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Performance Analysis of Scheduling Algorithms In Optical Burst Switching Networks

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***Abstract*—Optical Burst Switching (OBS) is developed as an alternative switching technique for next generation optical networks, which combines advantages of both optical circuit switching (OCS) and optical packet switching (OPS) and avoid disadvantages. There are certain performance related issues such as scheduling, burst aggregation, contention resolution and Quality of services that needs to be addressed in OBS. Scheduling of data burst in an optimal way is one of the key problem in optical burst switched networks. Another major issue is contention, contention occurs when more than one data burst try to reserve the same wavelength channel on an outgoing link. In this paper, comprehensive review pertaining the classification of different scheduling algorithms for optical burst switched network has been presented. It is seen that Best Fit algorithm is an optimal scheduling algorithm with reference to burst loss ratio. Contention can further be improved with reference to burst loss ratio.**

***Keywords*— WDM, OBS, Scheduling, FFUC, LAUC, Min-SV.**

I. INTRODUCTION

There have been a phenomenal increase in the demand for bandwidth over the years due to rapid growth in the number of Internet users and increase in bandwidth intensive applications such as voice-over-IP, video conferencing, interactive video on demand, and many other multimedia applications. To meet the ever growing demand of bandwidth, copper cables were replaced by optical fibers in both the access networks as well as in the backbone networks Optical fiber not only supports huge bandwidth but also have other advantages too such as lower bit-error rate, no interference problem and security advantage[2, 8].

Several approaches have been proposed to take advantage of optical communications and in particular optical switching. One such approach is Optical Circuit Switching (OCS) 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 lightpath. An alternative to optical circuit switching is Optical Packet Switching (OPS) [12]. 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. In order to provide optical switching for next generation Internet traffic in a flexible yet feasible way, a new switching paradigm called optical burst switching (OBS) was proposed in [2].Various OBS approaches with different tradeoffs have since been described. There are two common 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 (λ's) thus, costly O/E/O conversions are only required on a few control channels instead of a large number of data channels. There are still some difficulties in realizing all optical networks, such as the optical RAM is ongoing research now, and some technologies and standards have to be designed. So the processing of IP packets in the optical domain is still not practical yet, and the optical router control system is implemented electronically. Nowadays, we are mostly studying the semi-transparent optical transport networks. In optical transport networks, the control messages are processed electronically, and the data are propagated in the high-speed transparent data channels. To realize IP-over-WDM architecture, several approaches, such as Optical Circuit Switching (OCS) [8]. Optical Packet Switching (OPS) [4] and Optical Burst Switching (OBS) [3] have been proposed.

In Optical burst switching two types of nodes are their one is edge type and another is core type. Edge node is at the interference between optical and electronic domain and core and routing is done by core node. In optical burst switching two channels are there one is control channel carries control burst and another one is data burst which carries data burst. Data burst follows control burst during data transmission.

Of all these approaches, Optical Burst Switching (OBS) can be achieve a good balance between the circuit switching and optical packet switching, there by combining others benefits while avoiding their shortcomings.

TABLE I

Comparison of Switching Technologyb

Switc-Hing	B/W Utiliz-ation	Late-Ncy	Optical Buffering	Over-Head	Adap-Tivity
Circuit	Low	High	Not required	Low	Low
Packet	High	Low	Required	High	High
OBS	High	Low	Not required	Low	High

