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Performance Evaluation of Bandwidth Allocating Algorithms in Generalized Multi Protocol Label Switched Optical Networks to Enhance Quality of Service

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ABSTRACT Generalized Multi Protocol Label Switched (GMPLS) optical networks increase the network capacity by allowing large number of parallel links between nodes in a network which is the basic requirement in optical communication where hundreds of parallel links may exist between a pair of nodes. It also facilitates switchovers to alternate channels, rapid fault detection, fault isolation and reducing network downtime. In this paper, GMPLS network is proposed with dynamic users. Then the different bandwidth allocating algorithms have been implemented on the proposed GMPLS optical networks. The various algorithms involve Minimum Execution Time (MET) algorithm, Minimum Completion Time (MCT) algorithm and Opportunistic Load Balancing (OLB) algorithm. The considered algorithms are very popular but have not been implemented on GMPLS optical networks in the literature which shows the novelty of the work. The network performance is evaluated for each algorithm and compared with each other. The results reveal that MET reduces the blocking probability $< 0.1\%$ and latency < 1ms. This shows that MET gives the best performance among the considered algorithms and enhance the quality of service in terms of blocking probability, latency, makespan and energy consumption in GMPLS optical networks.

INDEX TERMS Bandwidth allocation, blocking probability, GMPLS.

I. INTRODUCTION

The main challenge in today's market is to achieve the rapidly growing bandwidth demand and different Quality of Service (QoS) requirements. These properties are to be maintained along with the security of the data which can be obtained by using optical fibers for telecommunication purpose [1]. Optical fiber provides large bandwidth and low losses. Optical networks use signals encoded in the form of light to transmit the required information among the nodes of communication networks. New and emerging use cases, such as the interconnection of geographically remote data centers (DC), are drawing attention to the need for provisioning end-to-end connectivity services spanning multiple and heterogeneous network domains [2]. This heterogeneity is due not only to the data transmission and switching technology (the so-called data plane) but also to the deployed control plane, which may be used within each domain to automate the setup and recovery of such services, dynamically. The choice of a control plane is affected by factors such as availability, maturity, operator's preference, and the ability to satisfy a list of functional requirements [3]. Off-site data backup or virtual machine migration involve an increasing amount of data traffic between remote and geographically dispersed data centers, requiring efficient network architectures in terms of cost, energy consumption, and reliability. Such architectures may combine flexible, finegrained, and adaptive intra-DC traffic control regarding forwarding entries and policies in a very dynamic context with long-haul, potentially multidomain aggregated inter-DC transport [4]. To increase the

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security and speed, Multi-Protocol Label Switching (MPLS) was employed in the optical network in late 1990's [5]. MPLS was found to be the technology which seems to solve QoS problem better than others, primarily due to its traffic engineering capabilities [6], [7]. It provides mechanism for faster transmission of packets through Internet Protocol (IP) routers. Traditional IP routers did not have any connections. The router determined the next hop using the destination IP address present on the received packet with the help of its own forwarding table which included the information on the network topology etc. It took a lot of time and process became slow, therefore, labels present in the packet were made generalized and Generalized Multi Protocol Switched (GMPLS) optical networks came into existence. GMPLS extends and acclimatizes the MPLS control plane by involving the label exchange pattern to manage any packet switched network [8]. GMPLS has introduced a revolution in optical networks for end-to-end transmission. The continuously increasing demand of optical communication has significantly increased the problem of interference and bandwidth scarcity. In other words, the efficiency of optical networks has degraded in terms of QoS [9]. GMPLS provides enhancements to MPLS to support network switching for wavelength, time and fiber switching along with packet switching. Traditional MPLS is designed to carry Layer 3 IP traffic by establishing IP-based paths and associating these paths with arbitrarily assigned labels. These labels can either be configured explicitly by a network administrator or dynamically assigned by a protocol such as the Label Distribution Protocol (LDP) or Resource Reservation Protocol (RSVP). In contrast, the main feature of GMPLS is that it can carry various types of Layer 1 through Layer 3 traffic. GMPLS labels and LSPs can be processed at four levels. The levels are Fiber-Switched Capable (FSC), Lambda-Switched Capable (LSC), Time-Division Multiplexing Capable (TDM), and Packet-Switched Capable (PSC) [10]. The policy adapting GMPLS minimizes the costs which involve bandwidth, switching and signaling [11]. GMPLS is capable of allocating suitable route based on the size of the network and computational constraints [12]. The control plane (signaling and routing) provided by GMPLS simplifies the network operation and management by managing network resources, automating end to end connections provisioning and providing the required QoS. The major problem in optical networks is Routing and Wavelength Assignment (RWA). Many studies have been carried out which investigated RWA problem [13], [14]. The GMPLS framework offers an approach to implement Internet Protocol (IP) over Dense Wavelength Division Multiplexing (DWDM) with different route assignments depending on the limitations occurring due to residual dispersion accumulated on the light wave path [15], [16]. The selection of light path connections can be efficiently done with the help of GMPLS [17], [18].

GMPLS labeling becomes more flexible than MPLS. A GMPLS label can represent a TDM time slot, a Dense Wavelength Division Multiplexing (DWDM) wavelength (also known as a lambda), or a physical port number. The labels can be derived from physical components of the network devices, such as interfaces. In GMPLS, the label includes the implicit values defined by the medium used.

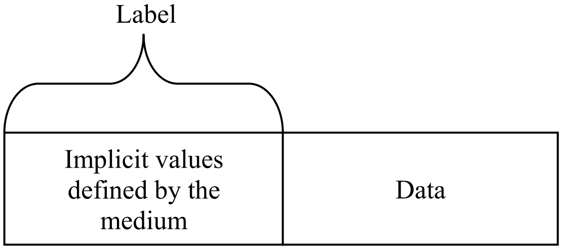

FIGURE 1. Packet format for GMPLS.

