A Comparative Study of Optical Burst Switching Network Techniques

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***Abstract*– This paper collects the data on currently in use techniques to implement optical burst switching in optical networks. A table enlisting the main differences is also enclosed in this work. A comparison is carried out between different types of optical burst switching techniques on the basis of network parameters. These parameters can include cost of the network, capacity requirements, QoS (Quality of Service) and network's traffic load. There are different environments in which these networks are implemented. These conditions and requirements of the network consequently ask for a specific area of efficiency from the designer. This paper will prove to be helpful for the network designers to decide their choice of switching technique while designing a network by enabling them to choose the best suited approach for their desired efficiency.**

***Keywords*– Optical Switching Techniques, Optical Networks and Optical Burst Switching**

I. INTRODUCTION

Optical network is a communication network which utilizes light as the travelling signal instead of electronic signals. Use of light provides high speed enabling fast communication around the world. Optical fiber is used to carry these light signals thus sometimes these are also referred as optical fiber networks. Use of light signaling gives these networks the name of photonic networks. WDM (wave domain multiplexing) MUX/DEMUX, optical amplifiers, optical switches, splitter and optical taps are some of the main components of a photonic network.

Wave domain multiplexing is the technique used in optical networks to multiplex different wavelengths of light in the single optical fiber. These wavelengths of light are formed through laser beam on which data is encoded. The laser beam is modulated by the unique set of data signals. This signal is also called source signal.

There are two main types of wave domain multiplexing mentioned as follow:

CWDM (coarse wavelength division multiplexing)

DWDM (Dense wavelength division multiplexing)

Like in any other network, optical fiber network also requires the signals amplification to cater for the channel noise. The only difference is instead of using the regular amplifiers, optical amplifiers are used to amplify the incoming light signals. There are a lot more than one channel being transmitted on a single optical fiber through multiplexing techniques. On reaching the destination node, there will be need to single out the desired channel at the output. Switches are used for this purpose. There are different switching techniques used in these switches.

Splitter is used to split a single signal into two signals and then transmit it using two different optical fibers. These are used to protect the signal from intruders.

The second section of the paper covers the brief introduction of the switching techniques and a brief comparison between the optical packet switching and optical burst switching. Third section has four different techniques for implementing the optical burst switching that have been chosen for the study and a detail on the adaptation of these techniques and their characteristics are also discussed in the same section. In the fourth section related work in this regard has also been studied and discussed which include the researches that have been performed by other researchers. In the discussion section inference drawn from the discussed researches are presented Conclusion section includes the comparative analysis of these techniques based on our selected parameters.

Optical burst switching (OBS) is an optical networking technique which is has been negotiated between optical packet switching and optical circuit switching. This solution enables dynamic sub-wavelength switching of data which removes throughput limitations and provides more efficient bandwidth utilization in optical networks.

II. OPTICAL SWITCHING TECHNIQUES

As the networks were evolving over the time, so were the components used in these to improve the efficiency. Researchers were always looking for the solutions to increase the speed, decrease the latency and improve the bit error rate of the networks. These trials gave birth to the following three main types of optical switching techniques.

- Optical Circuit Switching
- Optical Packet Switching
- Optical Burst Switching

A) Optical Circuit Switching

As multiplexing offer us the wider bandwidth, these switching techniques were introduced to manipulate the larger capacity. In circuit switching a devoted light path is established between an entry node (sender) to the desired exit node (receiver). Once this path has been established, the data can be sent between source and destination without the optical to electrical conversion or vice versa.

The optical circuit switching inherits all the disadvantage as the other circuit switching techniques. It increases the latency rate as it requires more time to set up the dedicated path. The bandwidth utility is also low given that the resources allotted to the dedicate path will not be used for the other data communication.

B) Optical Packet Switching

In optical packet switching, each packet is getting switched depending upon the information enclosed in its header at each node. The packet header which contains the information of the packet is processed either all optically or electronically after an optical-electronic (OE) conversion. This takes place at each node where data packet is going to be directed according to its control information in the header. The data payload of the packet is kept in the fiber delay lines and then forwarded later to the next node while the header is being processed [1].

