Cost Model Based Configuration Management Policy in OBS Networks

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Abstract. The one-way reservation strategy in Optical Burst Switching (OBS) networks causes a blocking problem due to contention in resource reservation. In order to solve this problem, in this paper, we propose a configuration management policy based on the operation cost model. We develop the operation cost model based on DEB according to network status information changed by guaranteed Quality of Service (QoS) and the network status decision algorithm, and develop policy decision criteria for configuration management by providing an alternate path using bounded range of the sensitivity of this cost. Finally, throughout our theoretical and experimental analysis, we show that the proposed scheme has stable cost sensitivity and outperforms the conventional scheme in complexity.

1 Introduction

The explosive growth of Internet traffic demands huge bandwidth in optical networks. Given that fact, bandwidth has increased dramatically due to advances in wavelength-division multiplexing technology. Optical packet switching (OPS) is considered a promising solution. However, limitations in optical technology such as optical buffering have yet to be resolved. Therefore, OBS was introduced as an intermediate technology. The most important characteristic of OBS is that it uses one way reservation by which data bursts are transmitted in offset time after transmission of control packets without any acknowledgement from the destination node [1]. Due to this one way reservation, when contention occurs at an intermediate node, two or more bursts that are in contention can be dropt. This is the reason why one of the critical design issues in OBS networks is finding efficient ways to minimize burst dropping resulting from resource contention.

To reduce the burst blocking probability and thus increase throughput, several viable methods are needed to solve the wavelength contention arising in OBS networks: buffering, wavelength conversion and deflection routing. In general, due to the immaturity in both optical buffering and wavelength conversion techniques, deflection routing has recently received a lot of attention. Deflection routing was first used as a contention resolution in mesh optical networks with regular topology. When a data unit arrives at an intermediate node in the network but finds that all wavelengths at the preferred port are not available, it will be switched to an alternate port. A deflection routing protocol for the OBS network has been proposed in many papers [2]-[4].

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As shown in these works, applying deflection routing in an OBS network can reduce data loss and average delay compared with data retransmission from the source. However, it can not be guaranteed that the control packet will reserve all the wavelengths across the destination over the alternate path, especially when traffic load is highly congested in a wavelength routed network. In addition, most of the deflection routing schemes that have been proposed do not address implementation problems encountered in the network such as architectural issues, control and management, and others. Therefore, we study a policy based configuration management model to compensate the existing control and management schemes in an OBS network.

In this paper, we propose an operation cost model based on the Quality of Service (QoS) guaranteeing scheme by decreasing the blocking rate and complexity in OBS networks. We consider operation cost based on the Deterministic Effective Bandwidth (DEB) and the additional cost when using the alternate path. Since total operation cost varies according to network status information, we propose a configuration management policy in which the sensitivity value of the total operation cost from DEB is estimated recursively from the Configuration Information Base (CIB). Through theoretical and experimental analysis, the proposed scheme outperforms the conventional scheme in complexity.

2 Operation Cost Model Based Configuration Management Policy

2.1 Operation Cost Model

In OBS networks, by sending a control packet before forwarding a data burst, resource reservation for the data burst can be carried out. Therefore, when a contention of resource reservation, which causes blocking status and QoS degradation, occurs, a cost for QoS degradation is represented by a DEB concept [5]. The cost based on DEB in a link (i, j) between source s and destination d is defined as follows [6],

$$C_{DEB}^{ij}(t) = C_{DEB}\left\{e_{D_{sd}}^{ij}(\alpha_{sd}^{ij}(t)) + \delta_{D_{sd}}^{ij}(D_{sd} - D_{sd}^{rq})\right\} \quad (1)$$

where $\alpha_{sd}^{ij}(t)$ represents the arrival curve of traffic flows in a link (i, j) between source s and destination d at time t. $e_{D_{sd}}^{ij}(\alpha)$ means DEB associated to given source s and the delay requirement D_{sd}^{rq} in a link (i, j). D_{sd} represents the actual delay of traffic that flows along to a path between source s and destination d. $\delta_{D_{sd}}^{ij}$ is a DEB sensitivity according to the delay variation, $\partial e_{D_{sd}}^{ij}(\alpha_{sd}^{ij}(t))/\partial D_{sd}$, in a link (i, j) between source s and destination d. C_{DEB} is a cost factor per unit of DEB.

