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A new kind of dynamic RWA algorithm with QoS and link protection under the constraint of wavelength continuity

Li Du[a],Yin Zheng[b],a*

[a]*Northeastern University, HePing strict WenHua road, Shen Yang, 110819, China*
[b]*Northeastern University, HePing strict WenHua road, Shen Yang, 110819, China*

Abstract

A new kind of dynamic RWA algorithm with QoS and link protection mechanism under the constraint of wavelength continuity is presented. Using a peculiar link protection method, a protection routing is established with unique links and working routing for every service request. Additionally, the wavelength information is taken into account to make the entire network load balanced with respect to routing choice. It is known that when the network is trouble-free, load balance is needed, and when there are some links destroyed in the network, a protection mechanism is needed. This new algorithm includes these two mechanisms while also adopting a kind of QoS guaranteed mechanism. This allows for a better network performance even under the situation that some links were destroyed and includes a higher quality of service guarantee and a lower rate of service blocking. The simulation results show that this algorithm can significantly improve the rate of service blocking and guarantee the quality of service to meet expectations.

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Kewords:QoS; dynamic RWA; protection mechanism; wavelength continuity

1. Introduction

While the Internet has brought revolutionary changes to the world, the emergence of voice, video and other multimedia services on the network have put forward higher requirements. The birth of optical

* Corresponding author. Tel.: +8613840304540; *E-mail address*: duli@ise.neu.edu.cn.
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networks gives us much convenience due to the ability to offer abundant bandwidth capacity. As one of the optical network's key technologies [1], the study of the RWA [2-4] (Routing and Wavelength assignment) problem is very important. In a traditional RWA algorithm, the solutions generally first choose the routing and then assign the wavelength. There are several issues in this solution [5-6]--to be discussed later on, so in this work a new solution is proposed to solve the existing defects and give the service requests a better QoS guarantee [7-9] when finishing the routing choice and simultaneously assigning the wavelength. If there is not any protection mechanism [10-11], when some links are broken down, the network's performance will be deteriorated seriously, so it is necessary to apply some protection mechanism.

In this work, a new kind of dynamic RWA algorithm with QoS and link protection mechanism under the constraint of wavelength continuity is first presented and then compared with traditional RWA algorithm and some improved dynamic RWA algorithms [12-14]. Whether the network is working normally or with some links destroyed, the presented algorithm can not only optimize the blocking rate (by load balance) [15], but also support QoS well. A necessary experiment is then presented in order to validate the predicted conclusions mentioned above.

2. Experimental

2.1. Separate RWA (Sep RWA for short)

In the optical network, this RWA algorithm is considered as a very basic and simple algorithm. By examining its defects, a better RWA algorithm can be created. In this RWA algorithm, three things are done: first, a routing is chosen for the service request, then an available wavelength on the routing is chosen, and finally a quality of service guarantee is made. The specific descriptions of this RWA algorithm are as follows:

Step 1 Initialize the whole network, and set the link weight to be 1 for every link in the network. Then, according to OSPF (open shortest path first), find a minimum of routing hops to create an end-end connection for service requests.

Step 2 Make every multiplexed wavelength a number from 1 to N. If there isn't any wavelength available, the service request is blocked, otherwise choose a minimal wavelength number to create the service connection (First-Fit wavelength assign algorithm).

Step 3 When there are both higher and lower priority level service requests, ensure that the higher priority level service request is routed and assigned a wavelength first.

It is obvious that this RWA algorithm, when calculating routing through OSPF, doesn't refer to any information about wavelength. This makes it unable to balance the load (the amount of every link's working wavelengths tends to be balanced) and therefore it is unable to optimize the network's blocking rate.

2.2. Improved RWA (Imp RWA for short)

This RWA algorithm overcomes the separate RWA algorithm's inherent defects, for in this algorithm the link weight isn't set as 1 all of the time. Instead, it changes with the amount of the wavelengths that are available in the link. The more available wavelengths, the lower that the link weight is, allowing it to perform load balancing last. And once an appropriate routing has been chosen, a relevant wavelength is assigned. The specific descriptions of this RWA algorithm are as followings:

Step 1 Initialize the whole network and set every link's basic link weight b_{ij}=1 (or any constant).

Step 2 When the service request arrives, find the relevant routing according to OSPF. If there are two or more routings available, calculate to choose the one which has the maximum summation of available wavelengths in its every link path.

Step 3 Apply the First-Fit wavelength assignment algorithm. Change the link weight, if a link path has used one wavelength correctly then its weight is increased by 1, if it has used two wavelengths then its weight is increased by 2, and so on. If a link path's weight is bigger than N+1, set its weight to be ∞.

