An Efficient Composite Scheduling Algorithm for OBS Networks	Giải thuật lập lịch phức hợp hiệu quả cho các mạng OBS 6 h 29
Optical Burst Switching (OBS) is a promising paradigm for the next generation internet. Data channel scheduling algorithm is one of the key issues in OBS networks. In this paper, an efficient composite data channel scheduling algorithm is proposed, this algorithm select LAUC or LAUC-VF to schedule the arriving burst according to	Chuyển mạch burst quang (OBS) là một mô hình đầy hứa hẹn cho internet thế hệ tiếp theo. Thuật toán lập lịch kênh dữ liệu là một trong những yếu tố then chốt trong các mạng OBS. Trong bài báo này, chúng tôi đề xuất một thuật toán lập lịch kênh dữ liệu hiệu quả, thuật toán này chọn LAUC hoặc LAUC-VF để lập lịch cho burst đến theo thông tin hiện tại của void

the current information of void interval of data channel. The algorithm reduces scheduling time of data burst while minimizing void interval of data channel. Simulation results show that the scheduling time of the proposed algorithm is close to LAUC, and the performance of data burst loss probability is better than LAUC-VF.	interval (quãng dừng khoảng trống) của kênh dữ liệu. Thuật toán giúp giảm thời gian lập lịch của burst dữ liệu trong khi vẫn giữ void interval (quãng dừng khoảng trống) của kênh dữ liệu ở mức tối thiểu. Các kết quả mô phỏng cho thấy rằng thời gian lập lịch của thuật toán đề xuất gần bằng LAUC, và hiệu suất của xác suất mất burst dữ liệu tốt hơn LAUC-VF.
1. INTRODUCTION	1.GIỚI THIỆU
For the sake of satisfying the requirement of increasing bandwidth and reduce the cost of maintenance of networks, several approaches have been proposed to take advantage of optical communications and in particular switching technologies in optical networks. Of all these switching technologies, Optical Circuit Switching (OCS) based on wavelength routing needs to establish a lightpath 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. Optical circuit switching is relatively easy to implement, but it lacks efficiency while handling the abrupt traffic and the changing link state. Other switching technology is Optical Packet Switching (OPS). In optical packet switching, while the packet header is being processed at each intermediate node, the data payload must wait in the fiber delay lines and be forwarded later to the next node. Although optical packet switching is a most ideal choice, but the optical technology (such as optical buffer, optical logic chip, etc.) is not mature enough to support it. A new switching technology called Optical Burst Switching (OBS) was proposed	[redacted]

in [1], which combines the virtues of optical circuit switching and optical packet switching and has receive widely recognitions[2 5l.

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optical burst switching network consists of optical core routers and electronic Edge routers, Core router is mainly composed of an optical switching matrix and a switch control unit. Edge router assembles packets into Data Burst (DB) and corresponding Burst Header Packet (BHP) [&-SJ, DB is switched and transmitted in core networks through all optical channel without Optical to Electronic (0/E) or Electronic to Optical (E/0) conversions, BHP contains all the necessary routing information (such as length of DB, offset time, etc,) to be used by the switch control unit at core router to switch the DB, BHP is transmitted through optical channel that is independent from data channel and 0/E and E/0 is needed at each core nodes, BHP is transmitted before corresponding DB, the interval between them is decided by the adopted protocol.

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One of the key issues in OBS networks is Data channel scheduling algorithm The DB loss probability and scheduling time of the algorithm is two main performance of the scheduling algorithm, An ideal scheduling algorithm should be able to handle BHP before the DB arrives and to find out a fit channel for the DB, If a reservation cannot be finished before the DB arrival, the DB will be dropped (so as to say the scheduling time should be as short as it can), Generally speaking, an efficient scheduling algorithm can reduce the DB loss rate and enhance the

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bandwidth utilization ratio by fast scheduling DB

Several algorithms have been proposed to schedule DB, Two typical of such algorithms are Latest Available Unused Channel with Void Filling (LAUC-VF)[3 and Latest Available Unscheduled Channel (LAUC)[3 LAUC-VF can put a new burst in void interval between two data bursts, but it has a slow execution time, On the other hand, LAUC dose not utilize any void interval between two data bursts, so its execution time is short, but bandwidth utilization ratio is low,

In this paper, we propose an efficient composite data channel scheduling algorithm, which select LAUC or LAUC-VF to schedule the arriving burst according to the current information of void interval of data channel. It can reduce scheduling time of data burst while minimizing void interval of data channel, i.e., it can increase the bandwidth utilization and decrease the end-to-end delay of data burst.

