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Priority Based Wavelength Routed WDM Networks: A Queueing Theory Approach

Manoj Kr. Dutta[1], V.K. Chaubey[2]
[1] Birla Institute of Technology & Science/EEE Group, Pilani , India
Email: mkdutta@bits-pilani.ac.in
[2] Birla Institute of Technology & Science/EEE Group , Pilani , India
Email: vkc@bits-pilani.ac.in

Abstract—: **The present paper proposes a new model for priority assignment to the incoming call connection request for all optical WDM communication, adopting standard queuing theory concept. The model has been proposed for three different levels of call connection priorities, categorizing them into three types of signals as type0, type1 and type2 according to increasing priority, and generation probabilities of P_0, P_1 and P_2 respectively. The traffic at the node will be serviced according to the priority leveled on the header of the assigned packets. A traffic throughput model has been developed to evaluate the blocking probability of three types of connection requests.**

Index Terms— **Priority Assignment, Blocking Probability, Packet Service Probability**

I. Introduction

The development of the information society imposes basic requirements for modern communication network by demanding huge capacity and guaranteed quality of services. The main reason is wide spread usage of IP, over which, not only data, but also voice and video, i.e. multimedia contents are also being transmitted [1].

All optical communication has been proposed as a promising candidate for providing high-speed networking [2-4] because of the huge bandwidth of optical fiber. Optical communication can support a bandwidth in the range of THz utilizing wavelength division multiplexing system [5]. Several technologies have been proposed for WDM networks, including broadcast and select, wavelength routing, optical packet switching (OPS), and optical burst switching for optimum traffic routing and network management[6,7]. In an OPS network, the key component is the optical interconnect (or optical switch) which forwards the packets to their destinations. As in other packet switched networks, the WDM interconnect needs to combat output contention. In a WDM interconnect; output contention arises when more than one packet on the same wavelength are destined to the same output fiber at the same time. When this occurs, one will have to either temporarily store some of the packets in a buffer, or to convert wavelengths of the packets to some idle wavelengths by wavelength converters [2].

At the optical buffer the packet is delayed for some time, which depends on the granularity of the delay line after that the packet will come out of the delay line and attempt to be transmitted again along with the newly arrived packets. If it fails to be served then the packet will be dropped or blocked. But by using limited range of wavelength converter the packet blocking probability can be reduced significantly. The blocking probability decreases with increase in the number of wavelength channels also [5]. However as shown in the performances of network with limited range wavelength converters are close to those with full range wavelength converters even when the conversion range is small. Therefore it is a more realistic and cost-effective way to provide wavelength conversion ability.

All existing WDM wavelength assignment algorithms so far (as far as we know after a thorough study) do not support the priority concept [8]. Lack of priorities in the current wavelength assignment algorithms can severely limit the viability of WDM networks as the next generation networks. For example, in practice, an on-line trading or video-conferencing connection, e-booking, Tele medicine should normally be considered more important than an ordinary file transfer application. Emphasis has also been made to put more intelligence onto the WDM nodes to implement distributive or online traffic control [9–13] to achieve a better network management through efficient routing and switching [14].

In this present paper, a concept of queueing-based channel assignment for a WDM network has been introduced to incorporate priority in the selection of light path for optical traffic management. This priority-queueing based channel assignment ensures the transmission of a high-prioritized packet prior to a low prioritized one. Therefore, it can handle a variety of traffic having different applications and priorities. To achieve this let us assume that S output channels are allocated to a generic system model, a part of which will be used by all of the type0, type1 and the type2 calls, a separate part will be used only by the type1and type2 another one part of the available channels will be used only by the type2 calls.

II. Analytical Model

The state of the output channels should be modeled as shown in the figure 1. The output state could be

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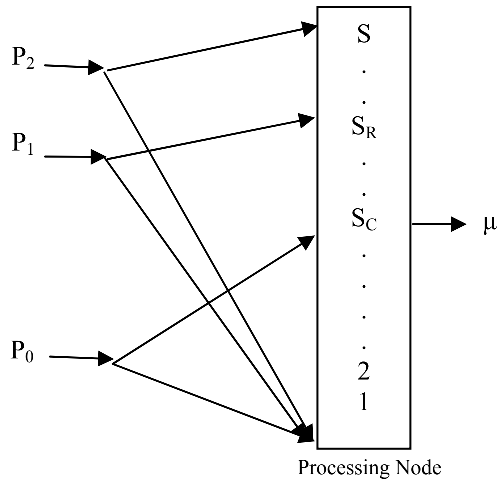