Using above Eq. (1), the cost based on DEB is defined as follows:

$$C_{DEB}^{sd}(t) = \sum_{ij \in N_{sd}} C_{DEB}^{ij}(t) \,. \quad (2)$$

N_{sd} represents nodes that belong to the path between source s and destination d.

When a QoS constraint traffic by Service Level Agreements (SLAs) is transmitted across OBS networks, contention in the reservation process of a network resource can occur. At that time, in order to guaranteeing a required QoS for the traffic in contention within a tolerable range by the SLAs, an alternate path can be provided. In this case, the additional cost of the alternate path can be considered in two parts: the additional setup cost and the penalty resulting from transmission throughout the alternate path such as detour cost [7]. For the formulation, the variable $x_{i,j}$, which represents whether or not a link (i, j) is included in the path, is defined as

$$x_{i,j} = \begin{cases} 1, & \text{if the path includes a link } (i,j) \\ 0, & \text{otherwise} \end{cases}. \tag{3}$$

Using Eq. (3), when there is an alternate path between source s and destination d, the number of passed nodes before a current node in this path, H_{sc}^{sd}, and the number of remaining nodes after a current node in this path, H_{cd}^{sd}, are represented by,

$$H_{sc}^{sd} = \sum_{\forall i,\, i+1 \in N_{sc}} x_{i,\,i+1} \qquad H_{cd}^{sd} = \sum_{\forall i,\, i+1 \in N_{cd}} x_{i,\,i+1}. \tag{4}$$

N_{sc} and N_{cd} represent the number of nodes between source and a current node, and the number of nodes between a current core node and destination, respectively.

Using above Eq. (4), the cost of providing a alternate path is derived as follows:

$$C_{alt}(t) = C_{altsetup}(t) + C_{apc}(t) = C_{altsetup}\exp(\gamma.H_{cd}^{sd}(t)) + C_{apc}\left\{H_{A_{cd}}^{sd}(t) - H_{P_{cd}}^{sd}(t)\right\} \tag{5}$$

where $C_{altsetup}$ and C_{apc} are the unit cost by an additional path set up and by penalty from using an alternate path, respectively. γ is the proportional constant. $H_{cd}^{sd}(t)$ represents the number of remaining nodes after a current node in this path. $H_{A_{cd}}^{sd}(t)$ means the number of remaining nodes after a current node in the alternate path, and $H_{P_{cd}}^{sd}(t)$ means the number of remaining nodes after a current node in the primary path.

When a network provider determines that the alternate path isn't needed under the contention situation, resource reservation isn't possible, and the traffic is blocked. In this case, a penalty cost by this blocked traffic occurs, and this penalty cost is affected by the service type of traffic [7]. The penalty cost by burst drop is defined as follows:

$$C_{be}(t) = C_{be}\sum_{ij \in N_{sd}} S_{ij}(t). \tag{6}$$

C_{be} represents the penalty cost factor per unit. This cost is influenced by the service type of application. $S_{ij}(t)$ is defined as the service-specific cost function according to traffic flows on the link (i, j) between source s and destination d [7].

2.2 Cost Sensitivity Based Configuration Management Policy (CS-CMP)

Since the operation of configuration management in a network is different according to the network status, the operation cost is derived differently by the network status. In order to derive the operation cost model according to the network status for the configuration management policy, we consider the network status in an OBS network. This network status is divided into three statuses according to the guaranteed required QoS as follows: the status guaranteeing the required QoS (NS_{deb}), the status guaranteeing the tolerable QoS by providing the alternate path (NS_{alt}), and the burst drop status (NS_{be}).