The rest of the paper is organized as follows. In the next section, we analyze advantage and disadvantage of LAUC and LAUC-VF algorithm. In section III, we describe the proposed algorithm in detail. In section IV, we give the results of simulations and analysis the performance of the proposed algorithm based on DB loss probability and execution time. Finally, conclusions are made in section V.

1. LAUC AND LAUC-VF SCHEDULING ALGORITHM

In OBS networks, when a BHP arrives

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at a node, a data channel scheduling is employed to assign a data channel on the outgoing link for the unscheduled DB. That is to say, when a corresponding BHP arrive core router, the channel scheduler should be able to find a usable data channel as output channel for each arriving DB on outgoing link of optical switching matrix, or a combination of a Fiber Delay Line (FDL) and an outgoing data channel. Otherwise, the DB and corresponding BHP will be dropped. When we design a scheduling algorithm, we should think about the DB loss probability and its execution time. In this section, we first describe the LAUC and LAUC-VF scheduling algorithm, and then, based on them, we propose our scheduling algorithm that is base on threshold. From now on, we suppose that the optical buffer has B FDLs with ith FDL being able to delay Di time, lSiSB.

LAUC is a scheduling algorithm that minimizes the output delay by selecting the latest available unscheduled data channel for each arriving DB. Supposed the arrival time t of a DB with duration L to the core router, the scheduler first finds the outgoing data channels that have not yet been scheduled at time t. If there is at least one such channel, then the scheduler selects the latest available channel for it, that is to say, the channel having the smallest void interval between time t and the end of last DB just before t, to arrange the arriving DB, and the channel's unscheduled time is updated to t L. If there is no available unscheduled data channel at time t, the scheduler will sequentially finds the latest available unscheduled data channel at time t D DiD 1::;; i ::;; B D,

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if there is still no available unscheduled data channel at time tDDi , the DB and the corresponding BHP will be dropped. The advantages of the LAUC algorithm are simplicity and ease of its implementation, for the scheduler needs only to remember the unscheduled time for each data channel

The shortcoming of the LAUC algorithm is that bandwidth utilization ratio is low, because the void interval between DBs is wasted.

The LAUC-VF algorithm is similar to the LAUC algorithm except that the free voids can be filled by new arriving DBs. LAUC-VF is a scheduling algorithm that minimizes the void interval time by selecting the latest available unused data channel for each arriving DB. Unscheduled data channel is just a special case of unused data channel. Supposed the arrival time t of a DB with duration L to the core router, the scheduler first finds the outgoing data channels that are available for the time period (t t L). If there is at least one such channel, then the scheduler selects the latest available channel, that is to say, the channel having the smallest void interval between time t and the end of last DB just before t, to arrange the arriving DB. If there is no available unused data channel at time t, the scheduler will sequentially finds the latest available unused data channel at time tDDiD 1:::; i:::; B D, if there is still no available unused data channel at time tD Di , the DB and the corresponding BHP will be dropped.

The LAUC-VF algorithm keeps the information of all void intervals of each channel, and arranges a new arriving DB by using of voids. So, the LAUC-VF algorithm can use bandwidth more

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effectively than the LAUC algorithm does, at the same time it can reduce the drop probability of DB. However, the execution time of the LAUC-VF algorithm is longer than the LAUC algorithm; especially when the number of voids is great, the time that the LAUC-VF algorithm searches a suitable void interval for an arriving DB will longer than the offset time of the DB, result in the failure of reservation.

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2. COMPOSITE DATA CHANNEL SCHEDULING ALGORITHM

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2.1. The basic idea of the proposed algorithm

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The basic ides of the proposed composite algorithm is that the algorithm selects LAUC or LAUC-VF to schedule the arriving burst according to the current information of void interval of data channel. So we call the proposed algorithm as void-based data channel scheduling algorithm. The algorithm firstly determine a threshold function according to the current void interval information, then the LAUC-VF algorithm is selected if the length of arriving DB is less than the threshold function, otherwise the LAUC algorithm is selected. The proposed algorithm can not only minimize void intervals of the data channel but also reduce the scheduling time of the DB, namely, the proposed algorithm can improve the bandwidth utilization of data channel and reduce the end-to-end delay of data burst.

