Analysis of Wavelength Conversion and Deflection Routing in Optical Burst Switched Network

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ABSTRACT
In Optical Network contention is one of the big problem. Contention occurs when more than one burst demand for same output wavelength channel in same time. Wavelength conversion and deflection routing are the methods to resolve contention in Optical Network. In this case of wavelength conversion if any contentions occur then one of the burst's wavelength have to be changed from its current wavelength to another free wavelength channel. Another one is Deflection routing, in this case one of the contending burst is send in another route rather than primary route towards it's destination. This paper is for investigating of the effect of wavelength conversion and deflection routing in Optical Burst Switched network, i.e. here comparison is made between these different contention resolution schemes using Queueing model.

Categories and Subject Descriptors
C.2.m [Computer-communication Networks**]:** Miscellaneous

General Terms
Theory.

Keywords
Wavelength Conversion (WC), Deflection Routing (DR).

1 INTRODUCTION
Optical Network is well accepted as a future backbone network in Internet model [1]. Optical Burst Switching is also well accepted as the switching technology in Optical Network [2]. Optical Burst Switching is the technologies, which combines the positive features of both Optical Packet Switching and Optical Circuit Switching, but remove the disadvantages of both Optical Packet Switching and Optical Circuit Switching [3]. Optical fiber has huge bandthwidth; Wavelength Division Multiplexing (WDM) technology is the appropriate technology to utilize the huge bandwidth. In WDM the bandthwidth is divided into many wavelengths, like a highway which has different lanes where different vehicles can go its own speed don't interferes with one another. But the main problem in this network is the management of this huge bandwidth in efficient way. For brief discussion consider a network in Fig: 1 which has five nodes and each link has two wavelengths w0 and w1. In optical network, a message is sent from one node to another node using a wavelength continuous route; this is called ***lightpath*** [4] and the requirement that the same wavelength must be used on all the links along the selected route is known as the ***wavelength continuity constraint*** [4]. Again assume that <0,2>, <1,3>, <2,4>, <3,0> and <4,1> these pairs of nodes wants to communicate to each other's and for that they request as respectively. The Fig: 1 shows a possible way of routing four *lightpaths* P0, P1, P2 and P4, where Pi is the *lightpath* emanating from node *i*. Since P0 uses wavelength w0, P1 can use only w1, as P0 and P1 share a link, called ***distinct wavelength assignment constraint*** [4]. So *lightpath* P2 can use only w0 and also P3 can use only w1. Therefore, a *lightpath* cannot be established from node 4 to node 1 even though bandwidth (wavelength) is available on links (4, 0) and link (0, 1), due to the wavelength continuity constraint property. To solve the problem a wavelength converter is needed at node 0, which can convert the incoming signal of w1 wavelength to w0 wavelength. This method is called wavelength conversion, which can be applied at a contending node.

There is also another method to reduce contention in optical network that is Deflection routing. In this case one of the contending burst is send in different path rather than primary path [5][6][7]. From Fig: 2 each of the nodes 1 and 2 want to send burst in same time so there is a contention in node 4, in this case one of the burst can be routed to another route here it is following the route 2-4-5-6. So deflection routing is also an efficient technique to reduce burst in optical burst switched networks. This paper is arranged like as: in section 2 analysis of the wavelength conversion using queuing theory is done, is section 3 analysis of the deflection routing using queuing theory is done.

2 ANALYSIS OF A NODE USING QUEUEING THEROY
Consider the following obs network. See Fig: 3 in the case where there are three incoming links to the node and one outgoing link. Let say that each link has three wavelengths. Also considering the arrival process and service process is as Poisson process.

2.1 Without Wavelength Conversion
There is no wavelength conversion then the queuing model will be M/M/ 1/1. So the state transition diagram for first case is in Fig: 4. Where λ is traffic arrival rate and μ is the service rate of the queuing system. In case of without wavelength conversion

input signal and output signal will pass in same wavelength so it can be think as there is one server and here not considering the fiber delay line so the queue length is 1, so it can be think as a M/M/1/1 loss system [8]. The states of the system can be any one of the states.

Taking local balance from Fig: 4 this will be like as follow

$$p0 * \lambda = p1 * \mu$$

$$p1 = \frac{\lambda}{\mu} p0$$

$$p0 + p1 = 1$$

$$p0 = 1 - p1$$

$$p0 = 1 - \frac{\lambda}{\mu} p0$$

$$p0 = \frac{1}{1 + \frac{\lambda}{\mu}}$$

$$p1 = \frac{\frac{\lambda}{\mu}}{1 + \frac{\lambda}{\mu}}$$

Let us consider $\rho = \frac{\lambda}{\mu}$ then $p1 = \frac{\rho}{1+\rho}$ where p0 and p1 are the probability that the system will be in state 0 and state 1. From Erlang's-B [8] formula we can say that the probability of blocking will be

$$p_1 = \frac{\rho}{1+\rho}$$

$$= \frac{1}{1 + \frac{1}{\rho}} \tag{1}$$

when all the servers will be busy for service. This will occurs when there is no wavelength conversion.

2.2 With Wavelength Conversion

And if there is full conversion then it can be express as a system like M/M/3/3 or like as M/M/n/n queue [8]. So in this case blocking probability from [8] will be

$p_3 = \frac{\frac{1}{3!} \times \rho^3}{1 + \sum_{n=1}^{3} \frac{1}{n!} \times \rho^n}$ after calculating this is equal to $= \frac{1}{1 + \frac{3}{\rho} + \frac{6}{\rho^2} + \frac{6}{\rho^3}}$, so in case of M/M/n/n blocking probability is

$$p_n = \frac{\frac{1}{n!} \times \rho^n}{1 + \sum_{k=1}^{n} \frac{1}{k!} \times \rho^k} \tag{2}$$

If we compare the both above cases we can see that $p_3 \prec p_1$ and $p_n \prec\prec p_1$ so wavelength conversion will be beneficial rather than without wavelength conversion.

