

Performance Analysis of Node Architecture in WDM Mesh Network

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Abstract- This paper propose the routing and wavelength assignment(RWA) in Wavelength Division Multiplexing (WDM) mesh network architecture which composed of node that has light path assignment (G-node) and none light path assignment (NG-node) and supporting both wavelength conversion and non-wavelength conversion systems. For routing, the shortest main route and the second shortest alternate route are used and wavelength assignment is random to reduce blocking probability. In addition, the proposed analytical models can also predict the blocking probability. The results show that the proposed grooming node is superior to the method with using only none grooming node. Moreover, the results obtained from the analytical model are agreed well with the numerical results.

Keywords- Wavelength Division Multiplexing, Routing and wavelength assignment, Fixed-Alternate Path Routing, Queueing Theory, Grooming node.

I. INTRODUCTION

The Wavelength Division Multiplexing is an important roll for the data communication in the physical layer for routing and wavelength assignment.

There are many researchers who proposed their researches such as Batagelj[1], Song-Hong Ngo[2], Wang Yao[3] and K.Chaiwong[4,5]. Batagelj *et al.* [1] analyzed the node architecture which hasn't the routing and wavelength assignment in the WDM network with and without wavelength conversion by the mathematical model. Son-Hong Ngo *et al.* [2] proposed the Ant-Base Algorithm for arranging the routing and wavelength assignment and in order to reduce the blocking probability. Wang Yao *et al.* [3] presented the using all of routes in the WDM network which has the grooming node. Chaiwong *et al.* [4,5] offered the routing and wavelength assignment in the WDM Mesh network with and without wavelength conversion. They didn't only search the main and second routes but also calculate the blocking probability by the analytical and simulation models. After that, they analyzed the ability of the WDM Mesh which hasn't the grooming node on the node architecture with the routing and wavelength assignment.

This article presents analytical model of node architecture for the routing and wavelength assignment in the grooming node network which Fixed Alternate Path Routing is selected for RWA. It also analyses the routing assignment efficiency in the WDM Mesh network with and without the wavelength conversion on the G-node architecture for reducing the blocking probability of the network.

The rest of this article explains the grooming node structure in the second topic, the calculating concept the main and second routes in the third topic. Then, the fourth topic presents the details of the case study from the analytical

model, simulations model and its results. Finally, the conclusion of this article is presented in the fifth topic.

II. THE GROOMING NODE ARCHITECTURE

From Fig.1, the grooming node architecture without the wavelength conversion divides the traffic assignment by two parts. The first part is the grooming node which is worked by the WXC (Wavelength Switching Fabric). The second part is the GXC arrangement (Grooming Fabric). If the wavelength in the output is busy, its traffic will be sent to the GXC for putting the new packet which is IP/MPLS and will be redirected to the WXC for recalculating the new wavelength. The RX in the node will be convert the light signal to be electrical signal. Fig.2 is the grooming node architecture with the wavelength conversion which the equipment for the wavelength conversion is added in.

III. THE PROPOSED ROUTING AND WAVELENGTH ASSIGNMENT TECHNIQUE

In this section, the proposed technique to design the routing and wavelength in WDM mesh network for wavelength conversion and without wavelength conversion systems is described. The shortest routing path[6,7] which is the assigned light path is selected upon the criterion of the route that has the smallest number of used links (hops) on traffic grooming. Additionally, the proposed idea is relied on the fact that the second and the third shortest light path in the traffic grooming of WDM mesh network can also be used as alternative routes for sending traffic. In case that the main (first shortest) path is failed; the next shortest route will be used. Again, the third shortest path will be employed if the second route is blocked. However, if the main and two alternative paths are not available, the sending process then stops. For example in Fig. 2, there are six possible light paths for sending traffic between the node 0 and the node 5. In this case, one of route 1 or route 2 is selected to the shortest main path where another route is the first alternate path. Also, either route 3 or route 4 will be selected as the last alternate path[8].

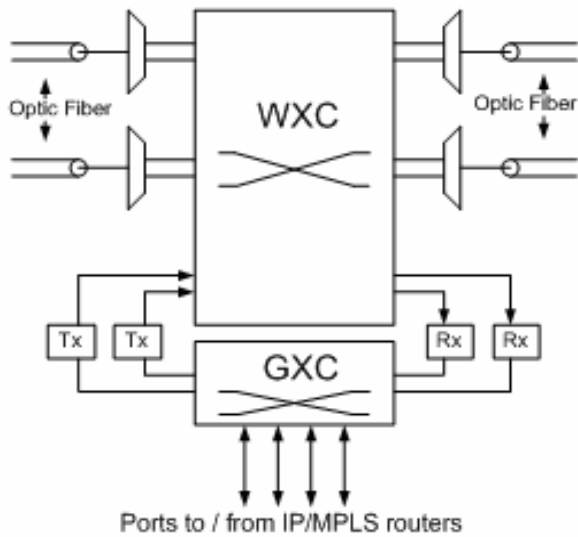


Figure1. The node architecture with the wavelength assignment but without the wavelength conversion.

