A scalable design for all-optical burst switching nodes

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Abstract— New services and high bandwidth demanding applications will dramatically change the operator’s requirements with respect to future network architectures and topologies. The advent of bandwidth-intensive video applications stimulates the design of high throughput and flexible network architectures. In this network evolution All-Optical Burst Switching (AOBS) can play a key role. AOBS is based on the all-optical label swapping (AOLS) principle. AOLS is a key functional type of optical burst switching that aims at forwarding bursts at line speed and intends to solve the potential mismatch between fiber capacity and burst forwarding node capacity. AOLS implements the routing and forwarding functions of MPLS (Multi Protocol Label Switching) directly at the optical domain. By using optical labels, the bursts are directed through the optical network without the use of fast speed electronics whenever a forwarding decision is necessary. The main advantage of this approach is the ability to route bursts independently of bit rate, burst format and burst length.

Keywords— all-optical burst switching, node design

I. INTRODUCTION

Current network topologies and architectures may be assumed to be insufficient to support the future, newly deployed services and applications, [1]. Indeed, these bandwidth-intensive services (e.g., video and TV applications) will lead to a significant growth in traffic volume and, together with high Quality of Service (QoS) requirements, this bandwidth growth insists the reforming of the current network architectures.

But it is not yet clear what will be the final requirements upon the network. Will the individual user behavior ask for more unicast traffic or will the majority of the new services be hosted by multicast or broadcast connections? Anyway, probably, business will ask for new, ad-hoc services instead of leasing fixed lines. Due to the ad-hoc and thus dynamic service provisioning it will probably be possible to better schedule the bandwidth demand. This can lead to a decrease of the capacity over dimensioning compared to the current network architectures, which improves the network functionality.

The new network architectures should also support an easy access (for domestic, science and business users). Therefore future networks should be scalable, flexible and user-centric.

This means the network model should be able to allow the users to adapt the network to their applications. Such a network evolves from the current service aware network that provides high bandwidth connections between users and resources to a service oriented and user-centric network with an integrated control plane. Such a control plane (e.g., an extended Generalized Multiprotocol Label Switched (GMPLS)-control plane, [2]) will have to treat bandwidth and computing resources in the network in the same way.

According to the presenters of [3], the final network solution will utilize hybrid OCS/OBS edge routers, active optically switched core nodes and advanced protocols in order to provide a service-oriented all-optical network infrastructure for evolving data-intensive and emerging Grid applications. On the one hand, bandwidth will be provided as wavelength routed bursts that offer the capacity granularity and flexibility that is asked for. On the other hand, all-optical networks can offer the routing speed and specification limitations (roundtrip delay...) demanded by the new applications. Besides that, all-optical burst routing can overcome the shortcomings of electronic routing and transparently route high capacity bursts, independent of higher network layers.

This paper describes how all-optical burst switching could be achieved and what are the pros and cons of this approach. It is structured as follows: Section 2 reasons why OBS could be the future and Section 3 describes how an all-optical scenario would fit into that. Section 4 depicts generally the all-optical burst switching node while Section 5 tackles the scalability issue.

II. THE CASE FOR BURST SWITCHING

Future network architectures and topologies will be designed in an application and service driven way. New dynamic bandwidth-intensive applications and services steer the network migration to abandon higher network layers, figure 1. Fewer network layers reduce the overhead insisting on a more bandwidth efficient data transport and a reduction of the infrastructure costs. This integration results in future Optical Transport Networks where the task of the optical layer is no longer limited to mere data transport but fulfills certain networking functionality.

Due to this, the bursty nature of applications will reflect directly in the transport layer. Therefore, efficient data transport is characterized by respecting the on-demand, asynchronous and variable length capacity requests.
Burst switching can form the solution to this. As an alternative to dynamic wavelength routing and packet switching, burst switching avoids long set-up and tear-down times for wavelengths, but provides the fine bandwidth granularity of packet switching without the need for buffering in the network.

**Figure 1.** The abandonment of network layers by burst switching

### III. THE CASE FOR ALL-OPTICAL BURST SWITCHING

All-optical burst switching nodes intend to route packets at wavelength-speed without converting them to the electronic domain. Providing the all-optical burst-functionality allows for abolishing the electronic data layer in the core nodes and permits to only use electronics in the control plane.

The recently proposed all-optical burst switching node designs suffer from bad scalability. AOBS is based on Label Switched Paths (LSPs) that are set up in advance by the control protocol, [4], sending a control header. The protocol reserves the bandwidth and switching resources for the burst in advance so no buffers are needed. The control plane thus tracks for each node which wavelength has free capacity on which moment.

