ISSN 22773061

Routing Strategies in Survivable Optical Networks

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ABSTRACT

Routing and wavelength assignment problem is one of the main problem in optical networks. The foremost problem is the routing problem after which the wavelength assignment is to be decided. In this paper we have proposed a routing strategy for optimization of the performance of the optical network in terms of blocking probability. The strategy proposed is better than the conventional algorithm in terms of blocking.

Council for Innovative Research
Peer Review Research Publishing System
Journal: INTERNATIONAL JOURNAL OF COMPUTERS & TECHNOLOGY
Vol 9, No 2
editor@cirworld.com
www.cirworld.com, member.cirworld.com

1. Introduction

Optical fibers are long, thin strands of very pure glass about the diameter of a human hair. They are arranged in bundles called optical cables and are used to transmit optical signals over long distances. An optical fiber consists of a cylindrical core of silica , with a higher refractive index, surrounded by cylindrical cladding, also of silica, with a lower refractive index [1]. The idea of optical communication using a fiber is that, if an optical signal passing through an optical medium with a higher refractive index, say μ_1, meets another optical medium with a lower refractive index, say μ_2, at an angle greater than the critical angle $\sin^{-1} \mu_2/\mu_1$, total internal reflection takes place where the signal is entirely reflected back into the denser medium [1]. Optical signal propagates through the core of the fiber using a series of such total internal reflections (Figure 1).

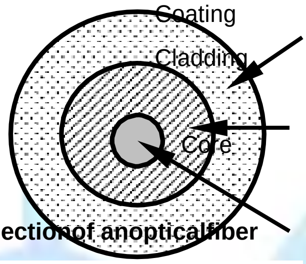


Figure1 Cross-sectionof anopticalfiber

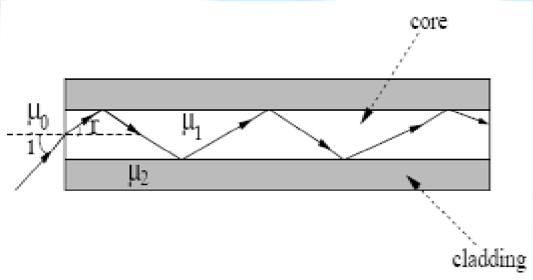


Figure2 Optical signal propagationusing total internal reflection

The potential transmission capacity of optical fiber is enormous. Especially, within the last 30 years, the transmission capacity has been increased dramatically. Theoretically, using advanced techniques such as DWDM (Dense WDM), the modest number of fibres as seen in Figure 1.3 could have sufficient bandwidth to easily carry the sum of all types of current data transmission needs for the entire planet. (~100 terabits per second per fibre). However, the transmission capacity of a fiber is strongly dependent on the length of the fiber. The longer a fiber, the lower is its achievable transmission rate [2]. Currently two types of optical fiber are in use – multimode fibers and single-mode fibers. Multimode fibers are often more convenient to utilize for short distances of a few hundred meters or less, as they are cheaper to install and the necessary equipment are less expensive. Multimode fibers can achieve data rates between a few hundred Mbps to around 10 Gbps, depending on the transmitter technology.

Figure3 A bundleof optical fibres

(Takenfromhttp://en.wikipedia.org/wiki/Optical_fiber)

Single-mode fibers are typically used for longer distances of a few kilometers or more. Currently a single encoded optical signal can be used to transmit at the rate of 2.5 Gbps, 10 Gbps or even 40 Gbps, over a distance of ten kilometers or more. Future systems may use higher data rates of 160 Gbps.

