Fault Tolerant Congestion Based Algorithms in OBS Network

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Abstract

In Optical Burst Switched networks, each light path carry huge amount of traffic, path failures may damage the user application. Hence fault-tolerance becomes an important issue on these networks. Blocking probability is a key index of quality of service in Optical Burst Switched (OBS) network. The Erlang formula has been used extensively in the traffic engineering of optical communication to calculate the blocking probability. The paper revisits burst contention resolution problems in OBS networks. When the network is overloaded, no contention resolution scheme would effectively avoid the collision and cause blocking. It is important to first decide, a good routing algorithm and then to choose a wavelength assignment scheme. In this paper we have developed two algorithms, Fault Tolerant Optimized Blocking Algorithm (FTOBA) and Fault Tolerant Least Congestion Algorithm (FTLCA) and then compare the performance of these algorithms on the basis of blocking probability. These algorithms are based upon the congestion on path in OBS network and based on the simulation results, we shows that the reliable and fault tolerant routing algorithms reduces the blocking probability.

Keywords: Optical Burst Switching Network; Congestion; Contention Resolution; Blocking Probability; Erlang Formula.

1. INTRODUCTION

Optical Burst Switching (OBS) is a technique to support bursty traffic over wavelength-Division-Multiplexed (WDM) networks [1].WDM offers the capability to handle the increasing demand of network traffic [2].Today up to several *T bits/sec* traffic can be carried by the optical link over long distance. With the introduction of WDM in optical communication, the discrepancy between optical transmission capacity and electronic switching capability increases [3].An OBS network is a collection of interconnected OBS nodes. An ingress OBS node assembles packets from local access network, for example, Internet Protocol (IP) packets, into burst and sends out a corresponding control packets (CP) for each data burst. The optical networks have the capacity to carry terra bytes of data per second through each node. The edge routers feed data into these networks. The basic diagram for WDM and network nodes is shown in Figure1.The data is typically carried over 10 Gbps wavelength channels. Once a channel is setup between source and destination, it can only carry packet traffic between selected source-destination pairs.

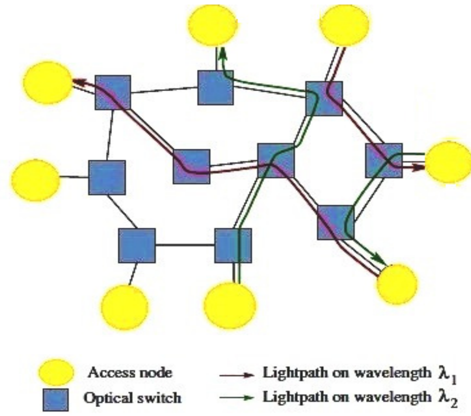

FIGURE 1: A wavelength-routed optical WDM network with lightpath connections

2. ROUTING STRATEGIES

A number of routing strategies have been proposed for OBS networks by researchers. These strategies can be classified as alternative, multi-path or single –path routing strategies. In general, a routing algorithm can be classified as static or adaptive. A static routing algorithm is one in which the routing procedure does not vary with time. But adaptive routing algorithms use network state information at the time of connection establishment [4]. Fixed routing is widely used static routing technique in which every s-d pair is assigned a single path. A call is blocked if its associated path is not available. In alternative routing each s-d pair is assigned a set of paths. In alternative routing, when the burst contention occurs, deflective mechanisms react to it and re-routes a blocked burst from the primary to alternative route. Alternative routing in OBS network can be either adaptive or non-adaptive. In adaptive alternative routing, a strategy is proactive calculation of alternative paths as well as their dynamic selection. The calculation of alternative paths can be performed in an optimized way. In non-adaptive both primary and alternative routing paths are fixed (static) and in most cases calculated with Dijkstra algorithm. A number of alternative paths can be given from a node to the destination. The aim of multi-path routing strategies is to distributing the traffic over a number of routing paths in order to reduce the network congestion. The path selection can be either according to a given probability or according to congestion on each path we can also say according to path congestion rank. Both adaptive (dynamic) or non-adaptive (static) strategies are considered for single path routing in OBS networks.