Figure 2 depicts the All-Optical Label Swapping block that contains the all-optical functionality to route the bursts from an incoming wavelength to the appropriate outgoing wavelength on which bandwidth is reserved. Although resources are reserved in advance, in AOBS, an optical label is sent together with the burst payload. This is contrary to optical burst switching where no additional label (next to the control header that reserved the bandwidth) is necessary to forward the burst through the network. In OBS, the control header updates the electronic switch memory with the correct settings to in advance reserve the capacity for the upcoming burst. At the moment the burst payload passes through a node the advance information sets the switches, so that the burst quasi automatically reaches the appropriate output port.

In AOBS, to forward the burst through the network, the label that is sent together with the payload is used. Burst forwarding is based on the MPLS principle, [2] and avoids the use of very fast (electronically controlled) optical switches.

The all-optical burst switching node design is studied in the LASAGNE project, [5]. But, the node architecture as it was proposed there seemed to be hardly scalable, figure 2 and [6]. Indeed, for each label that possibly enters the node, separated hardware should be installed. In figure 2, a burst enters the node at the left corner. Payload and label are separated. The payload is delayed while the label is investigated. The incoming label is compared to all possible incoming labels (local addresses) in the node. Per local address a correlator and a local address generator need be installed. If a local address equals the incoming label, that correlator generates a match pulse. This pulse is used to generate a new, outgoing label and to stimulate one of the all-optical flipflops. In advance, it is not known to which output port the packet should be sent and thus, which flipflop will be pulsed. Therefore all flipflop outputs are collected and brought to the optical notch filter. Because only the pulsed flipflop emits a wavelength different from the standard wavelength ($\lambda_0$) and the notch filter filters this $\lambda_0$, it is possible to tune the TWC with the appropriate internal wavelength. The internal wavelength will allow for the burst to reach the right output port of the node via an Arrayed Waveguide Grating (AWG).

The bad scalability of the nodes is due to the fact that for each burst label to recognize, the node needs individual hardware and that the functionality of figure 2 is installed for each wavelength. Solutions to this are on the one hand, the reduction of the number of labels needed to route all bursts in the network or on the other hand, providing architectures and mechanisms that share the label recognition and forwarding hardware among different labels. MPLS addresses the first issue by providing a LSP for a connection between a source and destination node. The burst's label then contains a local label that is valuable on a link of the path, [2]. The label value is swapped in each intermediate node of the burst's path. The label distribution protocol distributes the labels among the LSPs so that the number of labels is limited and makes sure that a packet receives the appropriate label to be able to be forwarded to the correct destination. [6] reports on the possibilities of MPLS in the all-optical layer and how it reduces the number of labels in the network.

**Figure 2.** Original all-optical node design with label swapping

### IV. A SCALABLE ALL-OPTICAL BURST SWITCHING NODE

A more scalable node design uses a separated label-wavelength on which the labels belonging to burst payloads on several data wavelengths are sent. The data wavelengths only carry payloads and thus do not need the functionality to swap burst labels. The label-wavelength carries the labels that were in used in the original design to route the bursts' payloads through the network. Control packets to reserve resources are sent in advance during LSP set up (as in the original design). This design permits to use less hardware to route all bursts and it also avoids fast electronics to set the switches' state in between the arrival of two bursts.
Figure 3 depicts the AOLS functionality which is installed for the label-wavelength. Only the right under part with the flipflops is installed per data wavelength. In this design there is no need for a label/payload separation because the labels and payloads are on different wavelengths. The labels enter the AOLS block in the upper left corner and are compared to the local addresses. Each label will refer to the data wavelength the according payload is on (there are n data wavelengths belonging to one label-wavelength) and to the LSP on this data wavelength the burst follows (N different LSPs per data wavelength). Therefore, there are n*N correlators needed and thus n*N different labels per label-wavelength. The appropriate correlator will give a match pulse, initiating the generation of the new label (again n*N possibilities) and tuning the correct flipflop. The number of flipflops depends on the number of output ports of the AWG the payload can be sent to. The flipflops are installed per data wavelength because they convert the data payload on a particular data wavelength and thus there are, in total, n*AOLs flipflops needed.

Different label-wavelengths arrive at the node; therefore there is a control AWG installed to send the labels to the outgoing label-wavelength to which the data wavelength of the burst’s payload belongs.

