Dynamically Provisioned Priority-Aware Algorithms in Shared Mesh Optical Networks

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Abstract. The paper introduces two novel algorithms, one each for static and dynamic traffic types, to improve the availability of high priority connection requests over shared mesh optical networks. The proposed algorithms are a complementary study to the previous work. The paper also proposes a new metric, maximum path availability, by which the proposed algorithms improve the performance of high priority requests by reducing blocking probability, increasing availability satisfaction rate, and with better resource utilization using dynamic negotiation of service level agreement parameters between a customer and service providers. In a multi-homed network topology, the introduced algorithms along with the proposed metric can help the customers to modify, refine and further process the final connection requests to better comply with service providers' network capacity. The simulation results show improvements on preserving the high priority class of traffic for both static and dynamic traffic types compared to other protection schemes in shared mesh optical networks.

Keywords: Shared mesh optical networks, priority-aware algorithm, dynamic service level agreement negotiation, static maximum path availability algorithm, dynamic maximum path availability algorithm, and maximum path availability metric.

1 Introduction

Typically in a shared-mesh path restoration scheme over WDM networks, the service providers' goal is to provide a reliable connection with minimum resource allocation. This paper explores the need for having a dynamic mechanism to propagate and refine the requirements requested by service level agreement (SLA) contracts, and develops the algorithms that are capable of handling and working in a dynamic environment. The paper discusses how the proposed algorithms benefit from dynamic SLA parameters propagation mechanisms to affect network performance and to develop new priority-aware algorithms which focus on SLA parameters including link availability. The paper introduces two priority-aware algorithms one for static and the other for dynamic traffic types for different priority levels. In a multi-homed network topology, the link availability information can be communicated using dynamic SLA negotiation mechanisms [1] and [2]. The customer side of the network is exposed to

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SLA information from all the service providers to which it is connected. The customer has the choice to pick the service provider that is the most suitable for satisfying the requested connection. It is shown that the proposed algorithms benefit from dynamic SLA negotiation between customer and service providers to reduce the blocking rate of high priority traffic streams, increase the availability satisfaction rate of connection requests, improve resource utilization including wavelength usage, and preserve high priority requests.

Two different types of traffic, static and dynamic, are considered in this paper and for each type of traffic, an algorithm is proposed. The characteristics of static traffic are known *a priori* and in this paper are considered as a matrix of requests with known parameters including source, destination, requested availability, and requested level of priority. In contrast, dynamic traffic has no knowledge of subsequent connection requests and requests are processed in the order in which they are received. Both traffic types, static and dynamic, are classified to three different priority traffic classes, Gold, Silver and Bronze.

The paper focuses on the priority-aware algorithms rather than the dynamic SLA negotiation mechanism, and it is assumed that there is an automatic mechanism for SLA parameters negotiation between service providers and customers. Examples of the protocols used for dynamic SLA negotiation have been discussed in [3]. Although some RFC standards such as [4] and [5] have discussed the extensions to OSPF-TE opaque link state advertisements (LSAs), none of them supports and propagates SLA parameters. As a brief explanation of how the negotiation can be accomplished, the dynamic mechanism through which some vital SLA parameters are negotiated is assumed to be done by defining new extensions to OSPF-TE opaque LSAs [6]. It is assumed that a dynamic SLA negotiation mechanism can be implemented and the proposed algorithms can benefit from this facility to improve network performance.

The paper is organized as follows: in Section 2, the related work concerning priority-aware algorithms is discussed. Section 3 introduces two novel priority-aware algorithms for static and dynamic traffic types. In Section 4, simulation environment and performance analyses of the proposed algorithms are presented. Section 5 presents conclusions and future work.

2 Related Work

In previous work [7], a priority-aware pre-provisioning algorithm has been proposed based on the SLA-parameters negotiation for shared-mesh WDM networks. The pre-provisioning algorithm in [7] shows performance improvements over conventional shared-mesh protection [8] and [9] and priority-aware algorithms [10] and [11] with respect to availability satisfaction rate for high-priority connection requests. The simulation results in [7] have shown that the static pre-provisioning algorithm preserves the high-priority connection requests better than the lower priority connection requests. However, the nature of SLA negotiation in the pre-provisioning algorithm is static as the pre-provisioned requests are calculated based on the initial link availability of the network. That is, although the pre-provisioning algorithm in [7] benefits from a static SLA negotiation, there is no dynamic mechanism to inform the customer about the changes in the availability of the requested paths.

