Optical Packet/Burst Switching

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Abstract — **This article gives an overview of trends in optical networking technologies. Today (D)WDM is able to offer large bandwidth interconnections and to date is mainly deployed on a point-to-point basis. To add more networking functionality to the optical layer, three classes of operation methods are presented and evaluated: circuit switching, optical packet switching (OPS) and optical burst switching (OBS).**

Keywords — **optical packet switching, optical burst switching, DWDM**

I. Introduction

The introduction of optical fiber technology has caused a huge rise in bandwidth capacity. This increase continues by using several different wavelengths on the same fiber: (Dense) Wavelength Division Multiplexing ((D)WDM). As a result of this evolution the network nodes have to switch huge amounts of data in very short times. This moves the bottleneck away from transmission to switching: although current electronic packet switches can handle high bit rates and increase is still ongoing, the demand and availability of bandwidth is raising at a much faster rate. To match switch technology to the huge bandwidth capacities of WDM, migration towards optical switches is foreseen. The bandwidth inefficiency of today's circuit switching transport layer is tackled by both Optical Packet and Optical Burst Switching.

II. Circuit Switching

In current networks DWDM is used in a circuit switched way. Point-to-point connections are set up between different routers semi-statically, which are installed manually and therefore are rarely changed (also called lightpaths). These connections reserve the full wavelength on the fiber, for the whole time. This coarse granularity results in poor occupancy of the available wavelengths: even though capacity on a fiber is huge, it is not used efficiently.

Circuit Switching nevertheless has some advantages. First of all, a reliable connection is made between two routers. The only way data can get lost is due to transmission errors, which are very rare in optical fiber. Secondly the Optical Cross-Connects (OXC) can be quite simple and relatively slow (order of seconds) so their cost can be low.

Current evolutions in Circuit Switched networks are looking into more dynamic behavior. Set-ups and tear-downs of lightpaths can occur more frequently, to accommodate changing traffic patterns. This means OXCs must be made remotely controllable and need faster operation. Still there is a limit on the timescale. Setting up a lightpath needs an end to end reservation and confirmation, so at least one Round Trip Time (RTT) is needed to set up the path. Consequently, in order to efficiently utilize the resources, the occupation time of a light path needs to be large enough in comparison to the RTT.

III. Optical Package Switching

To take full advantage of the available resources Optical Packet Switching (OPS) is considered very promising. The key concept is to occupy the wavelength only when data has to be sent. To this end, data is packetized: a chunk of data is assembled in the so-called payload, and a preceding header is added, containing information on (a.o.) the destination where the payload has to be sent to. The network nodes function as packet routers (hence the name Optical Packet Router, OPR): based on the header information (and possibly the lambda and/or port the packet is received on), the decision were to forward it to (in terms of outgoing port and lambda) is taken. The architectural concept of such an OPR is depicted in Figure 1.

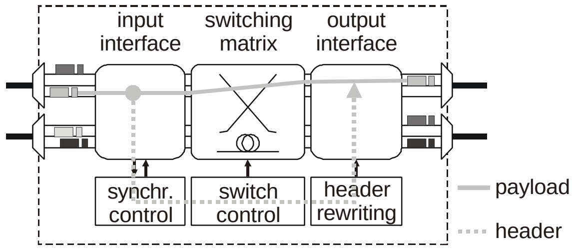

Figure 1: Conceptual architecture of an OPR

To date, the proposed OPS approaches have been of a hybrid nature: the relatively complex packet header processing is performed electronically, independent of the optical payload. Thus, optics are exploited to deliver the desired capacity and switching functionality, whereas electronics are used for routing and forwarding. This decoupling between routing/forwarding and throughput allows the OPS layer to provide a range of networking protocols, without compromising the powerful transmission capabilities of WDM.

A. Research issues in OPS

There are three principal domains in which approaches to OPS differ. A first, rather fundamental issue, is the packet format. Different techniques to attach the header to a packet have been proposed: transmission on a separate wavelength, sub-carrier multiplexing (SCM) (e.g. as in CORD [1], OPERA [2]), serial transmission of header and payload on the same wavelength (e.g. WASPNET [3], KEOPS [4]). As this header is decoupled from the payload, its bitrate can be substantially lower than that of the payload – thus allowing to use electrical processing, as explained before.