Step 4 Calculate the total link weight. If the chosen routing's total weight is less than ∞, it means that the service request was accomplished successfully, otherwise the service request was blocked. Go to step 2.

Step 5 When there are both higher and lower priority level service requests, ensure that the higher priority level service request is routed and assigned a wavelength first.

In this RWA algorithm, we have applied to the network a smaller blocking rate and a better QoS performance, but when there are some links broken down both the performance of the blocking rate and the QoS will be deeply affected It is therefore necessary to offer the network some protection mechanism to give it an additional level of optimization.

2.3. RWA with protection mechanism (Pm RWA for short)

To increase network satisfaction (a smaller block rate and a higher QoS guarantee) even when there are some link paths in trouble, it is necessary to give the network some protection mechanism. The specific descriptions of this RWA algorithm are as follows:

U_{ij}^{k} is used to show in a link path L_{ij} the wavelength λ_k's relevant information:

$$U_{ij}^{k} = \begin{cases} 0, & \lambda_k \text{ is available} \\ 1, & \lambda_k \text{ is used by lower priority services request's protection link paths} \\ 2, & \text{other} \end{cases} \quad (1)$$

The cost function of link e_{ij}^{k} and link e_{ji}^{k} is:

$$C(e_{ij}^{k}) = C(e_{ji}^{k}) = \begin{cases} b_{ij}, & U_{ij}^{k} = 0 \\ b_{ij}(1+M), & U_{ij}^{k} = 1 \\ \infty, & \text{other} \end{cases} \quad (2)$$

Among them, b_{ij} is the link's basic cost and is composed of many factors, including the length of the link, the construction cost, and so on; M is a constant and is influenced by the max hops of the whole network (represented by N), and M needs to meet the constraint ($N \leq M < \infty$).

The mathematical model of choosing routing and assigning wavelength between node A and node B can be shown as:

$$\text{Weightopt} = \min \left\{ \sum_{p \in P} \sum_{e \in E} C(e) \cdot X_{ep} \cdot X_p \right\} \quad (3)$$

Where Weightopt shows the total cost between node A and node B.

This contains two special conditions: first, when $X_p \geq 2$, the link path is chosen which has the maximum summation of available wavelengths; and secondly, for the lower priority services request, the Weightopt is also constrained by the condition $Weightopt \leq b_{ij} \cdot M$.

P is the collection of routings between node A and node B, E is the collection of links in the network's physical topology, C(e) is the cost of link e, and the definition of X_{ep} and X_p is:

$$X_{ep} = \begin{cases} 1, & \text{link e has been chosen by routing p} \\ 0, & \text{link e hasn't been chosen by routing p} \end{cases} \quad (4)$$

$$X_p = \begin{cases} 1, & \text{routing p is chosen from P} \\ 0, & \text{routing p isn't chosen from P} \end{cases} \quad (5)$$

The specific algorithm program is:

Step 1 In the network's physical topology G, initialize the cost of the links.

Step 2 Wait for light trigger events: if it is a service connection request, distinguish the priority of the service and go to step 3; if it is service quit request go to step 4.

Step 3 Establish light connections for different service priority connection requests.

- (1)Assuming that the service connection is requested between node A and node B, and has found routing p through OSPF:
  a) If the total cost of p is ∞ (for lower priority service request is Mb_{ij}), service request is blocked. Go to step 2.
  b) If the total cost of p is less than ∞ (for lower priority service request is Mb_{ij}), then an appropriate routing has been found and a relevant wavelength has been assigned successfully.
- (2)Establish protection routing for the working routing.
  Change the cost of every link that is used by the working routing to be ∞ (this changed cost can only be perceived by the protection routing that is relevant to the working routing), then the way to find the protection routing is the same as the working routing; If (1) (2) have be done successfully, go to step 4, else go to step 2.

Step 4 Release the resource that is occupied by the optical service requests, recover the relevant link's cost to be the initial value, and go to step 2.

3. Performances evaluation

The network's physical topology used in the experiment represents a small Internet Service Provider's backbone network with 9 nodes and 12 duple-links and is shown in **Fig.1**.

Fig.2 (a) and **Fig.2** (b) show separately the comparison for both rate of service blocking and QoS satisfaction between separate RWA and improved RWA. It indicates that there is almost no difference in the rate of blocking and QoS satisfaction between the two algorithms when the traffic is lower. But the improved RWA shows much greater performance with increasing request numbers.

