An Adaptive Parameter Deflection Routing to Resolve Contentions in OBS Networks

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Abstract. Currently, the contention resolution is one of research focuses for optical burst switching (OBS). The paper presents a new contention resolution scheme, named as ***adaptive parameter-based deflection routing***, which can control the deflection according to the time-varying traffic load and the QoS requirements. Compared with other schemes, the simulation results show that it can improve the overall *BLP* and the individual *BLP* of each class burst, and alleviate the offset-time deficit on QoS guarantee.

Keywords. Contention, Deflection Routing, Optical Burst Switching, QoS

1. Introduction

Currently, many approaches[1]-[5] are proposed to resolve the burst contentions for OBS networks. Among them, the deflection routing is much more promising because of its lower requirements for optical components. However, the existing deflection routing algorithms[3]-[5] have some drawbacks in the control strategy and the path optimization. Motivated by the situations, the paper proposes a new contention resolution scheme, called ***Adaptive Parameter Deflection Routing*** (***APDR*** for short), which features largely in the adaptivity to the traffic load and the QoS requirements.

The rest of the paper is organized as follows. The adaptive parameter and optimization rule are defined in Section 2, where ***APDR*** is also proposed. Section 3 illustrates ***APDR***'s results and comparisons with its counterparts through numerical simulations. Finally, this paper is summarized in Section 4.

2. *APDR*: The Adaptive Parameter Deflection Routing Algorithm

OBS network can be represented as a connected graph $G(N, E)$, where N represents its nodes and E represents its links. $\{D_{ij}\}$ denotes the distance matrix of $G(N, E)$.

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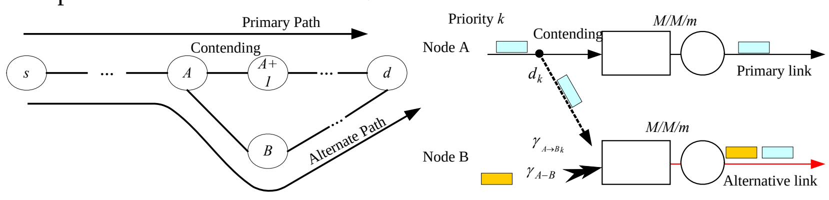
Assumed that the wavelength each link can support is *m*, and the *k+1-th* priority of burst has precedence over the *k-th* one.



(a) The deflection routing in the link *A-B* (b) The analysis model of the link *A-B*

Fig. 1. The analytical model of the *APDR* scheme

As a node *A* illustrated by *Fig.1a*, the contention probability $L_{A,\ A+1}$ of the primary link *(A, A+1)* will worsen with the increase of traffic load. The contending bursts can be deflected to other alternate link (e.g., link *(A, B)*) if it has available resource. Obviously, this can reduce $L_{A,\ A+1}$, and increase the utilization rate of link *(A, B)*. However, when the traffic load exceeds a certain threshold, this positive effect will fade away because the premise of deflection exists no more[4]. Here, an adaptive parameter is introduced to control the deflection, which is the deflection probability $d_{A,A+1_k}$ for the contending burst of priority *k* in the link *(A, A+1)*. Naturally, if the priority of contending burst is higher, and its load is heavy, then the deflections should be restricted more strictly because of the resource preempting of high priority deflected burst over low priority normal bursts. Based on the requirements, the parameter can be simply defined by the following expression.

$$d_{A,A+1_k} = (1 - r_{A,A+1_k}^{\theta_k/k}) \cdot L_{A,A+1_k} \qquad \forall k \in [1,N] \tag{1}$$

where $r_{A,A+1_k}$ denotes the ratio of the individual load of *k-th* priority burst to the overall one, and $\sum_{k=1}^{N} r_{A,A+1_k} = 1 \cdot L_{A,A+1_k}$ denotes *BLP* of the *k-th* priority burst.

