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A Hybrid Model of Limited Burst Retransmission and Deflection Routing in Optical Switching Network

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Abstract**:** *Optical Burst Switching* (*OBS*) *is considered a promising optical switching technology for the future. However, a key issue of the OBS network is reducing dropped bursts due to contentions because there is no optical buffer at intermediate nodes. Several methods have been proposed to address burst contention, such as wavelength conversion, Fiber Delay Line* (*FDL*) *usage, deflection routing, or burst retransmission. Among these methods, deflection routing and burst retransmission are two approaches that do not modify the network infrastructure and can take advantage of idle resources on alternative connections. However, uncontrolled burst retransmissions and misrouting can lead to increased collisions, and potentially endless collision handling loops. This paper proposes a hybrid model of limited burst retransmission and deflection routing. Simulation results show that the proposed model has significantly improved resource utilization efficiency, burst-dropping probability, and end-to-end transmission delay.*

Keywords**:** *Deflection routing, Burst retransmission, Congestion resolution, Optical Burst Switching* (*OBS*)*, Network.*

1. Introduction

In recent years, people's communication needs have increased with a variety of services, so network systems must be able to provide large bandwidth and transmit a large amount of data at high speed [1, 3]. Optical networks, with Wavelength-Division Multiplexing (WDM) [5], have allowed high broadband speed and are a solution for the next generation of the Internet. Among them, Optical Burst Switching (OBS) technology is becoming a promising technology [19].

The characteristic of the OBS network is that the control packet BHP (Burst Header Packet) is separated from its data part (burst) in space and time; that is, the control packet will be sent first on a control channel, separate from the data channel and perform resource reservation for its burst at the core nodes of the network. With the way of data transmission as described, it is clear that the OBS network does not need optical buffers to temporarily store data bursts while waiting for switching processing at intermediate nodes (core nodes), and nanosecond speed switches are not required. However, this way of communication also puts pressure on how to have a BHP control packet reserve the resources and successfully configure the switch at the core nodes, ensuring the transmission of the data burst later. However, due to the natural explosion of data transmission networks and structures, the way of OBS network transmission, and the absence of optical buffering at intermediate nodes, burst congestion can occur when two or more control packets try to reserve the same channel at the output port at the same time. Therefore, the problem of solving burst congestion is significant in reducing data loss and improving the performance of the OBS network.

At present, some basic methods for dealing with congestion have been proposed, such as the use of fiber delay paths [8] to delay the arrival time of the burst until an output wavelength channel is available for scheduling, wavelength conversion [8] if the incoming burst is on a congested wavelength will convert to another available wavelength at the output port, deflection routing [**Error! Reference source not f ound.**, 16] is a method of resolving congestion by how to route a contention burst to an output port other than initially intended, or retransmit the burst [4, 11, 12] having the ingress node transmit a copy of the dropped burst when contention occurs at the core node. Deflection routing or burst retransmission are two methods that do not change the network system, can take advantage of available resources on other output port connections, and are being widely studied at present. However, uncontrolled burst retransmissions or deflection routing can lead to increased traffic flow, increased end-to-end communication delays, increased congestion for deflection routes, or possible deflected bursts can be repeated infinitely. In this paper, we will propose a hybrid model of burst retransmission and deflection routing. The proposed model promotes the advantages and limits the disadvantages of retransmission and deflection routing to improve the communication delay, the burst loss probability, bandwidth utilization rate, and the utilization efficiency of the OBS network

2. Related works

There are some approaches to retransmission and deflection routing that have been proposed to solve congestion at network core nodes, in which the combined approach of scheduling, retransmission, and deflection routing. Those have been considered as a solution to reduce the probability of burst loss, reduce communication delay, and increase the amount of traffic sent into the network.

The basic idea of the retransmission mechanism is to allow contested bursts to be retransmitted in the OBS layer. Many authors have proposed retransmission models, which are divided into two categories: passive/reactive [8, 15, 19] and active [2, 11, 13]. Passive retransmission reduces the probability of burst loss significantly at low loads but at high loads 0.8, 0.9 the implementation of retransmission of lost bursts will no longer be effective, and there are some cases like bursts that are close to the destination but perform retransmission is now insignificant.

