Performance comparison of scheduling algorithms for IPTV traffic over Polymorphous OBS routers

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ABSTRACT

Recent research in Optical Burst Switched networks has proposed solutions to support subwavelength reservation for the periodic transmission of data bursts, which can coexist with conventional asynchronous bursts, bringing the Polymorphous, Agile and Transparent Optical Networks (PATON) [1]. Thus, network operators can distribute IPTV channels to their customers, whereby they can use the spare bandwidth for the transmission of best-effort traffic, making use of the free gaps in between such periodic reservations. This work proposes scheduling algorithms for the transmission of periodic channels using PATON, and studies the blocking probability observed by best-effort traffic, when such scheduling algorithms are used.

Keywords: Optical Burst Switching, IP Television, Service differentiation, CBR traffic.

1. INTRODUCTION

The introduction of Dense Wavelength Division Multiplexing (DWDM) technique [2] has multiplied data transmissions capacities for optical equipment. Thanks to the latest advances in optical transmission, 25 Tbps can be transmitted over the same fibre [3]. However, the reservation of one wavelength per user leaves unused most of the bandwidth capacity of this lambda. Optical Burst Switching (OBS) technology increases the utilisation level of the optical bandwidth. This is possible, because of aggregation of incoming packets into bursts and their further all-optically transmission across the network [4], [5].

The most common OBS signalling is Just Enough Time (JET) protocol [6]. JET reserves in advance a wavelength transmission time via a Burst-Control Packet (BCP). To configure the core nodes, BCPs are transmitted an offset time ahead. In-advanced reservation allows the separation of network resources for services with different QoS requirements. The proposal of Polymorphous, Agile and Transparent Optical Networks (PATON) architecture [1] uses this resource separation to propose a unique framework to support all optical services: lightpaths just like in Optical Circuit Switching (OCS), burst services (OBS) and Time Division Multiplexing (TDM) circuits with subwavelength capacity.

A core Polymorphous OBS (POBS) node is illustrated in Figure 1. This node has to deal with a complete wavelength reservation (denoted by 1), a TDM reservation (synchronous fixed time slots reserved, denoted by 2), and asynchronous best-effort bursts (single asynchronous reservations, denoted by 3).
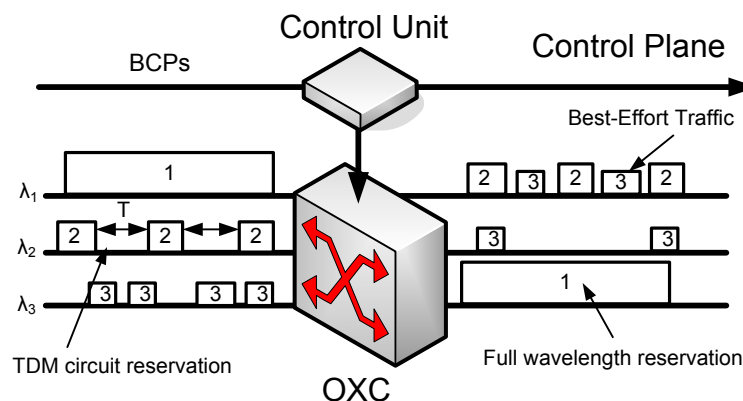

Figure 1: PATON architecture.

To provide these new services, the Burst Control Packets have got their attributes increased with respect to the conventional OBS architecture. For instance, there are fields like the periodic reservation time, which is used only for TDM services, while routing information is necessary for all services. Therefore, with the PATON architecture, the same underlying network infrastructure can be used to support all kind of optical services.

For this work, we shall consider the IP Television (IPTV) service using PATON technology. Using OBS, the provisioning of this service would require one BCP per TDM slot. Moreover, not all TDM slots are reserved because of the blocking probability. Nevertheless, sending one PATON's BCP, TDM circuit is established. Furthermore, the network operator can use the gaps in between each TDM slot to send best-effort traffic. Therefore, it is interesting to study the blocking probability given to such best-effort data bursts, assuming that the TDM circuit is given preference. To the best of our knowledge, this study has not yet been done.