3. FAULT TOLERANT ALGORITHMS IN WDM/OBS NETWORKS

The ability of network to with-stand failures is called as fault-tolerance. The failures in OBS networks can be classified into two categories i.e. wavelength level and fiber level failures [5].The wavelength level failure impacts the quality of transmission of each individual lightpath and fiber level failure affect all the light-paths on an individual fiber. The fault tolerance schemes can be classified into path protection and path restoration. In path protection, backup resources are reserved during connection setup and primary and backup paths are computed before a failure occurs. In path restoration, the source and destination nodes of each connection traversing the failed link participate in distributed dynamically discover an end-to-end backup route. If no routes are available for broken connection, the connection is dropped.

Random Packet Assembly Admission Control (RPAAC) algorithm is a traffic engineering mechanism which monitors the network congestion and proactively drops incoming packets at ingress nodes before they may actually become harmful to the network [6].This algorithm is performed via adjusting the value of the packet selection probability, which regulates the size of bursts and percentage of proactively dropped traffic, on attempts to prevent or optimize network congestion. Reliable and fault tolerant routing (RFTR) algorithm was proposed by G. Ramesh *et al* [5].In order to establish the primary path, this algorithm uses the concept of load balancing. For source-destination pairs, finding a route of light paths for the network with least congestion is called as load balancing. The traffic is routed over the lightly loaded links. Algorithm for solving the Dynamic Routing and Wavelength Assignment (DRWA) problem in wavelength routed optical networks was proposed by D.Bisbal *et al* [7].This algorithm provides the low call blocking probability and also employ very short computation time. The blocking performance of DRWA algorithm is measured in terms of the mean call blocking probability. A review of DRWA algorithm can be found in Zang *et al*. [8].In response to source – destination connection request, a route is chosen from pre-calculated set, and then a wavelength is assigned to it following a wavelength assignment policy. If the selected route cannot be established on any wavelength, a new route is selected. If none of the routes in the set has an available wavelength, then call is blocked. Assigning wavelength to different paths in a manner that minimizes the number of wavelengths used under the wavelength-continuity constraint. There are various types of wavelength assignment heuristics that attempt to reduce the blocking probability i.e. First-Fit, Random, Least-Used, Most-Used, Min-Product, Least-Loaded [9], Max-Sum, Relative Capacity Loss, Wavelength Reservation and Protecting Threshold. Zing *et al* [8], introduced a new wavelength assignment algorithm called Distributed Relative Capacity Loss (DRCL), which is based on Relative Capacity Loss (RCL).They compared the performance of DRCL with RCL (with fixed routing) and FF (with fixed and adaptive routing) in terms of blocking probability and concluded that it perform better than FF (with adaptive routing) in the reasonable region.

Z. Jing *et al* [1] investigated a novel fault-tolerant node architecture using a resilient buffer(R-buffer).In their model buffer is attached for each outgoing link. The outgoing data burst will be tapped and stored in a buffer for short period of time (T_s) such that the bursts are expected to reach the other end of link if no failure is detected on this link during T_s. In case of link failure, burst stored in the buffer will be sent out via the backup routes. The data stored in buffer will be discarded after time period T_s so that the space of the buffer can be reused for future use. M. Ahmed *et al* [4] present adaptive routing i.e. Adaptive Unconstrained Routing (AUR) and wavelength assignment and evaluate their performance on the basis of blocking probability. Unconstrained routing scheme consider all paths between the s-d pairs. This is accomplished by executing a dynamic shortest path algorithm with link cost obtained from network state information at the time of connection request. This scheme is called AUR. They examined the performance of AUR in conjunction with different wavelength assignment schemes i.e. Random, Least-Used (SPREAD) and Most-Used (PACK) on the basis of blocking probability as a function of load per s-d pair. The Most-Used scheme has best performance, followed by Random and then by Least-Used. A new class of alternate routing was also proposed by H.Hiroaki *et al* [10] to achieve better performance of the network with different numbers of hop counts. Normally, the connection with shorter hop counts is likely accepted while the one with more hops encounters more call blocking. In optical network without wavelength conversion, the performance is degraded as the number of hop counts is increased [11].In alternate routing method with limited trunk reservation [10],connections with more hops are provided more alternate routed in proportion to the number of hop counts.