Fig.1: System Model with priority connection

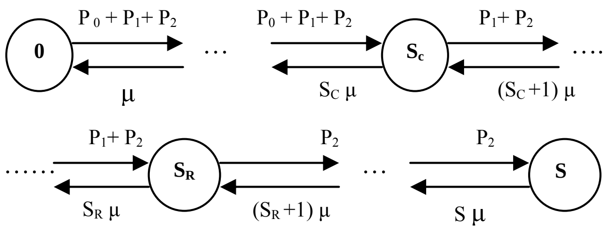

Fig. 2: State transition diagram for figure 1

represented by (S+1) states Markov model, with each state indicating the number of busy channels [15]. This leads to a state transition diagram of the M/M/S/S model as shown in fig 2.

One way of assigning priority to urgent and very urgent call connection request are by assigning (S_R - S_C) channels exclusively for both the urgent request and very urgent request where (S-S_R) channels are assigned exclusively for the very urgent call connection request among the S output channels. S_C channels are shared by all types of connection requests. Here P_0 , P_1, P_2 are originating probabilities of type0 call, typ1 call and typ2 call respectively. μ is the packet service probability.

The steady state probability P(i) can be determined with the state transition diagram in fig. 2. The state balance equations can be obtained as

$$i\,\mu P(i) = (P_0 + P_1 + P_2)\,P(i-1) \quad \text{for } 0 \le i \le S_C$$

$$i\,\mu P(i) = (P_1 + P_2)\,P(i-1) \quad \text{for } S_C < i \le S_R \qquad (1)$$

$$i\mu P(i) = (P_2)\,P(i-1) \quad \text{for } S_R < i \le S$$

Using these equations recursively, and the addition of all (S+1) states as

$$\sum_{i=0}^{S} P(i) = 1 \qquad (2)$$

The steady-state probability P(i) can be obtained as

$$P(i) = \frac{(P_0 + P_1 + P_2)^i}{i!\,\mu^i} P(0) \quad \text{for } 0 \le i \le S_C$$

$$P(i) = \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{i-S_C}}{i!\,\mu^i} \quad \text{for } S_C \le i \le S_R$$

$$P(i) = \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{i-S_C}.P_2^{\,i-S_R}}{i!\,\mu^i} \quad \text{for } S_C \le i \le S$$

Where,

$$P(0) = \Big[\sum_{i=0}^{S_C} \frac{(P_0 + P_1 + P_2)^i}{i!\,\mu^i} + \sum_{i=S_C+1}^{S_R} \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{i-S_C}}{i!\,\mu^i} + \sum_{i=S_R+1}^{S} \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{i-S_C}.P_2^{\,i-s_R}}{i!\,\mu^i}\Big]$$

The blocking probability B_0 for a normal connection request i.e type0 signal is for the useable channels S_C,

$$B_0 = \sum_{i=S_C}^{S} P(i) \qquad (5)$$

Similarly the blocking probability B_1 of an urgent connection request i.e, type1 signal having channel access from 1 to S_R can be derived as

$$B_1 = \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{S_R - S_C}}{S_R!\,\mu^{S_R}} P(0) \qquad (6)$$

Finally the blocking probability B_2 having access to all the given channels S can be expressed as ,

.

$$B_2 = \frac{(P_0 + P_1 + P_2)^{S_C}.(P_1 + P_2)^{S_R - S_C}.P_2^{\,S-S_R}}{S!\,\mu^S} P(0) \qquad (7)$$

These equations are used to evaluate the node performance under the modeled traffic and proposed priorities.

III RESULTS AND DISCUSSION

Relations shown in the equations (5) , (6) and (7) clearly reveals that the blocking probabilities are varying with strategies adopted in priority planning for traffic engineering..

The above equations are used to compute the blocking probabilities for given generation probabilities of the incoming traffic at the proposed node. Fig 3(a) and 3(b) present the blocking probabilities for all the incoming traffic with the same generation probability equal to 0.001 involving 10 channels at the processing node.

