A Performance Study of different OBS Scheduler Implementations

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Traditional optical WDM networks set up end-to-end optical connections by reserving a wavelength. Unfortunately, this coarse granularity leads to inefficient use of network resources. An attempt to alleviate these problems is Optical Burst Switching (OBS), where the packet header is sent a time T_{offset} ahead of the payload. The payload is then switched transparently, based on the reservation made by the earlier received header. As we will show in our study, different reservation strategies are possible, having a significant impact on the achievable throughput. We developed several alternatives, and evaluated them through simulations.

Introduction

Recently, Optical Burst Switching (OBS) was developed as an alternative networking technology [1], which represents a balance between Optical Circuit Switching (OCS) and Optical Packet Switching (OPS). In OCS, one or more wavelengths are reserved between source and destination, relatively simple to realise but requiring a certain amount of time for channel establishment and release. Furthermore, each channel occupies at least a full wavelength (2,5 or 10 Gb/s), which is very inefficient when the network has to transport variable traffic, like the dominant IP protocol. This dominance of IP and its variability strongly motivates the development of OPS, where packets are entirely switched in the optical domain. The lack of efficient optical storage capacity and the limited optical processing functionalities, however, hinder cost-effective implementation of OPS in the foreseeable future. OBS tries to combine the best features of both OCS and OPS, while avoiding the aforementioned drawbacks.
In [2], the main characteristics of OBS were defined as:

- OBS granularity is between OCS and OPS.
- Separation between control information (header) and data (payload). Header and payload are usually carried on different channels with a strong separation in time.
- Resources are allocated without explicit two-way end-to-end signalling, instead so-called one-pass reservation is applied.
- Bursts may have variable lengths.
- Burst switching does not require buffering.

Motivation for an efficient reservation strategy

The loss of bursts can have different reasons. Two important causes are:

- *Congestion of data bursts in the data channels*: Congestion occurs when, at a given moment, the number of bursts is greater than the number of available channels. With the absence of buffering, a data burst will immediately be lost. Such a type of loss also appears in OPS. Also congestion of control packets is possible, but usually this aspect is neglected.

- *Blocking of data bursts in the data channels:* Blocking, on the other hand, is typical of OBS. An unwise reservation in the past can lead to blocking of a new data burst. Figure 1 contains an example of blocking. Suppose only channel c and d are present: the new burst can not be allocated on either channel. If we had reserved burst F on channel d and H on c, there would be sufficient place available on channel c for the new burst. A good reservation mechanism can prevent the original situation. In the next section, we explain several alternatives for the realisation of the OBS scheduler.

The different reservation strategies

Often, there are various possibilities (i.e. different wavelengths available) when allocating a new data burst. In general, data channel scheduling algorithms can be classified into two categories: with and without void filling (VF). VF means that the voids between two earlier allocated bursts can be filled by a new arriving data burst. A scheduler without VF can only allocate a new burst on a specific channel after all the earlier reserved bursts on that channel. Of course, a strategy without VF is less efficient than one with VF. In Figure 1, the new burst can only be allocated on channel i or j, if we use a scheduler without VF. The disadvantage of VF is a more complex scheduler requiring more processing time. Nevertheless, in this paper, we will restrict ourselves to a scheduler which uses VF, because of its greater efficiency.