Optical packet switching is the ideal switching technique that all the researchers aspire to achieve. But there are still many hurdles in achieving this goal. The first is the very complicated control required to switch each packet at a very high rate. This also requires a buffer since the data payload of the packet will be waiting in fiber while its header is being processed by the router at each node.

There is another technique which provides us with a compromise between the above described two techniques.

C) Optical Burst Switching

Optical burst switching offers us the dynamic sub-wavelength switching of data which removes the through put limitation and provides us more efficient bandwidth utilization.

At the edge node of the OBS network, various types of user's data are combined and then this data is transmitted as bursts. Each burst has its control packet which contains its information. This packet gets transmitted on a separate allocated control channel. This control packet can contain the information of hundreds of data channel due to its smaller size [1]. An O/E/O conversion of the control packet takes place at each intermediate OBS node and electrically switched to get configuration with the switch.

There is an offset time being set in the network. Offset time is the time required by the core to process the control packet information before it can allocate resources to the coming burst. This is also referred as the processing configuration delay [1]. Appropriate offset time will allow the data burst to switch in an optical domain without any delay. This will reduce the need of optical RAMs or FDLs (Fiber delay lines) at the intermediate nodes. Nevertheless, the burst-level granularity leads to a statistical multiplexing gain which is absent in optical circuit switching [1]. Furthermore, it allows a lower control overhead per hit than that in optical packet switching, [1].

D) OBS Architecture

The Fig. 1 depicts the OBS architecture quite clearly.

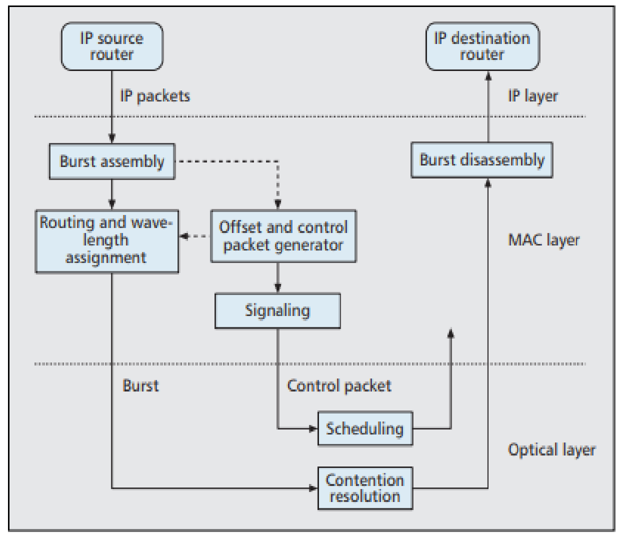

Fig. 1: Optical burst switching network architecture

Optical Burst Switching Network Edge:

Burst assembly, routing and wavelength assignment, offset and control packet generators and signaling takes place at OBS network edge.

The burst assembly assembles the data packets received by IP source router depending the burst assembling algorithms. These algorithms are based on the time threshold (T) and burst length (B) parameters which are adjustable or can be static as well. Various time and/or burst length-based assembly algorithms can be designed based on these onsets [3].

Two type of signaling is used in OBS:

Distributed signaling with one-way reservation

Centralized signaling with end-to-end reservation

Distributed signaling with one-way reservation:

User sends the control packet on an isolated out of-band control channel before transferring the corresponding burst. Burst size and length information is enclosed in control packet. O/E/O conversion will be performed on this packet at each node. It will reserve the resources for one way trip of the packet. If the receiver side will want to transmit data it will have to secure its own resources.

Examples: just-in-time (JIT) signaling, Just-enough-time (JET) signaling.

Centralized signaling with end-to-end reservation:

A request to set-up a connection is sent by the packet source (user) to central server. User becomes aware of the connection establishment through an acknowledgement sent by the central server [2].

Offset:

Data burst follows its control packet after sometime known as offset. The offset allows the control packet to be handled by the switch. This includes obtaining the required resources, and organizes the optical switch at transitional OBS nodes, in a way that the following burst can pass through each transitional OBS node without having to wait for the resources or switching fabric. The offset time is set to the point that the all of these functions can be performed before the arrival of data burst. Isolation of different traffic classes can be achieved by setting different offset time hence, providing the differentiation of services [4].

OBS Network Core

OBS network core consist of scheduling and contention resolution.