Not only PATON, but other solutions allow the combination of periodic reservations and asynchronous traffic: Synchronous OBS [7], Synchronous-Stream OBS [8] and Wavelength-Routed OBS [9]. PATON is selected because it covers the functionalities of all of them. A preliminary analytical performance study with synchronous and asynchronous traffic is done in [7]. In this article, the authors carry out an analysis of SOBS solution, but focused on the payload problem because of the transmission of small bursts. To solve this problem, they define grooming algorithms both synchronous and asynchronous data bursts using Fiber Delay Lines (FDLs) on attempts to maintain a high level of network utilisation. The authors study the throughput of both types of traffic when different grooming policies are applied.

The reminder of this work is organised as follows: section 2 explains the IPTV traffic capture system. Section 3 defines the scheduling algorithms for the periodic transmissions. Section 4 calculates an analytical formula for the computation of the blocking probability experienced by best-effort traffic. Section 5 shows the simulations and analytical results. Finally, section 6 concludes this work with a brief discussion and future work.

2. TRACE CAPTURE SYSTEM

This work intents to make a fair performance comparison among various scheduling algorithms for IPTV traffic in the most realistic scenario possible. To achieve this goal, it is absolutely necessary to obtain a detailed characterization of the IPTV traffic that a service provider sends to its customers.

In this light, we have captured the traffic that a client of a Spanish IPTV service provider receives at his home when he is watching a TV channel. Figure 2 shows the architecture of the Trace Capture System. Basically it consists of a computer running Wireshark tool[1], connected directly to an ADSL router. The ADSL router receives all traffic for the user: Internet traffic and TV channels. Therefore, the Trace Capture System must be able to filter and collect only IP TV traffic.

The capture process lasted 10 minutes and the trace size was about 300 MB. The trace analysis showed that the channel was encoded with MPEG-2 and its bit rate was around 4.16 Mbps. These parameters correspond to the Standard Definition Television (SDTV) codification [10]. Additionally we found that the IPTV traffic streams were basically Constant Bit Rate (CBR) with packet interarrival times of 2.5ms. Thus, in the following, we shall use these parameters in the simulation set.
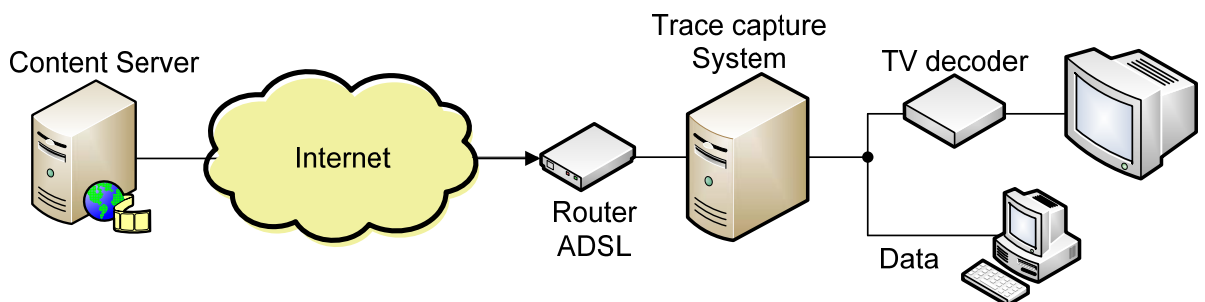

Figure 2: Architecture of the trace capture system.