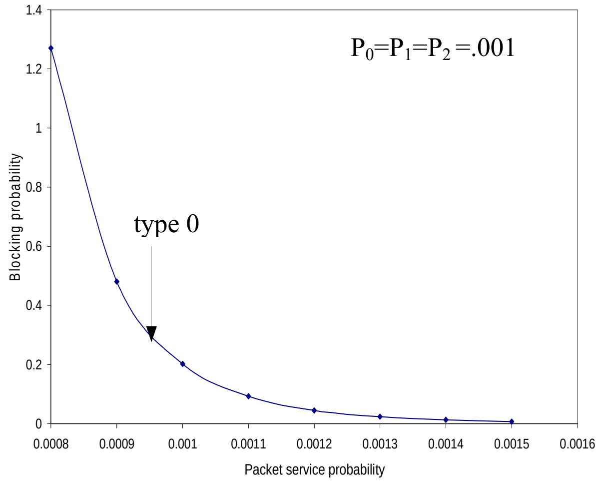

Fig. 3(a)

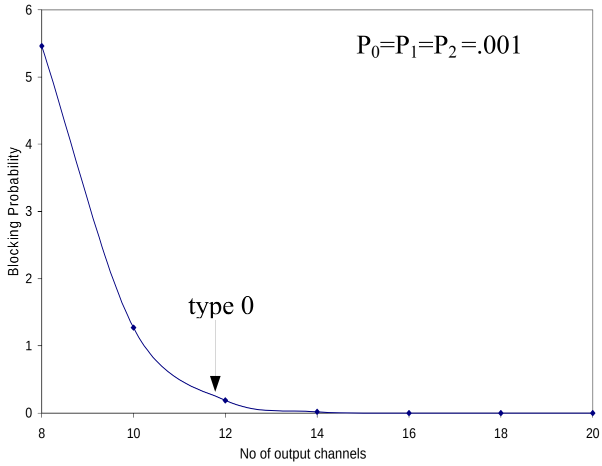

Fig. 4(a)

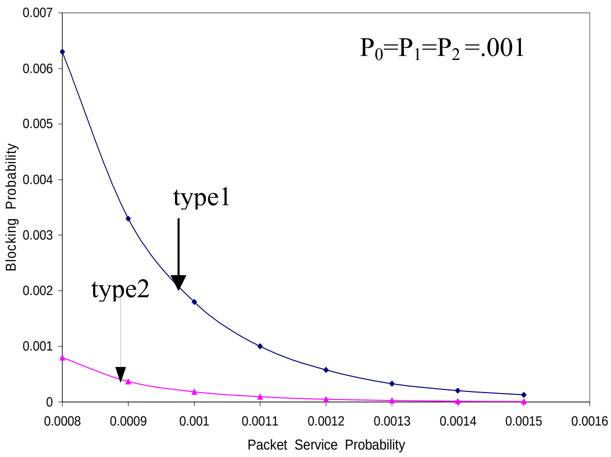

Fig. 3(b)

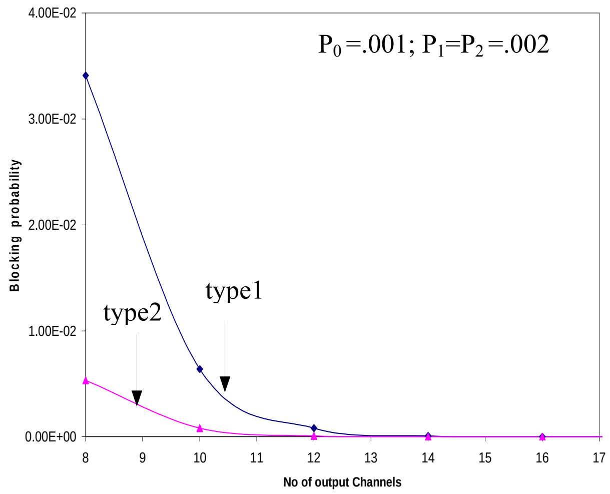

Fig. 4(b)

Fig3: Blocking probability Vs Packet service probability
(a) Type 0 (b) Type1 and Type 2

Fig4: Blocking probability Vs Number of output channels
(a) Type 0 (b) Type1 and Type 2

For the computation purpose channels 1-8 have been assigned for all types of incoming traffic and channel 9 is assigned for type 1 & type2 traffic, leaving channel 10 only for type 2 which is assumed to possess the highest priority.