For deflection routing [2], the basic idea is that when the incoming burst is congested at the original output port, instead of the dropped burst, it will route to another output port. The advantage of deflection routing is that it can utilize the free resources on the other outbound connection and, at the same time, reduce the cost of hardware devices such as retrofitting wavelength converters or FDL optical delay lines. However, in skewed routing, a burst that is deflected will make the path to the destination longer, leading to increased latency and reduced signal quality. Furthermore, it can lead to the possibility of the burst being infinitely repeated in the network and possibly leading to further congestion.

To take advantage of the advantages of burst retransmission and deflection routing and overcome the shortcomings of the above two methods, some authors [18] have proposed. Some models combine retransmission and deflection routing. The authors in [2] have proposed a model called Hybrid Deflection Routing (HDR) that combines retransmission and deflection routing. When contention occurs, the skewed routing method will be used; if the skewed routing encounters an error, the burst retransmission technique will be applied. As follows:

When a Data Burst (DB) arrives at an ingress node, a control packet (BHP) is sent first along the Shortest Path (SP). If the BHP packet reaches its destination node, an ACK (ACKnowledged) packet is sent back to announce the successful transmission.

In case the control packet cannot reserve a wavelength at a congested intermediate node, the algorithm will try to find another suitable path (with the second shortest path) and schedule the burst on the output port found to reach the destination. Upon reaching the destination, an ACK packet is sent back to the source node to announce the successful transmission.

- If the BHP cannot find another path, it will crash. In that case, a NACK (Not ACKnowledged) packet is sent back to the source node to notify the corresponding data burst has been dropped.
- The burst can be retransmitted each time a NACK packet returns to its source node.

In the case depicted in Fig. 1, the HDR algorithm will increase the line delay, but the deflected congested burst will still fail, forcing retransmission. Due to the misdirection path passing through more nodes, it fails to do so, leading to a significant increase in latency.

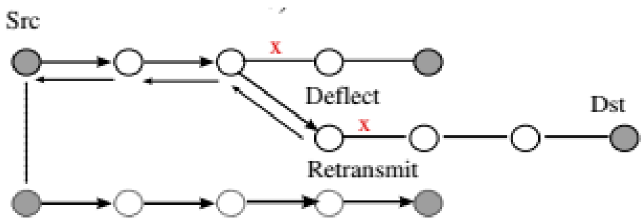


Fig. 1. Retransmission and deflection routing

This problem will occur more often as network traffic increases, resulting in a significant decrease in network performance. Therefore, in some cases, it is better to retransmit the burst immediately than to deflect it.

Author [2] proposes a Limited-HDR Algorithm (LHDR Algorithm) to improve the HDR Algorithm. In this algorithm, the choice between deflection and retransmission is decided based on the hop count of each journey. The deflection routing will be performed when the burst has passed more than one node and the deflection stroke is shorter than the primary stroke; otherwise, the burst will be retransmitted. As follows:

- When a BHP control packet arrives at a core node, it looks for an available wavelength on the default outgoing connection.
- Without this available wavelength, there are two possible scenarios:
  - Deflection: BHP will be sent on a different route with at least one available wavelength;
  - Retransmission: BHP will be dropped, and a NACK packet will be sent back to the source node.

This limitation allows the LHDR Algorithm to reduce the number of cases where aberrant routing is forced to retransmit, thereby increasing the advantages of combining redirection and retransmission to improve network performance.

Another algorithm that also performs a combination of redirection and retransmission is also proposed in [9, 5] – AHDR (Adaptive Hybrid Deflection and Retransmission). AHDR decides the choice between deflection and retransmission according to an adaptive mechanism. In AHDR, a success probability threshold based on Burst Loss Rate (BLR) and connection performance is used dynamically to decide between deflection and retransmission based on network state information. To be able to obtain this information, the AHDR algorithm uses the sending and receiving of ACK and NACK packets to report valuable statistics about the network conditions stored by all nodes. AHDR not only uses ACK and NACK packets as a signaling function like the LHDR Algorithm but also uses them to convey some statistics about the state of connections, BLR usage, and network performance, which measure each link to calculate the probability of success.