GMPLS labeling becomes more flexible than MPLS. A GMPLS label can represent a TDM time slot, a Dense Wavelength Division Multiplexing (DWDM) wavelength (also known as a lambda), or a physical port number. The labels can be derived from physical components of the network devices, such as interfaces. In GMPLS, the label includes the implicit values defined by the medium used. There is no need for a switch to read label in the header of each packet. The label is an inherent part of the switch fabric and the switching operations depend on wavelength and timeslot etc as shown in the packet format of GMPLS in Fig. 1. It uses the physical property of the received data stream to identify the Label Switched Path (LSP) i.e. LSPs are implicitly labeled in GMPLS [19]. It increases the network capacity by allowing large number of parallel links between nodes in a network which is the basic requirement in optical communication where hundreds of parallel links may exist between a pair of nodes. It also facilitates switchovers to alternate channels, rapid fault detection, fault isolation and reducing network downtime. The various control plane architectures include GMPLS, GMPLS with path computation element (GMPLS/PCE) and SDN. The GMPLS approach is an entirely distributed control plane, relying on routing and spectrum assignment (RSA) algorithms implemented in every node [20]. The GMPLS architecture is same as MPLS which is shown in Fig. 2.

In GMPLS optical networks, both signaling and RSA are performed fully distributed and each node is required to take care of computing, establishing and maintaining corresponding lightpaths itself. Moreover, each node take advantage of physical layer impairments (PLIs) information in its RSA unit where routes are determined by the corresponding source node of the demand considering the available resource constraints [21], [22]. GMPLS is considered a layer 2.5 networking protocol. Layer 2 carries IP packets over simple LANs or point-to-point WANs, while layer 3 uses internet-wide addressing and routing using IP protocols [23]. GMPLS sits in between with additional features for data transport across the network. Considering a centralized controller, decoupled from the data plane of the corresponding network, one may facilitate programming of the network. To this end, SDN

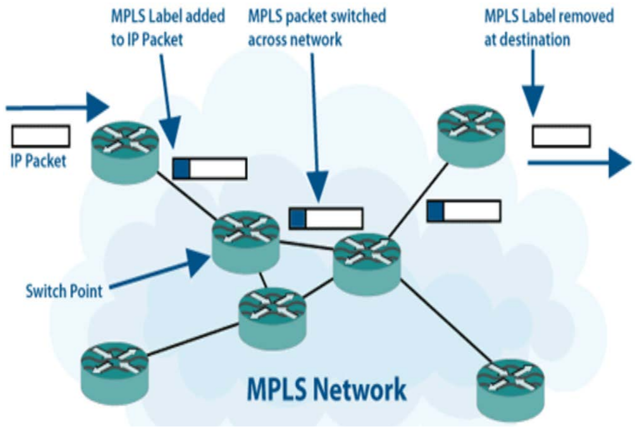

FIGURE 2. GMPLS node architecture.

is used by the centralized controller to perform both RSA computation and lightpath provisioning. It takes advantage of a flexible and open standard interface to control network elements for operators in contrast to the fact that GMPLS is usually deployed in a closed and proprietary development [24]. Our work greatly contributes to enhance the QoS of GMPLS optical networks by allocating bandwidth in an efficient manner with limited resources. The algorithms implemented in our presented work consume minimum time to complete the task. By using the selected algorithms, blocking probability decreases to large extent which in turn enhances the traffic load that can be handled by GMPLS network.

Till now, a number of popular bandwidth allocation techniques have been implemented on cloud computing networks [25], [26] but not on GMPLS optical networks. In our previous papers, models for blocking probability have been developed [27]. Moreover, we have implemented Minimum Execution Time (MET) algorithm on our proposed GMPLS optical network in the conference paper [28]. This paper extends our conference paper work and includes the implementation of different algorithms individually and then the performance of all these algorithms is compared with each other. In our previously published paper in an International conference, we just presented our basic idea. We had taken limited users and they were further limited to a single band. This paper is an extension of our previously reported results with infinite number of users. This paper is meant for realistic scenario as far as future generation networks are concerned. The current work is also based on multi bands.

In brief, this paper is an advanced version of our previously reported work having infinite users, multi bands and realistic scenario of future generation GMPLS optical networks.

II. GMPLS OPTICAL NETWORK

In this section, a plot that contains the complete GMPLS optical network having different users placed at their positions is presented. It also shows the location of servers placed in the network. The network length and network width are defining the area of the GMPLS optical network.

The Fig. 3 is plotted for the GMPLS optical network containing the users and servers at their specified positions. Also, it depicts the requests arising from one user to the neighboring users in the network. The requests are not known in advance. They occur randomly and the availability of server is checked at that particular time. The red stars in the network area represent the position of the users generating requests. The blue squares on the right side represent the position of servers performing the function of allocating wavelength and link rates to the demanding users maintaining the routing table and link stability.

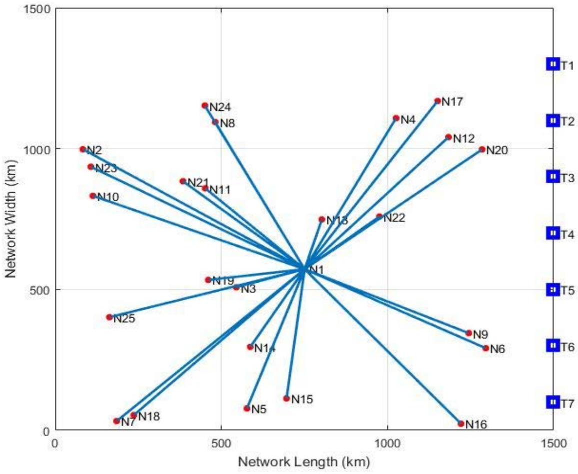

FIGURE 3. Scenario of GMPLS optical network showing the requests generated format for GMPLS.