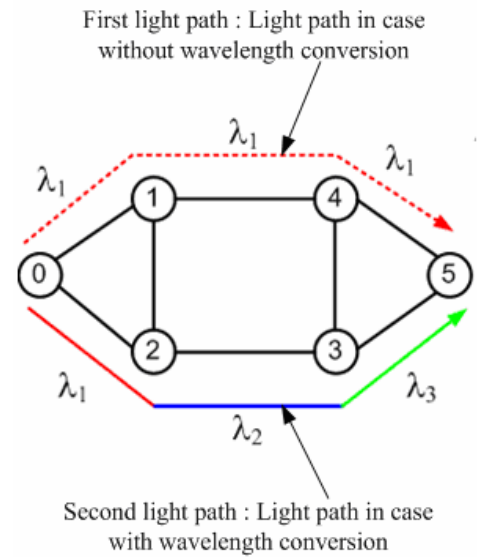


Figure 3. The shortest paths for WDM mesh networks in case of with and without wavelength conversion

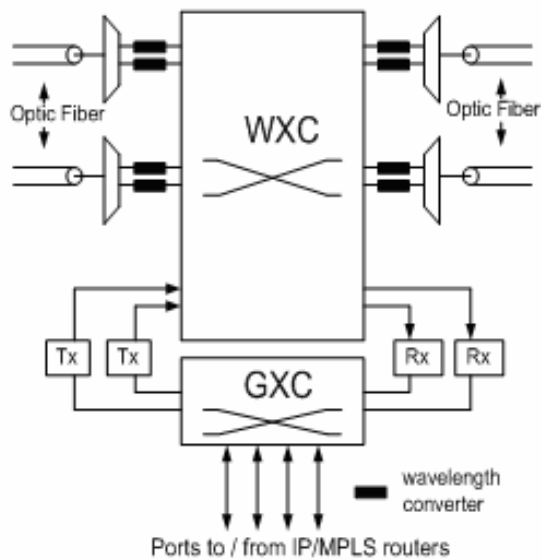


Figure2. The node architecture with the wavelength assignment with the wavelength conversion.

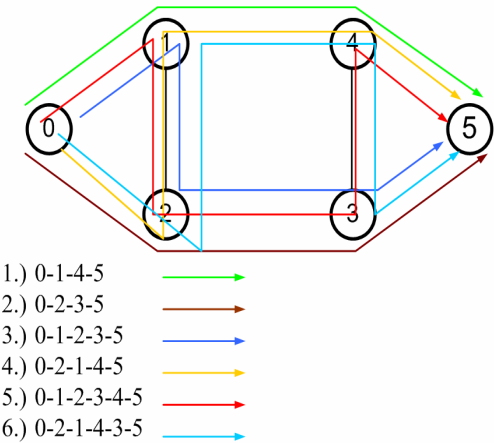


Figure 4. Illustration of the all possible light paths for sending traffic from the node 0 to the node 5

VI. THE STUDY CASES AND NUMERICAL RESULTS

A. Analytic Model

The node architectures from fig.1 and fig.2 are model by queueing model of a wavelength conversion system and a without wavelength conversion system are illustrated in Fig. 5 and 6, respectively

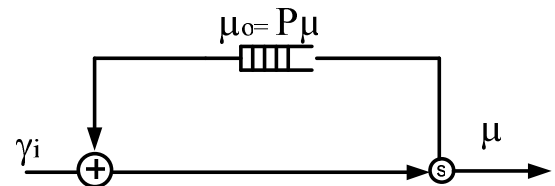


Figure 5. The queueing model in the without the wavelength conversion (G-node)

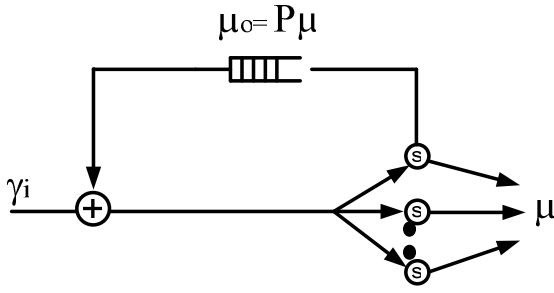


Figure 6. The queueing model in the node with wavelength conversion (G-node)

- γ_i : arrival rate.
 μ_o : the out coming rate without the wavelength service.
 P : the probability without the wavelength service.
 μ : the out coming rate with the wavelength service.