L. Kungmeng *et al* [2] also investigated on class of adaptive routing called Dynamic Wavelength Routing (DWR), in which wavelength converters are not used in the optical network. They introduced two algorithms: Least Congestion with Least Nodal-degree Routing (LCLNR) and Dynamic Two-end Wavelength Routing (DTWR) algorithms. Their objective is to maximize the wavelength utilization and reduce the blocking probability in the optical network. In their algorithms a route is determined by calculating their cost or weight function. In LCLNR algorithm, avoid routing dynamic traffic through congested links, thus reducing blocking probability. They concluded that number of connected calls by LCLNR algorithm is slightly decreased when the traffic load is increased. But in DTWR, number of call connected is increased with higher traffic load. Their results show that DWR does not increase the blocking probability when DTWR selects longer routes. X.Masip-Bruin *et al* [9] proposed a routing scheme in which the routes are determined based upon the twin criteria of minimizing the number of hops and balancing the network load, resulting in the reduction of both network congestion and blocking probability. Their proposed Minimum Coincidence Routing (MCR) algorithm was based on either the hop length or wavelength availability. The MCR algorithm exploits the concept of minimum coincidence between paths to balance the traffic load, thereby reducing the network congestion. This algorithm computes the end-to-end paths by considering the routes that have fewest shared links and minimum hops. The research on optimization of blocking probability on OBS networks was also done by Z.Rosberg *et al* [12].They introduced a reduced load fixed point approximation model to evaluate blocking probability. Also they compare the route blocking probabilities using Just-Enough-Time (JET), Segmentation, Least Remaining Hop-count (LRHF) and Most Traversed Hop-count (MTHF) policies. In MTHF, bursts that have traversed the most number of hops have the highest priority. MTHF improves the blocking probabilities of long routes provided that their prefixes do not collide or equal priority routes. LRHF has an effect similar to MTHF, but on short routes. So LRHF and MTHF priority can be used for service differentiation between long and short routes.

3. PROPOSED FAULT TOLERANT ALGORITHMS

In this paper we propose two algorithms Fault Tolerant Optimized Blocking Algorithm (FTOBA) and Fault Tolerant Least Congestion Algorithm (FTLCA). The objective of our algorithms is to minimize blocking probability. Our analytical models are designed under the following assumptions:

- A call connection request of s-d pair is based on a Poisson distribution with arrival rate ▯. The average service holding time is exponentially distributed with mean $1/\mu$. The offered congestion (Erlangs) per node is $\rho = \eta/\mu$.
- Each station has array of transmitters and receivers, where λ is the wavelength carried by the fiber.
- The optical network is set of nodes interconnected by single-fiber links.
- Each fiber-link is bi-directional and each link has λ wavelength channel.
- No Queueing of connection request. If a connection is blocked, it immediately discarded.
- Link loads are independent.
- We have assumed dynamic path allocation in this paper.

To calculate the blocking probability we will use the Erlang-b formula as in equation (1). The Erlang formula has been used extensively in the traffic engineering of optical communication. Erlang is defined as dimensionless unit of traffic intensity. It is dependent on observation time. The maximum that a facility can be in use is 100% of the time. If the observation time is 10 minutes, and facility is in use for the full time, then that is 1 Erlang.

$$P_{b(C,\lambda)} = \frac{\frac{C^{\lambda}}{\lambda!}}{\sum_{i=0}^{\lambda} \frac{C^{i}}{i!}} \qquad (1)$$

Where $P_{b(C,\lambda)}$ is the Blocking Probability for C congestion and λ wavelength.