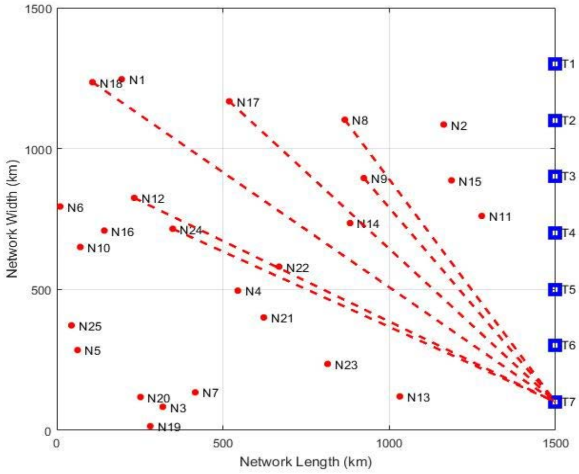

FIGURE 4. Scenario of GMPLS optical network showing connection establishment.

The Fig. 4 represents the scenario of GMPLS optical network containing the users and servers at their specified positions. It shows the assignment of server with least execution time to the demanding users in the GMPLS optical network. When the users send request to send their data, the network servers are analyzed in terms of least completion time i.e. the time to complete the request by each server is estimated and the server with minimum execution time gets selected. Then the selected server allocates the wavelengths and link rates to the users and data transfer occurs. The red lines show the connection between the users and the server.

In this particular result, second server is found to complete the task at the earliest and is selected for the connection establishment.

III. PERFORMANCE METRICS

This analysis of performance metrics for bandwidth allocation is based on blocking probability, cost, makespan, latency and energy consumption. The performance metrics are discussed below:

A. BLOCKING PROBABILITY

Probability is defined as the extent to which an event is likely to occur, measured by the ratio of the favorable cases to the whole number of cases possible. Blocking probability for cleared calls is given by equation 3.1 [27], [28].

$$B_p = \frac{Blocked\ Requests}{Total\ Requests} \tag{3.1}$$

The blocking probability is formulated by using Erlang B formula because it calculates the blocking probability of a buffer-less loss system, where a request that is not served immediately gets aborted, causing that no requests become queued [29]–[31]. Blocking occurs when a new request arrives at a time where all available servers are currently busy [32], [33]. But the link independence assumption is not applicable in optical networks [34], thus, Kelly's reduced load is also considered to amend link independence imprecision in calculating the blocking probability after considering the poisson random variable for number of calls and mean call duration [35]–[39].

B. COST

The network cost is defined as proper utilization of the available resources. The main parameters affecting the cost in the network are the network capacity and the transmission speed [40]. If the network capacity increases or the transmission speed increases in the network then the network cost will decrease. The cost is represented in equation 3.2.

$$Cost = TE_x \times \min\left[E_x\left(t\right)\right] \times N \tag{3.2}$$

where TE_x is total energy consumption by the network, $E_x\left(t\right)$ is execution time, N is total number of nodes.

C. LATENCY

Latency is defined as the calculation of delay. In a network, latency measures the time it takes for some data to get to its destination across the network [41]. The latency is given by equation 3.3.

$$Latency = BP_x \times \min\left[E_x\left(t\right)\right] \times \sum_{x=1}^{N} C_x \times N \tag{3.3}$$

where BP_x is the blocking probability, C_x is the cost.

D. MAKESPAN

Makespan is used to estimate the maximum completion time of the network by evaluating the finishing time of the latest task i.e. when all the tasks are scheduled. If the makespan of specific network is not minimized then the demand will not be completed on time [40]. It is represented by equation 3.4.

$$Makespan = \frac{\sum_{x=1}^{N} E_x\left(t\right) \times \sum_{x=1}^{N} C_x}{N \times R_x} \tag{3.4}$$

where R_x is number of requests per user.

E. ENERGY CONSUMPTION

The energy consumption in a network depends on average rate of the power consumption of users during the time of operation [41]. The power consumed refers to the power depleted in the acquisition and processing the signals in addition to transmit and receive power. The power consumption is represented in equation 3.5.

$$Energy\ consumption = \frac{E_T\left(x\right) \times Queue\ size}{N} \tag{3.5}$$

where is $E_T\left(x\right)$ is the energy consumed by requesting user.

IV. IMPLEMENTATION OF DIFFERENT BANDWIDTH ALLOCATING ALGORITHMS ON GMPLS OPTICAL NETWORKS

The basic problem in GMPLS optical networks is routing and wavelength assignment. It has been a challenge to achieve an efficient use of optical cross connects in the optical next generation internet deploying a GMPLS based control plane [42]. The various routing algorithms have been developed like policy based resource allocation methods for GMPLS optical networks and design based routing algorithm. Different critical features of service oriented GMPLS optical networks like provisioning with advance schedule, resource management have to be resolved [43]. This paper involves the implementation of various bandwidth allocating algorithms on GMPLS optical networks like Minimum Execution Time algorithm, Minimum Completion Time (MCT) algorithm and Opportunistic Load Balancing (OLB) algorithms. The other bandwidth allocating algorithms include First Come First Serve (FCFS) algorithm and Sufferage algorithm. FCFS algorithm sorts tasks by the order of their coming requirement of users which means request coming first will be handled first and the next request is considered only after completion of the first one [44]. The sufferage algorithm begins by calculating assessment of tasks for the minimum and second minimum completion times. The second stage of this algorithm determines the difference of these values and task with a minimum difference (sufferage) is allocated to the consistent resource [45]. The literature review shows that MET, MCT and OLB perform better than FCFS and sufferage algorithms in cloud computing [40], [46]. Also, it is found from the literature that these algorithms are implemented on cloud computing networks but have never been implemented on GMPLS optical networks. The various bandwidth allocating algorithms implemented on MPLS optical networks include a resource orchestration [47], open shortest-path-first traffic engineering (OSPF-TE) and resource-reservation protocol traffic engineering (RSVP-TE) [48], [49], Dynamic Online Routing Algorithm (DORA) [50], online algorithm for dynamically routing bandwidth guaranteed label switched paths [51], constraint based routing algorithm [52], routing and wavelength assignment scheme for DWDM long-haul optical networks [15], Bandwidth guaranteed QoS routing algorithm [53], distributed spectrum assignment approach [54], [55]. All the three selected algorithms consume less time to execute the requests as compared to other techniques reported in the literature. Thus, MET, MCT and OLB are implemented on the GMPLS optical network and then their performance is compared with each other. MET algorithm does not consider the queue size which gets improved in MCT algorithm [41]. MCT considers the queue size but the drawback of MCT is that it does not consider the size of data to be transferred so prioritized users get neglected sometimes.