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3.2 Average Void-Based (AVB) data channel scheduling algorithm

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Given the arriving burst's length is l and it arrives a core node at the time t. Let M is the total number of void intervals, is the jth void interval, and be represent as an ordered pair (s1, ej), where s1 and e1 are the starting and ending time of the void interval , respectively, with s1 >	[redacted]
1. The average length of current void intervals can be expressed with If l :2: V , we adopt LAUC algorithm to schedule the coming burst, otherwise, we adopt LAUC-VF algorithm. 3.3 Weighted Average Void-Based (WAVB) Data Channel Scheduling Algorithm	[redacted]
According to the previous condition that was suppose, we denote the weighted average length of current void intervals by	[redacted]
Where a1 is the weighted coefficient of the void interval ; and the more s1 is close to t, the bigger a1is. On the contrary, the value of a1is less. If l Vw , we adopt LAUC algorithm to schedule the coming burst, otherwise, we adopt LAUC-VF algorithm. There is a little difference between AVB and WAVB about the calculating threshold, their basic idea is almost consistent. If the length of a coming DB is longer than the threshold value, that is to say, the probability that the void interval is longer than the DB's length lis very little, so, it is not fit to use the void to arrange the new DB, we should adopt LAUC algorithm to schedule the coming DB, for example, data channel D3 is chosen in fig. 1(a). If the length of	[redacted]

a coming DB is little than the threshold value, the probability that the current void interval can arrange the new DB is bigger, accordingly, we adopt LAUC algorithm to schedule the coming DB. In this way, we can improve the bandwidth utilization of data channel, for example, data channel D2 is chosen in fig. 1(b).

4. SIMULATION RESULT AND ANALYSES

In this section, we evaluate the performance of the void- based data channel scheduling algorithms by computer simulation. Supposed that the assembly algorithm [?J based timer is applied. DB arrivals to core router are Poisson process with rate A. DB length is an exponential distribution with an average length of 1OOms and composed of integer IP data packets. Each IP data packet has the fixed size of 1250 bytes. The data channel transmission rate is 1OGbps. All the burst has the same initialized offset time, the value of which is 20us the processing time of BHP in each node is 2.5us. Eve; link has 8 data channels, the route between two nodes can be obtained by the Dijkstra algorithm.

The simulation result of the data loss ratio of different algorithms is show in Fig.2. Seeing from the figure, the performance of our proposed AVB and WAVB is superiority to the other two algorithms. When the network traffic load is light, the DB loss probability of LAUC-VF is superiority to AVB and WAVB. With the increasing of the load, the performances of AVB and WAVB

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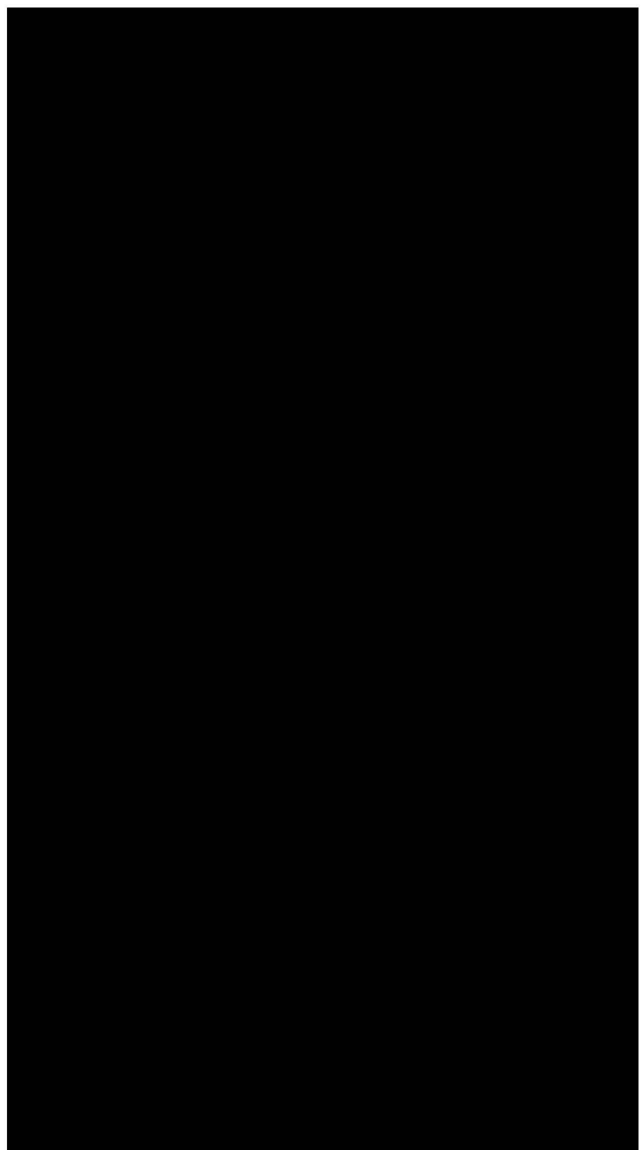
are superiority to the LAUC-VF, that's because LAUC-VF spends a large amount of time to find available data channel, when the cost time overrun the offset time, to schedule the burst is unsuccessful. At the same time, we can obtain that the performance of WAVB algorithm is a little better than AVB, and they can reduce the DB loss probability and improve the network performance by selecting the different schedule algorithm, certainly, the chosen algorithm depends on the current void information of data channel and give bigger weighted coefficient to the latest void interval.