Fault Tolerant Least Congestion algorithm (FTLCA):

The FTLCA algorithm is basically on congestion on paths between the s-d pairs. The blocking probability mostly occurs due unbalancing of congestion on paths between s-d paths. First algorithm selects the s-d pair, and then calculates the number of available paths between the selected s-d pair. After the calculation of number of available paths, checking of congestion on each path will be done. Then algorithm sorts the values of congestion in increasing order. Normally we assume that the path with minimum congestion will offer least blocking probability. On this criterion algorithm selects the first path in order of congestion. After the selection of path, the checking of path for fault that leads to blocking probability. If fault exits then select the second path in order of congestion, otherwise call will be established on selected path.

Fault Tolerant Optimized Blocking Algorithm (FTOBA):

Similar to FTLCA, the FTOBA is also congestion based but in this algorithm blocking probability on each will be calculated. First algorithm selects the s-d pair, and then calculates the number of available paths between the selected s-d pair. After the calculation of number of available paths, checking of congestion on each path will be done. After calculating the blocking probability for each path, arrange the paths in increasing order of blocking probability. The first path will be selected in order of blocking probabilities. Then algorithm checks the call which is blocked or not, because least blocking, does not mean that there is no fault when we chose the path with least blocking probability at the time of call establishment the call may be blocked due to any fault. If call is blocked then select the next path in the order of blocking probability. If call not blocked then, call is established.

Then flow chart shown in Figure 2 and Figure 3 more illustrate the mechanism of FTOBA and FTLCA algorithms.

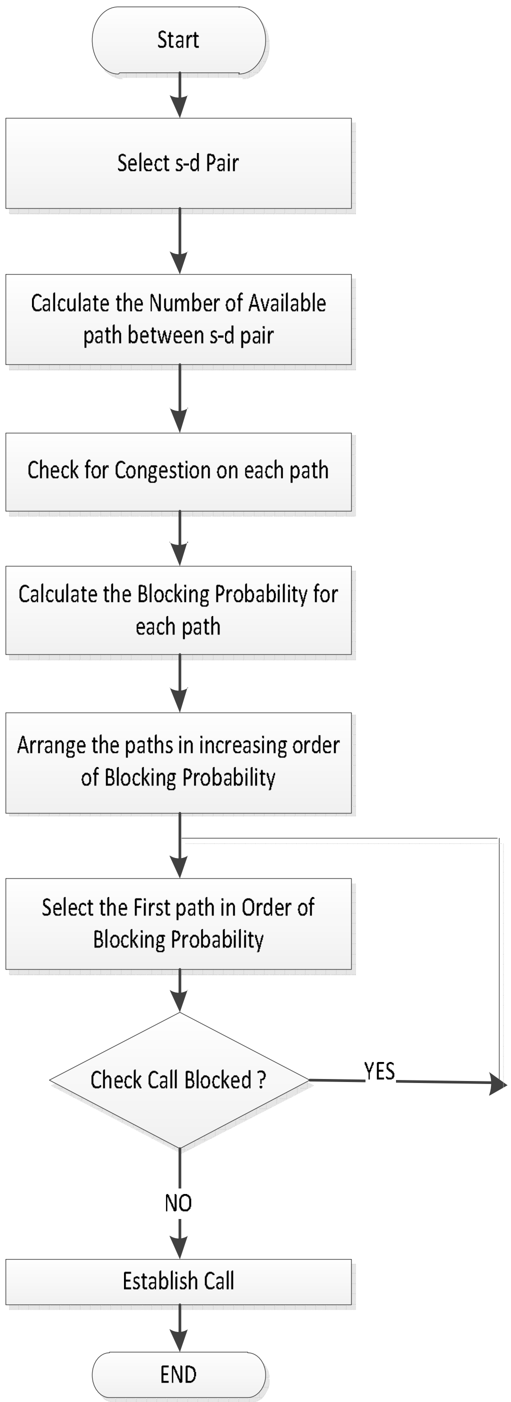

FIGURE 2: Fault Tolerant Optimized Blocking Algorithm (FTOBA)

