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Optical Burst Switching Network: An Overview

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Abstract *--- Optical Bursts Switching (OBS) is a relatively new optical switching paradigm. In this paper, I give an introduction to optical burst switching (OBS) and compare it with other existing optical switching paradigms like circuit and packet switching. Contention and burst loss in OBS networks are major concerns. In this paper I have also discussed about OBS network architecture and enabling technologies of OBS. To resolve contentions, an interesting alternative to discarding the entire data burst is to partially drop the burst. Partial burst dropping is based on burst segmentation concept that its implementation is constrained by some technical challenges, besides the complexity added to the algorithms and protocols on both edge and core nodes. In this paper, the burst segmentation concept is investigated, and an implementation scheme CPQ is proposed and evaluated.*

Keywords *--- Optical Circuit Switching, Optical Packet Switching, Optical Burst Switching, OBS Network, Burst Segmentation*

I. INTRODUCTION

Over the last decade, the field of networking has experienced growth at a tremendous rate. The rapid expansion of the Internet and the ever increasing demand for multimedia information are severely testing the limits of our current computer and telecommunication networks. In order to meet these growing needs, optical wavelength-division multiplexing (WDM) communication systems have been deployed in many telecommunications backbone networks. In *WDM* systems, each fiber carries multiple communication channels, with each channel operating on a different wavelength. Such optical transmission systems have the potential to provide over 50 Tb/s on a single fiber.

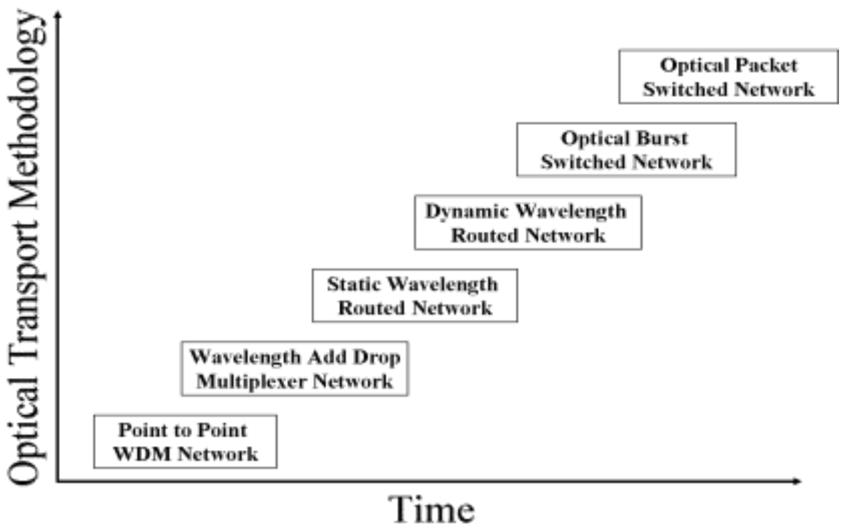

Figure.1. Evolution of optical transport methodologies

Figure 1 shows the evolution of the different optical transport methodologies. The **first generation** optical network architectures consist of point-to-point WDM links. Such networks are comprised of several point to point links at which all traffic arriving to a node is dropped, converted from optics to electronics, processed electronically, and converted from electronics to optics before departing from the node.

The **second-generation** optical network architectures are based on wavelength add-drop multiplexers (WADM), where traffic can be added and dropped at WADM locations. WADMs can allow selected wavelength channels on a fiber to be terminated, while other wavelengths pass through untouched. In general, the amount of bypass traffic in the network is significantly higher than the amount of traffic that needs to be dropped at a specific node; hence, by using WADMs, we can reduce the overall network cost. WADMs are primarily used to build optical WDM ring networks, which are expected to deploy in metropolitan area markets (MAN).

In order to build a mesh network consisting of multi-wavelength fiber links, appropriate fiber interconnection devices are needed. The **third-generation** optical network architectures are based on all-optical interconnection devices. These devices fall under three broad categories, namely passive star couplers, passive routers, and active switches. The passive star is a broadcast device. A signal arriving on a given wavelength on input fiber port of the star coupler will have its power equally divided among all output ports of the star coupler. A passive router can separately route each of several wavelengths arriving on an input fiber to the same wavelength on different output fibers.

A. Optical Circuit Switching:

Wavelength-routed optical networks employ optical circuit switching in which all-optical wavelength paths (light paths) are established between pairs of nodes. The establishment of light paths involves several tasks. These tasks include topology and resource discovery, routing, wavelength assignment, and signaling and resource reservation. Topology and resource discovery involves the distribution and maintenance of network state information. Typically this information will include information on the physical network topology and the status of links in the network.