A. MINIMUM COMPLETION TIME ALGORITHM

A bandwidth allocation technique named as Minimum Completion Time is implemented for allocating bandwidth in an efficient manner for proper utilization of available resources in the GMPLS optical network. In this technique, bandwidth is allocated to users on the basis of predictable completion time at the servers i.e. it calculates the minimum time required to complete the request considering the queue length at each server so that bandwidth can be allocated to another user. It finds the server that completes the coming request, i.e. the data gets transferred from the source to the destination completely, in minimum time. Thus, the bandwidth can be allocated in an efficient manner in this process reducing the blocking probability which in turn improves the quality of service in GMPLS optical networks.

1) PRINCIPLE AND WORKING

MCT algorithm finds the resource which takes minimum time to complete the task in random order [41]. It takes in account the number of users waiting for the server in a queue i.e. it considers the queue size at each server but has no concern with the time taken by that particular server in executing that request. The priority of server allotment does not wait for the next request. The server will then provide the connection by assigning the wavelength and link rates, taking in account their routing table and link stability.

2) FLOWCHART

In this algorithm, the position of users and servers is defined in the specified network area. It is done randomly as the users are not static in nature. The range of wavelengths and link rates are specified, keeping in mind the routing table and link stability.

The flowchart for MCT algorithm is shown in Fig. 5. Now, when the requests from different users occur, the time to complete the task by each server is estimated. Then the queue at each sever is observed. The server with least number of users in queue i.e. server with minimum queue size is identified and the server having least predictable completion time period after considering the queue size is allocated to the respective users. That is why the proposed algorithm is named as Minimum Completion Time algorithm. After the allocation of servers to the users, the available wavelengths are assigned to the demanding users. The link rates are evaluated to maintain the link stabilities and are provided to the users. Then the performance is evaluated in the GMPLS optical network.

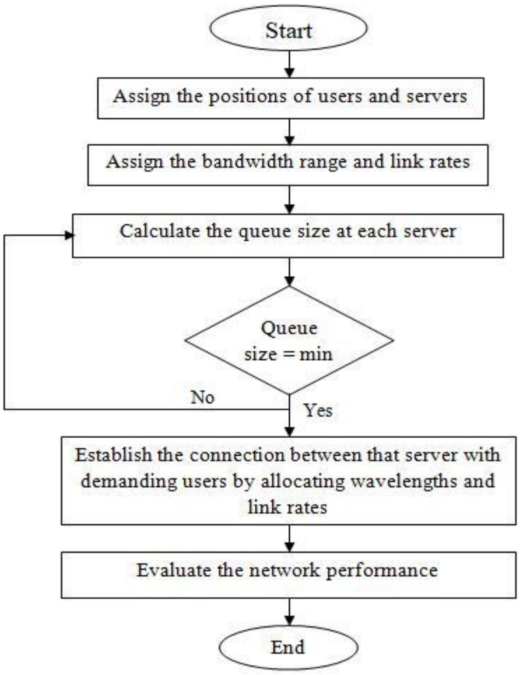

FIGURE 5. **Flowchart for MCT algorithm.**

3) RESULTS AND DISCUSSIONS

In this section, the results are plotted for the blocking probability with respect to the number of wavelengths available at the time of user request. Different graphs are plotted for various parameters like latency, cost, makespan and traffic load after implementing MCT algorithm.

Fig. 6 depicts the variation of blocking probability with respect to the increasing traffic load in the GMPLS optical network. As the traffic load increases, the channels or the wavelengths get occupied, therefore, the user requests get blocked but by using MCT technique, more traffic load can be handled without blocking as the channels get available recurrently due to the use of least completion time concept. The graph shows that the blocking probability increases with the increased traffic load but its value remains below 1% using MCT technique.

The blocking probability in GMPLS optical network and the number of wavelengths available at the time of request

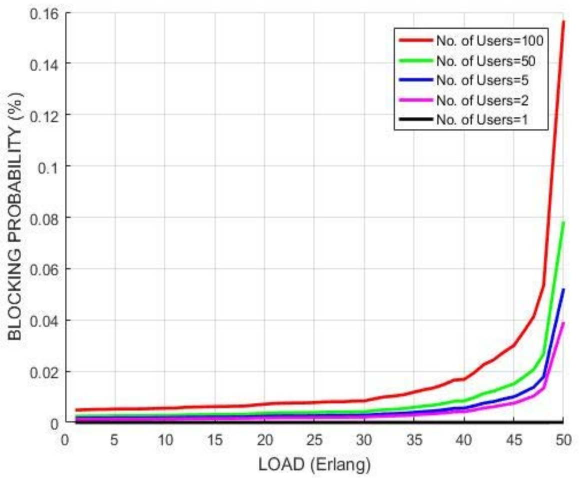

FIGURE 6. **Blocking probability as a function of load.**

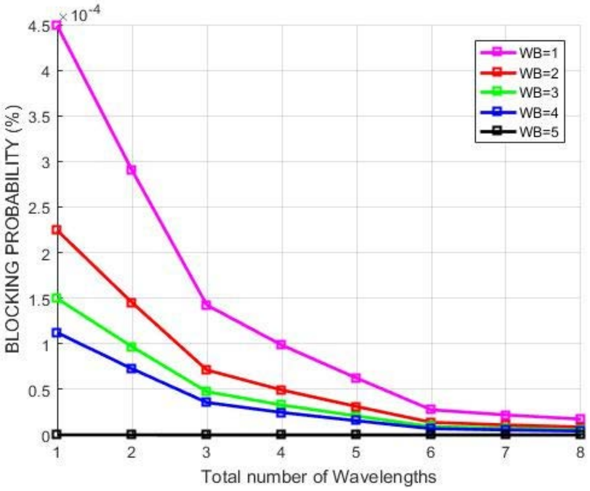

FIGURE 7. **Blocking probability as a function of number of available wavelengths.**

is represented in Fig. 7. The wavelength range is divided in different Wavelength Bands (WB). The plot reveals that the blocking probability decreases with increase in the number of available wavelengths. The MCT technique uses the concept of minimum completion time due to which the wavelengths gets available frequently. Thus, the number of available wavelengths increases and the call drops decreases which in turn decreases the blocking probability.