From Fig.6, we can model the probability of no-available wavelength with the binomial distribution as the equation (1).

$$P = \binom{N}{K} p_{rob}^k (1 - p_{rob})^{N-k} \quad (1)$$

- N : number of all wavelength in the node.
 K : number of wavelength used in the node.
 p_{rob} : the probability of the chosen wavelength.

From the equation (1), there will be the probability of the no-available wavelength when $N = K$; so the equation(1) can be written as

$$P = p_{rob}^k \quad (2)$$

We can calculate the traffic intensity in the system as the equation(3).

$$\rho = \frac{(\gamma_i + P\mu)}{\mu} \quad (3)$$

The node architecture in Fig.5 is the model of the node without wavelength conversion, it has the only one wavelength service for all of the connection. Which can model that the queueing system has the only one service so M/M/1/k/∞ [9] is the qualification of connection which is according to the queueing theory. Its blocking probability is according to the equation(4).

$$P_{bn} = \frac{\rho^k (1 - \rho)}{1 - \rho^{k+1}} \quad (4)$$

- M : the calls arrival are generated based on the Poisson arrival assumptions
 M : the service time are generated based on exponential service assumptions
 1 : number of service
 k : number of buffer
 ρ : traffic intensity
 ∞ : number of customer.

The node architecture in Fig.6 is the model of the node with wavelength conversion. It applies the Erlang'B systems which is calculate from the queueing theory with M/M/m/m/∞. The blocking probability or the formula of Erlang'B [9] is as the equation(5) :

$$P_{b(\rho, m)} = \frac{\rho^m / m!}{\sum_{k=0}^m \frac{\rho^k}{k!}} \quad (5)$$

where

- ρ : traffic intensity
 m : number of server (wavelength)
 $P_{b(a, m)}$: blocking probability.

The equation (5) can be defined from M/M/m/m/∞ queueing system when the parameters M/M/m/m/∞ respectively are

- M : the calls arrival are generated based on the Poisson arrival assumptions.
 M : the service time are generated based on exponential service assumptions.
 m : number of server.
 m : number of buffer.
 ∞ : number of customer.

The blocking event in each node is independent the blocking path can be determined by multiplying probability blocking of each node. After that, we calculate the average of blocking probability in the system with wavelength conversion according to the equation(6) and without conversion according to the equation(7).

$$P_{aven} = \frac{\sum_{i=1}^H (P_{bn})^i}{H} \quad (6)$$

$$P_{ave} = \frac{\sum_{i=1}^H (P_{b(a, m)})^i}{H} \quad (7)$$

H : number of node
 P_{aven} : The average of the blocking probability in without wavelength conversion.
 P_{ave} : The average of the blocking probability in the system with wavelength conversion.

B. Simulation model

The simulation model proposed in this paper is implemented by node architecture on a WDM mesh network in Fig. 3 for both wavelength conversion and no wavelength conversion systems. In the simulation, the number of traffic is set to 200 Erlang. The generated traffic is based on the poisson arrival and service assumption is an exponential. The number of wavelength used in the simulation is 16 wavelengths. The method of RWA is the Fixed alternate path routing.

Simulation model for the proposed method

1. Receiving the traffic quantity which increases from 1 to the highest quantity.
2. Choosing the node from the source to the destination together with the routing assignment.
3. Doing the wavelength assignment
 -If the wavelength is no available : When the traffic can't be sent ,it will be resent to the IP/MPLS Port for choosing the wavelength again and if the wavelength is still busy ,the alternative route will be chosen.
 -If the wavelength is available: The traffic can be sent to the fifth step.
4. Calculating the blocking probability.
5. Deciding to exit from the system and doing again from the first step to the last step due to all of traffic quantity.

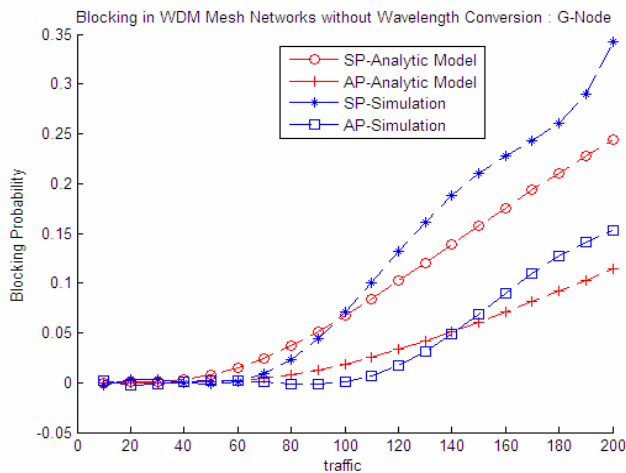


Figure 7(a)

