Dynamic Service Differentiation in OBS Networks

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Abstract—In this paper we propose an edge-to-edge closed-loop scheme to provide Quality-of-Service (QoS) in Optical Burst Switching (OBS) networks. Performance parameters for each burst flow are exchanged by a feedback message called Service Control Message (SCM) which is processed only at the edge/ingress nodes. According to the information contained in the SCM the edge nodes could adapt the values of some flow parameters (typically burst assembly parameters and offset time) to apply differentiated quality of service to the various flows. Simulations results are presented to investigate the feasibility of this new proposal.

I. INTRODUCTION

The OBS transport architecture is based on a bufferless WDM network, where data bursts consisting of multiple packets are created at border or ingress nodes. The process of aggregating and assembling input packets is called burst assembly: the most common burst assembly techniques are timer-based or threshold-based, when burst are created and sent at periodic time intervals or with fixed size respectively. Bursts are switched by intermediate or core nodes along the network all-optically. This is possible thanks to a control message or header which is transmitted ahead of the burst and whose goal is to configure the switches along the path before the arrival of the corresponding data burst. These are separated at the source node by a fixed time interval called offset time that allows the core nodes to be configured before the burst arrival.

Today, many multimedia applications have strict requirements in terms of delay, bandwidth or loss rate. In this context, traffic should be divided into Quality-of-Service (QoS) classes based on their different characteristic. For an optical network to be truly able to support carrier-grade traffic, an important issue is how the WDM layer supports differentiated services. Since no efficient optical buffering is available yet, this goal should be pursued without buffering.

In [1], a prioritized offset scheme was proposed to provide QoS in a bufferless OBS network. Higher priority bursts are given a larger offset time with respect to lower priority bursts. By providing higher offset the probability of reserving the resources for higher priority bursts is increased, while in turn the loss of higher priority bursts is decreased. Another possible approach consists in specifying a priority degree inside the header packet, so as providing differentiation by different contention resolution policies. In [2] burst differentiation policies are discussed using segmentation, i.e. assigning to the packets different positions inside the burst. In [3] the desired level of performance is achieved by intentionally burst dropping. Also the adoption of different signalling reservation strategies (e.g., one-way or two-way) can be used to guarantee a given and bounded loss rate [4].

All these methods rely on a static in-advance reservation or preemption of a fixed amount of resources, so that the link capacities are not fully exploited to let room to high priority flows. In addition, information on the whole network (e.g. round trip times, connection durations) has to be available in advance; so these methods can not be considered viable strategies to accommodate highly dynamic internet-like traffic flows, i.e. asynchronous flows with unknown duration. To better deal with a dynamic environment, a possible solution to provide a desired loss is to use a congestion control method by adjusting the burst sending rate or intentionally dropping burst at the edge nodes: e.g. in [5] the flow rates are adjusted according to some feedback information to control loss rate on per flow basis, while in [6] rate adjustment and feedback information have been combined to intentional dropping.

In this paper we propose to apply a QoS mechanism based on an explicit feedback signalling message sent to each edge node and indicating a required variation of one among three burst assembling parameters: offset time, time-threshold and length-threshold.

The rest of the paper is organized as follows: Section II specifies some relevant assumptions that we consider in this work to fairly evaluate the service differentiation induced by the parameter tuning. In Section III we give a detailed description of our proposal for a dynamic service differentiation feedback mechanism in OBS networks. Finally, in Section IV we quantify the service differentiation achievable by modifying assembly parameters and offset time and we provide a set of preliminary results that confirm the feasibility of our proposal.

II. NETWORK AND NODE ASSUMPTIONS

We consider an OBS network formed by N nodes connected by L links, each characterized by the number of data channels it carries, W, and the capacity of each channel, C.

Ingress nodes are supposed to have enough memory to store incoming packets and egress nodes do not drop bursts, so that losses only come from congestion at the bufferless core nodes. In order to avoid that signalling strategy would affect
the results, we resort to a simple one-way signalling protocol, JET, and a simple scheduling procedure, called LAUC with the Void Filling extension [6]. Signalling is out-of-band and control channels are dimensioned so that headers loss and queueing time are negligible.

III. DYNAMIC SERVICE DIFFERENTIATION

In our model, flows with different service requirements are generated at any time by any ingress node. Our objective is to improve the performance with respect to a given probe parameter (e.g. loss ratio) according to specific flow service requirements.