B. OPPORTUNISTIC LOAD BALANCING ALGORITHM

A bandwidth allocation technique named as Opportunistic Load Balancing algorithm is implemented for allocating bandwidth for proper utilization of available resources in the GMPLS optical network. This algorithm is a static load balancing algorithm and it does not consider the present status of the server. This makes an effort in keeping all nodes busy. The algorithm controls unexecuted tasks quickly to the nodes that are accessible within the system. Every task could be randomly assigned to the node [41].

1) PRINCIPLE AND WORKING

OLB algorithm is a static load balancing algorithm that assigns the server to the users by opportunity. It finds the resource that is available at the time of user request and assigns it to the user. It does not consider the execution time or completion time taken by the server. It simply assigns the server on the basis of availability. This is the reason that this algorithm does not give good results in terms of load balancing. As this algorithm is least concerned with the time taken for execution of task, the process becomes slow with this algorithm.

2) FLOWCHART

The flowchart for OLB is shown in Fig. 8.

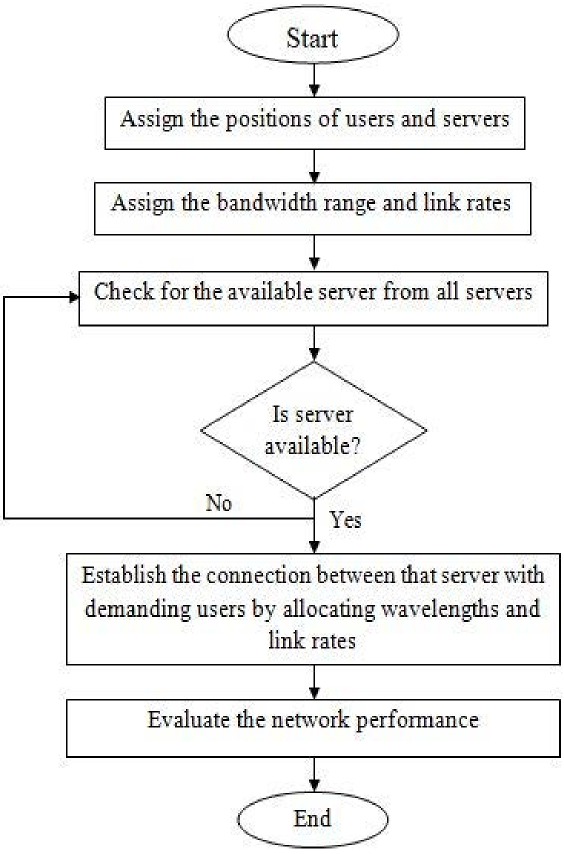

FIGURE 8. **Flowchart for OLB algorithm.**

In this algorithm, the position of users and servers is defined in the specified network area. It is done randomly as the users are not static in nature. The range of wavelengths and link rates are specified, keeping in mind the routing table and link stability. Now, when the requests from different users occur, the servers are analyzed for their availability irrespective of the time taken by them to execute or complete the task assigned to them. The available server is then assigned to

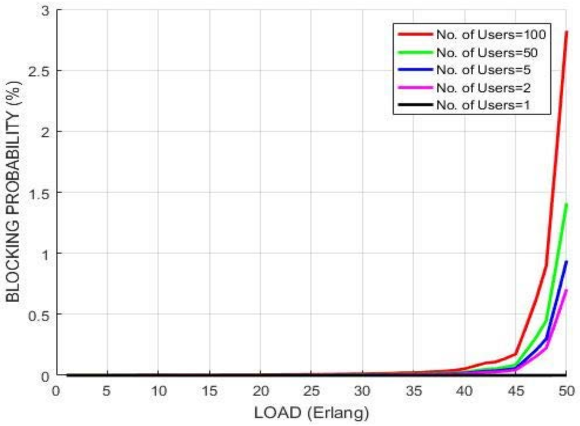

FIGURE 9. Blocking probability as a function of load.

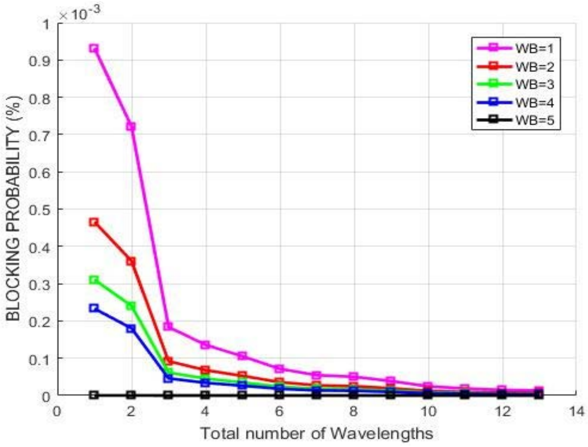

FIGURE 10. Blocking probability as a function of number of available wavelengths.

the desired users. After the allocation of servers to the users, the wavelengths are assigned to them and the link rates are evaluated to maintain the link stabilities and are provided to the users. Then the performance is evaluated in the GMPLS optical network.

3) RESULTS AND DISCUSSIONS

In this section, the results are plotted for the blocking probability with respect to the number of wavelengths available at the time of user request. Different graphs are plotted for various parameters like latency, cost, makespan and traffic load after implementing OLB algorithm.