From *(1)*, we can observe that the parameter for the lower priority burst is higher. However if its parameter is too high, it is possible that the deflection operation can obtain only a little insignificant *BLP* improvement relative to the resources consumed by the low priority deflected burst. Therefore, it is necessary to make a tradeoff between the priority and the parameter. Here, the tradeoff is obtained through a damper factor θ_k of the *k-th* priority burst, which can adjust the sensitivity of the parameter to the burst priority. Of course, the adjustment should satisfy the constraint.

$$\sum_{k=1}^{N} (1 - r_{A,A+1_k}^{\theta_k/k}) = 1 \tag{2}$$

As illustrated *Fig.1a*, the node *A* deflects the contending burst in the probability $d_{A,A+1_k}$ to an optimal deflection path from the contending node *A* to destination node *D* via the node *B*. Here to easily describe the deflection path, a Boolean variable x_{A,B_k} is defined as follows.

$$x_{A,B_k} = \begin{cases} \mathbf{1} & if\ Link(A,B) \in Alternat\_Path(A,D) \\ \mathbf{0} & otherwise \end{cases} \tag{3}$$

Then a constraint for the deflection path can be deduced as follows.

$$\sum_{j \in \mathrm{N}} x_{A,j_k} - \sum_{i \in \mathrm{N}} x_{i,A_k} = \begin{cases} 1 & if\ \mathrm{A = s} \\ -1 & if\ \mathrm{A = d} \\ 0 & otherwise \end{cases} \qquad \forall A, s, d \in \mathrm{N},\ and\ \forall k \in [1, N] \tag{4}$$

Assumed that the initial loads in *(A, A+1)* and *(A, B)* are $\gamma_{A,A+1}$ and $\gamma_{A,B}$, respectively. If the *k-th* priority bursts is deflected to the node *B*, the deflected load will add to the link *(A, B)*, which can be expressed as follows

$$\gamma_{A \to B_k} = (r_k \gamma_{A,A+1}) \cdot L_{A,A+1_k} \cdot d_{A,A+1_k} \qquad \forall k \in [1, N] \tag{5}$$

Known from [7]-[10], if the offset-time difference between different burst priorities is enough, the overall performance of OBS network can keep steady regardless of the number of priorities. Therefore from *Fig. 1(b)*, we can get the *BLP* of priority *k* in the link *(A, B)* after its deflection.

$$L_{A,B_k} = \frac{B(\sum_{i=1}^{k} (\gamma_{A \to B_i} + \gamma_{A,B}), m) - \sum_{i=1}^{k-1} C_{A,B_i} L_{A,B_i}}{C_{A,B_k}} \tag{6}$$

where *B(·)* denotes *Erlang B* formula, and C_{A,B_k} denotes the ratio of the individual load of *k-th* priority burst to the overall one in the link *(A, B)* after deflection, written as follows,

$$C_{A,B_k} = \frac{\gamma_{A \to B_k} + \gamma_{A,B} \cdot r_{A,B_k}}{\gamma_{A,B} + \sum_{i=1}^{N} x_{A,B_i} \gamma_{A \to B_i}} \tag{7}$$

Similarly, the overall *BLP* $L_{A,B}$ in the link *(A, B)* after deflection can expressed as follows,

$$L_{A,B} = B(\gamma_{A,B} + \gamma_{A \to B_k}, M) \tag{8}$$

In deflection routing, it is possible that *DB* (data burst) abnormally arrives at the intermediate nodes prior to its corresponding *BHP* (burst head packet). So these *DBs* must be dropped due to the ***offset-time deficit*** resulting in the previous deflection efforts to be fruitless. For the problem, [3]-[4] proposed one solution, i.e., *FDL* (Fiber Delay Line) buffering. However since it is unknown whether and where a burst to have conflict with others, the location and quantity of *FDL* to be configured cannot be decided. Obviously, it is too difficult to resolve it by *FDL* buffering[3]-[4]. Here, the paper tries to resolve it by the nonlinear integer programming to search an optimal deflection path. Naturally, it can be regarded as the following constraint of the optimal path.

