CHAPTER 6

MULTILEVEL FEEDBACK QUEUE
WAVELENGTH ASSIGNMENT ALGORITHM IN
SURVIVABLE OPTICAL WDM NETWORKS

6.1 INTRODUCTION

To face the growing traffic demand in optical networks, WDM technologies provide the increase in network capacity (Rajkumar et al 2008 and Vinh Trong Le et al 2005). The light-path must travel on the same wavelength from source node to destination node in optical WDM networks. Routing of traffic sessions is subjected to wavelength continuity constraint. Wavelength converters allow the network to support huge amount of traffic. However, such converters are likely to be expensive. Hence, this work focuses on the RWA problem without wavelength converters. RWA determines the routes and assignment of wavelengths to light-paths, using the available number of wavelengths. In WDM networks, RWA problem is a key issue in managing the resources. The process of routing the light-paths was discussed in Chapter 4. This chapter is concerned with the wavelength assignment problem.

In optical network, fault management is essential for the robustness and reliability of both the network and the services carried over it. To predict the failures and to guarantee proactive fast re-routing of the network, an ANN based fault detection and localization algorithm was developed and reported in chapter 3. For recovering the network from failures, a hybrid adaptive load
shifting approach has been implemented. FF and other wavelength assignment algorithms such as RF, LU and MU algorithms face non-uniform utilization of wavelengths which leads to increase in connection drop rate. In RR wavelength assignment algorithm, the connection request waits indefinitely in the queue for the requested wavelength. So, the average queuing delay will be more in case of RR wavelength assignment algorithm.

The objective of this chapter is to develop an algorithm for wavelength assignment that minimizes the average connection drop rate and utilizes the wavelengths equally in a network that has a fixed number of wavelengths.

6.2 RELATED STUDY

Anpeng Huang et al (2008) developed LAF routing algorithm, FM wavelength assignment and SPP scheme to achieve high-level performance in Africa TWO network. From the simulation results, it is observed that the suggested SPP algorithm provided better resource distribution and achieved load balancing in the network.

Two classes of adaptive QoT aware RWA algorithm for networks with physical impairments was compared and presented by Siamak Azodolmolky et al (2010) .When networks are heavily loaded, calls are blocked because of poor QoT, measured by BER. The reported fair QoT-aware adaptive RWA algorithm decreases the BER and improves the fairness in blocking probability and BER without any connection drop in the network.

Based on the combination of given FF list with a dynamic constraint on XPM incidence, Raul Almeida et al (2008) implemented a wavelength assignment algorithm. It has been shown that the use of dynamic constraint on XPM incidence on the wavelength assignment improves the
blocking performance obtained by strict FF assignment with carefully selected impairment-aware lists.

Jun He et al (2009) discussed and presented a new heuristic offline wavelength ordering algorithm for wavelength allocation. Based on the performance of wavelength assignment algorithms in Shortest Path and Fixed Alternate routing, they studied the impact of guarantee with the QoS, by combining both BER and latency constraints. From the results, it is observed that the reported heuristic algorithm minimizes the crosstalk due to adjacent wavelength power leaking through WDM de-multiplexers.

Tarek Hindam (2009) explained the behaviour of different strategies to analyze the RWA problem in reasonable time. The algorithm has explained the dependence between the number of representation graphs and the shortest light-path in terms of hops.

To solve the dynamic wavelength assignment problem in wavelength-convertible networks, Ching-Fang Hsu et al (2009) presented a heuristic algorithm, named LWCC. Simulation results show that LWCC outperforms the existing algorithm significantly in terms of blocking performance. Also, the performance of LWCC is not as sensitive to waveband granularity compared to the existing algorithm.

Nina Skorin-Kapov et al (2010) investigated the RWA problem in transparent optical networks. They presented a novel objective criterion, called the maxLAR approach. Comparing the results with existing approach, the reported maxLAR approach obtained better improvement in network security.