In this paper, we consider burst scanning for division of the network status. Through burst scanning, the burst per channel can be measured by the number of bursts and the average burst size at a source edge node. The method for measuring the burst is to record the number of busy channels when scanning the channel periodically. The average burst size can then be obtained by dividing the amount of total traffic as the number of bursts. When the channels which the node can use are given as L_1, L_2, L_3, ... , L_i , we can expect the traffic load in the channel L_i as $T_{L_i} = B / S$ where B means the number of bursts, and S is the number of scanning [8]. In this process, we assume the burst size is larger than the period of the scanning, since when a longer period of scanning than the burst size occurs, the possibility of error in measuring traffic increases.

When the traffic load increases, the node can not assign a resource for the burst. Thus, we can expect contention situation by this measured traffic load. The network status is determined as follows:

$$NS = \begin{cases} NS_{deb} & \text{when } T_L \le \gamma_1 \cdot C \cdot i \\ NS_{alt} & \text{when } \gamma_1 \cdot C \cdot i \le T_L \le \gamma_2 \cdot C \cdot i \\ NS_{be} & \text{when } T_L \ge \gamma_2 \cdot C \cdot i \end{cases} \tag{7}$$

where $0 < \gamma_1 < \gamma_2 < 1$ and $T_L = \sum_i T_{L_i}$. γ_1 and γ_2 are the utilization factor. T_{L_i} is the amount of traffic in the i th channel, L_i and T_L is the amount of traffic through a link. i is the number of channel. C is the channel capacity. If the measured traffic is under the lower boundary by the utilization, the network status is NS_{deb} . If the measured traffic is between the lower boundary and the upper boundary, the network status is NS_{alt} . If the measured traffic is over the upper boundary, the network status is NS_{be} .

Using Eq. (7) and cost functions from the previous section, the total cost function in a path between source s and destination d is derived as follows:

$$F_{sd}(t) = \begin{cases} C_{DEB}^{sd}(t), & T_L \le \gamma_1 \cdot C \cdot i \\ C_{DEB}^{sd}(t) + C_{alt}(t), & \gamma_1 \cdot C \cdot i \le T_L \le \gamma_2 \cdot C \cdot i \\ C_{be}(t), & T_L \ge \gamma_2 \cdot C \cdot i \end{cases} \cdot \tag{8}$$

The total cost function means the cost in order to provide the path which guarantees QoS. When the data burst is transmitted from source *s* to destination *d* through an OBS network, if a bandwidth for guaranteeing the QoS constraint of this data burst is assigned, only the cost based on DEB is considered for the total cost function. However, if that bandwidth can't be assigned due to contention of resource or blocking status, the alternate path is needed to guarantee the QoS. In this case, the total cost function is represented by a sum of the cost based on DEB and the cost that results from providing the alternate path. Moreover, when it is no meaning that guarantees the QoS because of a continuous increment of operation cost, the total cost is represented by the penalty cost.

When the total cost from Eq. (8) is considered between source and destination, to increase this cost means that the cost for guaranteeing the required QoS increases, especially when network status changes such as the case of providing an alternate path. When the amount of traffic per each channel is expected by the burst scanning, the sensitivity of the total cost, $\zeta_F^{sd} = \partial F_{sd}(t) / \partial C_{DEB}^{sd}(t)$ from Eq. (8) and Eq. (2), means the variance of total cost according to the variance of the cost based on DEB between source *s* and destination *d*. Thus, we can derive the sensitivity according to the network status using the total cost function, *F*, as follows:

$$\zeta_F^{sd} = \begin{cases} 1, & T_L \le \gamma_1 \cdot C \cdot i \\ 1 + \dfrac{\partial C_{alt}(t)}{\partial C_{DEB}^{sd}(t)}, & \gamma_1 \cdot C \cdot i \le T_L \le \gamma_2 \cdot C \cdot i \\ \dfrac{\partial C_{be}(t)}{\partial C_{DEB}^{sd}(t)}, & T_L \ge \gamma_2 \cdot C \cdot i \end{cases} \quad (9)$$

