

A Study of Lightpath Rerouting Schemes in Wavelength-Routed WDM Networks

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Abstract — Rerouting is a viable and cost-effective approach to decrease the blocking probability in legacy circuit-switched networks. We study lightpath rerouting in optical WDM networks in this paper. We investigate two different lightpath rerouting strategies, namely, *passive rerouting* and *intentional rerouting*. Passive rerouting means rerouting established lightpaths to accommodate new lightpath requests which will otherwise be blocked. Intentional rerouting is to intentionally reroute existing lightpaths during their life period without affecting other lightpaths, so as to achieve a better load balancing. Through extensive simulation studies, we draw the following conclusions: 1) when there is wavelength conversion, passive rerouting works much better than intentional rerouting; 2) when there is no wavelength conversion, a naïve-wavelength-retuning algorithm can achieve the most benefit of passive rerouting while path-adjusting does not help too much.

I. Introduction

Wavelength Division Multiplexing (WDM) has been studied for more than two decades, and it is widely used for long-distance communications nowadays. However, a more promising technique is the wavelength-routed all-optical WDM networks [22]. A wavelength-routed all-optical WDM network consists of optical wavelength routing nodes called *wavelength routers* interconnected by optical fiber links. Each fiber link can support a number of wavelength channels by using WDM. A *lightpath*, i.e., an optical communication path, is setup between the source node and destination node upon receiving a connect request from the clients [5]. To establish a lightpath, it is normally required that the same wavelength channel should be allocated on all the links along the route. This limitation is known as the *wavelength continuity constraint*.

In this paper, we are mainly concerning with dynamic traffic model, in which lightpath connection requests arrive over time dynamically and each lightpath has a random holding time. Some of the lightpath requests could be blocked if there is currently no common free wavelength along the route. One of the primary design objectives of wavelength-routed all-optical WDM networks is to minimize the blocking probability. To achieve this goal, lots of efforts have been made in the literature, mainly in two different directions:

(1) *Routing and Wavelength Assignment (RWA) algorithms* [2, 4, 7, 9, 11, 15, 17, 20, 21, 30]: Existing research results have shown that adaptive routing algorithms can usually achieve better performance than static routing

algorithms. In adaptive routing algorithms, a set of candidate routes are pre-calculated for each source-destination node pair. Once the lightpath has been setup, its physical route is usually not allowed to be changed.

(2) *Wavelength conversion* [12, 18, 19, 23, 28]: Wavelength conversion means changing the optical signal from one wavelength to another. It can eliminate the wavelength continuity constraint and thus improve the blocking performance. In this paper, we only consider two cases: no wavelength conversion, and full wavelength conversion.

In this paper, we study a third direction of improving the blocking performance: *lightpath rerouting*. Normally, once a lightpath has been setup, its physical path and its wavelength won't change so as to guarantee a smooth and continuous data communication. Lightpath rerouting means the action of changing the physical path and/or wavelength of an established lightpath. There could be different reasons to perform lightpath rerouting. For example, if a lightpath is corrupted because of link failure or node failure, the lightpath has to be rerouted to another path. But in this paper, we do not consider network failures. In stead, we are more interested in studying the benefit of lightpath rerouting in terms of decreasing the blocking probability.

We study two different rerouting strategies in this paper. The first one is called *passive rerouting*. The idea is that, once a lightpath request cannot be satisfied by the current network, we could try to reroute some existing lightpaths such that the new lightpath request can be accepted. An example of passive rerouting is shown in Fig. 1, where each link can support two wavelengths. In Fig. 1 (a), assume lightpath L_{12} is originally setup between node 1 and node 2 using the blue wavelength, and lightpath L_{23} is setup between node 2 and node 3 using the red wavelength. Due to the wavelength continuity constraint, a new lightpath request between node 1 and node 3 has to be blocked. Consider the case in Fig. 1 (b), where passive rerouting is allowed: We can first reroute lightpath L_{23} from the red wavelength to blue wavelength (using the same link); afterwards we can successfully setup the lightpath L_{13} between node 1 and node 3 using the red wavelength. In this example, the physical path of lightpath L_{23} is not changed; in stead, only its wavelength is changed. This is referred to as *wavelength-retuning* [13]. In case the physical path of an establish lightpath is changed, we call it *path-adjusting*.