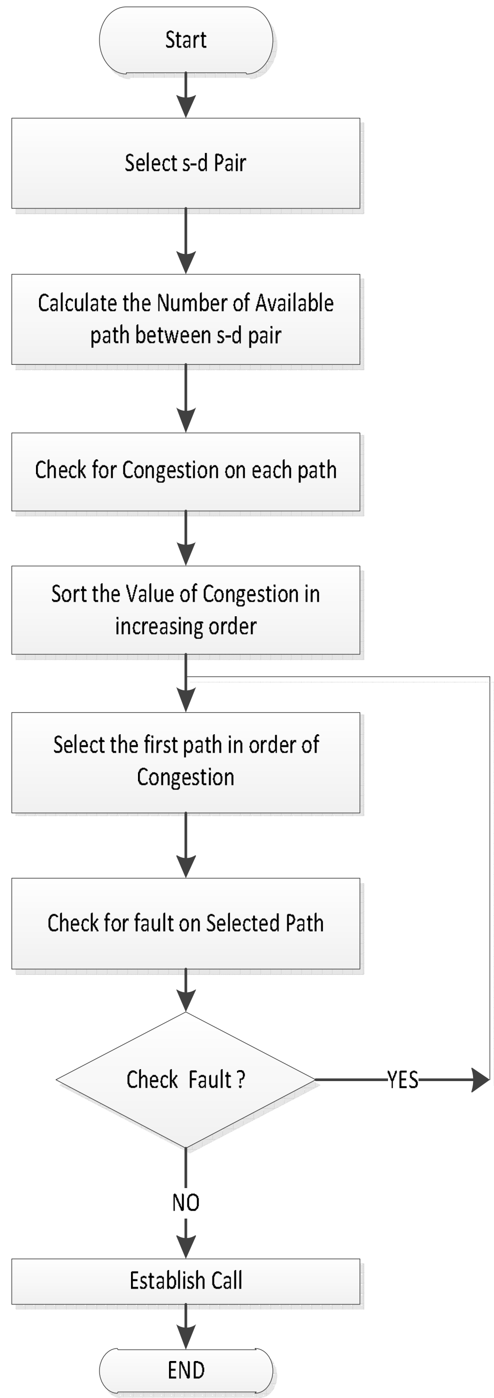

FIGURE3: Fault Tolerant Least Congestion Algorithm (FTLCA)

4. RESULTS AND DISCUSSION

The simulation is carried out on simulation software MATLAB 7.5 of Mathwork. Both the algorithms i.e. FTOBA and FTLCA are compared depending upon wavelengths, congestion and number of paths. We have fixed the value of paths P=25 and congestion in Erlangs, number of wavelengths is varied. The dynamic path allocation has been adopted for these algorithms. Due to dynamic routing algorithm the congestion on every path will be in random at different time of call establishment.