3. SCHEDULING ALGORITHMS FOR PERIODIC TRANSMISSIONS

As previously stated, PATON allows network operators to share network resources between periodic synchronous reservations and best-effort traffic. However, some algorithms can be used to schedule the periodic IPTV transmissions (Figure 3 and Figure 4). Let us define four scheduling policies:

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[1] http://www.wireshark.org/

- **First Fit (FF):** This algorithm inserts all TV channels together in the first free wavelength. As the IPTV traffic has priority over asynchronous traffic, IPTV reservation is always allocated in the first lambda (Figure 3).
- **Round Robin (RR):** This algorithm allocates reservations in the first free lambda, like FF. However, RR stores the wavelength previously used, so the next search starts in the next lambda. Therefore, RR reserves one time slot every $T_{off} + T_{on}$ in each lambda (Figure 3).
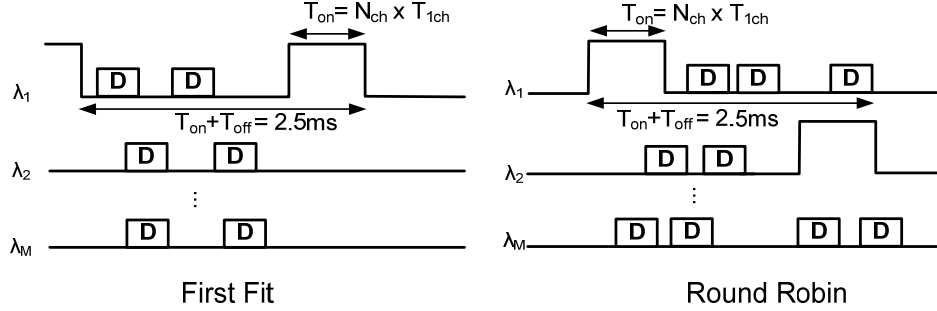

Figure 3: First Fit and Round Robin scheduling algorithms.

- **Synchronous Round Robin (SRR):** SRR uses all lambdas when TV channels are transmitted. One reservation is done in each wavelength so N_{ch}/M channels are transmitted per slot (Figure 4). Consequently, the T_{off} period is greater than in the two previous algorithms.
- **Synchronous Shifted Round Robin (SSRR):** SSRR is similar to SRR, with the difference that the reservation in each lambda is shifted T_{on}. The reason is that this algorithm transmits the first N_{ch}/M channels and, after this, it allocates the next reservation in the following wavelength. This algorithm allows the use of all wavelengths, avoiding the "blind" areas that SRR creates (Figure 4). By "blind" areas, we refer to those at which no data burst can be scheduled because of CBR traffic.
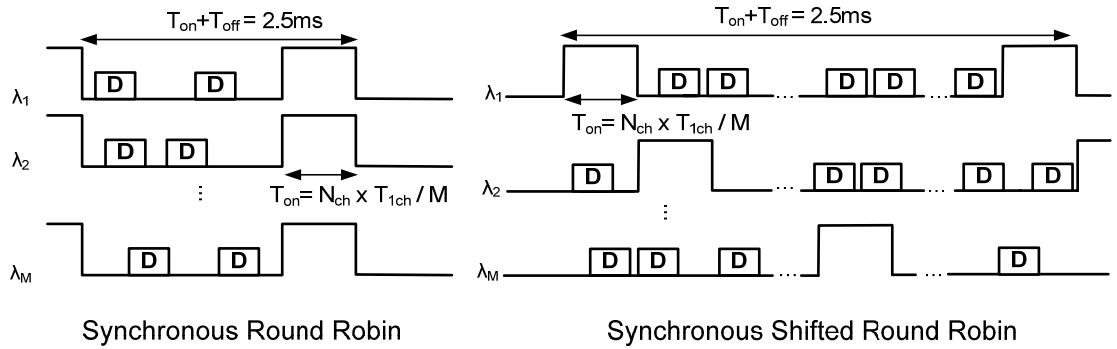

Figure 4: Synchronous Round Robin and Synchronous Shifted Round Robin algorithms.