The variation of blocking probability with respect to the increasing traffic load in the GMPLS optical network is represented in Fig. 9. As the traffic load increases, the channels or the wavelengths get occupied, therefore, the user requests get blocked but by using OLB technique, more traffic load can be handled without blocking as the channels get available recurrently due to the use of least execution time concept. The graph shows that the blocking probability increases with the increased traffic load but its value remains below 1% using the OLB technique.

Fig. 10 depicts the relation between the blocking probability in GMPLS optical network and the number of wavelengths available at the time of request. The plot reveals that the blocking probability decreases with increase in the number of available wavelengths. When the number of wavelengths is increased in the network then the availability of wavelengths for the new users gets increased and thus the blocking probability gets decreased by using OLB technique.

C. MINIMUM EXECUTION TIME ALGORITHM

A dynamic bandwidth allocation technique named as Minimum Execution Time is implemented for allocating bandwidth dynamically in an efficient manner for proper utilization of available resources in the GMPLS optical network. In this technique, bandwidth is allocated to users on the basis of predictable execution intervals at the servers i.e. it calculates the minimum time required to execute the request so that bandwidth can be allocated to another user. It has no concern with the number of users in a queue at that server [41]. It finds the server that executes the coming request in minimum time. Thus, the bandwidth can be allocated in an efficient manner in this process reducing the blocking probability which in turn improves the quality of service in GMPLS optical networks.

1) PRINCIPLE AND WORKING

MET algorithm finds the resource which has minimum execution time to execute the task. It allocates the work to the resource based on first comes first service i.e. the user sending request for the channel to transfer data first will be allotted least time consuming server at priority. The algorithm is least concerned with the amount of data to be transferred. The priority of server allotment does not wait for the next request. The process is least concerned with the queue length present at that particular server. The server will then provide the connection by assigning the wavelength and link rates, taking in account their routing table and link stability.

2) FLOWCHART

In this algorithm, the position of users and servers is defined in the specified network area. It is done randomly as the users are not static in nature. The range of wavelengths and link rates are specified, keeping in mind the routing table and link stability. Then the coverage area among the neighboring users is calculated and the routing table is maintained. The distance among all the users and server is investigated. If the distance is not greater than zero then it means the user is finding distance with itself so it needs to update the routing table. But if the distance is found to be greater than zero then the servers are analyzed for least time consumption to execute the task. Now, when the requests from different users occur, the time to execute the task by each server is estimated and the server having least predictable execution time period is allocated to the respective users. That is why the proposed algorithm is named as Minimum Execution Time algorithm.

After the allocation of servers to the users, the available wavelengths are assigned to the demanding users. The link rates are evaluated to maintain the link stabilities and are provided to the users. Then the performance is evaluated in terms of blocking probability and latency in the GMPLS optical network. The flowchart of MET algorithm is shown in Fig. 11.

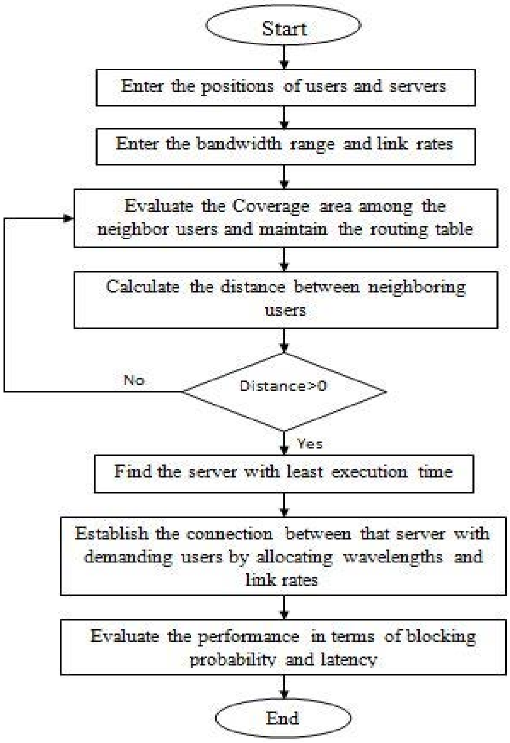

FIGURE 11. **Flowchart for MET algorithm.**

3) RESULTS AND DISCUSSIONS

In this section, the results are plotted for the blocking probability with respect to the number of wavelengths available at the time of user request and traffic load. Different graphs are plotted for various parameters like latency, cost and makespan after implementing MET algorithm.

The variation of blocking probability with respect to the increasing traffic load in the GMPLS optical network is represented in Fig. 12. As the traffic load increases, the channels or the wavelengths get occupied, therefore, the user requests get blocked but by using MET technique, more traffic load can be handled without blocking as the channels get available recurrently due to the use of least execution time concept. The graph shows that the blocking probability increases with the increased traffic load but its value remains below 1% using the MET technique.

Fig. 13 depicts the relation between the blocking probability in GMPLS optical network and the number of wavelengths available at the time of request. The plot reveals that the blocking probability decreases with increase in the number of available wavelengths. The MET technique uses the concept of minimum execution time due to which the wavelengths gets available frequently. Thus, the number of available wavelengths increases and the call drops decreases which in turn decreases the blocking probability. Thus, the quality of service for the complete network increases.