Scheduling: Inside the core, resources are either released or acquired according to the burst requirement. There are two categories of burst scheduling algorithms [5].

- Non-void-filling
- Void-filling algorithms

Contention resolution: The blockage of packets or contention takes place when more than one burst opt for the same resource. There are many techniques which are used to resolve the problem. Optical buffering (FDL, SDL), deflection routing, wavelength conversion, and burst segmentation are of its many examples. These techniques can be used in combination as well to get the desired results.

OBS MAC layer: OBS MAC layer correspond to OBS medium access layer. The above described function takes place at this layer. Before reaching to the destination node, data passes through burst dissembler where it gets divided into its intended channels.

The Fig. 2 describes the difference of nodal architecture between these three techniques.

Before jumping to the third section a comparative table is given below which compares all three switching techniques?

After being familiarized with the OBS architecture the table entries will also make logical grounds.

The Table I depicts the advantage and disadvantages of these techniques over each other.

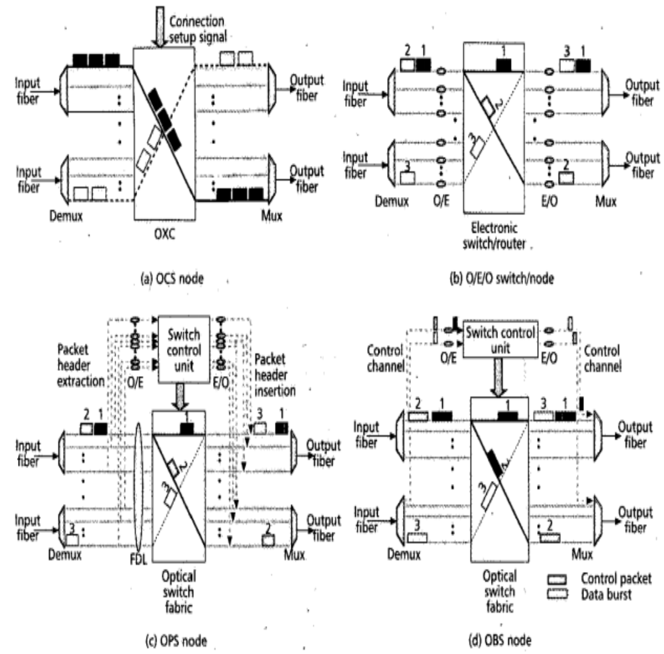

Fig. 2: Nodal architecture comparison of different switching technique

Table I: comparative analysis of switching techniques

Sr. No	Optical Switching Technique	Bandwidth Utilization	Latency	Optical Buffer	Adaptivity
1	Circuit	Low	High	Nil	Low
2	Packet	High	Low	Yes	High
3	Burst	high	Low	Nil	High

III. OPTICAL BURST SWITCHING TECHNIQUES

Architectural detail of the OBS network gives us insight on how these techniques can be different from each other. By using a different burst assembler algorithm or a different contention resolution or signaling technique can result into a different type of technique for OBS implementation.

Now we will discuss in detail the four different techniques used to implement the optical burst switching. These techniques have been selected after surveying the Internet.

1. Optical Burst Switching for self-similar traffic
2. Just-in-time signaling for WDM optical burst switching networks
3. Deflection routing in optical burst-switched networks
4. Optical burst switching in IP-over-WDM networks

A) Optical Burst switching for self-similar traffic

In OBS technique we know that data (IP packets) is transmitted in the form of data bursts along with a control channel. A burst assembly mechanism has been proposed in this technique aspiring to achieve delay limitation and reduced auto-correlation which defines the degree of self-similarity [7].

These IP packets need a new packetization protocol in order to be aggregated in a burst. These data bursts can be of fixed length [8] as well as variable length [9] but both of these cases will require a common thing. In this technique an algorithm is proposed to optimize burst assembly delay.

This algorithm was especially designed to reduce the effect of self-similar trafficking effect on the network performance.

Following are the steps taken to implement this algorithm:

1) A logical queue is associated with each destination at the edges of the burst switch cloud (let us number the possible destinations using index i. i belongs to [1:M] [7].

2) A time counter T_i is started any time a packet arrives directed to destination i and queue i is empty [7].

3) When T_i reaches the window threshold W_i, a burst is created and queued for transmission on the data channel: if the length of the burst is less than b, then it is padded to b [7].