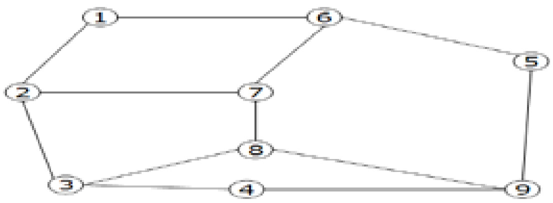

Fig.1 Network topology

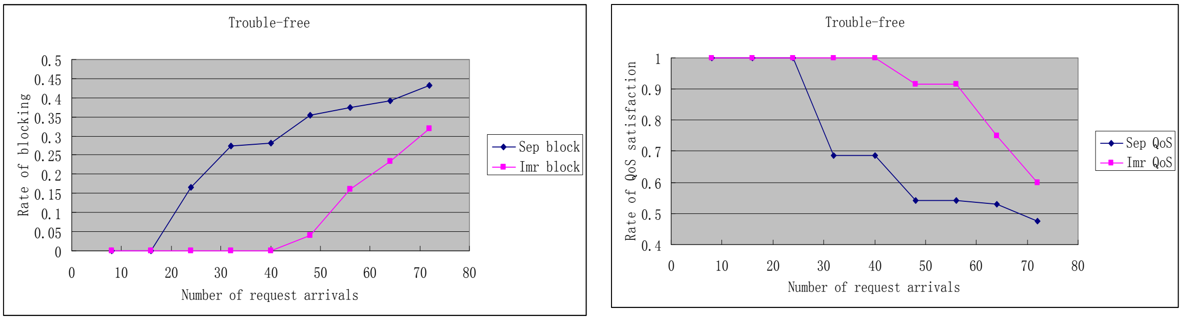

Fig.2 (a) (b) Performance comparison between Sep RWA and Imp RWA in the trouble-free network

Fig.3 (a) and **Fig.3** (b) show the comparison both in the rate of service blocking and QoS satisfaction between improved RWA and Pm RWA algorithm. It shows that when there are some broken links, the performance of the improved RWA will be negatively influenced while the Pm RWA algorithm still performs better than improved RWA. From **Fig.3** (c) we can gain a conclusion that the Pm RWA algorithm needs greater network resources for the establishment of protection routings.

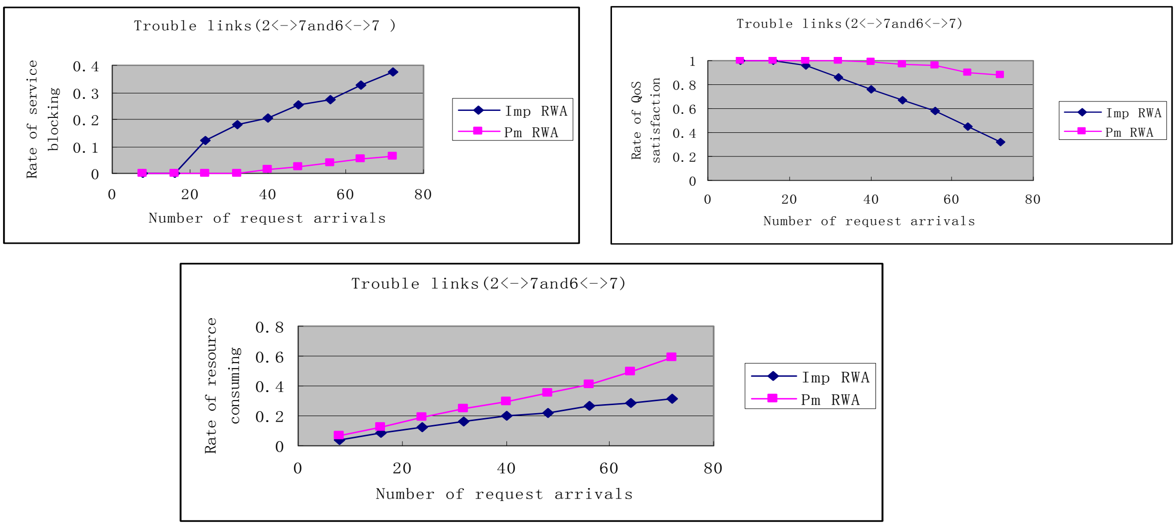

Fig.3 (a) (b) (c) Performance comparison between Imp RWA and Pm RWA with some links destroyed

4. Conclusions

(1) Improved RWA algorithm can obviously improve on the defects of separate RWA. It can also make the whole network load balanced, so that in the same trouble-free condition it can accomplish a lower block rate, a higher QoS guarantee, and a bigger throughput.

(2) When compared with the improved RWA algorithm, the Pm RWA algorithm doesn't contain the same link between protection and working routing. It can therefore perform well even with some links destroyed. In equivalent traffic, it needs greater network resources, so when the network has abundant resources and there are some frequently broken links, it can be considered to be more advantageous.

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