The second rerouting strategy is called *intentional rerouting*, by which existing lightpaths are dynamically rerouted to a more suitable physical path to achieve a better load balancing during its whole life period. This technique could be very useful if a lightpath holds for a very long period. When a lightpath was setup at the very beginning, it could select a good physical path at that time; but the network traffic distribution is changing all the time, and it is possible that the previous physical path may not always be a good choice. Therefore it is possible to improve the overall blocking performance by dynamically changing the physical paths of existing lightpaths. An example of intentional rerouting is depicted in Fig. 2.

The remainder of this paper is organized as follows. Previous work on passive rerouting and intentional rerouting is reviewed in Section II. Then we discuss our passive rerouting algorithms and intentional rerouting algorithms in Section III and IV, respectively. Our simulation results and analysis are given in Section V. Finally, Section VI concludes the paper.

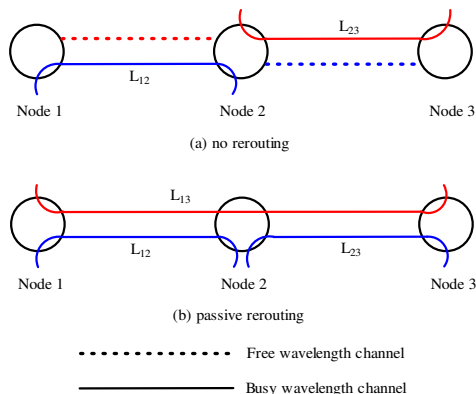


Fig. 1. An example of passive rerouting

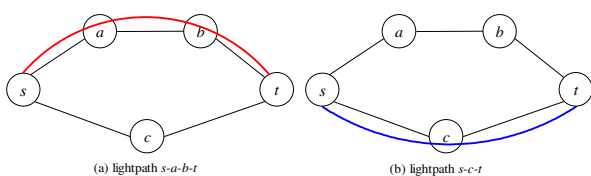


Fig. 2. An example of intentional rerouting

II. Related Work

The concept of rerouting is originally introduced in the design of circuit-switched telephone networks [1, 10]. It has also been applied to optical WDM networks recently [3, 6, 8, 13, 14, 16, 26, 27, 29]. Rerouting is simply the action of switching an active *circuit* (or *virtual path* in ATM network, *lightpath* in WDM network) from one route to another route without changing the source and destination. A comprehensive survey of rerouting techniques can be found in [24]. An analysis of rerouting in circuit-switched network is

given in [25], which mainly studies symmetrical fully connected networks.

In [13, 14], rerouting is used as an approach to alleviate the effects of wavelength continuity constraint when there is no wavelength conversion. Specifically, a rerouting scheme called *move-to-vacant wavelength-retuning* (MTV-WR) was proposed by the authors, which has a very short lightpath disruption period. *Move-to-vacant* means rerouting a lightpath to a free path without affecting other established lightpaths. *Wavelength-retuning* means retuning the wavelength of a lightpath without changing its physical path. In MTV-WR, a few existing lightpaths may be reassigned to different wavelengths without changing their physical paths, in order to accommodate a new lightpath request which will be otherwise blocked. By simulation studies, MTV-WR has been shown to reduce the blocking probability by 30% on average. The main concern of their rerouting algorithm is to minimize the lightpath disruption time. In [16], the authors have developed a sophisticated time optimal rerouting algorithm aiming to further shorten the disruption time. In the above rerouting schemes, the average number of rerouted lightpaths per rerouting case is more than one and increases as the request arrival rate gets higher.

Passive rerouting in WDM networks with sparse wavelength conversion has been studied in [26]. In sparse wavelength conversion WDM networks, only some nodes in the network can do wavelength conversion [23]. The author extends the work of [14, 16] to semi-lightpath routing/rerouting. However, only wavelength-retuning is studied. In [29], a departure-triggered rerouting strategy has been proposed. It performs rerouting at the time when an existing lightpath is due for departure. After releasing a lightpath D , it tries to reroute some other lightpath P whose source node and destination node are both on the path of lightpath D , in case wavelength resources can be saved by this rerouting action.