This may lead to larger availability of channels for type1 and type2 traffic to ease the packet processing. The blocking probability is found to be an order of difference for the type0 case as compared to the tyep1 and type2 incoming traffic. The graph shown in the fig 3(a) depicts the blocking probability for type0 and fig 3(b) shows the same for the remaining type1 and type2 traffic. It may be inferred that the blocking probability for all the case are qualitatively similar, but type0 traffic has significantly higher blocking probability as compared to other types of consideration due to lower number of available channel in this case.

It is obvious to note that for a high speed processor the blocking probability of incoming traffic reduces to almost zero, hence making the outgoing traffic independent of priority. This is also evident from the graph shown fig 3(a) and 3(b) for service probability beyond 0.0015.

The model can further be used to investigate the effect of variation of output channels on the blocking probability. Fig.4 (a) and 4(b) shows the influence of output channels variation for a fixed value of packet service probability and generation probabilities. Here it is observed that the blocking probability decreases for all types of incoming traffic with the increasing in available number of output channel.

The model can further be used to investigate the effect of variation of output channels on the blocking probability. Fig.4 (a) and 4(b) shows the influence of output channels variation for a fixed value of packet service probability and generation probabilities. Here it is observed that the blocking probability decreases for all types of incoming traffic with the increasing in available number of output channel.

The model has also been used to find out the effect of generation probabilities on blocking probabilities by changing P_1 and P_2 from 0.001 to 0.002 keeping the output channels unchanged. Fig. 5(a) and 5(b) represent

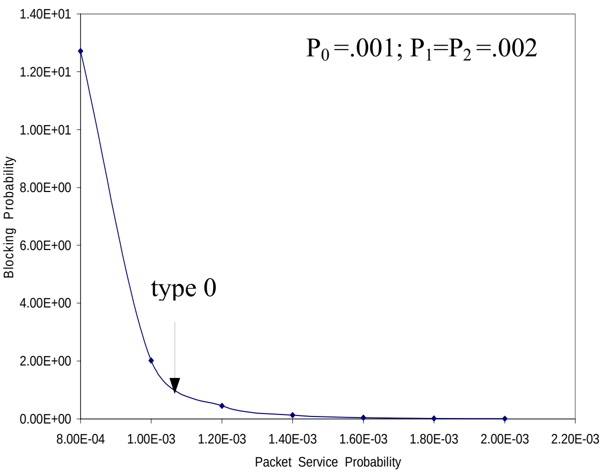

Fig. 5(a)

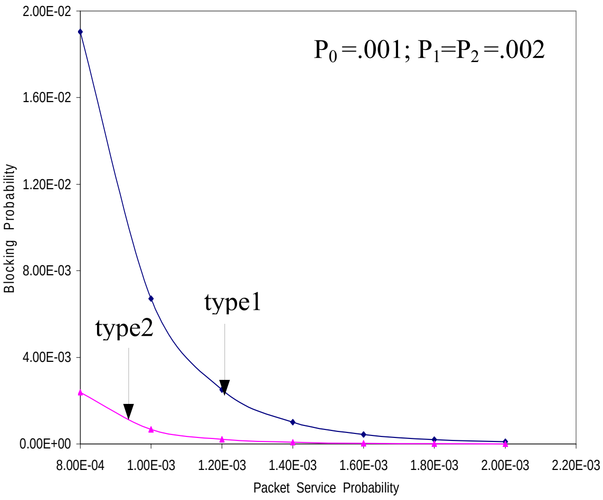

Fig. 5(b)

Fig5: Blocking probability Vs Packet service probability
(a) Type 0 (b) Type1 and Type 2

the blocking probability for a node processor with same specification as used for fig 3(a) & 3(b) except the generation probability.

The qualitative behavior for this case is found to be same as discussed in fig.3 (a) and 3(b) with a significant quantitative difference. This signifies that the increment in generation probability can be counter balanced by increment of packet service probability or by increasing the number of output channels. These strategies may be used for proper traffic management in a WDM network. It is envisaged that proper priority control and dynamic allocation of available channels in different priority category opens a scope for lower blocking probability.

IV. CONCLUSION

In this paper, a generic analytical approach is proposed to evaluate the performance of a priority assigned all optical WDM node for three different types of calls . Markov model in queuing theory has been applied to find the blocking probabilities for three different types of priority based calls. It is concluded that assignment of priorities and the number of available output channels result a remarkable influence on the blocking probabilities for incoming traffic.

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