1.1 Optical Signal Amplifiers

While traveling through the optical fiber, a part of any optical signal is always lost due to a variety of factors, including scattering, absorption, and bending, even though the modern day optical fibers are made from extremely pure silica. Signal amplifiers are therefore required, especially for long-haul transmission cables, to boost up the weak signals. There are several different types of optical amplifiers that are being used in today's optical communication systems. Among them three most widely used are Semiconductor optical Amplifiers (SOA), Erbium-Doped Fiber Amplifiers (EDFA), and Raman Amplifiers [3]. A typical semiconductor optical amplifier (SOA) is a waveguide structure with a semiconductor gain medium [4], similar to a semiconductor laser. Due to their compact size, reduced power consumption and reduced cost of fabrication, semiconductor optical amplifiers are popular for short to intermediate reach, narrow band gain applications [5]. The disadvantages of SOAs include much narrower wavelength bands, reduced amplification, and higher noise figure than erbium-doped fiber amplifiers (EDFA) [6]. EDFAs are widely used in line amplifiers for long distance links and other applications requiring high output power, high data rates, and low noise. An EDFA can simultaneously amplify signal light of multi wavelengths within an amplification spectrum band. Therefore, it is widely used as an optical amplifier applied to a wavelength division multiplexing (WDM) transmission system. A recent technology uses a circuit of EDFA to fully exploit the spectrum of all-wave fiber and it is called ultra wide-band EDFA [7]. Raman amplification is also becoming increasingly important in optical communication systems, in particular in high-bit rate WDM and DWDM systems. An important advantage of Raman amplification is that the effective optical signal-to- noise ratio is significantly lower than that of an erbium-doped fiber amplifier for the same gain. However, the Raman amplifier not only has very low optical amplification efficiency, but also needs a high-priced pumping light source, thereby increasing the size and the price of the optical amplifier module [6].

1.2 Routing and Wavelength Assignment (RWA)

The logical topology in a WDM optical network is defined using a set of logical edges or lightpaths. To establish a lightpath, it is important to find a suitable route for it in the physical topology and assign a channel to it for every fiber in its route. Given a physical topology and a set of connection requests, the problem of setting up of lightpaths and assigning channels to each of these lightpaths is known as Routing and Wavelength Assignment (RWA) problem [21]. In a network where no wavelength converter is available, a lightpath must be assigned the same channel on all the fiber links it traverses, satisfying the wavelength continuity constraint. In networks with full wavelength converters at each node, the channel used by a lightpath may vary from one fiber to another.

2. Literature Review

In the past decade we have observed a phenomenal growth of telecommunication networks, which was mostly driven by ever-increasing user demands for new applications as well as continuous advancements in the technologies involved. With the introduction of optical fibers as the data communication medium, which can provide a huge bandwidth capacity, today’s optical networks can easily handle the unprecedented bandwidth demand of the modern day communications [1].

Ahmed Mokhtar *et. al.* [8], proposed the adaptive routing algorithms to improve the blocking performance of the network. They considered routing and wavelength assignment in wavelength-routed all-optical networks with circuit switching. They adopted a general approach in which they considered all paths between a source–destination (s–d) pair and incorporate network state information into the routing decision. This approach performs routing and wavelength assignment jointly and adaptively and outperforms fixed routing techniques. They also presented adaptive routing and wavelength assignment algorithms and evaluated their blocking performance. They have also obtained an analytical technique to compute approximate blocking probabilities for networks employing fixed and alternate routing.

Yoo Younghwan *et. al.* [9], presented four adaptive routing algorithms which favour paths with near-maximum number of available wavelengths between two nodes, resulting in improved load balancing. These presented adaptive routing algorithms were simulated and compared with least loaded and fixed routing algorithms for small networks. First-fit wavelength assignment policy was used for simulation of these proposed algorithms.

G. Mohan *et. al.* [10], considered wavelength rerouting in wavelength routed wavelength division multiplexed networks with circuit switching. The lightpaths between source–destination pairs were dynamically established and released in response to a random pattern of connection arrival requests and connection holding times. They also presented a time optimal rerouting algorithm for wavelength-routed WDM networks with parallel Move-to-Vacant Wavelength-Retuning (MTV-WR) rerouting scheme.

R. Ramaswami *et. al.* [11], considered the problem of routing connections in a reconfigurable optical network using wavelength division multiplexing. They derived an upper bound on carried traffic of connections for any routing and wavelength assignment algorithm in a network.