4) T_i is reset to 0 and it remains so until the next packet arrival to queue [7].

A simulation was modeled by the proposers of this algorithm to prove their hypothesis. The theory which they presented was that burst assembly function can reduce the degree of self-similarity in the network traffic. Since the self-similar traffic is a random process categorized under stochastic processes, Hurst parameter was chosen to measure the self-similarity of the traffic. Logarithmic R/S plots were drawn to evaluate the hurst parameter of input and output traffic [7].

Result of these simulation suggested that hurst parameter which is a measure of self-similarity was reduced using this particular algorithm and if the threshold window is increased for burst it can more be improved but it would result in burst assembly delay trade-off. But the delay characteristics of the self-similar traffic also showed that the highly correlated traffic would lead to a smaller delay due to high burstiness.

So if the delay is our concern then this technique can be helpful to cater for self-similar traffic while keeping the delay in check.

B) Just-in-time signaling for WDM optical burst switching networks

One of the other components at a network edge is the signaling which is controlling the offset timing and generation of control packet.

The JIT-OBS paradigm equip the optical network with very low latency rates, one way reservation of resources for transportation of bursts of data. It provides the desirable features from the other two switching techniques. It possess out-of-band control packet processing that removes buffering of data packets at intermediary nodes, while reducing the setup time, and maximizing the switching (cross-connect bandwidth) efficiency [10].

The Fig. 3 explains just in time signaling paradigm. Some of the notations which are used in the pictures as follow:

tp : time taken at each node to process the protocol message

tc : time taken by WDM switch to cross-connect

t_d : initial delay time

JIT sequence start with a message sent by the initiation station to the attached switch which will be responsible for the all the control functions. WDM reply to this message by telling that the setup connection has been begun and also encapsulate with it is the delay time required by the switch before it can process the data burst in other words time which should be taken by the initiator before sending its data burst to the switch. The delay time is estimated through a routing algorithm. The source transmits its burst after the delay time is over. On receiving the message from the source, WDM switch will reserve the wavelength and transmits the message to the next node. Cross connection is being performed in parallel due to the control packet while the message is being hopped between nodes. When the destination receives the message it acknowledges with a "connect" message to the source /sender. When source is done transmitting its data, it will send a "release" message. WDM switch will now release all the reserved resources for this connection and a connection cycle is complete.

By implementing the time delay sent by switches, it is apparent that buffer is being implemented at the source node where electronic memory is cheap instead of implementing it at the intermediate nodes where incorporation of fiber delay lines brings complicacy in the network structure.

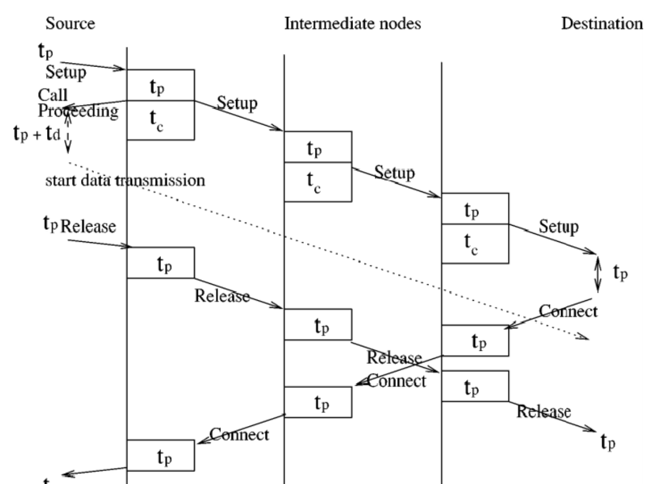

Fig. 3: Just in time (JIT signaling)

JIT signaling is designed and evaluated under the MONET project. The signaling protocol software implementation itself was tested and validated in the MONET Washington, DC test bed network [11].

The implementation of WDM over the networks has introduced with a wide range of bandwidth but as it was predicted in [12], and bandwidth will not be our problem, latency will be the major challenge to overcome.

C) Deflection routing in optical burst-switched networks

Deflection routing is one of the techniques to resolve contention in the OBS core.