In addition, a choice has to be made whether fixed-length optical packets (necessitating fragmentation and reassembly capabilities at the interfaces to client layers), or variable length optical packets will be used. The latter usually amounts to Optical Burst Switching (OBS, see below). For fixed length

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OPS, the choice remains to operate the network synchronously, using a time-slotted approach, or running asynchronously [5]. Unslotted operation simplifies the implementation, but link throughput is lower because of a higher probability of contention.

This brings up the second important issue that OPS has to address: contention resolution. As the optical equivalent of RAM is unfeasible, alternative approaches have been devised based on Fiber Delay Lines (FDLs). Critical design parameters are number and size of the buffers and the configuration in which the FDLs are used (e.g. output, shared, recirculating). Different buffer strategies have been proposed [8]: (i) imitating electronics (as in KEOPS [4], ATMOS [7], SLOB [8]); (ii) use deflection routing to avoid buffering or reduce it to an absolute minimum (e.g. references in [6]); or (iii) exploit the wavelength dimension as a shared resource to reduce the amount of buffering, i.e. by sharing capacity over multiple wavelengths [3].

From an architectural viewpoint, buffers can also be classified as being single or multi-stage, forward or feedback. Since all-optical buffers today are technologically hard to realize, there seems to be a consensus that they should be avoided as much as possible or at least be limited to a minimum.

The third domain in which research on OPS is performed is in technology. Recurring themes concern synchronization, regeneration, lambda conversion and the optical switching fabric. For the latter, there are basically two options: a first is to employ a wavelength routing switch, where the desired output is reached by using the appropriate wavelength; an approach deployed in WASPNET and OPERA, but was also of studied in KEOPS; the alternative is to use a space switch such as the broadcast and select architecture that was chosen in KEOPS. The main difficulty is that these switching fabrics have to be able to switch very fast (on a packet-per-packet basis).

IV. Optical Burst Switching

As discussed in the previous section, OPS has some drawbacks: stringent synchronization, optical memory, very high speed header processing, etc. We will now discuss an alternative to OPS, Optical Burst Switching (OBS) [9]. OBS tries to take the best of the worlds of Circuit Switching and Packet Switching.

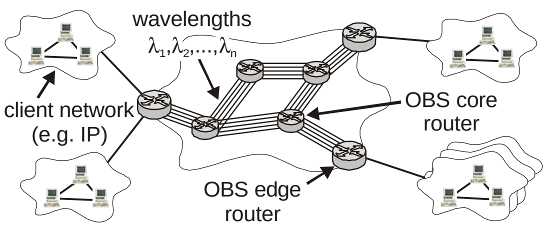

Figure 2: An OBS network

An OBS network consists of edge routers (ER) and Core Routers (CR) (see Figure 2). In the ER traffic sharing some common attributes (e.g. destination) is aggregated during a certain amount of time. This aggregated data is then used to form a burst. A time T_o before the data is sent out, the offset time, a header is sent out on a separate control channel. On the arrival of the header in a CR, this header is opto-electronically converted and processed. The info in the header allows the CR to be configured correctly the moment the payload arrives, making the use of delay lines unnecessary. Notice that there is no opto-electronic conversion needed for the payload, so it stays in the optical domain from ingoing ER to outgoing ER.

A. *Evaluation*

As already said no delay lines are needed for header processing. However there is still a possible contention problem (two bursts going to the same output). One way to solve this problem is the use of buffers. But this again leads to the use of bulky FDLs.

Another approach is the use of scheduling mechanisms, to prevent or avoid contention. Using this technique the ERs are no longer completely free to send their data any time, but they are controlled by a scheduling algorithm. The use of such a scheduling technique is one of the issues now studied within the IBCN group.

OBS is inherently an asynchronous technique, so synchronization is no issue here.

B. *QoS in OBS*

For current and new network technologies QoS (Quality of Service) is extremely important. The days when all traffic was treated in the same way are over. Nowadays we want different kinds of traffic to be handled differently, according to the importance (and price paid). OBS is very well suited to adapt to QoS [10]. By increasing the offset time T_0, we get higher priority. This is very similar to making reservations in a restaurant: the earlier you make a reservation, the higher your chance on success will be.

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