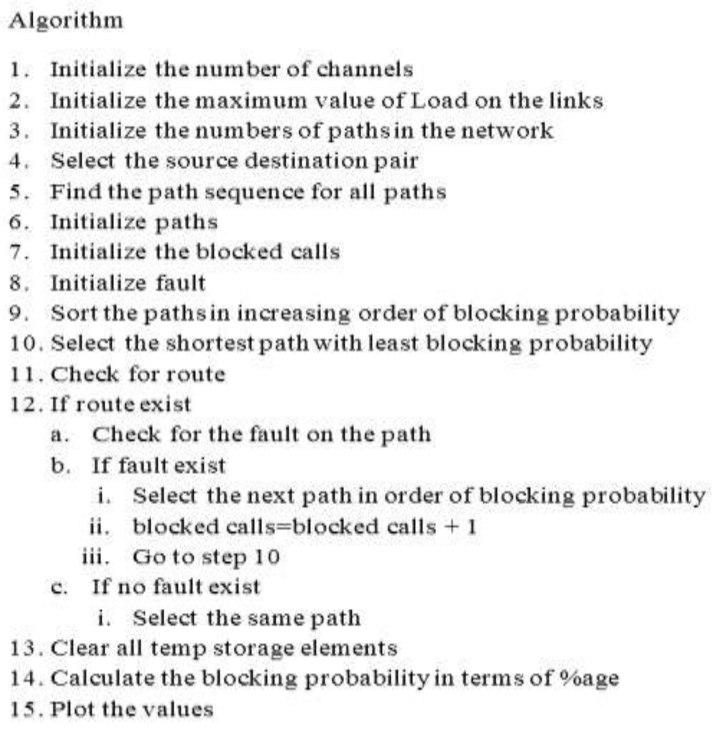
R. Ramamurthy *et. al.* [12], proposed an approximate analytical model that incorporates alternate routing and sparse wavelength conversion. They considered an optical network which employed wavelength routing cross-connects that enabled the establishment of wavelength-division-multiplexed connections between the node pairs. The simulations studied the relationships between alternate routing and wavelength conversion which were performed on three representative network topologies.

Xiaowen Chu *et. al.* [13], considered rerouting as an effective approach to decrease the blocking probability in legacy circuit-switched networks and proposed a routing algorithm. They also implemented intentional lightpath rerouting in all-optical WDM mesh networks. They proposed a Dynamic Least Congested Routing (DLCR) algorithm which dynamically switches the lightpath between the primary route and alternate route according to the network traffic distribution. Extensive simulation results showed that DLCR algorithm achieved better blocking performance than traditional routing algorithms including shortest path routing, fixed-alternate routing and least congested path routing.

Wang Yao *et. al.* [14], studied the rerouting approach and proposed different rerouting schemes for the provisioning of multi-granularity connections in two-layer wavelength-routed optical networks with grooming capability. They considered the dynamic traffic environment where connection requests arrive and depart dynamically. The rerouting procedure was applied only when the normal routing fail. They employed rerouting approach to improve the network throughput under the dynamic traffic model. They proposed two rerouting schemes, Rerouting at Lightpath Level (RRAL) and Rerouting at Connection Level (RRAC). A qualitative comparison was made between RRAL and RRAC. They have also proposed the critical-wavelength-avoiding one-lightpath-limited (CWA-1L) and Critical-Lightpath-Avoiding One-Connection-limited (CLA-1C) rerouting heuristics, which were based on the two rerouting schemes respectively. Simulation results showed that blocking probability was significantly reduced by these rerouting schemes.

3. Proposed Strategy for Routing

In this section we will proposed a strategy for routing in optical networks. We have proposed a routing algorithm in this thesis which is an improvement of the shortest path algorithm. In this algorithm first of all the source-destination (SD) pair is selected and after selection of the SD pair the route is being established by using the shortest path algorithm (Dijkstra Algorithm). When the route is selected then that route is checked for the fault. This fault is assumed as a dynamic fault so the routing is dynamic routing. The route is checked for the fault; if the fault does not exists then the blocking probability is reduced and if the fault exist on the selected path then the path is left and the next path in the order of shortest path is selected. In this way the blocking probability is reduced to a certain extent. This algorithm can be easily explained with the help of following points.