The author in [10] proposes the CPDR Algorithm (Combine Probabilistic Deflection and Retransmission Algorithm) to simulate the waste of resources and reduce the burst loss of the protocol that combines deflection and retransmission, which is better than pure deflection and transmission. The CPDR Algorithm is also a dynamic method like AHDR. The probability of deflection and retransmission is determined based on the level of congestion in the network. BLP is considered an indicator of congestion. Nodes calculate the BLP of outgoing links based on received ACK packets.

The results in [5] and [**Error! Reference source not found.**] show that AHDR i s more effective than the LHDR method when the load is less than 1 Erlang; when the load is equal to 1 Erlang, the BLR of these two methods is equivalent (about 0.1). At low load, AHDR performs more deflection; at high load, AHDR reduces the amount of deflection and increases the number of retransmissions to reduce BLR. But, a more significant number of retransmissions will cause lower performance. Thus, at high load, the AHDR method does not achieve the optimal burst loss rate compared to the LHDR method. Meanwhile, according to the results in [10], using the CPDR Algorithm; when the load is less than and equal to 1 Erlang, the BLP is almost zero, when the load is equal to 9 Erlang, the BLP is 0.1. Therefore, CPDR overcomes the disadvantage of AHDR under high load.

However, the above statements still have some unresolved issues, such as retransmission delay, offset time, communication throughput on the retransmission route, and deflection. The deflection calculation is based on the minimum number of nodes passing through, which is not suitable because, in some cases, the communication delay on the deflection path is larger than the burst lifetime, so the implementation is calculated in terms of degrees. Therefore, it is more appropriate to calculate based on the transmission delay. In this study, we propose a hybrid model of burst retransmission and deflection routing based on communication delay and network traffic on the retransmission and at the output port on the deflection path. The simulation and analysis results will confirm the advantages of this proposed model.

3. The hybrid model of limited burst retransmission and deflection routing

Consider an OBS network with support for retransmission and redirection, where the ingress node is responsible for replicating the assembled burst and storing a copy of it for retransmission purposes. In contrast, the core node plays the role of control over retransmission and deflection routing when an incoming burst cannot be scheduled. As shown in Fig. 2, a burst after being assembled will be duplicated at the input edge node: the main burst will be sent to the core network, while the replicated burst will be stored in a buffer for retransmission.

Assuming the ingress edge node is equipped with a buffer large enough to store copies of completed bursts, a copy is deleted when its main burst is successfully transmitted, and an ACK packet is received. The burst copy will also be deleted if its lifetime expires.

At the core node (which computes iteratively and stores the paths to ensure optimal routing), a scheduling algorithm (such as BFVF [13]) is called when a burst arrives. If the scheduling is successful, the burst is forwarded to the subsequent node, and this is repeated at the subsequent core nodes until the burst reaches its destination (outbound node). However, if the scheduling fails, retransmission or deflection routing conditions will be taken into account.

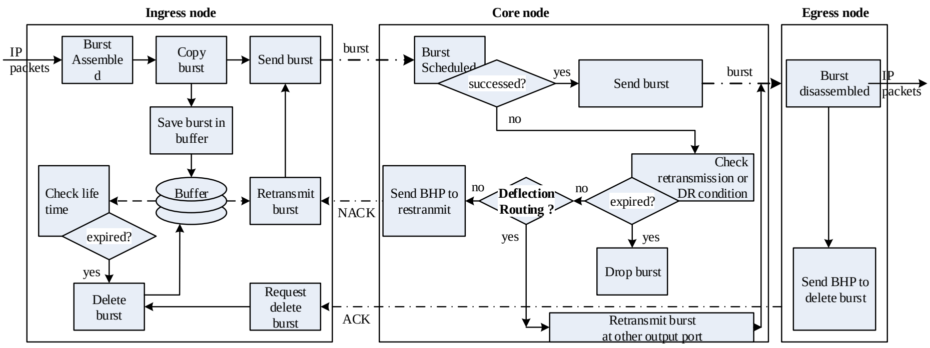


Fig. 2. A hybrid model of limited burst retransmission and deflection routing

A burst will be considered for retransmission or burst deflection over a different path to its destination if its lifetime is sufficient for retransmission or if it is possible to route the burst through a separate output port for routing purposes. The current bias and bandwidth on the outgoing connections have not reached the congested level. If both conditions are satisfied, the model will choose which state reduces the communication delay more.