In a wavelength-routed WDM network, this information may include the availability of wavelengths on a given link in the network. A common protocol for maintaining link state information in the Internet is the Open Shortest Path First (OSPF) protocol. The problem of finding routes and assigning wavelengths for light paths is referred to as the routing and wavelength assignment (RWA) problem. Typically, connection requests may be of two types, static and dynamic. In the Static Light path Establishment (SLE) problem, the entire set of connections is known in advance, and the problem is to set up light paths for these connections while minimizing network resources such as the number of wavelengths or the number of fibers in the network. For the Dynamic Light path Establishment (DLE) problem, a light path is set up for each connection request as it arrives, and the light path is released after some finite amount of time.

B. Optical Packet Switching:

As optical switching technology improves, we may eventually see the emergence of photonic packet-switched networks in which packets are switched and routed independently through the network entirely in the optical domain without conversion back to electronics at each node. Such photonic packet-switched networks allow for a greater degree of statistical multiplexing on optical fiber links and are better suited for handling bursty traffic than optical circuit-switched networks. An example of a basic photonic packet-switch architecture is shown in Figure 2.

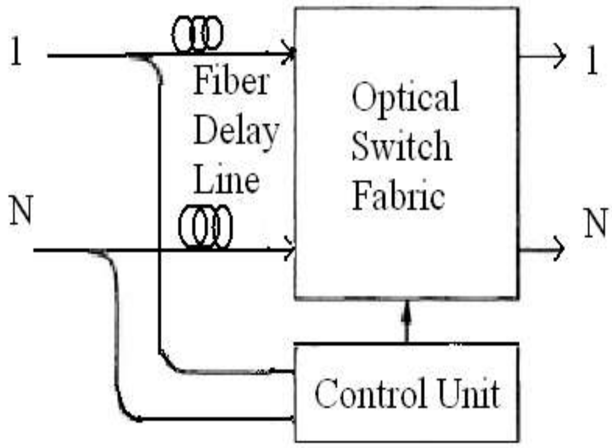

Figure.2. Photonic packet-switch architecture

A node contains an optical switch fabric which is capable of reconfiguration on a packet-by-packet basis. The switch fabric is reconfigured based on information contained within the header of a packet. The header itself is typically processed electronically, and can either be carried in-band with the packet, carried on a subcarrier frequency, or carried out-of-band on a separate control channel. Since it takes some time for the header to be processed and for the switch to be reconfigured, the packet may be delayed by sending it through an optical delay line.

In order for photonic packet switching to be practical, fast switching times are required. Currently, switching times for MEM-based switches are on the order of 1 to 10 ms, while semiconductor optical amplifier based switches have switching times which are less than 1 ns. The disadvantage of semiconductor optical amplifier switches is that they tend to be more expensive, and the switch architectures require signals to pass through optical couplers which results in additional power losses. While switching speeds are expected to improve in the near future, current technology is not yet mature enough to support photonic packet switching. Another challenge in photonic packet switching is *synchronization*. In photonic packet-switched networks with fixed-length packets, synchronization of packets at switch input ports is often desired in order to minimize contention. Although synchronization is typically difficult to achieve, a few synchronization techniques have been proposed and implemented in laboratory settings. Since network resources are not reserved in advance in photonic packet switching, packets may experience contention in the network.

C. Optical Burst Switching:

Optical burst switching is designed to achieve a balance between optical circuit switching and optical packet switching. In an optical burst-switched network, a data burst consisting of multiple IP packets is switched through the network all-optically. A control packet is transmitted ahead of the burst in order to configure the switches along the burst's route.

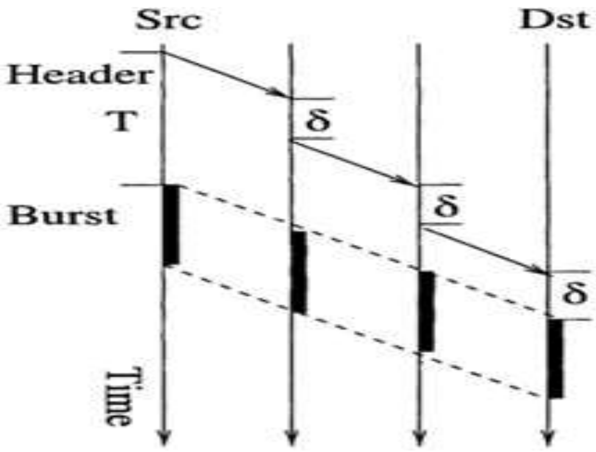

Figure.3. Offset time in OBS

The offset time (Figure 3) allows for the control packet to be processed and the switch to be set up before the burst arrives at the intermediate node; thus, no electronic or optical buffering is necessary at the intermediate nodes while the control packet is being processed. The control packet may also specify the duration of the burst in order to let the node know when it may reconfigure its switch for the next arriving burst. By reserving resources only for a specified period of time rather than reserving resources for an indefinite period of time, the resources can be allocated in a more efficient manner and a higher degree of statistical multiplexing can be achieved. Thus, optical burst switching is able to overcome some of the limitations of static bandwidth allocation incurred by optical circuit switching.