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Algorithm

1.  Initialize the number of channels
2.  Initialize the maximum value of Load on the links
3.  Initialize the numbers of paths in the network
4.  Select the source destination pair
5.  Find the path sequence for all paths
6.  Initialize paths
7.  Initialize the blocked calls
8.  Initialize fault
9.  Sort the paths in increasing order of blocking probability
10. Select the shortest path with least blocking probability
11. Check for route
12. If route exist
    a.  Check for the fault on the path
    b.  If fault exist
        i.   Select the next path in order of blocking probability
        ii.  blocked calls=blocked calls + 1
        iii. Go to step 10
    c.  If no fault exist
        i.   Select the same path
13. Clear all temp storage elements
14. Calculate the blocking probability in terms of %age
15. Plot the values
```

4. Results and Discussion

In this section, the simulation results of proposed routing algorithm have been shown. Also, the blocking probability of proposed algorithm is compared with some of the conventional algorithms. The simulation is carried out on simulation software MATLAB 7.2 of Mathworks. The blocking probability of network is calculated depending upon number of channels, load and the number of links.

The routing algorithm has been proposed for survivable networks and the performance of this routing algorithmis evaluated in terms of blocking probability and fairness. The results are shown in figure 5 – 12. The proposed algorithm was applied on the random network topology shown in figure 4.

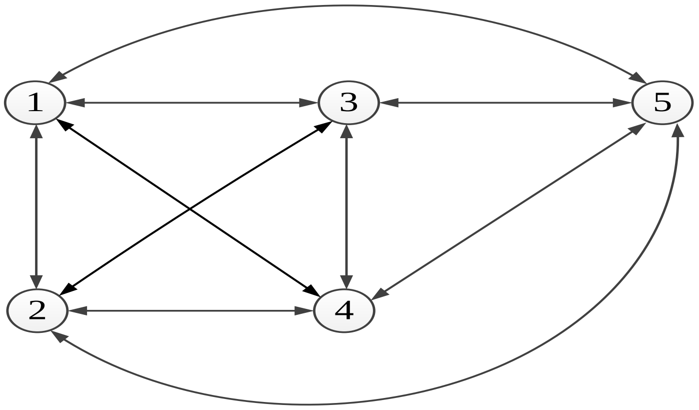

Figure 4 Network Topology

Table 1: Physical Route and number of wavelengths

S-D Pair	Physical Route	Wavelength	Route Length