In [6], the authors propose an *intentional rerouting* scheme in wavelength routed WDM networks. The basic idea is to intentionally reroute existing lightpaths to some vacant routes if better load balancing can be achieved. They propose a new adaptive routing scheme called Dynamic Least Congested Routing (DLCR) which dynamically switches existing lightpaths to the least congested routes.

Our work differs from previous work in the following aspects: (1) In passive rerouting with full wavelength conversion, we propose a heuristic move-to-vacant one-path-adjusting algorithm (MTV-OPA) with polynomial time complexity. Our simulation results illustrate that the MTV-OPA algorithm can improve the blocking performance significantly. (2) In passive rerouting without wavelength conversion, we propose a move-to-vacant naïve-wavelength-retuning (MTV-NWR) algorithm and also a path-adjusting algorithm. We show that our simple NWR algorithm can achieve very good performance, while the path-adjusting scheme can only provide very marginal improvement. (3) We

propose a generalized timer-based intentional rerouting framework.

III. Passive Lightpath Rerouting

In this section, we propose a set of passive lightpath rerouting algorithms. In the case of full wavelength conversion, wavelength-retuning does not make sense any more because there is no wavelength continuity constraint. We first describe a basic routing algorithm without passive rerouting; then we propose a passive rerouting algorithm which performs path-adjusting to accommodate the otherwise blocked new arrivals. When there is no wavelength conversion, we also first describe a basic routing algorithm without passive rerouting; then we propose an efficient passive rerouting algorithm using only wavelength-retuning; we further propose a passive rerouting algorithm which can perform path-adjusting in case wavelength-retuning does not help.

The physical topology of a wavelength-routed WDM network is represented by an undirected graph $G = (V, E)$ where V is the set of wavelength routers and E is the set of fiber links. Each fiber link can support a set of W wavelengths, denoted by $\Lambda = \{\lambda_1, \lambda_2, \dots, \lambda_W\}$. In the case of full wavelength conversion, a lightpath between node pair (s, t) is denoted by $p(s, t)$. In the case of no wavelength conversion, a lightpath between node pair (s, t) using wavelength λ_i is denoted by $p_i(s, t)$. The set of all currently existing lightpaths is denoted by L , and we denote the number of currently existing lightpaths as $|L|$.

A. With Full Wavelength Conversion

With full wavelength conversion, a lightpath can be setup if all the links along the path have at least one free wavelength. Since there is no wavelength continuity constraint, wavelength-retuning becomes meaningless.

In order to show the benefit of rerouting, we first describe a basic routing algorithm called Shortest Available Path Routing (SAPR) without using rerouting. This algorithm can be seen as an extension of the FAR algorithm [11]: upon arrival of a lightpath request, the shortest available path is selected to setup the lightpath.

Algorithm 1: SAPR under full conversion

- 1) For each connection request on node pair (s, t) , we first remove the links without free wavelengths from E , and then use *Breadth First Search* (BFS) [31] to find the shortest available path between node s and t .
 - 2) If there does not exist such a route with free wavelength channels, block the connection request directly.
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Lemma 1: The time complexity of the above routing algorithm is $O(|V| + |E|)$.

Proof: Because the running time of BFS is $O(|V| + |E|)$, the time complexity of SAPR under full conversion is $O(|V| + |E|)$.

With full wavelength conversion, the topology can be simplified by a weighted undirected graph $G = (V, E, w)$, where w represents the weight function mapping from link e to the number of free wavelength channels on it. If a lightpath request cannot be setup by the above SAPR algorithm, it is possible to adjust some established lightpaths in order to accommodate the new request. In order to shorten the lightpath disruption time, we limit the number of rerouted lightpath to be one. Therefore we name the algorithm Move-to-Vacant One-Path-Adjusting (MTV-OPA).