4. PERFORMANCE ANALYSIS

The following makes use of the Erlang B loss formula to derive the blocking probability of the best effort data bursts transmitted in between the on periods of IPTV transmission. Obviously, the Erlang B loss formula does not take into account the retroblocking effect of OBS networks (see [11]), which arises when the offset values are highly variable. For simplicity, in the following analysis we assume that the offset values are either constant or with low variability, thus making the Erlang B loss formula a good approximation to the actual blocking probability. The accuracy of such approximation is assessed in the experiments section.

The total probability theorem (eq. 1) takes into account the blocking probability of each case ("T_{on}" and "T_{off}" period) times the probability of the best-effort data burst to actually arrive in each case-

$$P_{BK} = P_{BK-off}P(T_{off}) + P_{BK-on}P(T_{on}) \tag{1}$$

Once the blocking probability is defined in terms of the Erlang-B formula and T_{on} and T_{off} periods, we can easily achieve the expression for the First Fit (eq. 2) and Synchronous Round Robin (eq. 3) algorithm.

- **First Fit algorithm:**

$$P_{BK} = \frac{T_{on} + D}{T_{off} + T_{on}} E_B(M-1, A) + \frac{T_{off} - D}{T_{off} + T_{on}} E_B(M, A) \tag{2}$$

- **Synchronous Round Robin:**

$$P_{BK} = \frac{T_{on} + D}{T_{off} + T_{on}} + \frac{T_{off} - D}{T_{off} + T_{on}} E_B(M, A) \tag{3}$$

5. RESULTS AND EXPERIMENTS

This section is split into three subsections. Firstly, we define the most important scenario parameters. Secondly, we study the blocking probability for the four algorithms with realistic values for the transmission of IPTV traffic. In the third part, we compare the formula obtained in the analysis section and the simulation results.

5.1 Scenario definition

Let us briefly outline a few design guidelines for a network operator which is willing to provide IP Television (IPTV) service to its customers using PATON. To simulate a realistic scenario, we will use the interarrival time of the Spanish IPTV provider trace (2.5 ms) and the bitrate (4.16 Mbps). The number of channels sent by an IPTV provider are in the range of 100 to 200, we assume $N_{ch} = 192$ channels.

Once CBR parameters are defined, let us define ρ as the average best-effort input to the system, defined as:

$$\rho = \frac{\lambda D}{M} \tag{1}$$

where λ is the number of arrivals per second, D is the burst length and M is the number of wavelengths.

Using previously defined parameters, the T_{off} period for FF and RR algorithms is 2.3ms, and 2.475ms for SRR and SSRR algorithms (M=8).

5.2 Scheduling algorithms performance evaluation

Figure 5-A shows the burst blocking probability for the four scheduling algorithms when varying best-effort load. In the light of the results, FF and RR algorithms achieve the best performance. SRR performance is the lowest, since it creates "blind" areas assuring the blocking of the incoming bursts in T_{off} periods. The behaviour of SSRR varies strongly with the burst length (Figure 5-B). When $D \approx T_{on}$, T_{on} shifted between lambdas is negligible in temporal terms, so SSRR performance is degraded. However, if $D \ll T_{on}$, T_{on} periods between consecutive reservations improves the non-blocking probability considerably. In this case, SSRR performance is closer to FF and RR.
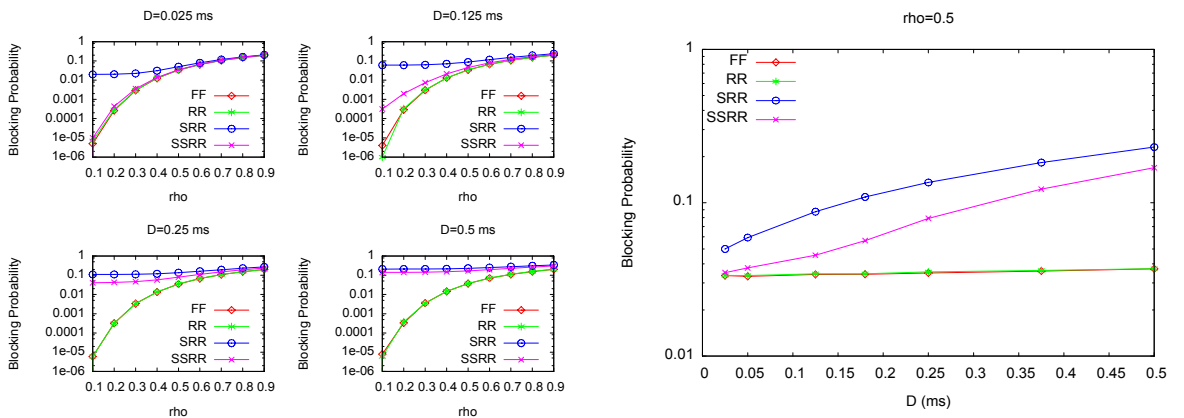
A. Best-effort load variation   B. Burst length variation