1-5	1-5	λ1	1
	1-4-5	λ1	2
	1-3-5	λ1	2
	1-2-5	λ1	2
	1-2-4-5	λ1	3
	1-2-3-5	λ1	3
	1-3-2-5	λ1	3
	1-3-4-5	λ1	3
	1-4-3-5	λ1	3
	1-4-2-5	λ1	3
	1-2-3-4-5	λ1	4

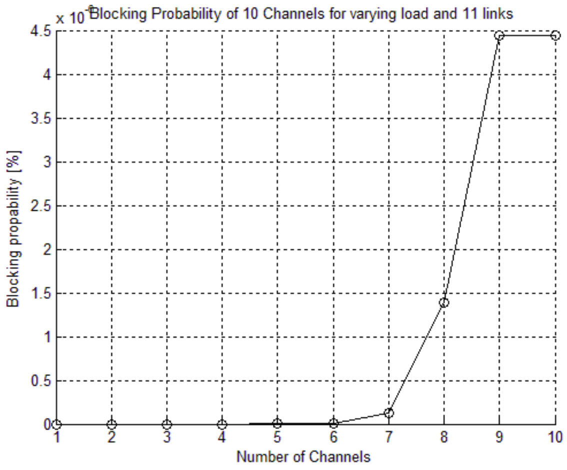

Figure 5: Blocking probability vs Number of channels for the network load = 10 (Erlangs)

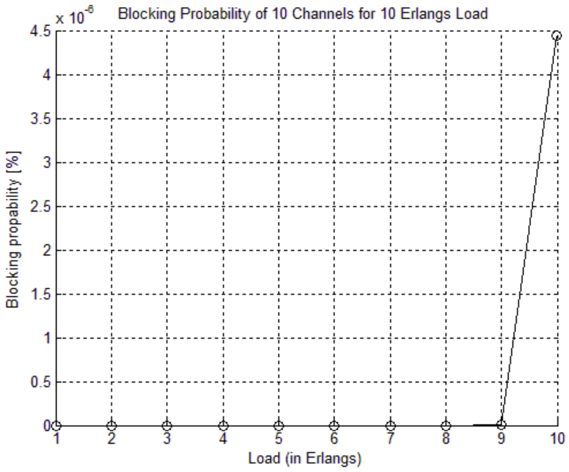

Figure 6: Blocking probability vs Load for 10 channels and Load =10 Erlangs

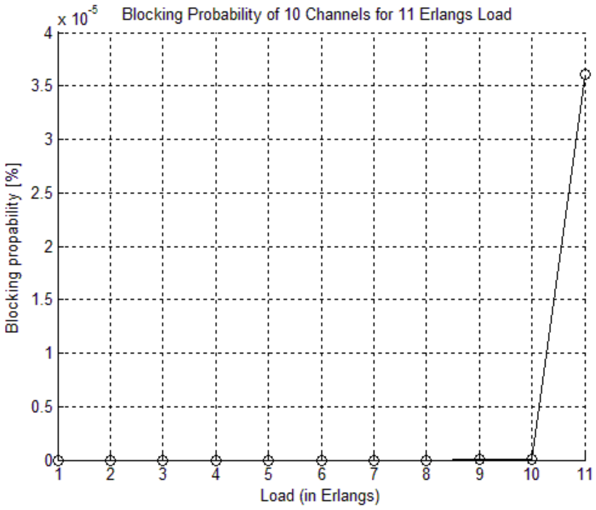

Figure 7: Blocking probability vs Load for 10 channels and Load =11 Erlangs

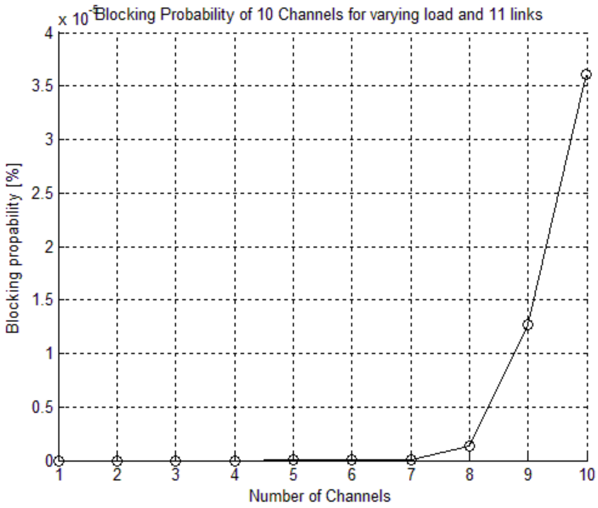

Figure 8: Blocking probability vs Number of channels for the network load = 11 (Erlangs)

Now when the value of maximum value of load is increased upto 11 and keeping all other values constant the dynamic load was fixed to be [10 11 8 9 9 5 8 2 8 1] and path {1-4-3-5} was selected and the average value of blocking probability was calculated as 0% as shown in figure 7– 8. Further when the maximum value of load was increased to 12 and the dynamic load was assumed as [1 2 10 9 4 12 1 6 5 10] by the algorithm then path {1-5 } was selected and is value of blocking probability was increased but again found nearly 0% as shown in figure 9 – 10. When the value of load was increased to 13 and the dynamic load was assumed as [3 7 6 9 10 10 4 9 9 3] by the algorithm then path {1-5 } was selected and is value of blocking probability was increased but again found nearly 0% as shown in figure 11 – 12

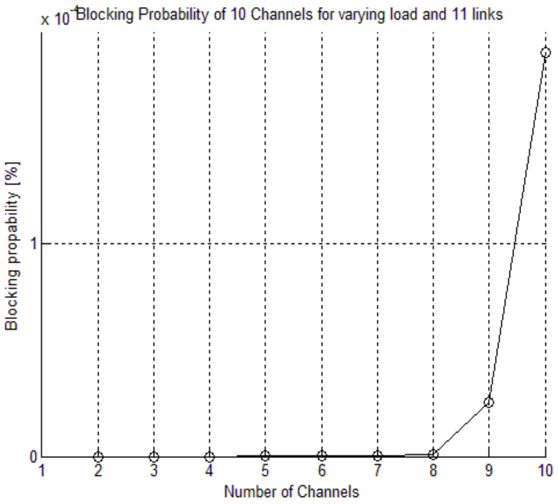

Figure 9: Blocking probability vs Number of channels for the network load = 12 (Erlangs)

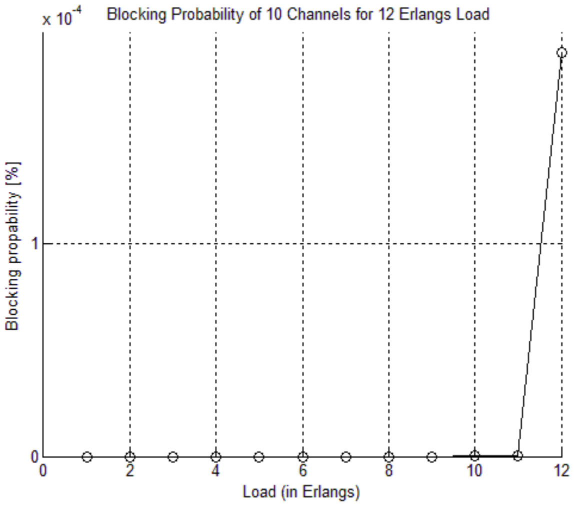

Figure 10: Blocking probability vs Load for 10 channels and Load =12 Erlangs

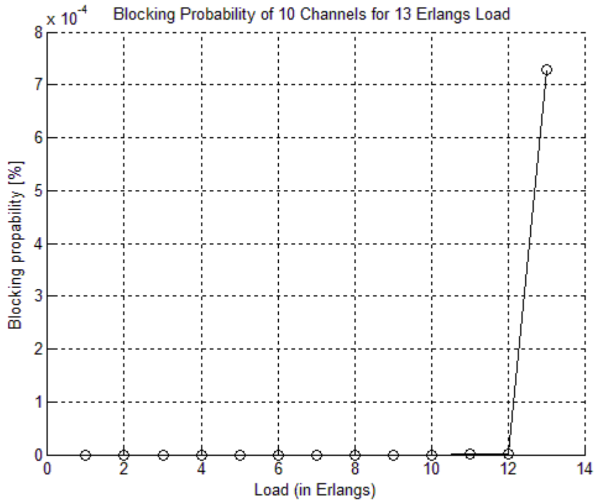