Algorithm 2: MTV-OPA under full conversion

- 1) For each connection request on node pair (s, t) , we first use BFS to find the shortest available route between node s and t . If there is no path with free wavelength channels, goto Step 2 to try to reroute one established path to accept this connection request:
 - 2) If L is empty, block this request; else goto Step 3.
 - 3) If L is not empty, select one existing lightpath from set L , say $p(s', t')$. Release¹ it in graph G , and remove it from L .
 - 4) For both nodes (s, t) and (s', t') , solve the maximum-flow problem with multiple sources and sinks. By adding a supersource s_0 and supersink t_0 , the maximum-flow problem with multiple sources and sinks can be reduced to an ordinary maximum-flow problem. If the value of the maximum flow is larger than 1, goto Step 5. Otherwise, restore the original path $p(s', t')$ in graph G and goto Step 2.
 - 5) On the induced subgraph G' where each link's flow is not zero, use BFS to find the shortest path for (s', t') . If such path cannot be found, restore the original path $p(s', t')$ in graph G and goto Step (2). Otherwise, update graph G and goto Step (6).
 - 6) On graph G , use BFS to find the shortest available path for the node pair (s, t) . If there does not exist such a path, goto Step (2).
 - 7) Perform path-adjusting on $p(s', t')$. Afterwards, we setup the new lightpath request for (s, t) .
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¹ The "release" operation is only conducted in the algorithm. It does not mean to release the physical lightpath. The same rule applies to the "restore" operation in Step 4 and Step 5.

Lemma 2: The time complexity of the above routing algorithm is $\mathcal{O}(|L||V|^3)$.

Proof: The running time of the maximum-flow problem is cubic in the number of nodes, i.e., $\mathcal{O}(|V|^3)$, by using the relabel-to-front algorithm [32]. Therefore the time complexity of the above MTV-OPA rerouting algorithm is $\mathcal{O}(|L||V|^3)$.

It is a natural idea that an algorithm may reroute a set of established lightpaths to accept the new connection request. Unfortunately, it is an NP-Hard problem, since it is a general case of maximum disjoint connecting paths problem, in which the capacity of each edge is just one-path. However, if the given topology is a directed graph, the problem can be solved in polynomial time by using our algorithm. We will first present the algorithm for the directed graph version of the maximum disjoint connecting paths problem. Then the algorithm can be easily generalized to the problem we are concerning, if the topology is a directed graph.

Definition: Maximum-Disjoint-Connecting-Paths Problem
Given a directed graph $G = (V, E)$, and a collection of k vertex pairs $T = \{(s_1, t_1), (s_2, t_2), \dots, (s_k, t_k)\}$, find the maximum number of vertex pairs in T that can be connected by disjoint paths on G respectively.

Theorem: The maximum-disjoint-connecting-paths problem can be solved in $\mathcal{O}(|V|^3 + k|E|)$ time.

Proof: The polynomial algorithm is as follows:

- (1) Add a supersource s_0 . For $\forall i, j, s_i \neq t_j$, add a directed edge from s_0 to s_i ;
- (2) Add a supersink t_0 . For any t_i , add a directed edge from t_i to t_0 ;
- (3) Let $n = 0$;
- (4) Let each edge's capacity be 1;
- (5) Solve the maximum flow problem from s_0 to t_0 ;
- (6) For each vertex pair (s_i, t_i) , find from s_i to t_i a path such that each edge's flow is not zero. If such path exists, $n = n + 1$ and update the flow on graph G ;
- (7) n is the maximum number of satisfied pairs in T .

The running time of Step 1-4 is $\mathcal{O}(k^2)$, Step 5 is $\mathcal{O}(|V|^3)$, Step 6 is $\mathcal{O}(k|E|)$, so the time complexity of the algorithm is $\mathcal{O}(|V|^3 + k|E|)$.

We claim that Step (6) is necessary, since the maximum number of satisfied pairs may not be as large as the maximum flow. However, it is clear that the maximum number of satisfied pairs must not be larger than the maximum flow. For example, in Fig. 3, the maximum number of satisfied pairs is 0, while the maximum flow is 2. ■

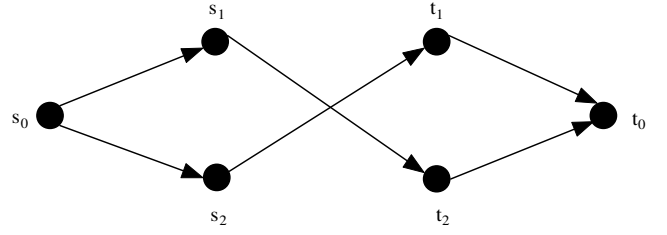


Fig.3. An example to illustrate Step (6)

B. No Wavelength Conversion

When there is no wavelength conversion, we can have two different approaches of passive rerouting: wavelength-retuning and path-adjusting.