II ARCHITECTURE OF OBS

Architecture of OBS network is shown in Fig.1. OBS network consists of two types of nodes: edge node and core node. Edge nodes are at the interface between electronic and optical domain. Edge nodes can be an ingress or egress node. Packets are assembled into bursts at ingress edge node, which are then routed through the OBS network and disassembled back into packets at egress edge node. A core node is mainly composed of an optical switching matrix and a switch control unit which are responsible to forward payload/ data burst. A node in OBS network consists of both optical and electronic components. The optical components are multiplexers (Mux), demultiplexers (Demux) and an optical switching network (OSN). The electronic components are input modules (IM), output module (OM), a control burst router (CBRT), and a scheduler. The control packet is then forwarded on the OM, which updates its control fields and transmits it to the selected outgoing fiber using the optical transmitter. An optical burst switch control unit transfers an incoming data burst from an input port to its destination output port. When an edge node intends to transmit a data burst, it sends a control packet on the control wavelength to a core node. At core node, the control packet on the control channel is input to the corresponding IM, which converts the control packet into electronic form. The control fields are extracted from the control packet. The scheduler maintains a control packet queue. The scheduler also reserves wave-length on the determined links for the upcoming payload. The control packet is then forwarded on the OM, which updates its control fields and transmits it to the selected outgoing fiber using the optical transmitter [2,3]. Just before the payload arrives, the switching element in the node is configured to connect the input port to the corresponding output port for the entire duration of the burst transmission. If the control packet is unable to reserve the wavelength then the control packet as well as payload is dropped. Fiber using the optical transmitter. Just before the payload arrives, the switching element in the node is configured to connect the input port to the corresponding output port for the entire duration of the burst transmission. If the control packet is unable to reserve the wavelength then the control packet as well as payload is dropped [2, 7].

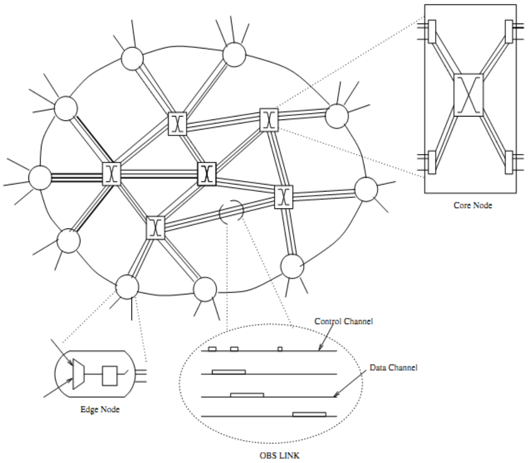

Fig.1: Architecture of OBS network

Edge node:

Edge node is at interface between the electronic and optical domain (can be ingress and egress). Packets are assembled into bursts at ingress node and dissembled into bursts at egress node.

Core node:

Core node composed of an optical switched matrix and switched control unit, Core node is responsible t forward data bursts.

III STATE OF ART OF BURST SCHEDULING ALGORITHMS

When a control packet arrives at a core node, a wavelength channel scheduling algorithm is used to determine a wavelength channel on an outgoing link for the corresponding data burst. The information required by the scheduler such as the expected arrival time of the data burst and its duration are obtained from the control packet. The scheduler keeps track of the availability of time slots on every wavelength channel. It selects one among several idle channels. The selection of wavelength channel needs to be done in an efficient way so as to reduce the burst loss. At the same time, the scheduler must be simple and should not use any complex algorithm, because the routing nodes operate in a very high-speed environment handling a large amount of burst traffic. A complex scheduling algorithm may lead to the early data burst arrival situation wherein the data burst arrives before its control packet is processed and eventually the data burst is dropped [2,15].

In this section we discuss various scheduling algorithms. These algorithms differ in their complexity and performance in terms of burst loss. Algorithms which consider unscheduled channels are called Horizon algorithm [2]. A channel is said to be unused for the duration of voids between two successive data bursts and after the last data burst assigned to the channel. According to scheduling strategy used scheduling algorithms can be classified as follows:

1) Horizon or Without void -filling.
2) With void-filling.

Representative of Horizon algorithms are: First Fit Unscheduled Channel (FFUC), Latest Available Unused Channel (LAUC) and that of void-filling algorithms are: First Fit Unscheduled Channel with Void Filling (FFUC-VF), Latest Available Unused Channel with Void Filling (LAUC-VF) and Minimum End Void (Min-EV) [2, 3].