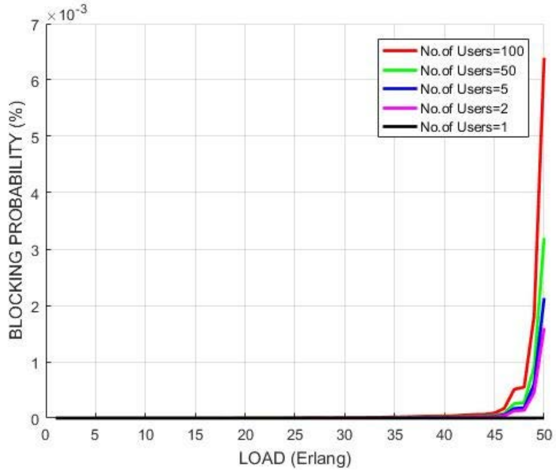

FIGURE 12. **Blocking probability as a function of load.**

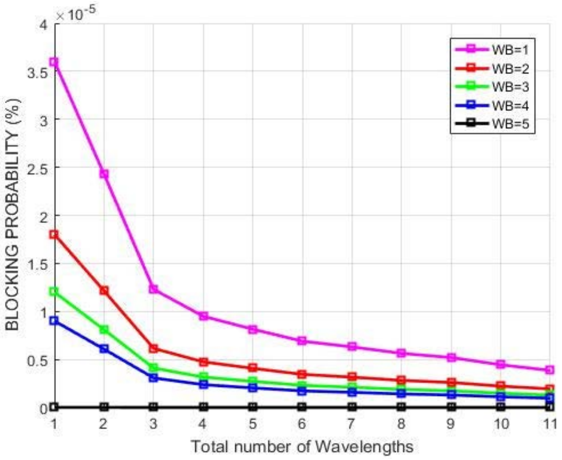

FIGURE 13. **Blocking probability as a function of number of available wavelengths.**

V. COMPARISON OF THE PROPOSED WORK WITH EXISTING ALGORITHMS

In this section, a comparison is carried out between the various performance parameters of the implemented algorithms with the existing techniques. The comparison is described in Table 1.

The Whale Optimization Algorithm (WOA) approach for optimum bandwidth allocation was implemented in wireless network [15]. The allocation was based on bandwidth reservation scheme in which bandwidth got distributed in such a way that there was balance in bandwidth demand. A modified sufferage heuristic algorithm Completion Time Based Sufferage Algorithm (CTSA) was based on completion time

TABLE 1. Comparison of implemented algorithms with existing work.

Algorithm → Parameters ↓	WOA [56]	CTSA [57]	Sufferage [41]	MET (This presented work)	MCT (This presented work)	OLB (This presented work)
No. of Users	---	100	100	100	100	100
Environment	Wireless	Cloud	Cloud	GMPLS	GMPLS	GMPLS
Type of bandwidth allocation	Static	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Makespan	---	5.78 ms	6.215 ms	4.86 ms	5.39 ms	5.68 ms
Blocking Probability	0.5	---	0.8	0.01	0.05	0.08

of tasks to evade the drawback of sufferage heuristic that it could not schedule the tasks powerfully [53]. This algorithm scheduled the given number of tasks to the various resources in cloud environment. As the resource utilization was maximized, the load of the resources also got balanced. A Quality of Service guided task scheduling model, being composed of some scheduling strategies and a QoS guided scheduling Sufferage-min heuristic algorithm was implemented in cloud computing [37]. The proposed model tried to improve the scheduling efficiency by dividing the tasks and resources into two groups of high QoS level and low QoS level and using different scheduling approach respectively.

The comparison table 1 reveals that the algorithms implemented in our presented work perform better than the existing algorithms with same number of users. The Minimum Execution Time (MET) gives the best results with makespan and blocking probability as 4.86 ms and 0.01 respectively. Minimum Completion Time (MCT) and Opportunistic Load Balancing (OLB) algorithm also perform better than the existing algorithms. That is why, we have considered these three algorithms and implemented on GMPLS optical networks to enhance the Quality of Service (QoS).

VI. COMPARISON OF DIFFERENT ALGORITHMS

In this section, all the three algorithms discussed in the above section are compared in terms of blocking probability, makespan, cost, throughput and energy consumption. The results are simulated in MATLAB 8.

Fig. 14 compares the performance of GMPLS optical networks in terms of traffic load after implementing the above mentioned three different algorithms. The variation of blocking probability with increasing traffic load is plotted. The plot reveals that the minimum execution time approach is able to achieve lowest blocking probability with increasing traffic load. This is because by using the MET technique, more traffic load can be handled without blocking as the channels get available recurrently due to the use of least execution time concept. The link of the route gets sufficient & shared bandwidths to transfer the packets from source to the destination user. Thus, the rate of call drops decreases which in turn decreases the blocking probability with increasing traffic load. The opportunistic load balancing approach gives the maximum blocking probability as it is least concerned with the execution or completion time of the server to complete the tasks.

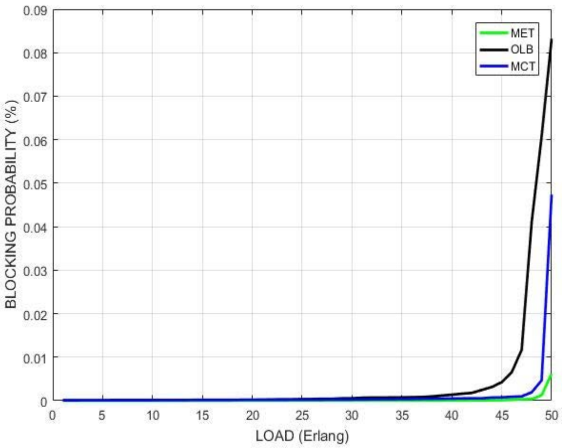

FIGURE 14. Blocking probability as a function of load.

The performance of GMPLS optical networks in terms of makespan and simulation time after implementing three different algorithms is compared in Fig. 15. The variation of makespan with increasing simulation time is plotted. The graph shows that the time taken to transmit the data from the source to the destination user is very less even if the simulation time of the whole process is more by using MET as compared to the other algorithms. Thus, MET is able to achieve lower path delays and fast speed. Therefore, the network becomes more stable by using MET than MCT and OLB.

