Analysis of Switching Techniques in Optical Network

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Abstract: **-In this paper, we give an introduction to optical burst switching (OBS) and compare it with other existing opticalswitching paradigms. We analyze and then compare performance models of a fast-adapting and centrally controlled form of optical circuit switching (OCS) with a conservative form of optical burst switching (OBS). We compare Optical Burst Switching with Optical Circuit Switching and Optical Packet Switching techniques.**

Keywords:-All-optical switching; optical packet switching; optical circuit switching; optical burst switching.

I. INTRODUCTION

With recent advances in wavelength division multiplexing (WDM) technology, the amount of raw bandwidth availablein fiber links has increased by many orders of magnitude. Meanwhile, the rapid growth of Internet traffic requires hightransmission rates beyond a conventional electronic router's capability. Harnessing the huge bandwidth in optical fibercost-effectively is essential for the development of the next generation optical Internet. Fig. 1 represents one view of how optical switching technologies may evolve to play an increasingly important role in future WDM optical networks. In Stage 1 of the evolution scenario in Fig. 1, switching at the IP packet level is carried out in electronic routers. This is where we stand today, with the core IP network gradually evolving from a point-to-point (Pt-Pt) WDM network, using WDM inks between intermediate routers, to optical circuit switched (OCS) networks, in which optical circuit switching provides additional functionality.

Stage 2 is a progression from OCS to optical burst switching (OBS). In OBS, bursts of data are switched optically rather than electronically. Unlike OPS, OBS does not require any buffers and is therefore arguably a

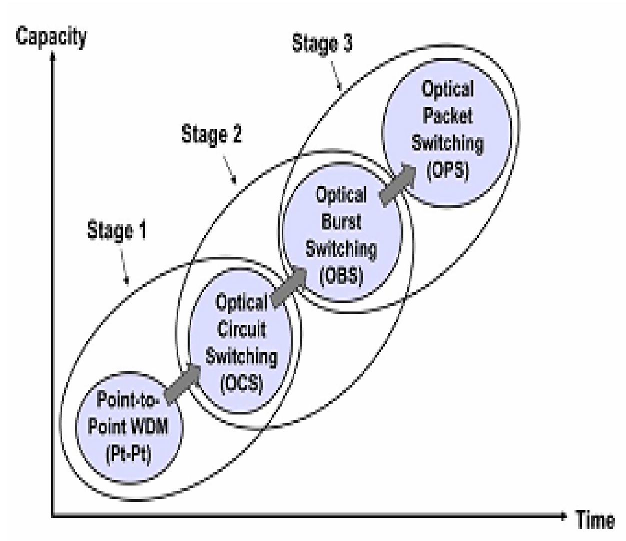

Figure1.Evaluation of Optical Switching Technologies

logical point of progression beyond OCS networks. Stage 3 of network evolution involves progression from OBS to optical packet switching (OPS), in which optical packets are switched and buffered in optical form before being forwarded into the next hop on the network.

Hence, number of approaches has been proposed to take advantage of optical communications and in particular optical switching.One such approach optical circuit switching is based on wavelength routing whereby a lightpath needs to beestablished using a dedicated wavelength on each link from source to destination. Once the connection is set up, dataremains in the optical domain throughout the lightpath. An alternative to optical circuit switching is optical packetswitching. In optical packet switching, while the packet header is being processed either all-optically or electronicallyafter an Optical/Electronic (O/E) conversion at each intermediate node, the data payload must wait in the fiber delaylines and be forwarded later to the next node [1, 2].

In order to provide optical switching for next generation Internet traffic in a flexible yet feasible way, a new switchingparadigm called optical burst switching (OBS) was proposed in [3–5]. There are twocommon characteristics among these variants:

- Client data (e.g., IP packets) goes through burst assembly/disassembly (only) at the edge of an OBS network;nevertheless, statistical multiplexing at the burst level can still be achieved in the core of the OBS network.
- Data and control signals are transmitted separately on different channels or wavelengths, thus, costly O/E/Oconversions are only required on a few control channels instead of a large number of data channels.

In this paper, we first introduce the basic idea of OBS, compare it with other switching paradigms and point outwhy OBS is a viable technology for the next generation optical Internet.