This employs the Just Enough Time (JET) signaling which gives rise to the contention problem because not enough offset time. Contention is caused where there more packets in the buffer than the system can handle and it will lead to the contention. But employing this technique provides a sufficient solution for not enough offset time problem [13].

In just enough time signaling, wavelength is only reserved for the duration of the burst during which it will be staying at the nodes according to its control packet information. Since it does not depend on a set-up and release message as the JIT does, resource utilization is better than the JIT. And the optical buffer problem is more severe while using the JET so this contention technique plays its role to provide the solution.

Consider a data burst originated from node S and destines to reach D. number of times a packets is transmitted between the intermediary nodes (hops) is represented by H. H is considered along a path which has been decided earlier. Let δ be the time taken at each hop for the processing of the control packet. The total delay experienced by control packet is not more than $\Delta=\delta \times H$ limiting the offset time T equal or greater than Δ. In the given example, pre-determined route include two hops. Everything works smoothly until the FDL failure occurs at B meaning when a resource required by the arrival packet is required but it's already been assigned to another packet. In this case the data is kept in the FDL until the required resource is free but when there is no buffer space available as well then the deflection route gets triggered. It's a good technique until the data burst arrives at the destination earlier than the complete processing of its control packet.

This is illustrated in the following Fig. 4.

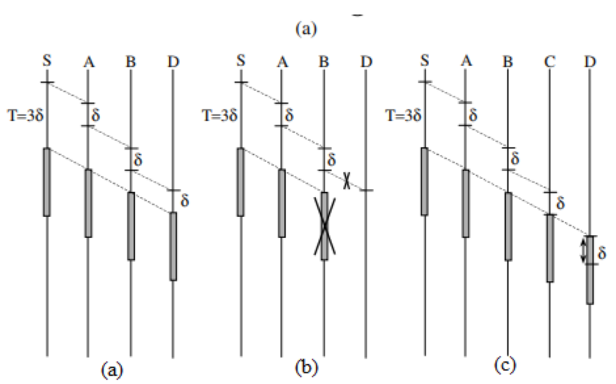

Fig. 4: Possible cases of Burst from S to D, (a) successful transmission, (b) FDL failure at B (c) Deflection routing triggered at B

To overcome this problem some solutions has been proposed and are in play.

1. Offset time can be increased so that control packet and burst can be synchronized. This technique is known as *Extra offset time*.
2. Packets which are to be deflected should be delayed at the previous hoop giving the control packet enough time for processing. this is known as *Delayed-at-previous-hops*
3. Instead of delaying the packets at each hop only introduce delay at the nodes which are congested sparing the process timings. This is known as *Delayed-at-congested-node*
4. Packets can also be delayed at the hop which they were being directed after facing the blockage at the current node. This is known as *Delayed-at-next-hop*

These are the prevention to follow in the deflection routing scheme. But there is another technique which proposes a queuing Markovian model [13]. A simulation has been done by the researches to determine the performance of their queuing model.

The network performance implementing the deflection routing was also simulated. The considered network topology is arpanet-2 composed of 21 nodes [13].

The performance analysis of the network showed that performance gain increases if the network undergoes though lesser no of wavelengths and lighter traffic load. However, the network gets exhausted when the number of channels (wavelengths) reaches to a certain limit because keeping the data in FDLs for a longer amount of time is not going to help if the network has reached its capacity [13].

C) Optical burst switching in IP-over-WDM networks

In this technique the goal is to minimize the number of fiber delay lines used in a network.

QoS is considered in this technique which usually requires the implantation of buffers in the network so that it can hod the data while the higher priority packets are being transmitted to avoid data loss.

The proposed OBS scheme to improve the QoS introduces a new offset time instead of buffer for separation of traffic classes. It is named ass offset-time-based scheme, which is appropriate for the execution of a buffer less WDM networks as it does not obligates the presence of any buffer (though the FDLs can be used to increase the QoS performance) [15].

This technique implements the isolation of traffic classed by giving an extra offset value to the prioritized classes. When this control packet with higher offset value is processed, a required resource (desired wavelength link on the output) will be acquired through delayed reservation (DR). This is facilitated by processing the control signal at each transitional node [6].