The conventional shared mesh algorithm presented in standards [8] and [9] takes advantage of constraint-based shortest path algorithm for path calculation. Although link availability is one of the most prominent parameters in SLA parameters negotiations, the algorithm in [8] and [9] does not consider the availability of the links as a constraint in the path calculations.

The priority-aware algorithms in [10] and [11] have presented a new insight to the definition of the path availability with respect to traffic priority level. In [10] the algorithm has been applied to a static traffic type and in [11] to a dynamic traffic type. The network performance improvements for both algorithms have been proven through both mathematical model and heuristics. Although the algorithms presented in [10] and [11] are priority-aware algorithms and they improve the blocking rate and availability satisfaction rate of shared mesh optical networks, they have no knowledge of what happens in the network dynamically in terms of availability of the requested paths based on the current status of the network resources.

The algorithm discussed in [12] has considered SLA parameters as important factors to guarantee customers' reliability. The new cost function definitions for both primary and backup paths' calculations in [12] and [13] have enabled the algorithm to introduce a novel case of protection, partial link-disjoint protection, and to increase the availability satisfaction rate and reduce restoration time of shared mesh WDM networks. Although the algorithm in [12] is an SLA-based algorithm, it does not benefit from a dynamic SLA communication mechanism to inform the customer about available paths which meet the availability requirements.

In contrast to the above mentioned related and previous work, the proposed work focuses on algorithms which take advantage of a dynamic mechanism for propagating requested paths' availabilities. The proposed algorithms use a dynamic environment to better serve high priority traffic.

3 Paper's Contribution

The main contribution of this paper can be summarized in three parts. In the first part, an algorithm is proposed by which new metric called maximum path availability (MPA) is introduced. The proposed metric plays an important role in performance improvements of the algorithms presented in the second and the third parts of the contribution. In fact the proposed metric is the basis of the introduced algorithms in this paper.

The MPA algorithm calculates the highest path availability offered by the service providers for any pairs of source and destination in a dynamic manner. That is, the algorithm updates the MPA matrix after any connection changes, either a connection request or a connection release. In fact, the algorithm is a generalized mechanism of the algorithm presented in [7]. In the algorithm presented in [7], it is assumed that the network has no traffic load when the initial maximum path availability is calculated and the parameter is calculated once forever, and is not updated over the network operation. In the previous work [7], the algorithm results in a parameter called initial maximum availability (IMPA) which is a special case of the MPA algorithm presented in this paper. The MPA algorithm in this paper updates the MPA matrix dynamically. Moreover, it is assumed that this dynamically updated metric is propagated through the network by a dynamic SLA negotiation mechanism and all the nodes have a unique and updated picture of the network in terms of MPA matrix.

As of the second and third parts of the contribution, two algorithms have been introduced taking advantage of the proposed metric presented in the first part of the contribution. The algorithms try to improve the performance of the high priority requests with regard to blocking probability and resource utilization. In this case, two different algorithms for static and dynamic types of the traffic are proposed, the static maximum path availability (SMPA) and the dynamic maximum path availability (DMPA) algorithms. To analyze the SMPA and DMPA algorithms' performance, two different simulation environments are developed and evaluated. The modules and the algorithms building the static and dynamic maximum path availability algorithms are discussed in Section 4 in detail, and the simulation environments are presented in Section 5.

4 Proposed Algorithms

4.1 Static Maximum Path Availability Algorithm

For static traffic type, it is assumed that the connection requests are known a priori. Each request is characterized by source, *s*, destination, *d*, requested availability for the n^{th} connection, A_{rn}, and requested traffic priority level, *p*. The n^{th} request can be shown as $C_n\ (s,\ d,\ A_{rn},\ p)$. The block diagram of SMPA algorithm is presented in Fig. 1. First, the requests are prioritized to find the highest priority request which meets the path availability requirements. The requests are stored in form of a connection request matrix (CRM), and are sorted in descending order of the requests' priority. The first request in the CRM whose availability is met is sent for the further processing. Secondly, the routing and wavelength assignment (RWA) module is applied to the request to find the most optimum paths. The wavelength and graph update module updates the link-wavelength status and the graph topology respectively. In a multi-homed network in which the customer can be served by several service providers as shown in Fig. 2, the maximum path availability algorithm module calculates dynamically the highest path availability offered by the service providers for any pairs of source and destination.