II. OPTICAL CIRCUIT SWITCHING

Optical circuit switching (OCS) is based on wavelength routing whereby a lightpath needs to be established using a dedicated wavelength on each link from source to destination. Once the connection is set up, data remains in the optical domain throughout the light path. OCS is relatively easy to implement but lacks the flexibility to cope with the fluctuating traffic and the changing link status. In this networking method, a connection called a circuit is set up between two devices, which are used for the whole communication. Information about the nature of the circuit is maintained by the network. The circuit may either be a fixed one that is always present, or it may be a circuit that is created on an as-needed basis. Even if many potential paths through intermediate devices may exist between the two devices communicating, only one will be used for any given dialog. In a circuit-switched network, before communication can occur between two devices, a circuit is established between them. This is shown as a thick blue line for the conduit of data from Device *A* to Device *B*, and a matching purple line from *B* back to *A*.

Once set up, all communication between these devices takes place over this circuit, even though there are other possible ways that data could conceivably be passed over the network of devices between them.Both OCS and OBS serve as umbrella terms for a broad variety of specific approaches to all-optical switching.As such, most all-optical switching techniques fall under the classification of either OCS or OBS, though there is a grey area

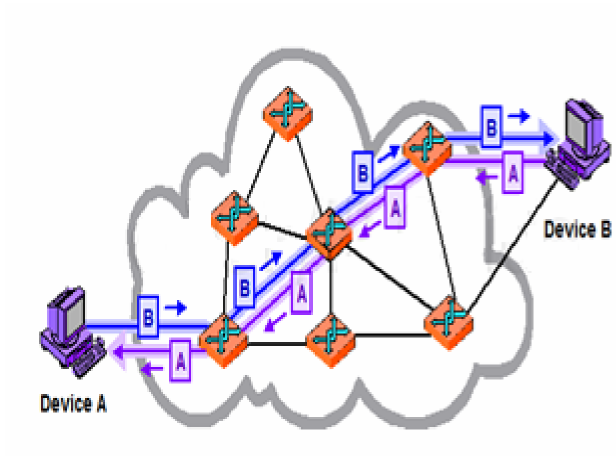

Figure 2. Circuit Switching Technique

encompassing switching techniques that exhibit defining characteristics of both OCS and OBS.In general, a switching technique in which no blocking is possible at a switch falls under the classification of OCS.

III. OPTICAL PACKET SWITCHING

In optical packet switching, while the packet header is being processed either all-optically or electronically after an Optical/Electronic (O/E) conversion at each intermediate node, the data payload must wait in the fiber delay lines and be forwarded later to the next node.

Optical packet switching (OPS) is conceptually ideal, but the required optical technologies such as optical buffer and optical logic are too immature for it to happen anytime soon.An OPS is the simplest and most natural extension of packet switching over optics. It consists of sending IP packets directly over an all-optical backbone. OPS is conceptually ideal, but the required optical technologies such as optical buffer and optical logic are too immature for it to happen anytime soon [6]. The biggest challenge that packets face in an optical switch is the lack of large buffers for times of contention. In contrast, existing optical buffering techniques based on fiber delay lines can accommodate at most a few tens of packets. With such small buffers, the packet drop rate of an optical packet switch is quite high even for moderate loads. An OPS tries to overcome the lack of buffers by combining two other techniques to solve contention: wavelength conversion and deflection routing. If two packets arrive simultaneously, and there are no local buffers left, the optical packet switch first tries to find another free wavelength in the same fiber, and if it cannot find it, it will try another fiber that does not have contention.

OPS have some shortcomings: less number of techniques available to solve the contention. In addition, packets no longer follow the same path, and so they may arrive out of order, which may be interpreted by TCP as losses due to congestion, and TCP may thus throttle back its rate. A problem that is perceived with OPS is that IP packet sizes are very short for some optical cross connects to be rescheduled. For this reason, several researchers have proposed using bigger switching units, called *bursts*, in an architecture called Optical Burst Switching.

IV. OPTICAL BURST SWITCHING

Optical Burst Switching (OBS) is a hybrid between packet switching and circuit switching. In an OBS network, various types of client data are aggregated at the ingress (an edge node) and transmitted as data bursts which later will be disassembled at the egress node. During burst assembly/disassembly, the client data is buffered at the edge where electronic RAM is cheap and abundant. The burst is sent through the all-optical core. In general, the burst is preceded by an out-of-band signaling message that creates a lightweight circuit with an explicit or implicit teardown time, through which the burst is sent.