2.3 Without Deflection Routing

If there is no deflection routing then the queuing model will be M/M/ 1/1. So in this case blocking probability from [8] will be same like as equation (1). It is

$$p1 = \frac{\rho}{1+\rho} \tag{3}$$

2.4 With Deflection Routing

Considering Deflection Routing only it can be express as a system like M/M/n/k, where n is the number of different route from that node to the destination node and k is the number of input link to that node. There is two cases, these are as follows:

- if n>k, i.e., means number of servers are greater than number of arrivals. In this case there will no blocking condition.
- if n<=k, means number of servers are equal to number of arrivals then blocking probability will be

$$p_n = \frac{\frac{1}{n!} \times \left[\frac{\lambda}{\mu}\right]^n}{1 + \sum_{m=1}^{n} \frac{1}{m!} \times \left[\frac{\lambda}{\mu}\right]^m}$$

$$= \frac{\frac{1}{n!} \times \rho^n}{1 + \sum_{m=1}^{n} \frac{1}{m!} \times \rho^m} \tag{4}$$

If we compare the both above cases we can see that $p_n \prec\prec p_1$ so deflection routing will be beneficial rather than without deflection routing.

2.5 With Deflection Routing and Wavelength Conversion

Also considering Deflection Routing and Wavelength Conversion in same time then it becomes a system like as M/M/n*λ/k*λ, where k, n has same meaning as previous case and λ is the number of wavelengths in a link. Considering $s = n * \lambda$ and $r = k * \lambda$ then the system is M/M/s/r, here again there is two cases

- if s>r, i.e., means number of servers are greater than number of arrivals. In this case there will no blocking condition.
- if s<=r, means number of servers are equal to number of arrivals then blocking probability will be

$$p_s = \frac{\frac{1}{s!} \times \left[\frac{\lambda}{\mu}\right]^s}{1 + \sum_{m=1}^{s} \frac{1}{m!} \times \left[\frac{\lambda}{\mu}\right]^m} = \frac{\frac{1}{s!} \times \rho^s}{1 + \sum_{m=1}^{s} \frac{1}{m!} \times \rho^m} \quad (5)$$

In this case values of s>n so $p_s < p_n$.

3 CONCLUSION

From the above discussion see in case of without wavelength conversion and without deflection routing blocking probability is high which is also expected. In case of with wavelength conversion this is less than the previous case. Also in case of without deflection routing blocking probability high rather than with deflection routing. It gives less blocking probability using both deflection routing and wavelength conversion. Here a comparison of the existing contention routing schemes is made.

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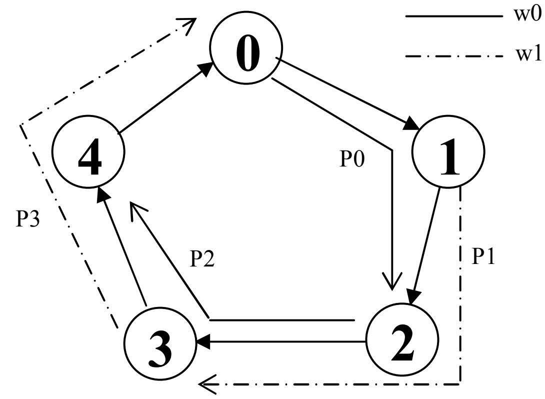

Figure 1: A wavelength routed network

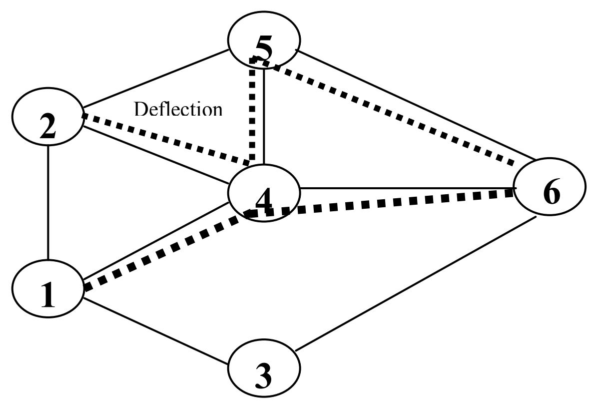

Figure 2: Deflection Routing

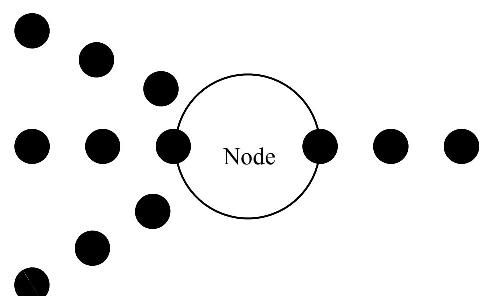

Figure 3: An OBS node

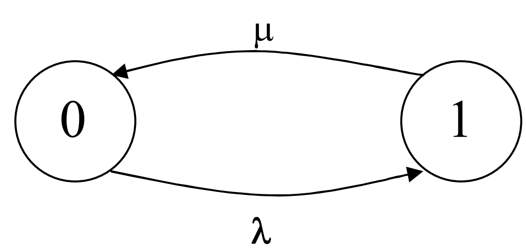

Figure 4: State transition diagram for M/M/1/1 queue

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