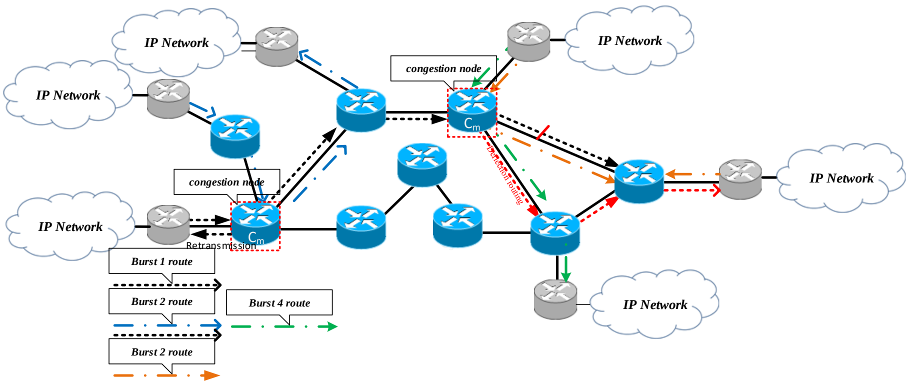


Fig. 3. A case of congestion in an optical burst switching network

Consider an end-to-end connection traversing n hops with bursts transmitted on paths 1, 2, and 3 as depicted in Fig. 3, assuming the processing time at the edge node is T_a (for burst aggregation) and $T_{a'}$ (for burst delay), the switching time at each core node is T_s and the propagation time in the optical network is T_p, the maximum end-to-end communication delay of a burst is

$T_{\mathrm{maxdelay}} = 2 \times (T_{\mathrm{a}} + n \times T_{\mathrm{s}} + (n-1) \times T_{\mathrm{p}} + T_{\mathrm{a'}}$; minimum transmission time from source to the destination: $T_{\mathrm{ub}} = T_{\mathrm{a}} + n \times T_{\mathrm{s}} + (n-1) \times T_{\mathrm{p}} + T_{\mathrm{a'}}$; Suppose a burst is congested at node $C_m (m < n)$ condition for retransmission of this burst is its communication delay to destination after retransmission with time $T_{\mathrm{ub}} + T_{\mathrm{NACK}}$ must be less than total lifetime max, T_{maxdelay}, with the time to retransmit the NACK control packet from the congested node m to the source node, $T_{\mathrm{NACK}} = m \times T_{\mathrm{s}} + m \times T_{\mathrm{p}} + T_{\mathrm{r}}$. With the condition to route the burst deflection through another output port, when finding a second path to transmit the burst to the destination and assuming the number of nodes passing on the deflection path to the destination is m', then the burst propagation time from source to destination is $T_{\mathrm{dr}} = T_{\mathrm{ub}} + T_{m'}$, where $T_{m'} = ((m + m') - n) \times (T_{\mathrm{s}} + T_{\mathrm{p}})$ and this time must be less than T_{maxdelay}. In the case of $T_{\mathrm{NACK}} > T_m$, then the proposed model will route the burst deflection routing through another output port, in the opposite case, retransmit the burst from the input edge node. As shown in Fig. 2, when burst 1 is congested at node $\mathrm{C_m}$, it performs deflection routing over the other path, while if congestion occurs at node $C_{m'}$ performs burst retransmission.

For a NACK packet, the information it needs to return includes the ID of the burst to be retransmitted, the remaining time of the burst (T_{ub}), and the burst channel. Based on this information, the ingress node will update the new lifetime of the retransmitted burst, as shown in Fig. 4.

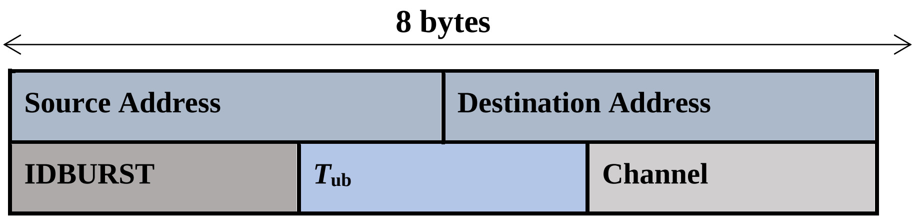


Fig. 4. The structure of the modified ACK packet

Another condition for a retransmission or deflection routing problem is that the current load circulating in the network cannot exceed a maximum threshold of available bandwidth. As recommended in [18], retransmission or deflection routing is only suitable when the normalized load is lower than 0.7 in order not to increase the current network congestion and to result in a deflection connection. The settings in the following section will also be based on this threshold value.