When we consider the sensitivity according to $C_{DEB}^{sd}(t)$, the sensitivity value of *F* is dominant to the variation value of both $C_{alt}^{sd}(t)$ and $C_{be}^{sd}(t)$. In this equation, we assume that the value in the drop status NS_{be}, in which the required QoS by SLAs is not guaranteed, is not considered, since our proposed scheme relates to guaranteed QoS. Therefore, ζ_F^{sd} dominantly depends on the term, $\Delta = \partial C_{alt}(t) / \partial C_{DEB}^{sd}(t)$, which means the variation of the cost for providing the alternate path according to $C_{DEB}^{sd}(t)$.

When the alternate path is used in a contention situation in an OBS network, the cost for providing this alternate path occurs. This cost increases when the number of hops in the provided alternate path increases as shown in Eq. (5). In high channel utilization of the overall network, the selected alternate path includes many hops since high channel utilization means that most channels have a traffic load which is closer to the boundary; meaning, most nodes are under the contention situation. Therefore, as shown in Fig. 1, the value of Δ can have a positive value because the cost for the alternate path increases. However, if the utilization of channels in an overall network is closer to the boundary, it becomes more difficult to reserve the resource for the data burst. Accordingly, the selected alternate path has to include more hops. This increment of the number of hops causes an increment of the cost by Eq. (5). Thus, the value of Δ increases, so that the point in which this value exceeds the upper bound occurs. This upper bound is given by SLAs. By this upper boundary, it is determined to provide the alternate path. Therefore, the tolerable range by SLAs is represented in Fig. 1. When the sensitivity of total cost, ζ_F^{sd}, has the boundary by $\zeta_F^{sd} \leq 1+\Delta$, the value exceeding this boundary has no meaning in the network operation cost point of view, so that it need not provide an alternate path in this case.

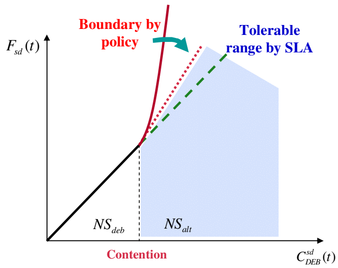

Fig. 1. Total cost *F* according to the DEB cost

3 Configuration Management Policy Decision Rule

In order to reflect the network status information, we make Network Status Information Base (NSIB) for collected network status information and Network Status Table (NST) as an updatable table. We assume that the value of NST, NS_{ij}, changes, and is then updated by the proposed algorithm according to the network status.

The condition factor C_h for a threshold check function is defined as follows:

$$C_h = H_{sc}^{sd} - H_{cd}^{sd}. \tag{10}$$

From Eq. (4), the value of this factor determines whether the current node is closer to source or destination. We have the condition factor by C_h, Q_h, as follows:

$$Q_h = \begin{cases} 1 & \text{if } C_h \geq 0 \\ 0 & \text{otherwise} \end{cases}. \tag{11}$$

If the current node is closer to destination *d*, the value of Q_h is one, otherwise, the value of Q_h is zero. Also we can obtain the other condition factor, $Q_{\delta_F^{sd}}$, from the boundary in section 2.3 and it is defined as follows:

$$Q_{\delta_F^{sd}} = \begin{cases} 1 & \text{if } \zeta_F^{sd} \leq 1+\Delta \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

where $\Delta = \partial C_{alt}(t) / \partial C^{sd}_{DEB}(t)$. $C_{threshold}$ means the boundary of ζ^{sd}_{F}. If ζ^{sd}_{F} is within the tolerable boundary $C_{threshold}$, the value of $Q_{\delta^{sd}_{F}}$ is one, otherwise, the value of $Q_{\delta^{sd}_{F}}$ is zero. When the decision factor is represented by a sum of above two condition factors, $Q_t = w_h Q_h + w_\delta Q_\delta$ (w_h, w_δ: weighting factors), the combined threshold check function can then be stated as

$$\mathrm{C}_{ALT} = \begin{cases} 1 & \text{if } Q_t = w_\delta + w_h \\ 0 & \text{otherwise} \end{cases}. \tag{13}$$