Table 1 Comparison of the different all-optical network technologies

Optical Switching Paradigm	Bandwidth Utilization	Setup Latency	Switching Speed	Overhead	Traffic Adaptively
Optical Circuit Switching	Low	High	Slow	Low	Low
Optical Packet Switching	High	Low	Fast	High	High
Optical Burst Switching	High	Low	Medium	Low	High

Table 1 summarizes the three different all-optical transport paradigms. It is clearly observed that the optical burst switching has the advantages of both optical circuit switching (and wavelength routed networks) and optical packet switching, while potentially avoiding their shortcomings. Although optical burst switching appears to offer some of the advantages over optical circuit switching and optical packet switching, several issues need to be considered before optical burst switching can be deployed in working networks.

In particular, these issues include burst assembly, signaling schemes, contention resolution, burst scheduling, and quality of service. A burst assembly scheme is required to determine how packets are assembled into bursts. Issues include when to assemble a burst, how many packets to include in a burst, and what types of packets to include in a burst. The burst assembly scheme will affect the burst length as well as the amount of time that a packet must wait before being transmitted. Assembly schemes based on timer and threshold mechanisms have been proposed in the literature.

A signaling scheme is required for reserving resources and configuring switches for an arriving burst. Common signaling schemes for reserving resources in OBS networks are tell-and-go (TAG), tell-and-wait (TAW), and just-enough-time (JET). In the TAG scheme, the source nodes send out a control message to notify downstream nodes of a burst's arrival. The source node then immediately follows the control message with the data burst, without waiting for an acknowledgement. In order to allow time for the processing of the control message and the configuring of the switch at each node, the burst may need to be buffered at each node.

In the TAW scheme, the source sends a control message to reserve resources for the burst along the path. The source then waits for an acknowledgement confirming that the reservations have been successful.

In the TAG and JET schemes, the source does not wait for an acknowledgement before sending a burst. Thus, it is possible that the reservations will not be successful at some node in the path. In this case, a burst that is in transit will experience contention. Contention occurs when more than one burst contends for the same resource at the same time. Contention may be resolved in a number of ways. One approach is to store one of the bursts until the appropriate resources become available. Another approach is to deflect one of the bursts to a different output port. A third approach is to convert one of the bursts to a different wavelength on the output fiber. When wavelength conversion is used, one problem is to determine the appropriate wavelength for a burst on an output link. This problem is referred to as channel scheduling. Several channel scheduling schemes that attempt to maximize channel utilization has been developed by researchers. These schemes are discussed later. A significant issue in networks is providing quality of service (QoS) for applications with varying requirements.

II. OBS NETWORK

An OBS network consists of core nodes and end-devices interconnected by WDM fibers as shown in Figure 4. An OBS core node consists of an optical cross connect (OXC), an electronic switch control unit, and routing and signaling processors [6]. An OXC is a non-blocking switch that can switch an optical signal from an input port to an output port without converting the signal to electronics. The OBS end-devices are equipped with an OBS interface and could be electronic IP routers, ATM switches, and frame relay switches, etc. Each OBS end-device is connected to an ingress OBS core node.

The end-device collects traffic from various electronic networks (such as ATM, IP, frame relay, etc.). It sorts the traffic per destination OBS end-device address and assembles it into larger variable-size units, called bursts. For each burst, the end-device also constructs a control packet, which contains information about the burst, such as the burst length, burst destination address, etc. The OBS edge router shown in Figure 5.