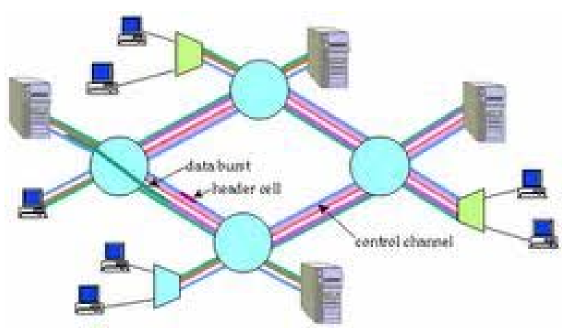

Figure 3. Basic Concept of Optical Burst Switching

Fig.3 explains the basic concept of optical burst switching. In OBS, a control packet is sent first to set up a connection (by reserving an appropriate amount of bandwidth and configuring the switches along a path), followed by a burst of data without waiting for an acknowledgement for the connection establishment.In other words, OBS uses one- way reservation protocols similar to tell-and-go (TAG) [7,8], also known in ATM as fast reservation protocol (FRP) or ATM Block Transfer with Immediate Transmissions (or ABT-IT) [9]. This distinguishes OBS from circuit-switching as well as from other burst-switching approaches using protocols such as Reservation/scheduling with Just-In-Time switching (RIT) [10] and tell-and-wait (TAW), also known in ATM as ABT-DT (Delayed Transmissions) [11], all of which are two-way reservation protocols.

OBS also differs from optical or photonic packet/cell switching mainly in that the former can switch a burst whose length can range from one to several packets to a (short) session using one control packet, thus resulting in a lower control overhead per data unit. In addition, OBS uses out-of-band signaling, but more importantly, the control packet and the data burst are more loosely coupled (in time) than in packet/cell switching. In fact, they may be separated at the source as well as subsequent intermediate nodes by an offset time as in the Just-Enough-Time (JET) protocol.By choosing the offset time at the source to be larger than the total processing time of the control packet along the path, one can eliminate the need for a data burst to be buffered at any subsequent intermediate node just to wait for the control packet to get processed. Alternatively, an OBS protocol may choose not to use any offset time at the source, but instead, require that the data burst go through, at each intermediate node, a fixed delay that is no shorter than the maximal time needed to process a control packet at the intermediate node. Such OBS protocols will be collectively referred to as TAG-based since their basic concepts are the same as that of TAG itself.

TABLE I. FUNCTION OF NODES IN OBS

Ingress Edge Node	**Core Node**	**Egress Edge Node**
Burst Assembly	Signaling	Burst Disassembly
Wavelength	Scheduling	Packet Forwarding
Edge Scheduling	Contention Resolution	Packet Forwarding

One way to support Internet Protocol(IP) over Wavelength Division Multiplexing(WDM) using OBS is to run IP software, along with other control software as a part of the interface between the network layer and the WDM layer, on top of every optical (WDM) switch. In the WDM layer, a dedicated control wavelength is used to provide the static or physical links between these IP entities. Specially, it is used to support packet switching between (physically) adjacent IP entities which maintain topology and routing tables. To send data, a control packet is routed from a source to its destination based on the IP addresses it carries to set up a connection by configuring all optical switches along the path. Then, a burst (e.g. one or more data IP packets or an entire message) is delivered without going through intermediate IP entities, thus reducing its latency as well as the processing load at the IP layer. Note that, due to the opaquenessof the control packet, OBS can achieve a high degree of adaptivity to congestions or faults (e.g. by using deflection-routing), and support priority-based routing as in optical cell/packet switching.

In OBS, the wavelength on a link used by the burst will be released as soon as the burst passes through the link, either automatically according to the reservation made (as in JET) or by an explicit release packet. In this way, bursts from different sources to different destinations can effectively utilize the bandwidth of the same wavelength on a link in a time-shared, statistical multiplexed fashion. Note that, in case the control packet fails to reserve the bandwidth at an intermediate node, the burst (which is considered blocked at this time) may have to be dropped.

In JET, a control packet reserves anoutput wavelength channel for a period of time equal to the burstlength, starting at the expected burst arrival time, which canbe determined based on the offset time value and the amountof processing time the control packet has encountered at thenode up to this point in time. If the reservation is successful,the control packet adjusts the offset time for the next hop and isforwarded to the next hop; otherwise, the burst is blocked andwill be discarded if there is no fiber delay line (FDL). In the lastseveral years, several other contention resolution techniques, includingdeflection routing and burst segmentation, were studied to reduce data loss in OBS networks.