To serve a connection request, Manousakis (2010) developed an IA-RWA algorithm and described the mechanisms required to compute them.
The IA-RWA algorithm calculates all the cost-effective and feasible light-paths for the given source-destination of the network.

For a concatenated ring network, Kiyo Ishii et al (2010) developed an optimal wavelength assignment algorithm that minimizes the number of wavelengths. They also presented the traffic separation scheme, hierarchical switching scheme for inter-ring traffic and introduction of efficient protection switching for reducing the switch scale of the nodes for a ring-concatenated network.

Namik Sengezer et al (2010) investigated the light-path establishment problem in the presence of physical layer impairments. They presented an efficient heuristic ROLE algorithm for the light-path establishment problem. This heuristic algorithm is shown to be superior to the existing Pre-ordering Least Impact Offline (POLIO) RWA algorithm.


6.3 PROPOSED MFWA ALGORITHM

In this section, the suggested MFWA algorithm is described in detail. MFWA algorithm is a dynamic wavelength assignment algorithm which minimizes the average connection drop rate in the network. MFWA algorithm overcomes the problems of wavelength assignment algorithms (addressed earlier). In MFWA approach, the scheduler determines the queue to which the light-path request should be sent. For wavelength assignment, new connection requests are sent to Queue $Q_3$, while the intermediate connection
requests are sent to Queue $Q_1$ and Queue $Q_2$ depending on the availability of wavelengths. Figure 6.1 shows the block diagram of the MFWA algorithm:

![Block Diagram of MFWA Algorithm](image)

**Figure 6.1 Block diagram of MFWA algorithm**

The suggested MFWA algorithm implements two or more scheduling queues. The processing steps of the MFWA algorithm are given below:

Let, $w_m$ denotes the set of wavelengths and $w_m = \{\lambda_1, \lambda_2, \lambda_3, \ldots \lambda_n\}$

Let, $Q_1, Q_2, Q_3$ be the queues and each queue assigned with $w_1, w_2, w_3$ wavelength sets.
Let, $X=x$, $Y=y$ and $M=m$ where $x$, $y$ and $m$ are number of queues, number of wavelengths and number of wavelength sets respectively.

1. Calculate the shortest path ‘$k$’ for every source-destination pair.

2. Connection requests are queued in First In First Out (FIFO) fashion.

3. If the scheduler receives the new connection requests $CR_{new}$:

   3.1 if any free space in the $Q_1$ is available

      3.1.1 if any free wavelength $\lambda_y$ in the wavelength set $w_m$ is available, assign the wavelength $\lambda$ randomly from the wavelength set $w_m$.

      assign $CR_{new} = RF(\lambda_y, w_m)$ \hspace{1cm} (6.1)

   3.2 else if any free space in the $Q_2$ is available

      3.2.1 if any free wavelength $\lambda_y$ in any wavelength set $w_m$ is available, assign the lowest indexed wavelength $\lambda$ from the wavelength set $w_m$.

      assign $CR_{new} = FF(\lambda_y, w_m)$ \hspace{1cm} (6.2)

   3.3 else if any free space in the $Q_3$ is available

      3.3.1 if any free wavelength $\lambda_y$ in any wavelength set $w_m$ is available, assign the first indexed wavelength for the connection request. The connection request chooses the next numbered wavelength $\lambda$ and so on for every subsequent request.

      assign $CR_{new} = RR(\lambda_y, w_m)$ \hspace{1cm} (6.3)
4. else go to Exception.

5. Exception :
   if all the paths has been tried
   then
       connection request is blocked;
   else
       select an alternate path and go to step 1;

6.4 SIMULATIONS

The experiments are carried out to analyze the performance of suggested MFWA algorithm. The performances of the existing algorithms are also presented for comparison by simulating a NSFNET that has a similar topology considered in the earlier chapters.