Figure 5: Comparison of burst blocking probability.

According to the results presented in Figure 5-A, First Fit algorithm is the one with best results. Therefore, an operator which wants to distribute IPTV traffic using PATON should schedule the synchronous traffic using the FF algorithm. Thanks to the calculations done for a real case, it is possible to send IPTV traffic over one wavelength.

5.3 Analytical and simulations results comparison

The previous section showed that the worst scheduling algorithm is the Synchronous Round Robin (SRR) algorithm and the best one is the First Fit (FF). This section presents a comparison between the analytical formulas compute for FF and SRR algorithms. The performance achieved by the other two algorithms (RR and SRR) is between them.

Figure 6-A illustrates the simulated and theoretical blocking probability for the FF algorithm when the burst length varies. The theoretical formula fits the simulated results in all the cases. However, when D is comparable to T_{off}, the theoretical results slightly differ from simulations.

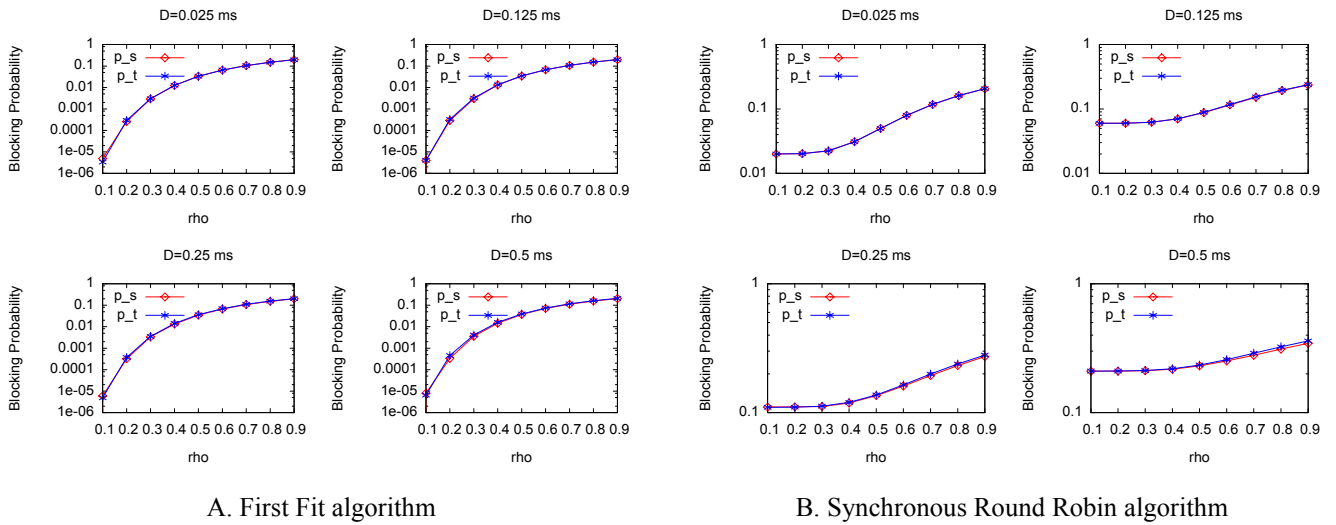| A. First Fit algorithm | B. Synchronous Round Robin algorithm |

Figure 6: Comparison of theoretical and simulation blocking probability.