The low speed switches are installed to provide the flexibility of assigning different outgoing labels to the payload and changing the outgoing data wavelength.

VI. SCALABILITY COMPARISON

In the study it is assumed that LSPs can be set over multiple data wavelengths in order to do statistical multiplexing and optimize the bandwidth used. Due to this, wavelengths can also be used for contention resolution, increasing the throughput of the network. Contention refers to the possibility that at the same moment bursts are competing for the same output wavelength. By allowing bursts to change wavelengths on their path, there is more space for the LSP set-up protocol to reserve the necessary capacity when needed. Drawback of this flexibility is that wavelength information can not be used to differentiate between LSPs because bursts belonging to the same LSP can arrive at a node on different wavelengths. As such, more labels are needed.

As a case study the backbone European Network and the increasing traffic predicted by [7] is used. Figure 4 compares the size of the different node designs. The size of the node is calculated as the weighted sum of the components. So, for example an MZI-switch weights 600 while a SOA weights 300. The weights are derived from [8]. The lower bound in the figure refers to the labeling strategy that does not allow for statistical multiplexing in the original swapping approach, [6]. In that case, it is not possible to change the wavelength of a burst and thus blocking probability will be higher.

The figure proves that the scalability of the node design with the separated label-wavelength is higher although the number of correlators per AOLS-block is higher. Indeed, if the number of labels needed to distinguish between all LSPs on one wavelength is N, then the number of correlators to be installed in the original AOLS-blocks is N. For the scalable approach, the number is n*N. This number is higher per AOLS-block but the number of AOLS-blocks to install is lower (one per wavelength in the original approach and one per label-wavelength in the scalable approach) because each AOLS-block processes the labels of different data wavelengths.

VI. CONCLUSIONS

This paper reasons the case for optical burst switching and in particular it explains the advantages of all-optical burst switching in the future. It is assumed that due to new applications bandwidth demand will evolve towards short, high capacity bandwidth connections which could be provided by all-optical bursts. This paper compares the original all-optical burst switching node design with a new, more scalable approach. A higher scalability is needed in order to make these node designs cost attractive.

REFERENCES

W1: The Seventh International Workshop on Optical Networking Technologies: Examining the Case for Optical Burst Switching

**Duration:**
Monday 27 November, 9:00 – 12:00

**Chair:**
Dr. Tarek El-Bawab, Jackson State University
Email: tbawab@jsums.edu

Optical Burst Switching (OBS) introduces a new method of switching at the granularity of optical data bursts. This is a granularity between optical circuits, which are wholesale large-bandwidth lightpaths, and optical packets, which are small date units that are difficult to buffer, process, and route using today’s optical technologies. As such, OBS has the potential to enhance bandwidth efficiency and cost effectiveness in transport networks, and can overcome some technical barriers facing optical packet switching. OBS has attracted a lot of interest among several research groups and has become a popular topic of study worldwide. Several equipment vendors have also looked at OBS thoroughly. Many in the optical networking community consider this technology enthusiastically, and have adopted the case for OBS.

A lot of OBS research efforts however are confined to network simulations, and assume green-field or hypothetical scenarios. In practice, several architectural, technological, and economic issues are involved in the OBS proposal. OBS requires dynamic capability to rapidly allocate optical wavelengths to data bursts, and to rapidly release them after burst transmission. It requires advanced burst assembly strategies, scheduling algorithms, signaling, and control schemes. Progress in some optical component technologies is desirable, and may be required. Many professionals find difficult to designing high-performance OBS solutions that can satisify all these requirements while achieving robustness, reliability, scalability, and economics. Some are concerned about how a new OBS-based transport layer would fit into existing network architectures, and how it would work with IP/ATM, SONET/SDH, and other existing layers. In this workshop, we discuss the case for OBS. We consider the potential of OBS deployment in practical networking applications. Contributions in all areas of OBS research and strategy are solicited. Focus on practicality, implementation, deployment, and economic issues; and on how the theme of this workshop is required for any proposal to be accepted. Electronic submission of proposals for participation (an abstract and participant bio) are invited no later than August 7, 2006. Notification of acceptance will be sent around September 4, 2006. Final submissions, which will be due on October 9, 2006, will complete:

1. Short paper (or extended abstract), Globecom style, no more than 2-3 pages.
2. Power point presentationSkim of the paper/Skalk, and
3. Preprint’s bio.

Proposals/submissions are to be addressed to tbawab@jsums.edu, or tarek.el- bawab@jsums.edu.

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