$$\sum_{i,j} x_{i,j_k}(D_{i,j} + t_p) \le \delta_k \qquad \forall i, j \in \mathrm{N}, \forall k \in [1, N] \tag{9}$$

where t_p and δ_k denote the *BHP* process time and the initial offset-time, respectively. After δ_k and $D_{i,j}$ normalized by t_p, $D_{i,j}+t_p$ and δ_k can simplify to $D'_{i,j}$ and δ'_k, respectively. Then *(9)* can be reduced as follows,

$$\sum_{i,j} x_{i,j_k} D'_{i,j} \le \delta'_k \qquad \forall i, j \in \mathrm{N} \tag{10}$$

In terms of *BLP* and the e2e delay involved with the deflection interference, we can design the objective function to formulate the optimal deflection path by the similar method of [5], which can be stated as follows,

$$Min \quad \sum_{i,j} [x_{i,j_k} \gamma_{i \to j_k} (D'_{i,j} + L_{i,j_k}{}^{\varepsilon_k}) + x_{i,j_k} \gamma_{i,j} (D'_{i,j} + L_{i,j}{}^{\varepsilon})] \tag{11}$$

where ε_k and ε denote the individual and overall burst-loss cost factor, respectively, which can adjust the contribution of the burst-loss to the optimization of deflection path. Under the constraints *(2)*, *(4), (9)-(10)*, we can obtain optimum solution { x_{i,j_k} } to the object function *(11)*, which means that we find optimal deflection path.

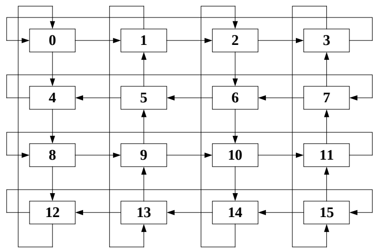
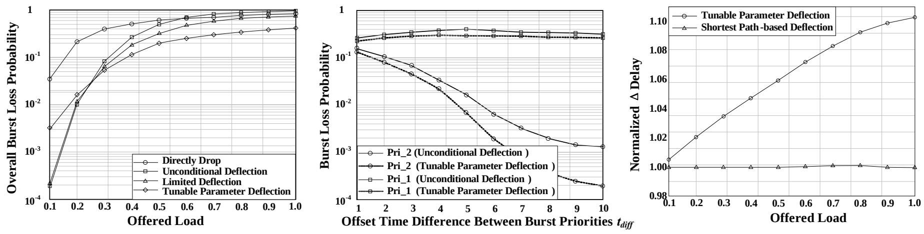


Fig. 2. 4×4 Manhattan street-based simulation network

3. Performance Study and Simulation Numerical Results

The following simulation will evaluate the performance of the proposed scheme in terms of *BLP* and the *e2e delay* by the comparisons with *Directly Drop*, *Unconditional Deflection*[4] and *Limited Deflection*[8]. Assumed that the simulation network is a 4×4 Manhattan street model illustrated by *Fig.2*, in which each link can support 4 wavelengths, its distance is one unit, and its data rate is 10Gbps. For simplicity of analysis, the burst is Poisson arrival, and its length L is fixed to 1Mbit. It can support 2 priorities, and the load ratio is assumed to be 0.5.

For different decision of deflection condition, *Fig.3(a)* illustrates their effects in terms of the overall *BLP* under different traffic load. Obviously, when traffic load is not heavy, i.e., $\rho<0.6$, the behavior of *Directly Drop* is the worst. Meanwhile the traffic load is much heavier, *APDR* can adaptively adjust the deflection probability according to the traffic load while *Limited Deflection* is insensitive to the variation of traffic load. Naturally, *APDR* behaves better than *Limited Deflection*. Compaered with *Directly Drop*, *APDR* can obtain the maximum gain *47%* in terms of the overall *BLP*.