Consider a network shown in Fig. 5 with nine input edge nodes $(E_1, E_2, E_3, E_4, E_5)$ and five core nodes $(C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9)$, Assume that for burst transmissions 1, 2, 3 are sent from the input edge node E_1, E_2, E_4 to the output edge node E_1, E_2, E_4, with corresponding processing times

$$T_a = 1.5\ \mu s, T_{a'} = 1.5\ \mu s,\ T_s = 1\ \mu s,\ T_p = 0.5\ \mu s,\ T_r = 0.15\ \mu s,$$

and consider the congestion occurring at two core nodes C_1 and C_7.

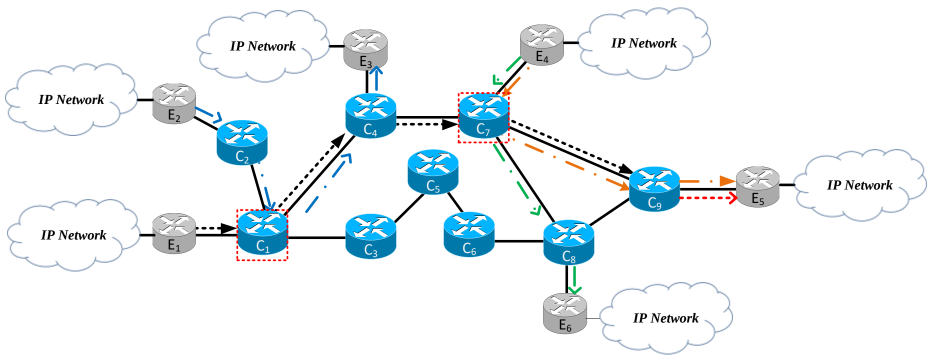


Fig. 5. An example of limited retransmission or deflection routing

Case 1. Suppose that the burst sent from node E_1 to node E_5 is congested at core node C_1. In this case, the model calculates the delay for burst retransmission and computes the delay on the congested burst deflection route as follows:

$$T_{maxdelay} = 2 \times (T_a + 4 \times T_s + 3 \times T_p + T_{a'}) = 17\ \mu s,$$
$$T_{ub} = T_a + 4 \times T_s + 3 \times T_p + T_{a'} = 8.5\ \mu s,$$
$$T_{NACK} = 2 \times T_s + 2 \times T_p + T_r = 3.15\ \mu s,$$
$$T_{ub} = T_{ub} + T_{NACK} = 11.2\ \mu s,$$
$$T_{dr} = T_{ub} + T_{m'} = 11.5\ \mu s.$$

For this case, the retransmission delay is smaller than the deflection, so the model proposes to perform burst drop and retransmission from the edge node into E_1.

Case 2. Considering the burst sent from node $E_1$to node E_4 is congested at the core node C_7, the delay if retransmission or deflection is calculated as follows:

$$T_{\max\text{ \_delay}} = 2 \times (T_{\mathrm{a}} + 4 \times T_{\mathrm{s}} + 3 \times T_{\mathrm{p}} + T_{\mathrm{a'}}) = 17\ \mu\mathrm{s},$$

$$T_{\mathrm{ub}} = (T_{\mathrm{a}} + 4 \times T_{\mathrm{s}} + 3 \times T_{\mathrm{p}} + T_{\mathrm{a'}}) = 8.5\ \mu\mathrm{s},$$

$$T_{\mathrm{NACK}} = 1 \times T_{\mathrm{s}} + 1 \times T_{\mathrm{p}} + T_{\mathrm{r}} = 1.65\ \mu\mathrm{s},$$

$$T_{\mathrm{ub}} = T_{\mathrm{ub}} + T_{\mathrm{NACK}} = 10.15\mu\mathrm{s},$$

$$T_{\mathrm{dr}} = T_{\mathrm{ub}} + T_{m'} = 8.5\ \mu\mathrm{s} + 1.5\ \mu\mathrm{s} = 10\ \mu\mathrm{s}.$$

For this case, the retransmission delay is larger than the deflection, so the model proposes to perform burst propagation deflection routing through node C_8.