We suppose that ingress nodes specify the requirements of each flows originating from them. They have no global network information about resource occupancy. Without loss of generality, we suppose that egress nodes monitor some per-flow state variables, e.g. blocking ratio or throughput, and so they are warned of any performance or requirement variation occurring to their flows. Whenever a change in the QoS of some flows is required, the egress nodes send back a Service Control Message (SCM) to the respective source nodes. After SCM has been received, ingress nodes have to react accordingly. SCM could be of two type: containing only row measure information or containing just the type of reaction, i.e. elaboration process could be located both at ingress and egress nodes. Core nodes only forward the control messages.

IV. PERFORMANCE RESULTS

We carried on a large set of simulations to verify the practicality of our proposal: in this early study, in a pseudo-dynamic environment, we varied the three assembly parameters to verify what level of service differentiation can be achieved only relying on assembly parameters dynamic modification. We consider the network scenario shown in Fig. 1: it consists of 3 nodes connected in-line, one ingress, one core and one egress node. The transmission rate is 10 Gb/s with 8 data channels; mean header duration is \(1\mu s\) and mean burst duration is \(100\mu s\); the switching time is \(10\mu s\) and the header processing time is \(20\mu s\). Two flows originate at the same source and terminate at the same destination. Each flow offers the same normalized load, \(\rho = 0.3\), and it is characterized by the same assembly parameters. We measure the burst loss probability at the core node under Poisson arrivals and exponential burst length hypotheses. These assumptions are adopted to avoid any influence due to the assembly policy because it is known that the statistical flows characteristics are modified by the adopted assembly procedure. Furthermore, values reported in the following graph are cumulative means from \(t = 0\).

In our simulations, after \(t = 20s\) the end node sends to the ingress node a feedback message (SCM) requiring a better service for one of the two flows. The ingress node has three options: it can vary the offset-time, or one of the trigger criterions (time or length). Since end-to-end delay is considerably affected by these variations, we consider that these flows are more delay than fault tolerant, i.e. they are prone to exchange additional delay for a better performance.

First, we investigate the variation of the offset-time at the ingress node. In Fig. 2 the original offset of \(50\mu s\); at \(t = 20s\) the offset of one of the flows is doubled.

Fig. 2. Burst loss probability at the core node. Flows have the same initial offset of \(50\mu s\); at \(t = 20s\) the offset of one of the flows is doubled.

Secondly, we observe the effects obtained by varying the burst length trigger parameter. In this case, burst length is initially fixed and their inter-arrivals are Gaussian distributed [7]. Fig. 4 shows the burst loss probability when the trigger length of one flow is doubled. In this case longer bursts achieve better performance, since they are more likely to capture the channels and, once allocated, they are more effective in preventing the shorter bursts to be scheduled. However, the

\[1\text{Burst length is reported in time units to have an uniform comparison value.}\]
connections last less than some minutes in a carrier grade reaction times in order tenth of seconds. Also, these reaction times seem to pay back the extra delay induced. Finally, we consider satisfying the reaction times in order of seconds measured the reaction times after a flow parameter is varied: the case with trebled assembly parameters (trigger time and/or burst length) does not seem to pay back the extra delay induced. Finally, we measured the reaction times after a flow parameter is varied: we consider satisfying the reaction times in order of seconds as we does not expect that connections last less than some minutes.

V. CONCLUSION

In this paper we have presented a preliminary study to investigate the practicality of inducing service differentiation on a per flow basis by modulating one out of the following assembly parameters: offset time, burst generation interval and burst generation length. Our proposal is to exploit feedback information collected by egress node and sent back to the ingress node by means of control messages to trigger an online modification of the assembly parameters, so influencing the QoS of the affected flows. The basic trade-off is that some additional end-to-end delay is experienced by data burst of the prioritized flows due to the additional queuing time spent at the ingress nodes. In our simulations, running a pseudo-dynamic environment, we showed that the offset time is the most promising parameter to be modified to induce service differentiation among flows in an OBS network, achieving a one-order-of-magnitude gain for reasonable increase of the end-to-end delay. On the contrary, the modification of burst assembly parameters (trigger time and/or burst length) does not seem to pay back the extra delay induced. Finally, we measured the reaction times after a flow parameter is varied: we consider satisfying the reaction times in order of seconds as we does not expect that connections last less than some minutes.

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