We first present a basic routing algorithm without rerouting, for performance comparison purpose.

Algorithm 3: SAPR under no conversion

- 1) Given the topology $G = (V, E)$, we first reproduce W copies of G (referred to as sub-graph), labeled by $\{G_1, G_2, \dots, G_W\}$, where G_i denotes the topology for wavelength channel λ_i . Due to the wavelength continuity constraint, a lightpath can only be setup within a sub-graph G_i .
 - 2) For each connection request on node pair (s, t) , we use BFS to find the shortest available route between node s and t from the graph set $\{G_1, G_2, \dots, G_W\}$. If there is a tie, break it by choosing the path with smallest wavelength index, i.e., by using the first-fit wavelength assignment policy [30].
 - 3) In case there is not such a path in all the W sub-graphs, the lightpath request has to be blocked.
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Lemma 3: The time complexity of the above routing algorithm is $\mathcal{O}(W(|V| + |E|))$.

Proof: For each sub-graph G_i , the running time of BFS is $\mathcal{O}(|V| + |E|)$. Since the algorithm needs to search all the W sub-graphs, its time complexity is $\mathcal{O}(W(|V| + |E|))$.

Next, we propose a passive rerouting algorithm using only wavelength-retuning. Different from the algorithms in [14, 17], we allow retuning only one lightpath to accommodate the new request, such that the algorithm is very simple and fast to be implemented, and its performance is almost the same of those in [14, 17]. The algorithm is named as Move-to-vacant Naïve-Wavelength-Retuning (MTV-NWR).

Algorithm 4: MTV-NWR

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- 1) For each connection request on node pair (s, t) , we first call the SAPR algorithm. If the request cannot be accepted, goto Step 2 to try wavelength-retuning one established path to accept the connection request:
 - 2) If L is empty, block it; else goto Step 3.
 - 3) If L is not empty, select one existing lightpath from L , say $p_i(s', t')$. Release it, and remove it from L .
 - 4) Using BFS to search the shortest path $p_i(s, t)$ in sub-graph G_i . If such a path exists, goto Step 5; otherwise, restore the original path $p_i(s', t')$ and goto Step 2.
 - 5) From the sub-graph set $\{G_1, G_2, \dots, G_W\} \setminus \{G_i\}$, check the existence of a path $p_j(s', t')$ which is a projection of $p_i(s', t')$ on sub-graph G_j . If there is a tie, break it by choosing the path with the smallest wavelength index. If such path cannot be found, release path $p_i(s, t)$ and restore the original path $p_i(s', t')$, and then goto Step 2.
 - 6) Assume the path selected in Step 5 is $p_j(s', t')$. Perform wavelength-retuning on $p_i(s', t')$, i.e., retune the wavelength from i to j . Afterwards, we setup the new lightpath request using $p_i(s, t)$.
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Lemma 4: The time complexity of the NWR algorithm is $O(W |L| |V|)$.

Proof: The running time of checking one adjustment is $O(W |V|)$. Therefore the time complexity of the above algorithm is $O(W |L| |V|)$.

It is obvious that wavelength-retuning cannot always help. Therefore we apply the previous MTV-OPA algorithm here, which tries to move the physical path of some established lightpath to accept a new request, in case MTV-NWR algorithm fails.

Algorithm 5: MTV-OPA under no conversion

- 1) For each connection request on node pair (s, t) , we first call shortest path routing algorithm to process it. If the request can not be accepted, goto Step 2 to try to readjust one established path to accept the connection request on node pair (s, t) :
- 2) If L is empty, block it; else goto Step 3.
- 3) If L is not empty, select one existing lightpath from set

L , say $p_i(s', t')$. Release it, and remove it from L .

- 4) If by BFS, one shortest path for node pair $p_i(s, t)$ can be found on sub-graph G_i , goto Step 5; else restore the original path $p_i(s', t')$ and goto Step 2.
- 5) From the sub-graph set $\{G_1, G_2, \dots, G_W\} \setminus \{G_i\}$, use BFS to find the shortest available path for node pair (s', t') . If success, goto Step 6. In case there is a tie, break it by choosing the path with the smallest wavelength channel index. If such path cannot be found, release path $p_i(s, t)$ and goto Step 2.
- 6) Assume the shortest path found in Step 5 is $p_j(s', t')$. Reroute the lightpath $p_i(s', t')$ to $p_j(s', t')$. Afterwards, we setup the new lightpath request using $p_i(s, t)$.