Case 3. In the event that the delay of retransmission, deflection routing is greater than T_{maxdelay} or the current throughput circulating in the network exceeds a maximum threshold of available bandwidth, the congested burst will be dropped.

The retransmission algorithm associated with the limited deflection routing is described in detail as follows where:

- $b_{\mathrm{ub}}(\mathrm{Source_{node}}, \mathrm{Destination_{Node}}, s_{\mathrm{ub}}, e_{\mathrm{ub}}, \mathrm{len_{ub}})$, unscheduled incoming burst, where $\mathrm{Source_{node}}$ is the source node, $\mathrm{Destination_{Node}}$ Is the destination node, Isis the arrival time, e_{ub} is the end time, and the $\mathrm{len_{ub}}$ is the number of packets in a burst;
- W is the Number of output channels per link $W = \{1, 2, \ldots, w\}$;
- $T_{\mathrm{a}}, T_{\mathrm{a}}, T_{\mathrm{s}}, T_{\mathrm{p}}, T_{\mathrm{ub}}, T_{\mathrm{r}}, T_{\max\text{ \_delay}}$;
- m is the number of nodes through which the burst has passed;
- m' = number of deflection nodes;
- $\mathrm{DIJKSTRA}(m, \mathrm{Destination_{Node}}, \mathrm{kt}, m')$ function finds the shortest path from a node to a node, returning kt = true, if the path is found, kt = false, when not found, and the number of hops passed.

Combined Retransmission and Deflection Routing Algorithm at Core Node ReS_RD_OBS

Input:

- $b_{\mathrm{ub}}(\mathrm{Source_{node}}, \mathrm{Destination_{Node}}, s_{\mathrm{ub}}, e_{\mathrm{ub}}, len_{\mathrm{ub}})$;
- $W, T_{\mathrm{a}}, T_{\mathrm{b}}, T_{\mathrm{obs}}, T_{\mathrm{b'}}, T_{\mathrm{a}}, m, m'$;

Output:

- Scheduled burst at channel sc or drop;

Process

(Initial) $\mathrm{sc} = -1;\ \mathrm{best\_utilisation} = \infty;$
$\mathrm{sc} = \mathrm{BFVF}(b_{\mathrm{ub}}, W);$
IF $(\mathrm{sc} \neq -1)$ **THEN**
$\mathrm{SCHEDULE}(b_i, \mathrm{sc});$
ELSE
$T_m = T_{\mathrm{a}} + m \times T_{\mathrm{s}} + m \times T_{\mathrm{p}};$
$T_{\mathrm{NACK}} = m \times T_{\mathrm{s}} + m \times T_{\mathrm{p}} + T_{\mathrm{r}};$
$\mathrm{Dijkstra}(m, \mathrm{Destination_{Node}}, \mathrm{kt}, m');$
$\mathrm{Offsetime} = \frac{s_{\mathrm{ub}} - t_{\mathrm{bhp}}}{m'};$
IF $(\mathrm{kt} = \mathrm{true}) \wedge (\mathrm{Offsetime} > 0)$ **THEN**
$T_m' = ((m + m') - n) \times (T_{\mathrm{s}} + T_{\mathrm{p}}));$

$T_{\text{dr}} = m' \times T_{\text{s}} \; + \; m' \times T_{\text{p}} + T_{\text{a}'}$;

ELSE $T_{\text{dr}} = \propto$;

$\text{BW}_{\text{now}} = \frac{\sum_{k=1}^{W} \sum_{1}^{|SB_k|} \text{len}_j}{\text{BW}}$;

IF $((T_{\text{NACK}} < T_{\text{Maxdelay}}) \vee (T'_m < T_{\text{Maxdelay}})) \wedge (\text{BW}_{\text{now}} < 0.7)$ **THEN**

IF $(T_{\text{NACK}} < T_{m'})$ **THEN**

$T_{\text{ub}} = T_{\text{ub}} + T_{\text{NACK}}$;