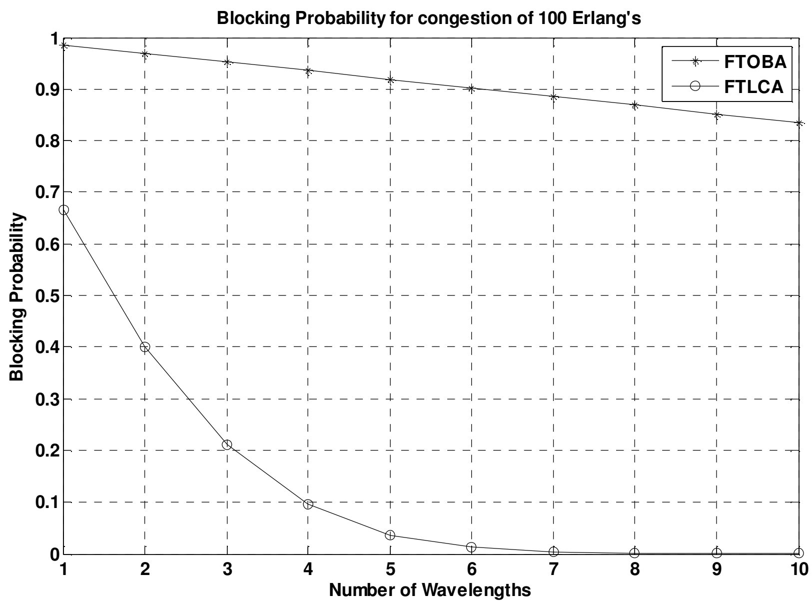

FIGURE 4: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 100 Erlangs and Wavelengths is 10

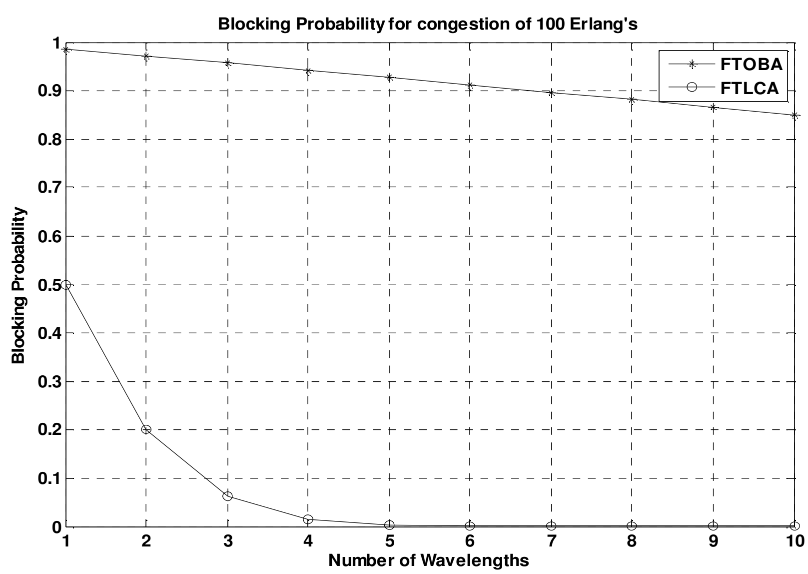

FIGURE 5: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 100 Erlangs and Wavelengths is 10

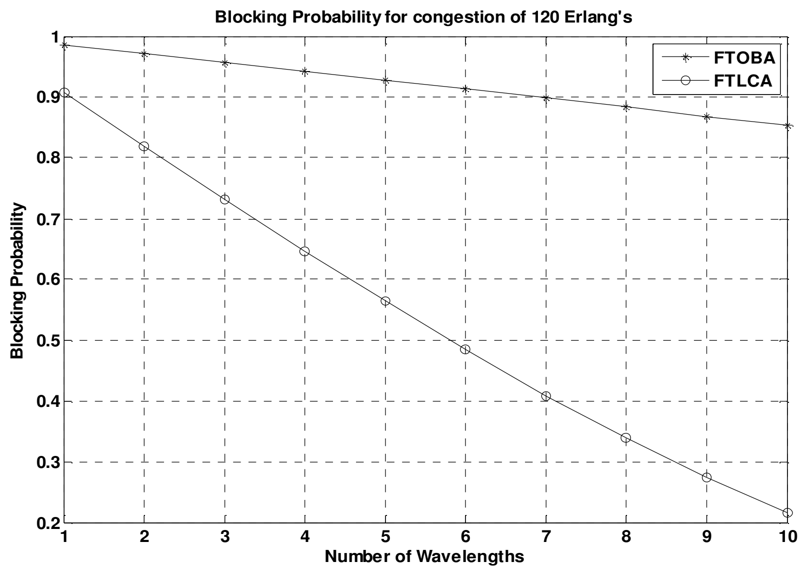

FIGURE 6: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 120 Erlangs and Wavelengths is 10