Lemma 5: The time complexity of the above routing algorithm is $O(W |L| (|V| + |E|))$.

Proof: The running time of adjustment once is $O(W (|V| + |E|))$. The time complexity of one-wavelength-path-adjustable rerouting is therefore $O(W |L| (|V| + |E|))$.

IV. Intentional Lightpath Rerouting

In intentional lightpath rerouting, an established lightpath dynamically adjusts its physical path according to some pre-defined criteria. One example is to switch the lightpath from a longer path to a shorter one; another example is to switch the lightpath from an over-loaded path to a slightly-loaded path. In this section, we propose a general framework of Timer-based Intentional Rerouting algorithm. It can work for both no wavelength conversion and full wavelength conversion.

Algorithm 6: Timer-based Intentional Rerouting (TBIR)

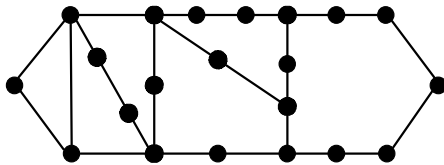
- 1) For each node pair (s, t) , we first pre-calculate the k -shortest paths, denoted by $p^1(s, t)$, $p^2(s, t)$, ..., $p^k(s, t)$. Each path $p^i(s, t)$ is associated with a weight value $w^i(s, t)$ which can be calculated by a pre-defined weight function. The design of the weight function could be very complicated. Usually it should consider lots of factors, e.g., the path hop-length, and the free wavelength distributions. We assume that a large weight value means a good candidate path. We also define a positive number *thresh* as a threshold to control the rerouting behavior.
- 2) For each connection request on node pair (s, t) , we

call the SAPR-NC algorithm to setup the lightpath request. It is possible that the selected path is different from any of the k -shortest paths. For each established lightpath, we associate a timer at the source node to trigger the intentional rerouting routine.

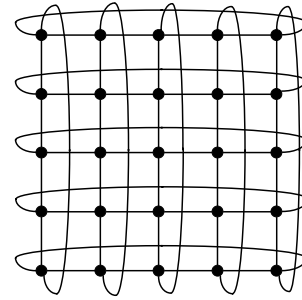
- 3) Once the timer of any lightpath $p(s,t)$ fires, perform the following routine:
 - (1) Calculate the weight value of the current path $p(s,t)$, denoted by $w(s,t)$.
 - (2) Calculate $w^i(s,t)$ for $i = 1, 2, \dots, k$.
 - (3) If $w(s,t) > \max\{w^i(s,t) : i = 1, 2, \dots, k\} - ts$, it is not necessary to do wavelength rerouting, goto Step (4); else, assume $w^j(s,t) = \max\{w^i(s,t) : i = 1, 2, \dots, k\}$, reroute the lightpath from $p(s,t)$ to $p^j(s,t)$ using the smallest available wavelength index as follows:
 - a. Setup a lightpath between (s,t) on path $p^j(s,t)$;
 - b. Switch the optical signal from the original lightpath $p(s,t)$ to the new one on $p^j(s,t)$;
 - c. Release the old lightpath on $p(s,t)$.
 - (4) Reset the timer.

The above algorithm tries to reroute an existing lightpath to one of the k -shortest path with the highest weight value and the difference between the weight values is greater than the pre-defined threshold. The algorithm has the following three advantages: First, it is simple to be implemented since the lightpaths are always rerouted to vacant paths. Rerouting of a lightpath does not affect other existing lightpaths. Second, the computational requirement is very low. Third, the lightpath disruption time is minimized to the physical limitation of switching the optical signal from one lightpath to another, since the data transmission is preserved on the old lightpath during the setup of the new one.