Working of algorithms is illustrated with the help of Fig.2. In Fig.2, control packet arrives at a node at time t_{CB}. Duration of payload is tburst and the offset time for the data burst is toffset. The offset time is calculated as:

$$t_{offset} = H * t_{setup}$$

Where H is number of hops from source to destination and tsetup is the time required for processing and switching the control packet. The time at which the burst bit of payload arrives at the node is $t_{CB} + t_{offset}$ and the last bit arrive at $t_{CB} + t_{offset} + t_{burst}$.

We define unscheduled channel and void channel as following:

Unscheduled channel: A wavelength channel is said to be unscheduled at time t when no data burst is using the channel at or after t.

Void channel: If a channel is unused for duration between two successive data bursts.

A First Fit Unscheduled Channel (FFUC)

First fit unscheduled channel (FFUC), selects an unscheduled channel for an in-coming payload/ data burst. FFUC keeps the unscheduled time for each data channel. When a control packet arrives, the FFUC algorithm searches all data channels in a fixed order and assigns the data burst to the first channel that is available at or after the arrival time of the payload [2, 3].

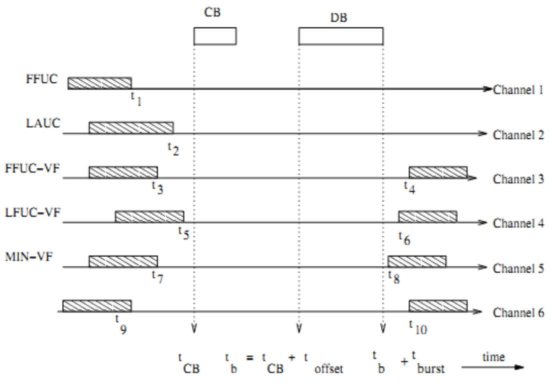

Fig.2: Illustration of Burst Scheduling Algorithms

In Fig.2, when a control packet arrives at a time tCB, the scheduling algorithm searches for all unused channels. Available unscheduled channels are channel 1 and 2. FFUC selects channel 1, since this is the first available channel. And the channel is reserved for the duration.

$$T_{duration} = [t_{CB} + t_{offset}, t_{CB} + t_{offset} + t_{burst}]$$

Advantage of the algorithm is speed due to the relatively small number of channels that it checks. The best implementation of the FFUC scheduling algorithm takes O(log w) time to schedule a data burst, where w is the number of wavelengths.

Disadvantage of the algorithm is low network resource utilization due to following reasons:

i. Does not consider voids that may appear between two already scheduled data bursts as a possible place for fitting the incoming data burst.

ii. Stops after first available channel.

B. Latest Available Unscheduled Channel (LAUC)

Latest available unscheduled channel (LAUC), selects an unscheduled data channel where the void created between consecutive scheduling of data bursts is minimum [2, 12]. In Fig.2, channel 1 and 2 are two unscheduled channel at tb. Scheduling on channel 1 creates a void (tb − t1) and in 2 is (tb − t2). Since (tb − t1) > (tb − t2), LAUC selects channel 2 for scheduling.

LAUC has the same complexity as that of FFUC. In addition, LAUC utilizes the network resources better than FFUC.

C. First Fit Unscheduled Channel With Void Filling (FFUC-VF)

In First fit unscheduled channel with void filling (FFUC-VF), all possible voids are found and the payload is scheduled on the first available void that is suitable for transmission [2, 8].

In Fig.2, voids are available on the channel 3, 4, 5 and the duration of voids are (t4 − t3), (t6 − t5) and (t8 − t7). FFUC-VF selects the channel 3 to schedule the data burst, because channel 3 is the first available void channel.

If n is the number of data bursts currently scheduled on every data channel, then a binary search algorithm takes log n time to check that the data channel is eligible or not. Thus the time complexity of the FFUC-VF algorithm is O(w log Nb), where w is the number of data channels.

D. Latest Available Unscheduled Channel With Void Filling (LAUC-VF)

Latest available unscheduled channel with void filling (LAUC-VF), searches all data channels to and an available void channel for the time interval ($t_b + t_{offset}$) and ($t_b + t_{offset} + t_{burst}$). Then select a channel, such that placement of new data burst create minimal void between newly arrival data burst start time and previous scheduled data burst end time[2, 8].