When the current node between source and destination is under a contention situation, if the node that is closer to destination *d* and the value of ζ^{sd}_{F}, which represents the sensitivity of the total operation cost, is within the tolerable range, the combined threshold check function C_{ALT} is one, so that the node makes a decision to deflect the alternate path. Otherwise, C_{ALT} is zero, so that the node makes a decision to drop the burst. When information is obtained from NST and NSIB, (a) of Fig. 2 shows the algorithm for decision of the threshold check function.

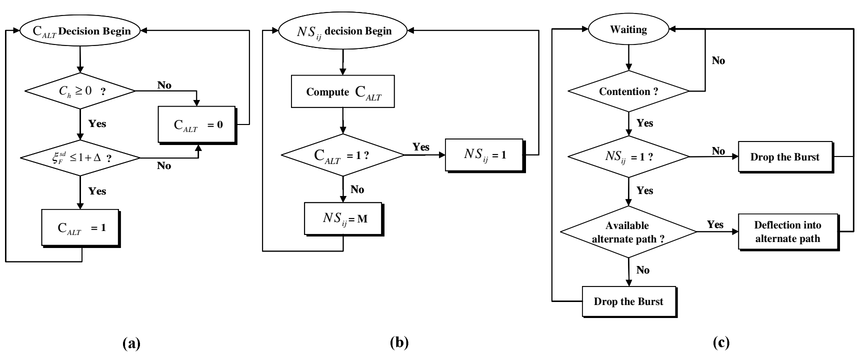

Fig. 2. The configuration management policy decision algorithm: (a) The threshold check function decision algorithm, (b) The NS_{ij} decision algorithm, (c) The CS-CMP algorithm

Next, (b) of Fig. 2 represents the algorithm for the decision of the network status on the link (*i*, *j*). We assume that the initial value of NST is zero. This algorithm is performed on the node under a contention situation. If contention occurs, the node computes C_{ALT} using the threshold check function algorithm. If C_{ALT} is one, NS_{ij} is then 1 because the network status at that time is NS_{ij}. Otherwise, NS_{ij} is M, which is bigger than the number of hops between source and destination in under NS_{be}. Finally, (c) of Fig. 2 shows the CS-CMP algorithm in order to decide the operation of configuration according to the information given by NST and NSIB. When the current node is under the contention situation, the node makes a decision whether the data burst is to be deflected to an alternate path or dropped according to the threshold check function, C_{ALT} .

4 Simulation and Results

In order to evaluate the performance of the proposed cost sensitivity based configuration management policy (CS-CMP), a simulation model is developed. We use the JET method of offset-based reservation in our simulation. The burst sources were individually simulated using the on-off model based on [2]. The simulation is carried out using a 14-node NSFNET topology. The transmission rate is 10 Gb/s, the switching time is 10 us, and the burst header processing time at each node is 2.5 us. The primary paths are computed using the shortest-path routing algorithm, while the alternate paths are the link-disjoint next shortest paths for all node pairs. Fig. 3 shows the results from this simulation.

The basic mechanism of CS-CMP is similar to CLDR. When the node is under a contention situation, an alternate path is provided by the threshold value. While CLDR uses linear programming for deflection routing, CS-CMP uses a comparison of the sensitivity of the total operation cost. As shown in Fig. 3, the blocking rate of CS-CMP increases an average of about 5.37% compared with CLDR. As well, the blocking rate of CS-CMP decreases an average of about 21.38% compared with DCR.