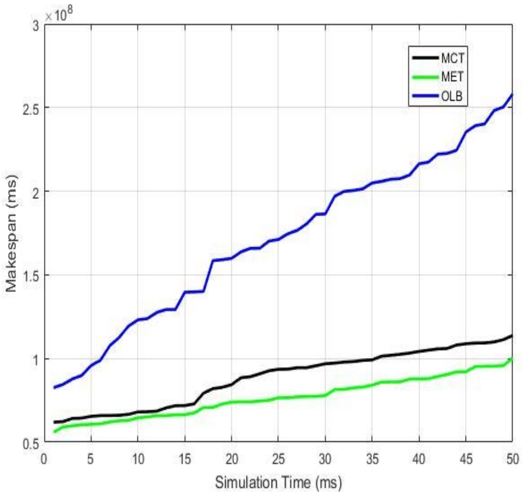

FIGURE 15. **Makespan as a function of Simulation Time.**

The variation of cost and simulation time after implementing the three different algorithms is compared for GMPLS optical networks in Fig. 16. The network cost is defined as proper utilization of the available resources. The cost should be as minimum as possible. The graph shows that the cost is minimum by using MET than the cases when MCT and OLB are used. This is because by using MET, the network speed increases which in turn enhances the capacity of the GMPLS optical network. The increased network capacity with limited resources leads to decrease in the network cost. The graph also reveals that OLB gives maximum cost as it assigns the server that is available at the time of user request without considering the time taken to complete the task by that particular server. This decreases the network speed and hence the cost increases in case of OLB.

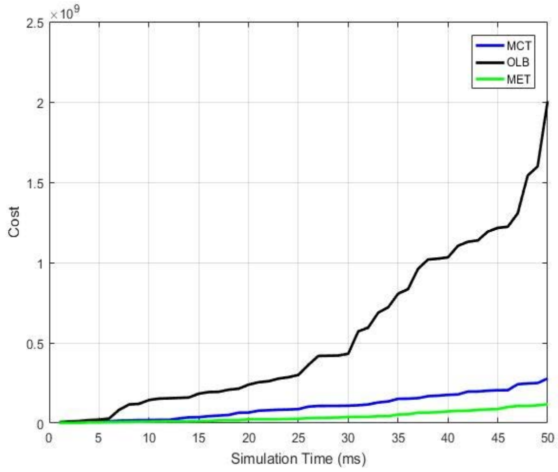

FIGURE 16. **Cost as a function of Simulation Time.**

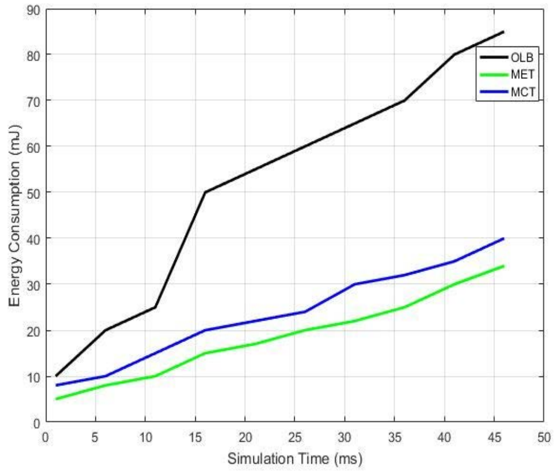

FIGURE 17. **Energy consumption as a function of Simulation Time.**

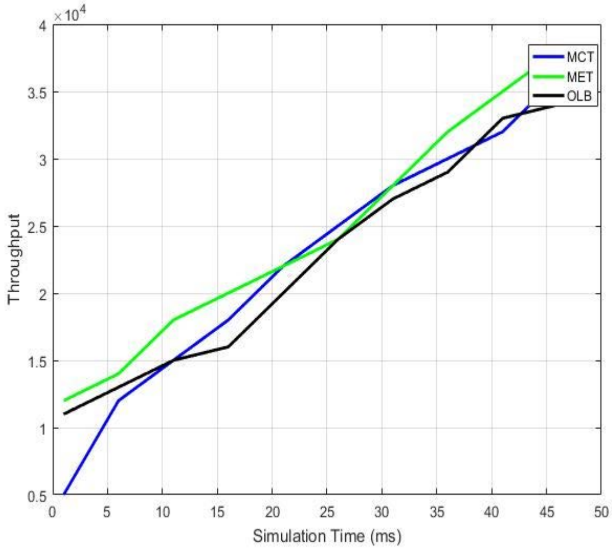

FIGURE 18. **Throughput as a function of Simulation Time.**

The variation of energy consumption and simulation time after implementing the three different algorithms is compared for GMPLS optical networks in Fig. 17. The energy consumption in a network depends on average rate of the power consumption of users during the time of operation. The power consumed refers to the power depleted in the acquisition and processing the signals in addition to transmit and receive power. It should be as small as possible. The graph shows that OLB consumes maximum energy while MET consumes the minimum. OLB assigns the server without considering its execution or completion time so the nodes consume maximum energy.

The performance of GMPLS optical networks in terms of throughput and simulation time after implementing the three different algorithms is compared in Fig. 18. The variation of throughput with increasing simulation time is plotted. Throughput is the rate of successful message delivery over a communication channel. It refers to how much data can be transferred successfully from one location to another in a given amount of time. The plot reveals that MET provides maximum throughput as compared to MCT and OLB. This occurs because MET gives minimum blocking probability in the network due to which more traffic load can be handled successfully whereas OLB gives maximum blocking probability in the network resulting in the decreased throughput.

VII. CONCLUSION

In this paper, we have proposed GMPLS optical network which includes users with vibrant positions. Then different static and dynamic bandwidth allocating algorithms are implemented on the proposed GMPLS optical network. The various algorithms implemented are Minimum Execution Time algorithm, Minimum Completion Time algorithm and Opportunistic Load Balancing algorithm. The above algorithms are considered due to their popularity and performance in cloud computing. Each algorithm is studied, analyzed and compared on the proposed GMPLS optical network in terms of various parameters like blocking probability, cost makespan, traffic load and latency.

The results reveal that MET gives the best performance among these algorithms and enhance the quality of service in GMPLS optical networks whereas OLB gives the worst performance among the three algorithms. The importance of our work is that these algorithms have not been implemented on GMPLS optical networks earlier as per the literature. The work can be extended by analyzing more algorithms on GMPLS optical network and improving the QoS of the whole process.

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