Figure 6-B illustrates the results for SRR. Analytical and simulation results are very close and only, when D length is similar to T_{off} and load is higher to 50%, the formula does not fit.

6. CONCLUSIONS AND FUTURE WORK

This article proposes the used of PATON for the distribution of IPTV traffic by a network provider. To make a realistic analysis, a trace from a real network operator is captured and analysed. Moreover, four scheduling algorithms for IPTV traffic transmission are defined.

Once a feasible scenario is defined, the performance of the scheduling algorithms in terms of blocking probability is compared. The simulations show that the lower blocking probability is achieved by the FF algorithm and the highest blocking values occur for SRR algorithm. On the other hand, the blocking probability of RR is slightly higher than in FF. Finally, SSRR performance is significantly influenced by the relation of D and T_{off}. Nevertheless, the performance of SSRR is always between FF and SRR. Concludingly, FF should be the scheduling algorithm for the transmission of IPTV together with best-effort traffic. Additionally this work provides the analytical formulas for the best (FF) and worst (SRR) policies. The simulations show that the two formulas are accurate.

In future work, we shall analyse this solution not only for the transmission of one TDM stream reservation, but for multiple stream reservations simultaneously.

REFERENCES

[1] C. Qiao, W. Wei, and X. Liu, "Extending generalized multiprotocol label switching (GMPLS) for polymorphous, agile, and transparent optical networks (PATON)," IEEE Communication. Magazine, vol. 44, no. 12, pp. 104–114, Dec 2006.

[2] International Telecommunication Union, "Recommendation on DWDM (G.692)".

[3] A. H. Gnauck, G. Charlet, P. Tran, P. Winzer, C. Doerr, J. Centanni, E. Burrows, T. Kawanishi, T. Sakamoto, K. Higuma; "25.6-Tb/s C+L-Band Transmission of Polarization-Multiplexed RZ-DQPSK Signals", Proc. of Optical Fiber Communication Conference & Exposition and the National Fiber Optic Engineers Conference (OFC/NFOEC), 2007.

[4] C. Qiao and M. Yoo, "Optical Burst Switching (OBS) – A new paradigm for an optical Internet," J. High Speed Networks, vol. 8, pp. 69–84, 1999.

[5] S. Verma, H. Chaskar, and R. Ravikanth, "Optical Burst Switching: A viable solution for Terabit IP backbone," IEEE Network, vol. Nov/Dec, pp. 48–53, 2000.

[6] M. Yoo and C. Qiao, "Just-Enough Time (JET): A high-speed protocol for bursty traffic in optical networks," in Proc.IEEE/LEOS Conf. Tech. Global Info. Infrastructure, Montreal, Canada, Aug. 1997, pp. 26–27.

[7] S. Sheeshia and C. Qiao, "Synchronous optical burst switching," in Proc. of BroadNets 2004, San Jose, California, USA, Oct. 2004, pp. 4–13. O.

[8] O. Yu and Ming Liao, "Synchronous stream optical burst switching," in Proc. of BroadNets 2005, Boston, Massachusetts, USA, Oct. 2005, pp. 1447–1452.

[9] M. Duser and P. Beyvel, "Analysis of wavelength-router optical bursts-switched network performance," in Proc. of European Conf. Optical Communications, Amsterdam, The Netherlands, Oct. 2001, vol. 1, pp. 46–47.

[10] G. Held, Understanding IPTV (Informa Telecoms & Media), AUERBACH, Oct. 2006.

[11] Y. Liang, K. Liao, J. W. Roberts and A. Simonian, "Queueing models for reserved setup telecommunication services," in Teletraffic Science for New Cost-Effective Systems, ITC 12, Italy, June 1988.