection techniques are discussed and their performance is compared for two different network scenarios. Section IV concludes the paper with some final remarks.

2. OBS NETWORKS AND CONTENTION RESOLUTION STRATEGIES

In OBS networks, the basic transport unit is a burst containing a certain number of IP packets grouped by destination address criteria and assembled at the ingress node. Each data burst can be regarded as an optical super packet travelling from source to final destination without any optical-electrical-optical (OEO) conversion. The data burst is preceded by the transmission of out-of-band control packets, containing the information necessary to reserve and configure the optical switching resources along the path from source to destination.

One of the simplest signalling architectures for OBS systems with one-way reservation is the Just EnoughTime (JET) signalling [1]. In JET OBS, each control packet contains information about the offset time, duration, and wavelength of its burst. By storing the offset time in the control packet, JET makes it possible to implement delayed reservation, so that the switch fabric is only configured for the duration of the burst. The data burst is transmitted after the offset time, without receiving any acknowledgement of the network. Therefore data bursts may content, at some point in the network, for the same network resources leading to burst drop.

Several methods have been proposed to reduce burst loss due to contention, including burst scheduling, optical buffering, burst segmentation, wavelength conversion, and deflection routing [7]. Despite the undeniable merits of the research conducted on such methods, and besides their goodness, there are also several important issues that need to be carefully considered.

Burst scheduling research revolves around two objectives that are somewhat in conflict: one is to address low loss and the other is to achieve fast processing [8]. The opposition between the two objectives is that, to achieve a lower loss rate, the scheduling algorithm need to maintain more information on the scheduled bursts, thus requiring more sophisticated processing.

The presence of optical buffers at the intermediate nodes to reduce contention, presently deployed through the use of fiber delay lines (FDLs) is severely limited. Besides bringing more complexity to the scheduling algorithms mentioned above, FDLs are subjected to signal quality concerns and physical space limitations that can prevent a node from effectively handle high load or bursty traffic conditions [7].

Burst segmentation, a contention resolution approach unique to OBS, takes advantage of the fact that a burst consists of multiple IP packets (or segments). Therefore, in a contention between two bursts, only the overlapping segments of a burst need to be dropped instead of the entire burst. However, several issues need to be carefully balanced: the choice of the segment length, either fixed or variable, must be a trade-off between the loss per contention and the amount of overhead per burst. The segmentation process must also preclude the excessive burst fragmentation that can occur as a side-effect, and that would incur into higher overhead with respect to switching, burst control and synchronization at the receiver [7]. The decision of which segments to drop (head or tail-dropping) is also an issue, and must consider the problem of in-sequence packet delivery [5].

Wavelength conversion is the process of converting the wavelength of an incoming signal to another wavelength for transmission on an outgoing channel. Although most OBS studies assume full wavelength conversion to remove the wavelength continuity constraint, currently, wavelength converters are expensive and complex devices; and this is expected to remain in the predictable future. Therefore, some limitation is expected on the wavelength conversion capabilities of optical networks with two important consequences: the performance
studies relying on the assumption of full wavelength conversion will underestimate the burst drop probability, and the absence of full conversion claims for efficient wavelength assignment policies [14].

Deflection routing is a method by which a secondary (typically longer) path may be chosen by a switch whenever the primary intended path is not available. But this method also poses implementation problems, most of them related with the accuracy of the offsets and prevention of out-of-sequence or looping conditions, likely to result in severe degradation of performance. Deflection can be regarded as unplanned multipath routing, but a better method to reduce congestion is probably planed multipath routing or load-balancing [6].

3. PRE-PLANNED PATH SELECTION MECHANISMS

In this section we discuss the performance and the application scenario of two static edge-node deployed routing strategies based on load balancing approaches. (a) path selection based on the minimization of the maximum congested link (MCL), (b) path selection based on the minimization of the maximum end-to-end congested path (MEC) [13]. Their performance is evaluated in terms of burst blocking and compared with the commonly used shortest path routing strategy.

The two strategies assume that the network operates with source based routing i.e. the ingress edge node selects a path for a burst from a set of $K$ previously calculated paths. The strategies comprise two steps: (a) calculation of $K$ eligible paths for each pair of nodes, (b) selection of one path, from the set of $K$ paths previously calculated.

3.1 Path selection based on the minimization of the maximum congested link (MCL)

The $K$ eligible paths for each pair of nodes are calculated solving an Integer Linear Programming (ILP) problem, which finds the $K$ shortest paths with less links in common for every pair of nodes in the network. The paths adopted for routing are then selected from that set of eligible paths with the objective of minimizing the blocking probability of the link with highest expected contention. This selection operation also involves a formulation and resolution of an ILP problem.

3.2 Path selection based on the minimization of the maximum end-to-end congested path (MEC)

In this strategy the $K$ eligible paths are calculated as in 3.1. The paths for routing are then selected so that demands have the smallest probability of contending with other demands on every link of the path, minimizing the end-to-end blocking. As in 3.1, this selection operation also involves a formulation and resolution of an ILP problem.

3.3 Performance Comparison

In this section, we compare the performance of both schemes for two different network topologies. For all scenarios JET-OBS signalling with source routing is considered. A complete routing decision is taken at the ingress node, i.e. the path over which the burst must travel is carried on the control packet that precedes the transmission of each data burst. The ingress nodes select a routing path from its routing tables, which are assumed to have been previously populated by the results of the path selection strategies discussed previously. Simulations were performed using C++ in combination with the discrete event simulator OMNET++.

Figure 1. shows the performance results of the MCL and MEC strategies (assuming $k=2,3,4$), compared with shortest path routing strategy, applied the ARPAnet (20 nodes, 62 links and 0.16 physical connectivity) and COST 239 (11 nodes, 52 links and 0.47 connectivity) networks. In both networks the nodes are assumed to be connected by links representing optical fibers with the same length, having 16 wavelengths per link with a transmission capacity of 10 gigabit/s per wavelength. Full wavelength conversion is assumed. The traffic considered is assumed to follow a Poisson pattern with a threshold based assembly method, with burst average size of 100K bytes. The results show that both strategies reduce the number of bursts being dropped when compared with the traditional shortest path approach, with exception of $k=4$ for the ARPnet. Generally, an increase in the value of $k$ corresponds to performance decrease. This performance degration, for high values of $k$, (ARPnet, MEC, k=4) can degrade the overall performance of the network when compared with the shortest path approach. The performance improvement is more relevant for the COST239 network, which is the topology that presents the higher physical connectivity. This happens, because its high connectivity permits to obtain alternative paths with similar number of hops when compared with the shortest path alternative.
Figure 1. Evaluation of the proposed strategies against the shortest path.

4. CONCLUSIONS
This paper discusses the applicability and evaluates the performance of two path selection strategies for OBS networks. Our results show that the performance of path selection strategies is highly dependent on the network topology, specifically the network connectivity. However, independently of the network topology our results show that, by choosing an appropriate value of $k$, the burst loss ratio of the network can be improved without incurring into link state dissemination protocol penalties. The static path selection strategies discussed can be applied as single path static routes and used alone to provide load balancing without the need for resource update signalling protocols or combined with other dynamic contention resolution schemes whenever the network needs to recover from instability.

ACKNOWLEDGMENTS
This work was supported by the Foundation for Science and Technology within the projects POSC/EEA-CPS/59556/2004 and PTDC/EEA-TEL/7168/2006.

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