The simulation result of the scheduling time of different algorithms show in Fig.3. We can obtain that the change of network load has a little affect in the schedule time of WAVB D AVB and LAUC algorithm, and the scheduling time of LAUC is close to zero, the scheduling time of AVB and LAUC is very small also. To the LAUC- VF algorithm, however, it's scheduling time increase with the traffic load. We can see that the scheduling time of AVB and WAVB is less than LAUC-VF under different traffic load. The main reason is that: In the LAUC algorithm, the scheduler needs only to remember the unscheduled time of each data channel, so its scheduling time complexity is O(W), where W is the number of data channels. As to the LAUC-VF algorithm, the scheduling time complexity is O(M), where M is the total number of all void intervals. Furthermore, if FDLs can provide B units delay, the scheduling time complexity of the LAUC- VF algorithm will be O(BM). To the WAVB



algorithm and AVB algorithm, their scheduling time complexity is less than LAUV-VF algorithm and slightly excess It is also worth pointing out that scheduling time of the LAUC-VF algorithm will be very long, with the increasing of the data channel number, which will affect badly the successful probability of scheduling burst, while those of the WAVB and LAUC algorithm almost keep unchanged The simulation result of DB loss probability under different offset time condition for different scheduling algorithms is show in Fig. 4, the loss probability of LAUC almost linearly increase with the offset time; however, the AVB D WAVB and LUAC-VF algorithm keep the loss probability low, and they are not sensitive to the change of offset time. The explanation on this phenomenon is that the channel produce the larger void interval with the increasing of offset time, LAUC doesn't utilize the void time interval, which waste a lot of bandwidth and result in the DB loss probability increasing, the other three algorithms utilize all the void time interval, that is to say, new DB fill the void time interval, so increasing the offset time has little affect in their loss probability

5. CONCLUSION

In this paper, basic on analyzing the LAUC and LAUC-VF algorithm, we proposed AVB algorithm and WAVB algorithm depending on the information of current void interval to adopt LAUC or LAUC-VF algorithm to schedule data burst. AVB and WAVB algorithm take the advantages of, and at the same time, avoid the disadvantages of the two existing algorithms, the LAUC and the LAUC-VF. Simulation results show that

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the proposed AVB and WAVB algorithm has a relative shorter scheduling time, while keep low loss ratio of DBs.	[redacted]
Composite scheduling combines advantages of horizon scheduling and void filling scheduling and removes their disadvantages. The basic idea of the algorithm is that, it firstly determine a threshold function according to the current void interval information. Void filling algorithm is selected, if the length of arriving DB is less than the threshold function, otherwise horizon algorithm is selected	[redacted]
LA-FFVF applies different scheduling criteria to select a channel for arriving bursts depending on their class of service. As previously mentioned, with JET as reservation mechanism, void filling is possible only when there are different classes of service managed through different extra-offset values. High priority bursts are assigned extra-offset times with the aim to get lower blocking probability values. On the other hand, low priority bursts, which have not extra-offsets, could reduce losses using void filling. Thus, LA-FFVF represents a sort of ”hybrid approach” in which LAUC is used for high priority bursts, to keep low the complexity being the priority guaranteed by extra-offset, whereas FFUC-VF is employed for low priority bursts in order to exploit voids and get a ”reasonable” complexity.	[redacted]
Figure 2 illustrates the LA-FFVF algorithm. In this case there are three data channels and one control channel. At the beginning, there are two bursts which occupy data channels 1 and 2 until t2 and t1, respectively. When the	[redacted]

control packet A1 arrives, A1 data burst is scheduled on channel 1 because is the latest available channel. Following the same criterion, data burst A2 is scheduled on channel 2. On the arrival of control packet B1, channel 3 is free and B1 data burst is here scheduled following First Fit criterion. On the arrival of A3 control packet, the latest available channel at t12 time is channel 2. Then, B2 data burst is scheduled in channel 2 using FFVF. Finally, B3 data burst is scheduled in channel 1 following first fit criterion.	[redacted]