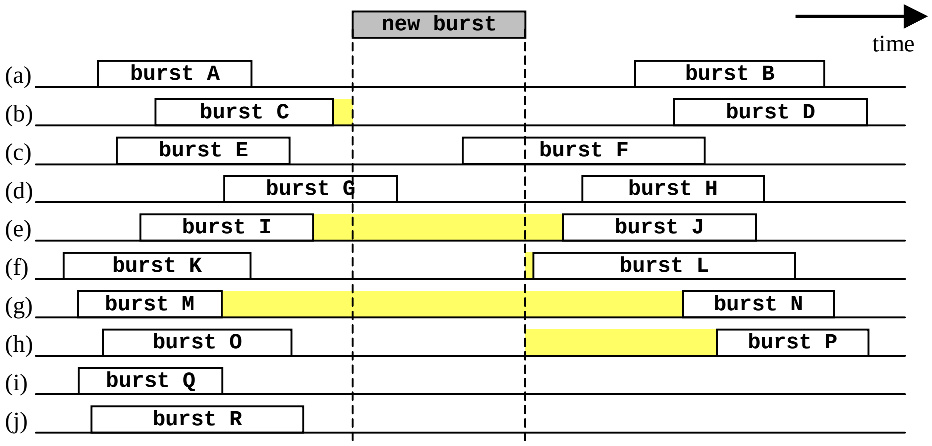

Figure 1: Comparison of several reservation strategies:
First Fit: (a) with VF, (i) without VF; LAUC: (b) with VF, (j) without VF;
Smallest Gap : (e); Smallest New Gap: (f); Biggest Gap: (g); Biggest New Gap: (h).

First Fit (FF) and Latest Available Unused Channel (LAUC) are two reservation strategies appearing frequently in literature [3]. FF will search all the data channels in a fixed order, and assign the first eligible channel found to carry the data burst. The advantage of this technique is its simplicity: once a free wavelength is found, it is not necessary to scan the other wavelengths. LAUC, on the other hand, chooses the wavelength with the smallest gap between the start of the new burst and the end of the previous burst. The basic idea of LAUC is to minimise the voids. Figure 1 illustrates both, FF and LAUC.
Next to FF and LAUC, we have also studied several other reservation mechanisms and Figure 1 (e - h) gives an overview of them. The difference between Smallest/Biggest Gap and Smallest/Biggest New Gap is that either we seek the original smallest/biggest

gap, or we minimise/maximise one of the newly created gaps (before or after the new data burst). LAUC is just a special case of Smallest New Gap, where only the gap before the new burst is considered. The idea behind Biggest (New) Gap is that there will be enough place available to still add other bursts in the same void.
However, the main incentive to implement Biggest (New) Gap is the possible combination with Smallest (New) Gap, resulting in a new strategy, Best New Gap. We have opted for the combination of Smallest New Gap and Biggest New Gap. If the smallest new gap is smaller than a given limit, then Best New Gap uses Smallest New Gap. In the other case, Best New Gap uses Biggest New Gap (Figure 2). The motivation for this strategy is that if we always apply Smallest New Gap, it sometimes happens that this gap is still rather large. Since it is the smallest void, this gap will mostly be too small for allocating later bursts. Consequently, over a certain limit, it can be useful to opt for Biggest New Gap, leaving room for next bursts to fit in.

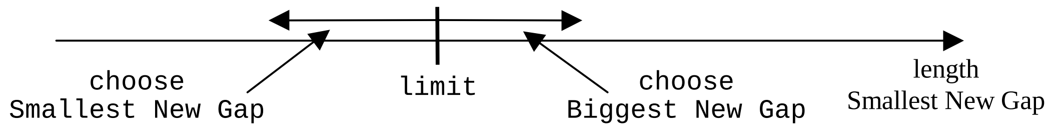

Figure 2: Illustration of Best New Gap.

A last strategy is Random Choice: from all the available channels, we randomly choose one. The next section presents some simulation results of the strategies described above.