Moreover, in order to evaluate the configuration policy decision scheme in terms of cost, we consider the traffic source that is leaky bucket constrained with an additional constraint in the peak rate based on [9]. We assume that the NS_{be} is under a blocked situation and the service-specific cost function, $S_{ij}(t)$, is the function used in [7] according to the type of blocked service. We consider 50 different network status tables according to randomly generated traffic patterns under the given conditions. We assume an interval among incoming traffic scenarios is a monitoring interval. For each scenario, we compare the values of total operation cost function between the CLDR [2] and the proposed CS-CMP. The results are shown in Fig. 4.

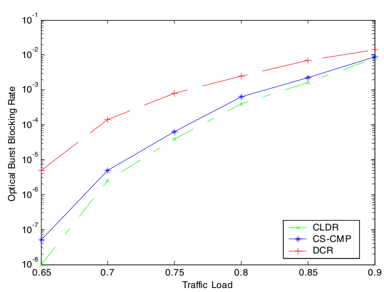

Fig. 3. Blocking rate comparison of CLDR and CS-CMP

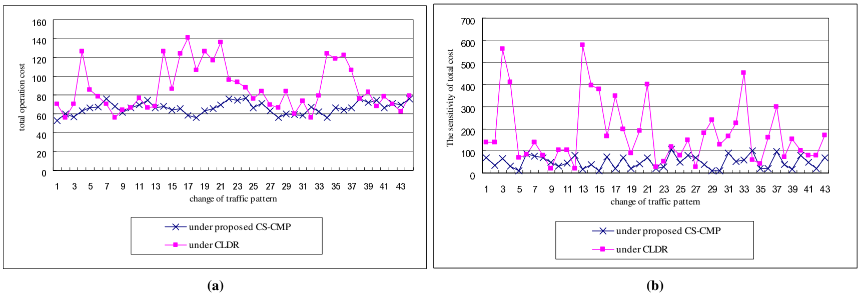

Fig. 4. (a) The total operation cost comparison, (b) The sensitivity comparison

For a comparison, the upper boundary for CS-CMP, $1+\Delta$, is assumed to be 100. In the case of CLDR, the total cost is about 4 times that of the proposed policy decision in terms of average total cost. This means that CLDR provides an alternate path in spite of high cost value. In addition, from the point of view of variation, the cost of CLDR fluctuates widely as shown in (a) of Fig. 4. Also, (b) of Fig. 4 shows that most of the sensitivity values in the case of CS-CMP are constant, at 100.

In order to compare complexity, we consider the big O function. For CLDR of [2], the complexity is represented by the iteration number of this algorithm which depends on the number of nodes. As well, each node runs linear programming in order to compute the alternate path. For this linear programming, each node has an algorithm iteration number of N^2 with the number of nodes, N. Thus, the total complexity for this algorithm can consider $O(N^3)$ with N. For DCR of [3] and CS-CMP, the complexity is computed in a similar way. Thus, the complexity for DCR depends on $O(N + N\log_2 N)$ and the complexity for CS-CMP is represented by $O(N^2)$.

5 Conclusion

In this paper, we proposed a configuration management policy for decreasing the blocking rate caused by contention as the critical issue. We also presented complexity in conventional schemes in OBS networks. For this configuration management policy, we developed an operation cost model based on DEB according to the network status information changed by guaranteed QoS. In addition, using the bounded range of the sensitivity of this cost, we proposed a network status decision algorithm, and developed policy decision criteria for configuration management by providing an alternate path. As shown in the comparison of the cost performance between our proposed scheme and conventional schemes, our scheme is performed under a stable state. As well, in comparing the blocking rate between our proposed scheme and conventional schemes, ours has good performance in terms of blocking rate. Moreover, by using the bounded range of the sensitivity of the total operation cost, our proposed scheme has a reducing effect of about 24% in terms of total operation cost. Finally, as the proposed scheme is applied to the OBS network, it is simple to implement in real networks and outperforms the conventional scheme in complexity.

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