$\text{SendNACK}(\text{IDBurst}, T_{\text{max\_delay}})$;

ELSE

$\mathbf{Routingdeflection}(\boldsymbol{b}_{\mathbf{ub}}, \boldsymbol{T}_{\mathbf{ub}}, \boldsymbol{m}')$;

$T_{\text{ub}} = T_{\text{ub}} + T_{m'}$;

ELSE

$\text{Drop}(b_{\text{ub}})$;

RETURN sc;

Controlled retransmission at the edge node

Input:

$\text{NACK}(\text{IDBurst}, \text{resendBurst})$;

Output:

Process

IF $(\text{NACK} = \text{resendBurst})$ **THEN**

$\text{Send}(\text{Burst}, \text{IDBurst})$;

ELSE

$\text{Delete}(\text{Burst}, \text{IDBurst})$;

RETURN.

4. Results and discussion

To prove the effectiveness of the model experimentally, we perform simulation settings ReS_RD_OBS and compare it with previously published retransmission models based on the probability of packet loss (packets contained in bursts), communication delay, and traffic sent into the network. The simulation environment is NS2 with the obs0.9a expansion pack [20] and C++ on the computer Intel Core 2 CPU 2.4 GHz, 2G RAM. The network model is simulated as described in Fig. 6, including five edge nodes $(E_0, \ldots, E_5)$ and nine core nodes $(C_1, \ldots, C_9)$.

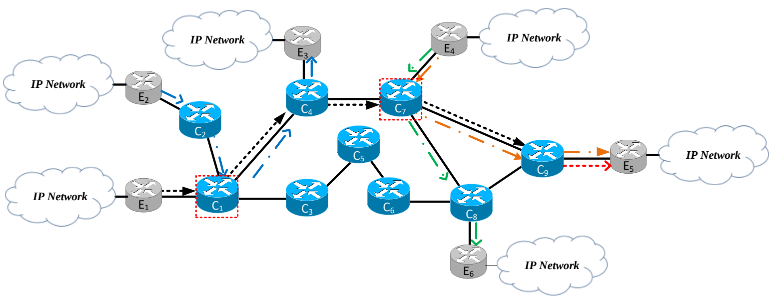
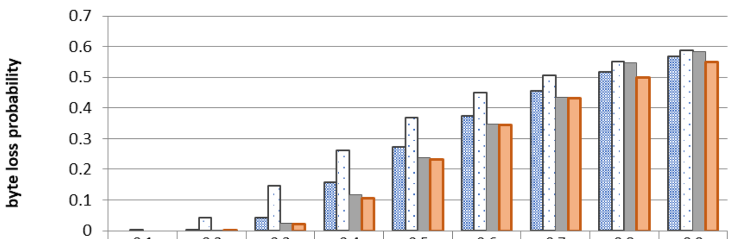


Fig. 6. Network simulation model

The bandwidth between nodes is 1Gb per 1 s; The incoming data streams at the edge node have a Poisson distribution with a packet size of 512 bytes. At each edge node, the hybrid burst aggregation threshold is used with a threshold length of 150 Kb and a time threshold of 100 µs. Each link has 8 data channels and 2 control channels. The simulation was performed with normalized loads from 0.1 to 0.9 and a simulation time of 20 s.

Simulation goals include:

- Comparison of byte loss probabilities among the models of passive retransmission, pure deflection routing, combined retransmission – deflection routing, hop-counted deflection routing, retransmission combined and deflection routing proposed model;
- Compare communication delay between the retransmission model combined with deflection routing, proposed model.