(a)The traffic load ρ versus the overall *BLP* ($\theta=\varepsilon=\varepsilon_k=1$)

(b)The individual *BLP* versus t_{diff} ($\theta=\varepsilon=\varepsilon_k=1$, $\rho=0.6$)

(c) The traffic load ρ versus the average e2e delay ($\theta=\varepsilon=\varepsilon_k=1$)

Fig. 3. The performance comparisons of *APDR* with other schemes

Next, let us further compare the QoS guarantee capacity between *Unconditional Deflection* and *APDR* under different offset-time difference t_{diff}. Assumed that their QoS schemes are based on the offset-time. As illustrated *Fig.3(b)*, when $BLP=1.1\times10^{-3}$, *APDR* can support the differentiated service if t_{diff} is about *6L*. But for unconditional deflection, its t_{diff} is about *8L*. For other *BLP* case, there is the same trend, i.e., the t_{diff} for unconditional deflection is more than t_{diff} for *APDR*.

Finally comparing with the shortest-path based deflection, we will evaluate the end-end delay of *APDR*. Here, we concern the end-end delay suffered only by the burst successfully arriving at the destination. Certainly, the delay of the shortest-path-based deflection is less than that of *APDR*. As illustrated *Fig.3(c)*, the delay of *APDR* increases along with the traffic load. At the worst case, the delay of *APDR* is higher than that of the shortest-path based deflection about *10%.* It shows that *APDR* behaves very well in terms of its end-end delay. This benefit roots in the item $(\gamma_{i\to j_k}\cdot D'_{i,j})$ in the expression *(11),* which can adjust the relationship between the deflection path length and the input traffic load, that is, if traffic load is heavier, then the deflected burst should choose much shorter deflection path.

4. Conclusion

This paper proposed an adaptive parameter-based deflection routing algorithm, called as *APDR*, which can adaptively adjust the deflection probability according to the traffic load and the burst priority. Using the method in literature [5], this paper designed an object function based on the deflection probability. Under the three constraints (2), (4) and (10), we can find an optimum deflection path derived from the linear programming solutions.

The simulation results show that *APDR* outperforms *directly drop*, *unconditional deflection* and *the limited deflection* in the improvement of the overall *BLP* and the guarantee of differentiated service. In addition, *APDR* can efficiently circumvent the offset-time deficit, and requires less t_{diff} to support QoS. This is very helpful to reduce the end-end delay of *APDR*, which cannot exceed that of the shortest-path-based deflection about 10%.

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Reference

[1] X. Y. Yang, M. R. Dang, Y. J. Mao, and L. M. Li, “A New Burst Assembly Technique for Supporting QoS in Optical Burst Switching Networks”, Chinese Optics Letters, 1(5): 266-268, May 2003.

[2] M. Yoo, C. Qiao, S. Dixit, “A comparative study of contention resolution policies in optical burst switched WDM networks”, SPIE vol. 4213, pp. 124-135.

[3] Hsu, T. Liu, N. Huang, “Performance analysis of deflection routing in optical burst-switched networks”, Proc. of IEEE Infocom’ 02 (New York, USA, June 2002), 1: 66-73

[4] X. Wang, H. Morikawa, T. Aoyama, “Burst optical deflection routing protocol for wavelength routing WDM networks”, Proc. of SPIE Opticomm’2000, 257-266,Oct. 2000.

[5] S.K. Lee, H.S. Kim, J.S. Song, D. Griffith, “A Study on Deflection Routing in Optical Burst-Switching Networks”, Photonic Network Communications, 6(1): 51-59

[6] Y. Chen, H. Wu, D. Xu, C. Qiao, “Performance Analysis of Optical Burst Switched Node with Deflection Routing”, Proc. of IEEE ICC, 2: 1355-1359, 2003

[7] M. Yoo, C. Qiao, S. Dixit, “QoS performance in IP over WDM networks”, IEEE Journal on Selected Areas in Communications, 18(10): 2062-2071, October 2000.

[8] H. Kim, S. Lee, J. Song, “Optical burst switching with limited deflection routing rules”, IEICE Transactions on Communications, E86-B(5): 1550-1554, 2003

[9] K. Dolzer, C. Gauger, J. Späth, S. Bodamer, “Evaluation of reservation mechanisms for optical burst switching”, AEÜ Int. J. Electron. Commun., 55(1): 1-8, Jan. 2001.

[10] H. Vu, M. Zukerman, “Blocking probability for priority classes in optical burst switching networks”, IEEE Communications Letters. 6(5): 214-216, May 2002