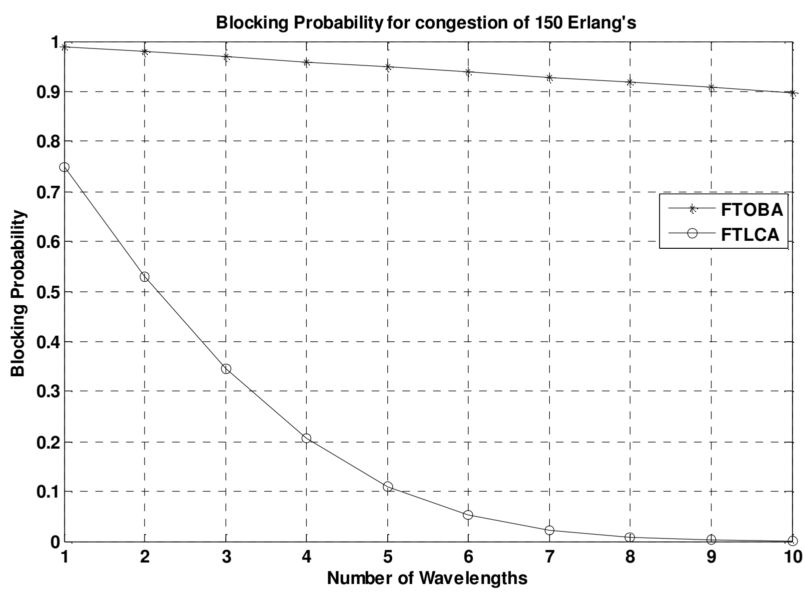

FIGURE 7: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 150 Erlangs and Wavelengths is 10

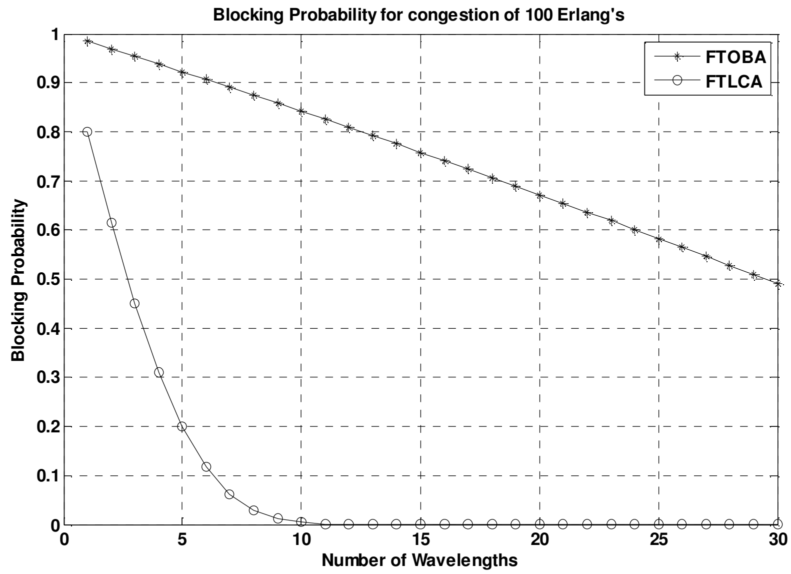

FIGURE 8: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 100 Erlangs and Wavelengths is 30