Since the number of FDLs have been reduce with the longer delay simulation was carried out between classless and QoS networks [15]. The simulation measured both Poisson and self-similar traffic. Burst loss probability was used to measure QoS performance. Maximum delay time as the FDLs provided the queuing delay. The offset time difference, the number of FDLs, the number of classes, and the number of wavelengths were used as parameters [15].

The results of simulation showed that when there are larger number of channels present, the burst loss probability of the networking possessing one class can also be lesser than that of the classless [15] but as the difference between offset times is decreased, the loss probability of each class in QoS OBS decreases to that of the classless case [15]. The delay can be countered with the low loss probability.

IV. RELATED WORK

Optical burst switching techniques are evolving all the time. Researches are always in the search to find a more optimized technique which provides the better wavelength utilization. Also studies have also been conducted to draw a comparison between techniques to single out the better one.

An early research was conducted by Yang.Chen, Chunming Qiao and Xiang Yu. In their research they firs compared different switching techniques with each other and concluded that optical burst switching is most cost effective and more suitable for higher data rate optical networks. They went on to discuss the component details of the optical burst switching and possible problems faced by the OBS networks at that time and their respective solutions.

A comparatively recent survey gathered the data on all the new emerging techniques of optical switching and compared it for the better bandwidth utilization [2]. These techniques included the optical flow switching and photonic slot routing. But to implement these techniques in a commercial network, further research is required to reduce the complexity introduced to the control and management planes by each of these optical switching techniques [2].

As the hurdles have been mentioned by the previous researcher in the implementation of optical flow switching a hybrid technique between optical packet switching and optical flow switching had been proposed and the performance was analyzed. Simulation result showed the p a higher performance dependency on the traffic load. It is shown in the results that for a large number of flows in traffic we get an improved average delay at the cost of loss probability with the same traffic load [14]. An overall significant improvement is obtained in terms of average delay using a hybrid switching technique over optical packet switching.

These researches take out the similar parameters for the comparison but the survey was conducted between different switching techniques. In this paper, it’s been tried to find out for the specific solution by remaining within the same technique. This research offers the solution in the same switching technique rather than looking into other domains.

V. DISCUSSIONS

All of the above OBS techniques in optical networks have been chosen from each of the OBS architecture component.

The first technique deals with the self-similar trafficking which is the most faced problems in internet IP networks. It shows that by implementing a very simple algorithm can help to deal with the self-similar traffic load. This algorithm is applied at the very first point of the architecture which is the burst assembly. By keeping the burst length in control with the minimum length limitation, self-similar traffic can be dealt with.

Signaling is controlling the control packet generation and offset timing. Just in Time and Just enough Time are the signaling techniques that have been discussed. Since JIT is not as resource efficient as the JET, JET can be implemented as a signaling technique thus the protocol as well. Deflection routing has also been implemented to resolve the contention in OBS network core. But further investigation showed that even after the implementation of deflection routing technique in the JET, even then it fails to give the performance gain after the certain number of wavelengths (channels) exceeds and can’t handle the higher traffic loads. So, for a larger network JIT signaling will result in better performance rather than its alternative. It’s been found out while the just enough time provides better utilization of resources but its performance starts to degrade resulting in an increase of loss probability.

Implementation of prioritization in the network has also been discussed in the fourth technique. QoS which provides the traffic classification have been implemented while minimizing the FDLs (fiber delay lines). This will make the network cost effective butt at the same time will introduce a new delay time added at the burst assembly along with the offset time.

VI. CONCLUSIONS

In the paper, a comparative study was conducted taking in account the different techniques proposed by researches to implement in the optical burst switching networks. These techniques were differentiated depending upon the different schemes implemented in their respective network component in the OBS architecture. In internet trafficking where the random nature of traffic is one of the issues the self -similar trafficking algorithm implementation of optical burst switching can be borrowed in the network. Provision of efficient resource utilization in JET does captivate the attention but it has low performance with greater number of nodes and large traffic. So, in a large network just in time signaling is more efficient working on the principal of set-up and release message packets. The QoS OBS scheme can be used in the networks where data from one channel is prioritized over the others but this will introduce an extra amount of delay in the system.

It was also observed that some of these techniques can be implemented along with each other to reach a compromise between the two and a hybrid approach can be implemented to utilize the benefits from both of the worlds as this translates the exact essence of Optical burst switching which is itself a compromise between optical circuit switching and optical packet switching.

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