Figure 11: Blocking probability vs Load for 10 channels and Load =13 Erlangs

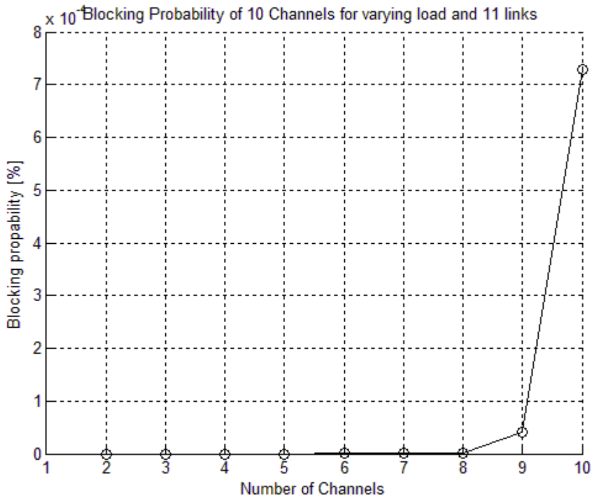

Figure 12: Blocking probability vs Number of channels for the network load = 13 (Erlangs)

We have applied the proposed algorithm on the network topology shown in figure 5.1. In the algorithm we have fixed some of the values and varied other to find the output. In our simulation results we have fixed the value of channels to 10 and for the given network topology the number of paths is fixed to 11 as per the table 5.1. For the given values we have varied the value of load (in Erlangs) and calculated the results for the given routing algorithm. The path sequence was entered as per the table 5.1 and the load was varied from 10 Erlangs to 1000 Erlangs respectively. The results are shown in figure 5.2 – 5.14. For figure 5.2 the Load was dynamically assumed to be [10 10 5 9 2 5 10 8 10 7] respectively by the algorithm and path {1-2-5} was found having minimum load and then this path was selected and was checked for faulty path also this path was fault free and was selected for connection. The value of blocking probability in this case was calculated nearly 0%. Figure 4 show that as the number of channels is increased the value of blocking probability is increased but still its value is very low and is of the order of 0%.

5. Conclusion

We can conclude that in this paper we have proposed a better wavelength assignment strategy for the better performance of optical networks. The result show that the blocking performance of the networks with the use of this algorithm is very improved and the value of this is nearly equal to zero which is better than any other algorithm proposed yet.

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