V. Performance Evaluation



(a) 21-node ARPA-2



(b) 25-node mesh-torus

Fig. 4. Network Topologies

The blocking performances of all the rerouting algorithms are evaluated by extensive simulation studies on a set of network topologies. Since we are only interested in the steady-state blocking probability, the data of initial transient period in each simulation are discarded. For each data point, 20 independent simulations are conducted and the 95% confidence interval of the blocking probability is estimated. In our simulations, the lightpath requests arrive to the network following a Poisson process; and each node pair has the same lightpath request arrival rate. The lightpath holding time is exponentially distributed with a unit time. Each fiber link can support 40 bi-directional wavelength channels. Due to the space limitation, we only present the simulation results of the following two topologies: 21-node ARPA-2 network (Fig. 4 (a)), and 25-node mesh-torus network (Fig. 4 (b)). The specific TBIR algorithm we are using in the simulation is based on the least-loaded principle: (1) $w(s,t)$ is the number of free wavelengths of path $p(s,t)$; (2) $k = 2$, which means that we use 2 candidate paths for each node pair; (3) $thresh = 2$, which means that intentional rerouting is performed only if the new path has at least two more free wavelength channels than the present path.

A. With Full Wavelength Conversion

The blocking performances of different routing algorithms in ARPA-2 and Mesh-torus are shown in Fig. 5 and Fig. 6. We can see that intentional rerouting does not help too much as compared with SAPR in ARPA-2, but it works much better in the dense network Mesh-torus. On the contrary, MTV-OPA algorithm can always decrease the blocking probability by a large margin, though the benefit is shrinking with the increase the traffic load. In a reasonable range of blocking probability ($<10\%$), we can conclude that MTV-OPA is an effective approach to improve the blocking performance.

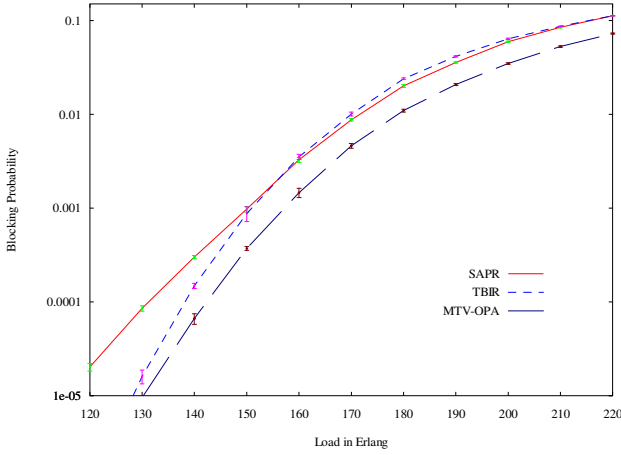


Fig. 5. Blocking performance of different rerouting schemes in ARPA-2, with full wavelength conversion

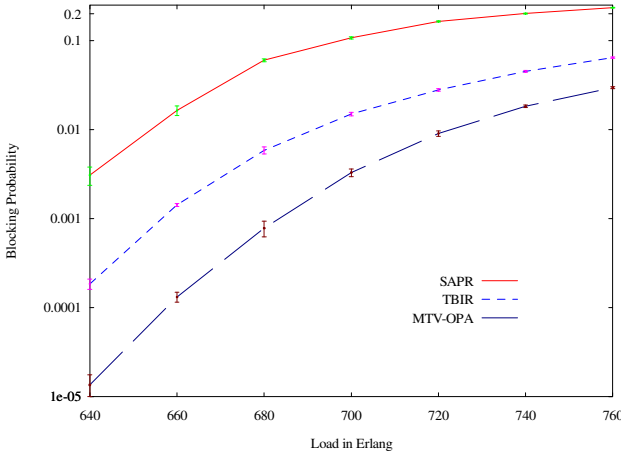


Fig. 6. Blocking performance of different rerouting schemes in Mesh-torus, with full wavelength conversion

B. No Wavelength Conversion

In the case of no wavelength conversion, we first show that wavelength-retuning can achieve the most benefit of passive rerouting. Note that, in MTV-OPA algorithm, upon arrival a lightpath request, we actually first call the SAPR algorithm. If it fails, we denote such a lightpath request “failed request”. We then call MTV-NWR algorithm; if it fails again, we try MTV-OPA algorithm. In Fig. 7, we show the percentage of (1) the number of requests that are rejected by SAPR but accepted by MTV-NWR; (2) the number of requests that are rejected by SAPR and MTV-NWR but are accepted by MTV-OPA; (3) the blocked lightpaths; over the total number of failed requests. It is shown that 96% of the failed requests can be accepted by simple MTV-NWR algorithm; and only 1% of the failed requests can be further accepted by MTV-OPA algorithm. Similar results have been observed in all other topologies we have studied. Therefore we suggest using only wavelength-retuning when there is no wavelength conversion.