6.4.1 Results and Discussion

Here, the simulation results for the suggested MFWA compared with the existing FF, RF and RR wavelength algorithms are presented. Traffic load of the network is compared with different metrics such as connection drop rate, packets received, average queuing delay and channel utilization. The load is assumed as 2MB, 4MB, 6MB, 8MB, 10MB, 12MB and 14 MB.
Figure 6.2 Variation of Connection drop rate with load

The variation of connection drop rate for the suggested MFWA and the existing algorithms for various traffic loads viz., 2MB, 4MB, 6MB, 8MB, 10MB, 12MB and 14 MB are depicted in Figure 6.2. It is seen from the Figure 6.2 that the connection drop rate for the suggested MFWA algorithm is significantly less than the existing algorithms. This improvement is due to the balanced utilization of wavelengths achieved in the suggested algorithm. In MFWA, the wavelength blocked demands and unutilized wavelengths move between the queues so that the wavelengths are utilized uniformly. For example, when the load is 8 MB, the connection drop rate with MFWA algorithm is only 0.44, whereas the drop rate achieved by the existing FF, RF and RR wavelength algorithms are 0.9, 0.66 and 0.47 respectively.
The variation of packet received with load is presented in Figure 6.3 for MFWA algorithm compared with the existing algorithms for various loading conditions. For a network load of 8 MB, it is observed that number of packets received by the suggested MFWA algorithm is 5500, whereas the existing FF, RF and RR algorithm receives only 3760, 4120 and 5140 packets respectively. This higher packet receiving capacity is possible due to the reduced connection drop rate achieved in MFWA algorithm.
Figure 6.4 Variation of Channel utilization with load

Figure 6.4 shows the utilization of channel by the suggested MFWA algorithm with reference to the existing wavelength algorithms. For a traffic load of 8 MB, the Figure 6.4 shows that the MFWA algorithm achieves channel utilization as 0.8 Mbps, whereas the existing FF, RF and RR wavelength algorithms achieves 0.34 Mbps, 0.38 Mbps and 0.72 Mbps respectively. From Figure 6.4, it is proved that MFWA algorithm achieves comparatively better channel utilization than the existing algorithms, since all the available wavelengths are utilized uniformly.
Figure 6.5 Variation of Average queuing delay with load

Variation of average queuing delay with load is given in Figure 6.5 for the suggested MFWA algorithm compared with the existing algorithms. It is observed that the average queuing delay using MFWA algorithm is significantly lesser than the existing algorithms. It is observed from the figure 6.5 that the average queuing delay using MFWA algorithm is significantly less than the existing algorithm. For example, when the network load is 8 MB, the average queuing delay using MFWA algorithm is 0.003 ms, whereas the average queuing delay for FF, RF and RR wavelength assignment algorithms are 0.007ms, 0.006ms and 0.0038ms respectively.
Figure 6.6 Variation of Wavelength utilization with wavelength number

Figure 6.6 shows the wavelength utilization by the suggested MFWA algorithm with reference to the existing wavelength algorithms. From the Figure 6.6, it is seen that the MFWA algorithm achieves uniform wavelength utilization, whereas the existing FF, RF and RR wavelength algorithms achieves unbalanced wavelength utilization than the suggested MFWA algorithm. The unbalanced wavelength utilization in the existing system is due to connection drop rate involved in FF and RF approaches, indefinite waiting time for the requested wavelength in RR approach. This improved wavelength utilization is due to uniform distribution of all available wavelengths in the suggested MFWA approach.
6.5 CONCLUSION

In this chapter, the performance of the suggested MFWA algorithm has been analyzed for various performance metrics such as connection drop rate, packets received, average queuing delay and channel utilization. MFWA algorithm improves the balanced and uniform utilization of wavelengths in the network. The uniform utilization of resources minimizes the average connection drop rate for the session requests in the network. By the simulation results, it is shown that the suggested algorithm achieves reduced connection drop rate and delay with increased channel utilization and throughput.