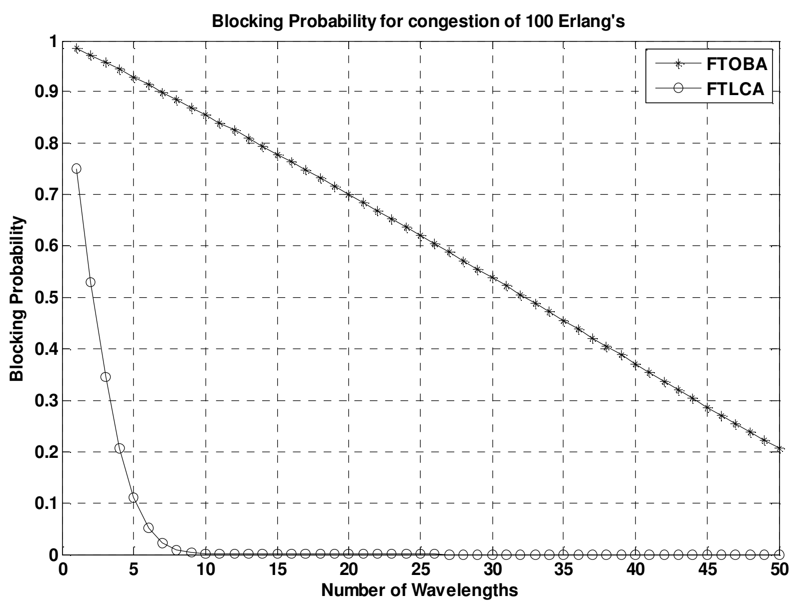

FIGURE 9: Comparison of FTOBA & FTLCA algorithms on the basis of Blocking Probability for Congestion of 100 Erlangs and Wavelengths is 50

The effect of random value of congestion on each path while using FTOBA and FTLCA algorithms is shown in Figure 4 and Figure 5.The Blocking probability is different for same number of wavelength in both the algorithms. But the effect of dynamic routing or random value of congestion is more in FTLCA algorithm as compared to FTOBA algorithm. The blocking probability with FTLCA algorithm is almost zero for '7' number of available wavelength and it remains zero for up to '10' number of wavelengths as shown in Figure 4.But in FTOBA blocking probability is lies between 80%-90% for these number of wavelengths. The blocking probability is decreased with increase in number of wavelengths in both the algorithms. The Figure 4 & Figure 5 shows the performance of both the algorithms when congestion in Erlangs on each path is 100 and there are '10' number of wavelengths.

Next we increase the maximum value of limit congestion on each path i.e. 120,150 Erlangs and number of wavelength as '10', results are shown in Figure 6 and Figure 7 respectively. It is observed that the increase in congestion does not affect the FTOBA algorithm. The blocking probability is nearly same as is in the case when maximum congestion on each path is 100 Erlangs. But in FTLCA algorithm the blocking probability is increased with increase in congestion. If we can limit the maximum value of congestion to a particular value than these algorithms are very effective.

In second part, we limit the maximum value of congestion 100 Erlangs and increased the number of wavelengths to 30 and 50 as shown in Figure 8 and Figure 9 respectively. With the increase in number of wavelengths the blocking probability decreases. As shown in Figure 9, for FTLCA the blocking probability is zero at '10' number of wavelengths and it remains zero up to '50' number of wavelengths. Similarly in FTOBA algorithm the blocking probability decreases with the increase in number of wavelengths. The blocking probability is 20% at '50' number of wavelength when maximum congestion on each path is 100 Erlangs.

5. CONCLUSION

In this paper, we have presented fault tolerant algorithms for the routing in optical network. We conclude that the performance of FTLCA is better than the FTOBA routing algorithm in optimizing the blocking probability to setup lightpath in network. It has been observed that the value of blocking probability is reduced with the increase in number of wavelengths. These algorithms are better than conventional algorithms as complexity of these algorithms is very less. Also these algorithms can be implemented in on-line path allocation process. If we can limit the maximum value of congestion to a particular value than these algorithms are very effective. Results have been proved that these algorithms can be used effectively in faulty OBS networks to yield better results.

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