The blocking performances of different routing algorithms in ARPA-2 and Mesh-torus without wavelength

conversion are shown in Fig. 8 and Fig. 9 respectively. It is very obvious that passive-rerouting performs much better than intentional rerouting.

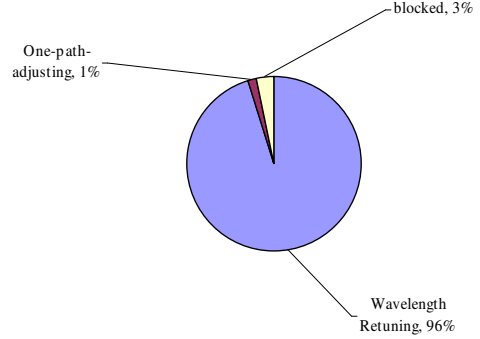


Fig. 7. Effect of MTV-NWR and MTV-OPA, no wavelength conversion

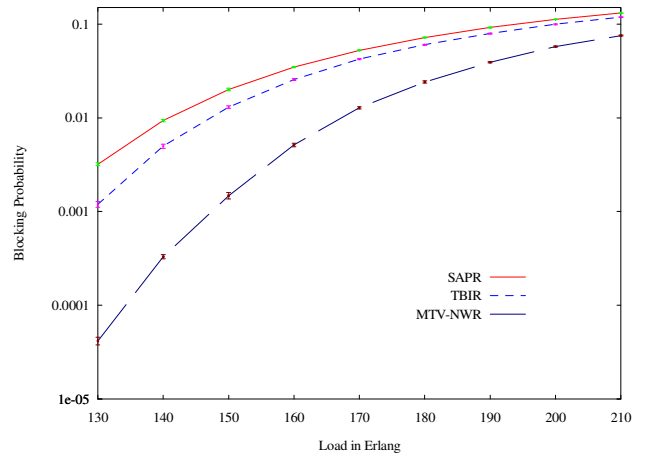


Fig. 8. Blocking performance of different rerouting schemes in ARPA-2, no wavelength conversion

VI. Conclusion

In this paper, we have studied two different rerouting strategies, namely, passive rerouting and intentional rerouting. Our main conclusions are as follows:

When there is full wavelength conversion, path-adjusting is the only way of passive rerouting. In all the topologies we have investigated, passive rerouting outperforms intentional rerouting a lot. The benefit of rerouting is more significant in dense networks, such a mesh-torus. When there is no wavelength conversion, wavelength-retuning is an efficient way to improve the blocking performance. Path-adjusting can only improve the performance of wavelength-retuning very marginally. Intentional rerouting can also improve the blocking performance, but not as notable as wavelength-retuning.

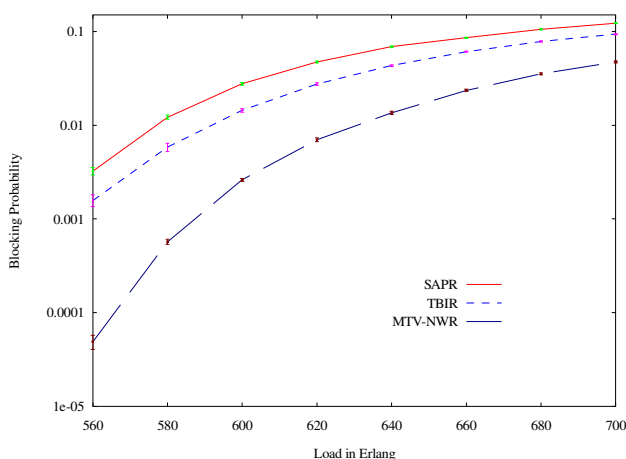


Fig. 9. Blocking performance of different rerouting schemes in Mesh-torus, no wavelength conversion

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