Given the fact that OBS uses one-way reservation protocolssuch as JET and that a burst cannot be buffered at any intermediatenode due to the lack of optical RAM (an FDL, if availableat all, can only provide a limited delay and contention resolutioncapability), burst loss could be a serious problem for OBSnetworks, especially when the system is adversely synchronizedand bursts repeatedly arrive in worst case or near worst case patterns. Since most of the commercial systems require an acceptableworst case performance, it is important to understandthe worst case performance and also design scheduling systemswith optimized worst case performance.

Since OBS takes advantage of both the huge capacity in fibers for switching/transmission andthe sophisticated processing capability of electronics, it is able to achieve cost reduction and leverage the technologicaladvances in both optical and electronic worlds, which makes it a viable technology for the next generation opticalinternet. Optical burst switching is anatural paradigm for bursty traffic which is common found inon-chip self-similar flows. Memory access overhead is amortizedby big burst length. It has outstanding advantages over electronic I/Osignaling in terms of throughput, latency and energyconsumption.

V. ANALYSIS OF THREE OF TECHNIQUES

A switching technique in which blocking *is* possible at a switch falls under the classification of OBS, though OPS is an exception since it is a classification in its own right. OBS is an optical analogue of switching techniques developed forone-way reservation in asynchronous transfer mode (ATM) communications, including tell-and-go and fast reservation protocol with immediate transmission. OBS and fast adapting forms of OCS are closely allied and differ mainly in that OBS is founded on one-way reservation, while OCS on two-way reservation. Through this key difference, OBS tradesoff an assurance of no blocking at each switch for a reduction in signaling delay. Comparative studies in of tell-and-wait and tell-and-go, ATM analogues of fast adapting OCS and OBS, respectively, concluded that trading off an assurance of no blocking at each switch for a reduction in signaling delay is favorable in long-haul communications. Sacrificing an assurance of no blocking at each switch is however more dire in optical communications since blocking is greater at an optical switch than a commensurately dimensioned electronic switch due to wavelength continuity constraints. In particular, a lightpath is constrained to a common wavelength in each fiber it traverses, whereas channels in electronic communicationsare indistinguishable, thus allowing greater multiplexing of channel capacity and hence lower blocking. As such, it appears trading off an assurance of no blocking at each switch is lessfavorable in OBS than in tell-and-go.

TABLE II. COMPARISION AMONG OCS, OPS & OBS

Switching Techniques	**OCS**	**OPS**	**OBS**
Bandwidth	Low	High	High
Latency	High	Low	Low
Buffering	No	Yes	Yes
Overhead	Low	High	Low
Adaptivity (traffic & fault)	Low	High-can take any path	High
Suitable for data size	>GB	~100-1500B	~tens of kB
Transfer Guarantee	Possible	No	No
Mis-ordering	No	Possible	No

If during the circuit establishment there is no bandwidth left for the burst, the node can either temporarily buffer the burst using the limited space of local fiber delay lines or it can try to deflect the burst circuit to another wavelength or another fiber. If none of these three options is available the incoming burst is then dropped at that node. From the point of view of the user flows, the behavior of OBS is closer to OPS than to traditional circuit switching techniques. If there is contention, information from at least one active flow is dropped at the intermediate nodes in OPS; with traditional circuit switching, new flows are blocked (buffered) at the ingress, but old, active flows are unaffected. In traditional circuit switching, once a flow has been accepted, it is guaranteed a data rate and no contention. For this reason, the end user does not perceive OBS as a circuit switched network, but rather as a packet-switched one that switches large packets.

Optical Circuit Switching:

*Advantages:*Natural QoS, reliability components and subsystems commercially available.

Disadvantages: Low flexibility and network utilization, Very high wavelength consumption, and large node size.

*Foreseen for the future:*Short term deployment.

Optical Packet Switching:

Advantages: Very high flexibility, Very efficient network utilization, reduced node size.

Disadvantages: Only preliminary components and subsystems available, high control complexity, Require more effort for packet recording.

Foreseen for the future: Waiting for technological breakthrough, especially for compact, low-cost optical components.

Optical Burst Switching:

Advantages: High flexibility, efficient network utilization.

Disadvantages: Control complexity, effort for traffic aggregation and resilience more complex.

Foreseen for the future: It is a viable solution for efficient optical networks. It is a mid-term deployment.