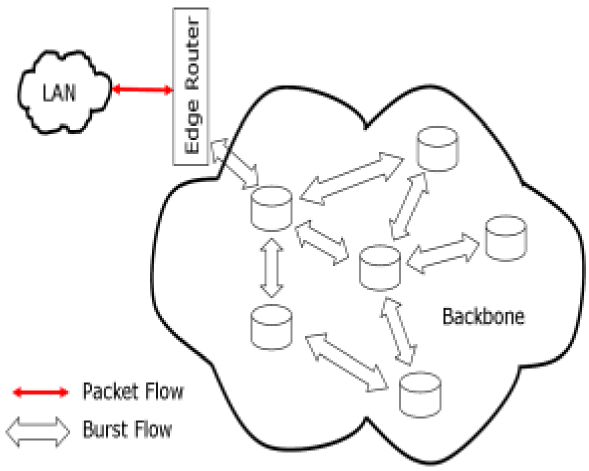

Figure.4. OBS Network

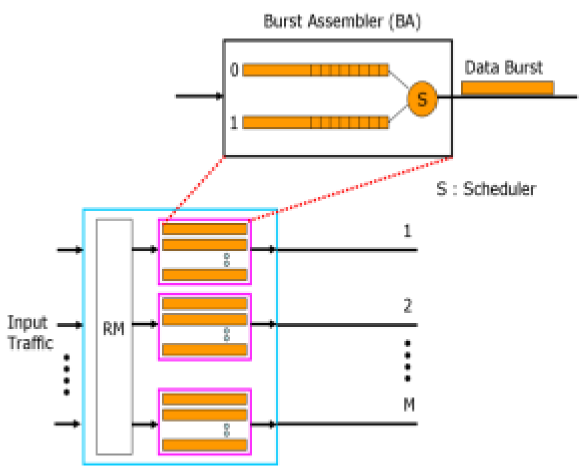

Figure.5. OBS Edge Router

This control packet is immediately sent along the route of the burst and it is electronically processed at each node. The function of the control packet is to inform the nodes of the impending data burst and to set up an end-to end optical path between the source and the destination. After a delay time, known as the offset, the end-device transmits the burst itself. The burst travels as an optical signal over the end-to-end optical path set up by its control packet. This optical path is torn down after the burst transmission is completed.

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III. BURST SEGMENTATION

Burst Segmentation was proposed by Vokkarane et al. to reduce packet loss in optical burst switched networks. Burst segmentation is designed upon OBS-JET architecture and it assumes fixed upper-layer packet size. This approach is comparable to OCBS in that it uses burst segmentation concept. In this technique the data burst is broken into multiple segments that may contain a single packet or multiple packets. Combined with deflection routing, the authors showed that their approach performed better than the "entire- burst-dropping" policy.

Two ways were proposed to implement this scheme: Segment-first: The remaining length of the original burst (i.e. the segments of the burst yet to be transmitted when the contending burst arrive) is compared to the contending burst. The contending burst is deflected in case it is the shorter one otherwise the original burst is segmented and its tail is deflected or dropped if the alternate port is busy. Deflection-first: The contending burst is deflected if the alternate port is free. If the alternate port is busy then a similar process to segment-first takes place and the lengths of both original and contending bursts are compared and the tail of the shorter one is dropped, as the alternate port is busy.

Accordingly, the following aspects are identified to be considered for an efficient and viable implementation.

Switching time (ST): ST is the time needed to reconfigure the switching fabric. ST depends on the design and implementation of the core node, and it may differ from a core node to another.

Data burst size: since the transmission of DBs depends on the transmission of their BCPs. The DB length should agree with minimum and maximum length requirements, to avoid congestion in the control channels. The same is true for the truncated burst (i.e. DB that lost some of its packets).

Segment Delineation: since the data burst are transmitted all-optically the segments' boundaries are transparent to the core nodes, and their sizes are not reflected in the BCP.

Fiber Delay Lines (FDLs): as in Optical Composite Burst Switching (OCBS), FDLs are needed to delay the data bursts while their control packets are being electronically updated with the new burst size, which increases the electronic processing time needed before forwarding the control packet to the next node.

Trail-control messages: generated by the node where the DB is being truncated. The trailing control message is needed to indicate the burst's new size to the downstream nodes, to avoid unnecessarily resource reservation or needlessly contention resolution actions.

Burst Segmentation implementation scheme: To effectively implement a burst segmentation strategy, it is noted that dividing each data burst into data segments (DSs) will not be sufficient, and representing each DS's control information in the BCP is not feasible (which is traditionally done).

Burst Control Packet Format: The proposed BCP's format provides constant transmission overhead and makes the BCP scalable to higher speeds, as it uses the Flow Control and Reservation Bits (FCRB) as the segments' length indicator instead of flags [2]. A brief description of the BCP in Figure 6 is provided here:

FCRB field: FCRB is created by the ingress-node to reflect the permitted segmentations. In the core-nodes, the SRS-length is multiplied by the number of 12 in FCRB to obtain the actual size of the corresponding DB. For example 01112 is an indication that the length of the DB is (3*SRS-length), and it might be segmented into three segments. The size of FCRB is dynamic that may vary from one DB to another, and the burst assembly algorithm controls it.