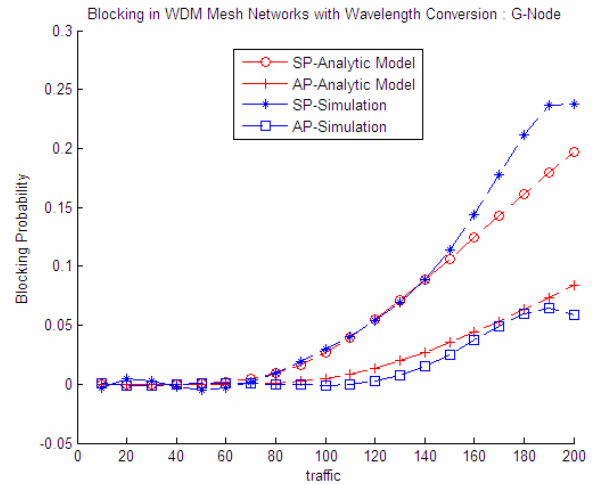


Figure 7(b)

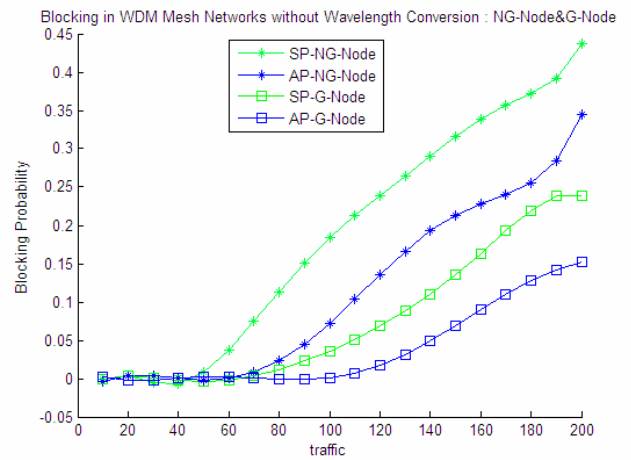


Figure 7(c)

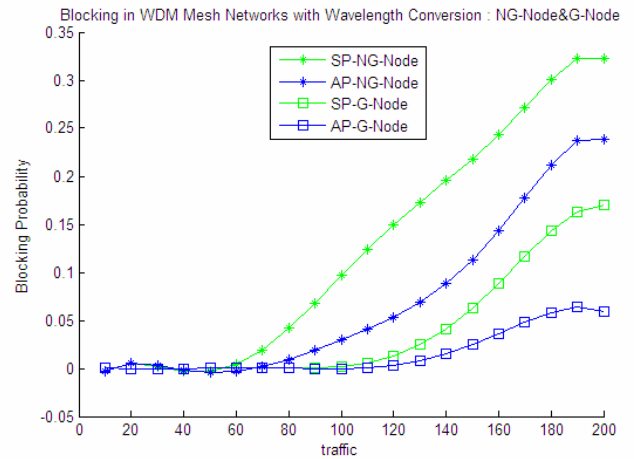


Figure 7(d)

SP-NG : Shortest Path Routing – None Grooming Node
 AP-NG : Alternative Path Routing – None Grooming Node
 SP-G : Shortest Path Routing –Grooming Node
 AP-G : Alternative Path Routing – Grooming Node

The result in figure 7(a) is the comparison of the blocking probability between the theoretical model and the simulation model in the system without wavelength conversion. Fig.7(b) is the result which is done by the system with the conversion, in the node architecture with the routing assignment, on the shortest route and is compared with the result of the alternative route. The result presents that the blocking probability of the alternative route is better than the only one shortest route. The route calculated by the theoretical model is enclosed the one from the simulation model.

Fig 7 (c) is the comparison of the result of the simulation model in the node architecture with the routing assignment but without the conversion. Fig7 (d) is the result of the system with the routing assignment, is compared with the node architecture with and without the routing assignment. Its result present that the node architecture with the routing assignment can give the blocking probability value which is better than the node architecture without the routing assignment.

VII. CONCLUSION

This article proposes analytical model of node architectures for WDM mesh network which are the grooming node and none grooming node, supporting both wavelength conversion and non-wavelength conversion systems. The RWA method based on Fixed alternative path routing. The results showed that the proposed grooming node is superior to the method with using only none grooming node. Moreover, the results obtained from the analytical model are agreed well with the numerical results obtained from simulations.

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