In Fig.2, channel 3, 4, 5, 6 have such void. The difference between start time of newly arrival data burst and already scheduled data burst whose end time is prior to the start time of new data burst on the channels 3, 4, 5 and 6 are:($t_b + t_{offset} - 3$), ($t_b + t_{offset} - t_4$), ($t_b + t_{offset} - t_5$) and ($t_b + t_{offset} - t6$) respectively. LAUC-VF select channel having minimum of the above time difference. So it selects channel 4 to schedule the incoming data burst. The time complexity of the LAUC-VF algorithm is O(w log Nb), where w is the number of data channels.

To implement LAUC-VF, switching control unit have to store usage information of all data channels. That makes LAUC-VF more complex compared to that of FFUC and LAUC. But it has higher network resource utilization.

E. Minimum End Void (Min-EV)

A variation of LAUC-VF algorithm is Minimum end void (Min-EV). It searches all data channels to and an available void channel to schedule the newly arrival data burst. Then, select a channel, such that placement of new data burst create minimal void between already scheduled data bursts start time and newly arrival data bursts end time[2, 3, 8].

In Fig.2, channel 3, 4, 5, 6 have such void. The difference between start time of already scheduled data burst and end time of newly arrival data burst on channel 3, 4, 5 and 6 are: ($t_4 - (t_b + t_{burst})$), ($t_6 - (t_b + t_{burst})$), ($t_8 - (t_b + t_{burst})$) and ($t_{10} - (t_b + t_{burst})$) respectively. Min-EV selects a channel having minimum of the above value. Therefore, channel 5 is selected. The bandwidth utilation is also better. The time complexity of the Min-EV algorithm is O ($\log_2$ Nb), where w is the number of data channels.

F. Minimum Starting Void (Min-SV)

In this algorithm, a scheduler keeps track of void for each channel. It also maintains start and end time of voids for each data channels. Scheduler tries to search for a void such that newly created voids are the smallest voids after scheduled bursts. The time complexity of the Min-SV algorithm is O ($\log_2$ Nb), where w is the number of data channels [8].

G. Best-Fit (BF) algorithm

In this algorithm, a scheduler keeps track of void for each channel. It also maintains start time and end time of voids for each data channels. Scheduler tries to search for a void such that newly created void is the smallest void before and after scheduled bursts [3, 8]. The time complexity of the Best-Fit algorithm is O ($\log_2$ Nb), where w is the number of data channels.

TABLE II

Performance Comparison of Different Scheduling Algorithms.

Algorithm	Complexity	Generated Code	Burst Dropping Probability	B/W Utilization
FFUC	O(log w)	Simple	High	Low
LAUC	O(w)	Simple	High	Low
FFUC-VF	O(w log Nb)	Simple	Low	High
LAUC-VF	O(w log Nb)	Complex	Low	High
Min-/EV	O(log2 Nb)	Simple	Low	High
Min-SV	O(log2 Nb)	Simple	Low	High
Best Fit	O(log2 Nb)	Simple	Low	High

Table II summarizes the comparison between the algorithms. It uses the following notation: (w) number of wavelengths at each output port; (Nb) number of bursts currently scheduled on every data channel.

IV CONCLUSION

With the comparative study of OPS, OCS and OBS, it is observed that the OBS is not only cost effective but also a viable solution for the next generation optical networks. All the scheduling algorithms for OBS network have been studied and it is found that Void filling algorithms performed better than horizon scheduling algorithms in terms of burst loss ratio. This is due to selection of void channels in void filling algorithms. The limitations of the void filling algorithms such as LAUC-VF and Min-EV algorithms lies in the fact that they consider only one side of a void. LAUC-VF, consider the void created between incoming data bursts start time and previous scheduled data bursts end time. Whereas Min-EV, consider the void created between scheduled data bursts start time and incoming data bursts end time. Due to this smaller size data bursts may be scheduled in a larger void whereas bigger size data bursts may get blocked. This is problem is resolved by Best Fit algorithm.

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