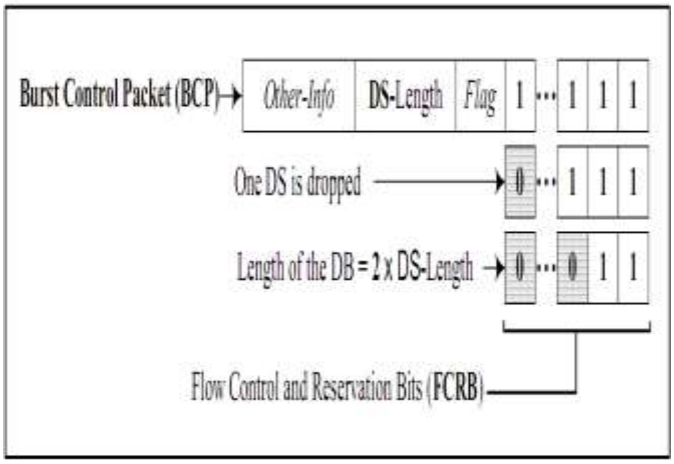

Figure.6. Control packets Format

Flag field: is a sequence of bits with a recognizable pattern that identifies the end of the FCRB field (as its size is not fixed), and the beginning of the DS-length field.

DS-length field: contains the length of one data segment. However, the DS-length combined with FCRB provides sufficient information about the DB's length and segmentation. To avoid congestion in OBS control-channel, DS-length should comply with a minimum length [2], which is the minimum permitted data burst length transmitted over the optical links.

Other-Info field: contains routing information (e.g. Burst destination Address), offset time, etc…

CPQ [control packet queuing] Scheme:

A WDM network provides huge bandwidth which could alleviate the effect of the explosive growth traffic demands. Challenges remain on how to efficiently provide QoS to applications in such a network. Methods in IP network do not apply to OBS because of the limitation of optical buffer. Control packets going through electronic of processing, buffering control packets in electric layer is possible. Following are the factors affecting the performance of the protocol. *Time window:* all control packets arriving in the time widow are buffered. *Larger*: more class 1 control packets can contest bandwidth; however, it adds the latency. *Small*: latency is small but it decreases the number of control packets in the queue. Other parameters like Queue size, offset time, etc…There are two classes of CPQ scheme. One is *Class 0* for non-real-time applications. Other is *Class 1* for real-time applications. There are also two Queues for control packets in electrical layer in OBS nodes. One is *Queue 0* for class 0, other is *Queue 1* for class 1. Following Figure 7 is the Queue based bandwidth reservation algorithm.

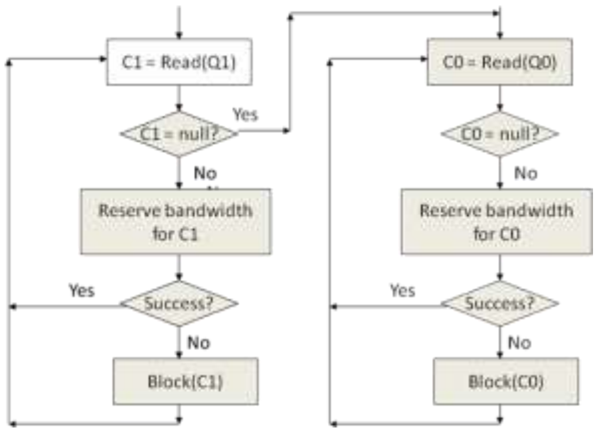

Figure.7. B.W. Reservation Algorithms

After simulation it is proved that blocking probability of Class 1 traffic in CPQ is, on average, 52.72% better than in FCFS, means Class 0 traffic is degraded in CPQ. Larger time window will benefit class 1 and penalize class 0. CPQ prefers small offset time. Based upon this in Future work different queue scheduling policies could be evaluated, like weighted queue.

IV. CONCLUSION

In this paper, an overview of the optical burst switching network and its current contention resolution techniques based on burst segmentation concept is provided. A new and effective implementation scheme is presented. With this scheme, the dropped segments are evenly distributed between the contending bursts to achieve some kind of fairness between traffic flows and to minimize the number of short data bursts.

Furthermore, the scheme enables the core nodes to monitor and manage the size (length) of the data bursts traveling within the network backbone. The scheme is simple, practical, and its implementation does not lead to any compromises on one of the main motivational reasons behind the emergence of the OBS paradigm, which is simplicity. Additionally, a new format for the burst control packet is proposed. With the new format, the length of the data burst and data segments can be shown, as well as, the number of the dropped segments and the forwarded segments using only a limited number of bits (Flow Control and Reservation Bits).

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