VI. IMPORTANCE OF OBS

Existing switching paradigms in optical networks are not suitable for bursty traffic transmission. Optical Burst Switchingallows the creation of high-speed all optical networks withpresent technology, compared to Optical Packet Switching that still suffers serious technological limitations andOptical Circuit Switching that has poor bandwidthutilization for bursty traffic.Switching techniques falling under the classification of OCS encompass a huge amount of switching timescales. At one extreme, techniques including wavelength-routed OBS, optical analogues of tell-and-wait, adaptive optical time-division multiplexing (OTDM) and fast circuit switching adapt on a millisecond timescale, either distributive or centrally, whereas at the other extreme, permanent and semi-permanent wavelength-routingremains static for possibly years. Fast adapting forms of OCS are criticized for signaling delays incurred in establishing a lightpath *in addition to* acknowledging its establishment through a signaling process referred to as two-way reservation. In particular, an edge router foremost signals its intention to establish a lightpath to each switch that lightpath traverses, or possibly to a central controller, after which it awaits a return signal acknowledginga lightpath has been established. At the other extreme, wavelength routing is criticized for its inability to rapidly time multiplex wavelength capacity among different edge routers,which may result in poor capacity utilization.

VII. CONCLUSION

OBS is a viable technology for the next generation optical Internet. In optical burst switching networks, a keyproblem is to schedule as many bursts as possible on wavelengthchannels so that the throughput is maximized and the burst lossis minimized. Existing switching paradigms in optical networks are not suitable for bursty traffic transmission. Optical Burst Switchingallows the creation of high-speed all optical networks with present technology, compared to Optical Packet Switching that still suffers serious technological limitations and Optical Circuit Switching that has poor bandwidth utilization for bursty traffic.

VIII. REFERENCES

[1]. D. J. Blumenthal, P. R. Prucnal, and J. R. Sauer, "Photonic packet switches: architectures and experimentalimplementations," *Proceedings of the IEEE*, vol. 82, pp. 1650–1667, November 1994.

[2]. G.-K. Chang, G. Ellinas, B. Meagher, W. Xin, S.J. Yoo, M.Z. Iqbal, W. Way, J. Young, H. Dai, Y.J. Chen, C.D.Lee, X. Yang, A. Chowdhury, and S. Chen, "Low Latency Packet Forwarding in IP over WDM Networks usingOptical Label Switching Techniques," in *IEEE LEOS 1999 Annual Meeting*, 1999, pp. 17–18.

[3]. M. Yoo and C. Qiao, "Just-enough-time (JET): A high speed protocol for bursty traffic in optical networks," in *Proceeding of IEEE/LEOS Conf. on Technologies for a Global Information Infrastructure*, August 1997, pp. 26–27.

[4]. C. Qiao and M. Yoo, "Optical burst switching (OBS)–a new paradigm for an optical Internet," *Journal of High Speed Networks*, vol. 8, no. 1, pp. 69–84, 1999.

[5]. J. Turner, "Terabit burst switching," *Journal of High Speed Networks*, vol. 8, no. 1, pp. 3–16, 1999.

[6]. J. Li, C. Qiao, J. Xu, and D. Xu, "Maximizing Throughput for Optical Burst Switching Networks",IEEE/ACM Transactions on networking, Vol. 15, No. 5, October 2007.

[7]. E. Varvarigos and V. Sharma, "The ready-to-go virtual circuit protocol: A loss-free protocol for multigigabit networks using FIFO buffers",

IEEE/ACM Transactions on Networking, Vol.5, No.5 pp.705-718, October 1997.

[8]. I. Widjaja, "Performance analysis of burst admission-control protocols", IEEE proceedings-communications,ISSN:1350-2425,Vol.142 No.1, pp.7-14, 1995.

[9]. H. Shimonishi, T. Takine, M. Murata, and H. Miyahara, "Performance analysis of fast reservation protocol with generalized bandwidth reservation method", In Proceedings of IEEE Infocom, Vol. 2, pp. 758-767, 1996.

[10]. G.C. Hudek and D.J. Muder, "Signaling analysis for a multi-switch all-optical network", In Proceedings of International Conference on Communication (ICC),0-7803-2486-2/95 IEEE, Vol.2, pp. 1206-1210, June 1995.

[11]. J. S. Turner, "Managing bandwidth in ATM networks with bursty traffic", IEEE Network, 0890-8044/92, pp. 50-58, September 1992.

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