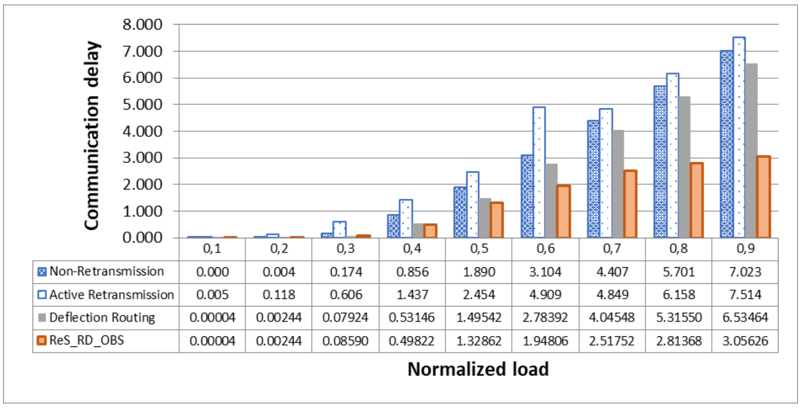
	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
Non-Retransmission	0	0.001521	0.042722	0.156401	0.271904	0.374917	0.456857	0.518465	0.567725
Active Retransmission	0.003425	0.041787	0.144971	0.262331	0.367681	0.450264	0.506561	0.552023	0.589445
Deflection Routing	0	0.000926	0.023535	0.116118	0.237202	0.346759	0.434284	0.548216	0.583785
ReS_RD_OBS	0	0.000926	0.021689	0.105700	0.233016	0.345409	0.433246	0.498625	0.551188

Normalized load

Fig. 7. Comparison of the Byte Loss Probability (BLP) of the non-retransmission, active retransmission, deflection routing, and ReS_SD_OBS

Through the simulation results shown in Fig. 7, when comparing the probability of byte loss between no retransmission, active retransmission, and passive retransmission, it shows that with active retransmission, the byte loss probability is higher than the other two models because when transmitting twice the flow into it, it will increase the congestion for the network and only suitable to perform guard transmission with priority bursts on a fixed link. Whereas with passive retransmission, the probability of byte loss is significantly reduced at low load, but at high loads of 0.8 and 0.9, the retransmission of lost bursts will no longer be effective, and this indicates true passive retransmission. Efficiency with the loads from 0.1 to 0.7. A comparison between the proposed model, passive retransmission, and deflection routing shows that the byte loss probability of the proposed model is significantly reduced at low loads and even on high loads. This can be explained because the retransmission model combined with the limited redirection is recommended when the scheduled incoming burst does not find the resource, at which point the model calculates the current bandwidth to determine the degree of network congestion. If the burst falls randomly due to the scheduling nature of the OBS network, the burst will be retransmitted; otherwise, when the load is high, the burst will be dropped and not retransmitted to reduce the congestion of the current network. Besides, the proposed model calculates the communication delay between retransmission and deflection routing to decide on a congestion burst.

A result is shown in Fig. 8 when comparing the communication delay when performing active retransmission, passive retransmission, deflection routing, and the proposed limited deflection routing combined retransmission model. It has been found that performing retransmissions or deviating routing reduces the communication delay for the network because the packets do not have to be resent from the source and reduce the burst aggregation time. The proposed retransmission model is significantly reduced compared to the remaining models when combined conditionally to solve congestion in the network and reduce communication delay, improving the operating efficiency of the optical burst switching network.



	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
Non-Retransmission	0.000	0.004	0.174	0.856	1.890	3.104	4.407	5.701	7.023
Active Retransmission	0.005	0.118	0.606	1.437	2.454	4.909	4.849	6.158	7.514
Deflection Routing	0.00004	0.00244	0.07924	0.53146	1.49542	2.78392	4.04548	5.31550	6.53464
ReS_RD_OBS	0.00004	0.00244	0.08590	0.49822	1.32862	1.94806	2.51752	2.81368	3.05626

Fig. 8. A comparison of the communication delay of the non-retransmission, active retransmission, deflection routing, and ReS_SD_OBS

5. Conclusion

Optical Burst Switching (OBS) is considered a promising communication technology for the near future. One significant challenge in OBS networks is the lack of optical buffers at intermediate nodes. When resource contention occurs between two bursts arriving simultaneously, one of the bursts may be dropped. To address this issue, several methods have been proposed, including burst retransmission and deflection routing for dropped bursts. Each method has its own advantages and disadvantages. Therefore, combining the benefits of both methods while minimizing their drawbacks is necessary. In this paper, we propose a hybrid model that integrates burst retransmission and deflection routing based on communication delay and network traffic conditions. This model considers retransmission delays and deflection path output port conditions. Simulation results demonstrate that our proposed model effectively alleviates congestion, reduces the likelihood of packet loss, decreases end-to-end communication delay, and improves overall network performance without requiring changes to the existing network infrastructure.

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