Simulation results

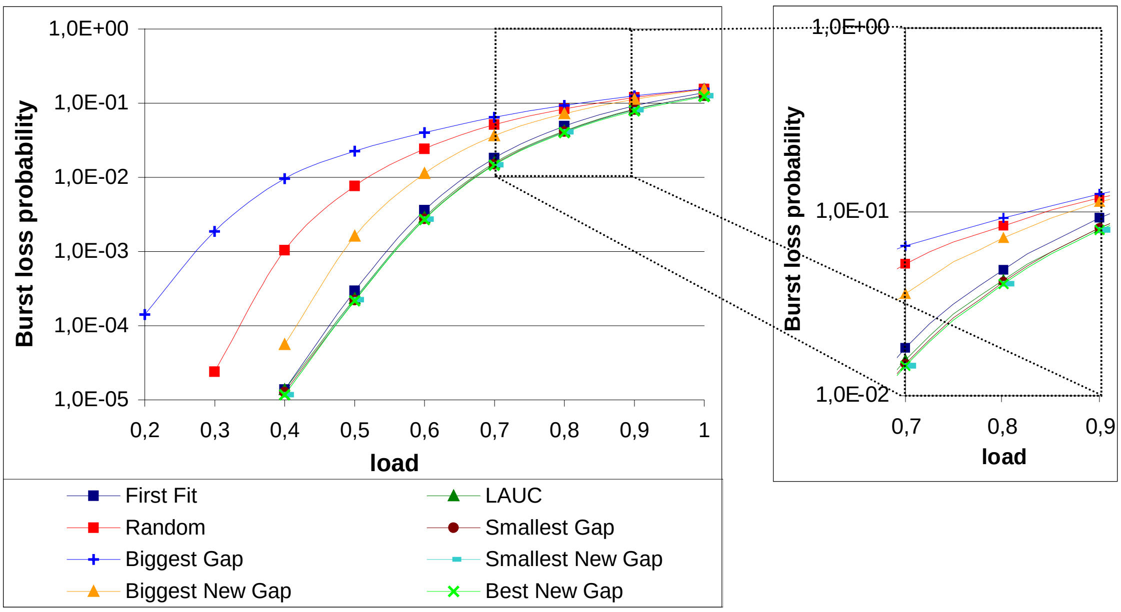

Figure 3: Burst loss probability vs. load, for 8 different reservation mechanisms.

Figure 3 shows burst loss probability versus load, for eight different reservation mechanisms. The simulation represents a single OBS node with 4 input fibres, 4 output fibres and 32 wavelengths. The burst length is negative exponentially distributed with a mean burst length of 32 μs. First, note that the loss in an OBS node is rather large. With a load of 0.8, the loss is at least 4%, and with a bad reservation mechanism, it is nearly 10%.

The figure depicts that at low load, the influence of the reservation strategy is larger. This can be intuitively explained since at lower loads there are more free wavelengths to choose from. Also, at higher loads, congestion is more likely, and the reservation strategies don't affect the loss as a result of congestion, proved by the converging of all mechanisms to the same loss value.

Best New gap is the most efficient mechanism, but its performance is very close to LAUC, Smallest Gap and Smallest New Gap. Due to its higher complexity (compared to LAUC), Best New Gap should only be applied, when efficiency is critical. Biggest Gap and Biggest New Gap were developed in consideration of the design of Best New Gap. Biggest Gap is a poor choice, and should only be used in combination with another mechanism. Also, Biggest New Gap is not very good, although its performance is better than Random Choice. Random Choice itself performs poorly, and is not preferable.

On the other hand, the simple FF algorithm has a very good performance, which is only a little bit worse than LAUC. Intuitively, we can explain the good behaviour of FF as follows: this strategy always chooses the first free wavelength, according to a certain fixed numbering. Consequently the first wavelengths are filled up as good as possible. Only if it is really necessary, the wavelengths with a higher number will be used, and as a result the chances to find a free wavelength for the next bursts increase. Since LAUC is proposed to minimise the wasted space during each new burst allocation, it is very logical that it is better than FF, but the improvement is remarkably low. Thus, First Fit, besides being very simple, is also a very good mechanism.

Conclusions

We have studied several reservation strategies for OBS. Eight different mechanisms were tested, and we have evaluated them through simulations. The simple FF-algorithm already has a very good performance, compared to other mechanisms. LAUC, which is developed to reduce the wasted space as much as possible is better than FF, but the improvement is not impressive. Furthermore, the limited improvement of our newly developed Best New Gap means that it is not easy to find a strategy that is better than LAUC.

We can conclude that it is very difficult to increase the efficiency of OBS with only a better reservation strategy. The losses in OBS are still very high, and it is not easy to improve the LAUC-algorithm. At any case, the difference between the reservation mechanisms is quite large, and some strategies (e.g. Random) should certainly be avoided.

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