The steps by which the connections prioritizing module of the SMPA algorithm affects the connection request matrix is shown in Fig. 3. Three levels of priorities, $p=1,\ 2,\ 3$, have been defined as Gold, Silver, and Bronze respectively. The requests belonging to each level of priority are stored in a corresponding set; S_p. Based on the prioritizing module presented in Fig. 3, the requests, C_{np}, with the highest priority are served first. As long as there are requests in the highest level of priority set which can meet the path availability requirements, for instance S_{Gold}, SMPA will not process the lower priority set, S_{Silver} for example. Those requests which meet the requirements, i.e. the requested availability of the requests (A_{rCn}) is lower than the offered availability (A_{oCn}) are kept in another set associated with the same priority level, S_{pp}, and are sent to service providers to be established. Those requests which do not meet the requirements requested in SLA are left for possible future opportunity and the next request in the same set will be processed. If the set regarding a certain level of priority

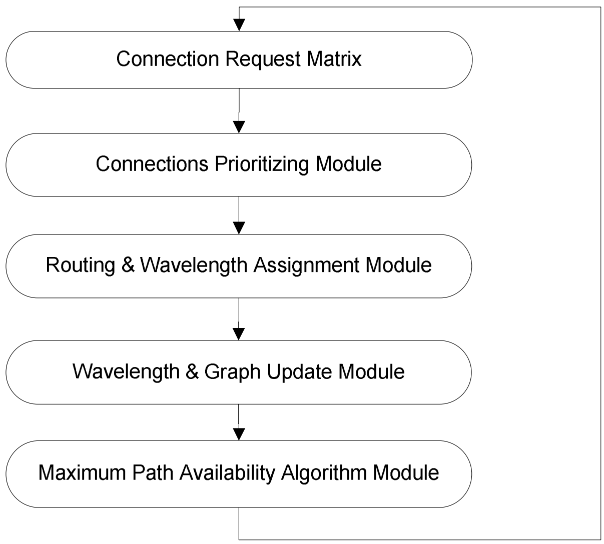

Fig. 1. SMPA algorithm block diagram

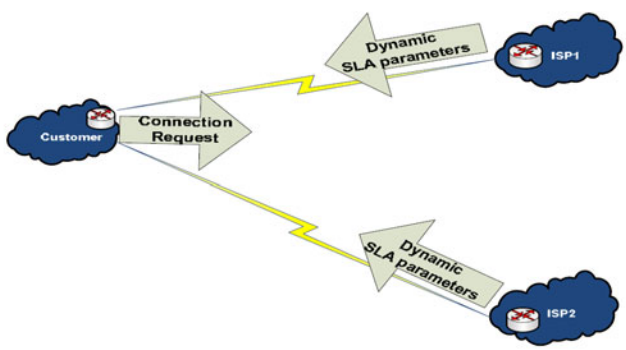

Fig. 2. Multi-homed network topology

is empty or the existing requests cannot be served, the next lower priority level set is processed. The output of the prioritizing module saved in S_{pp} is a refined request which will be processed by RWA module to be established as a connection. The connection requests in S_{pp} which are sent to RWA module for further processing are permanently removed from S_{pp} set. The RWA and wavelength update modules have been discussed in [7] in greater detail. The routing scheme which is used in the RWA module to determine the primary and backup paths is adaptive routing [14].

Before a path computation algorithm, Dijkstra's, is applied to the prioritized request to find the primary path, the cost of the links of the graph is modified by cost function presented in (1). Based on the cost function, if there is no bandwidth available on the link, the link is removed from the graph; otherwise the cost of the link is a function of the link availability. The way that the cost function is calculated in a logarithmic basis has been discussed in [15] in detail.

$$C_{P(i,j)} = \begin{cases} \infty & \omega_{ij} = 0 \\ -ln(a_{(i,j)}) & \omega_{ij} > 0 \end{cases} \tag{1}$$

where $C_{p(i,j)}$ is the cost of the link between nodes i and j for a primary path , $a_{(i,j)}$ is the availability associated with link between nodes i and j, ω_{ij} is the number of free wavelengths on the link between the nodes i and j.

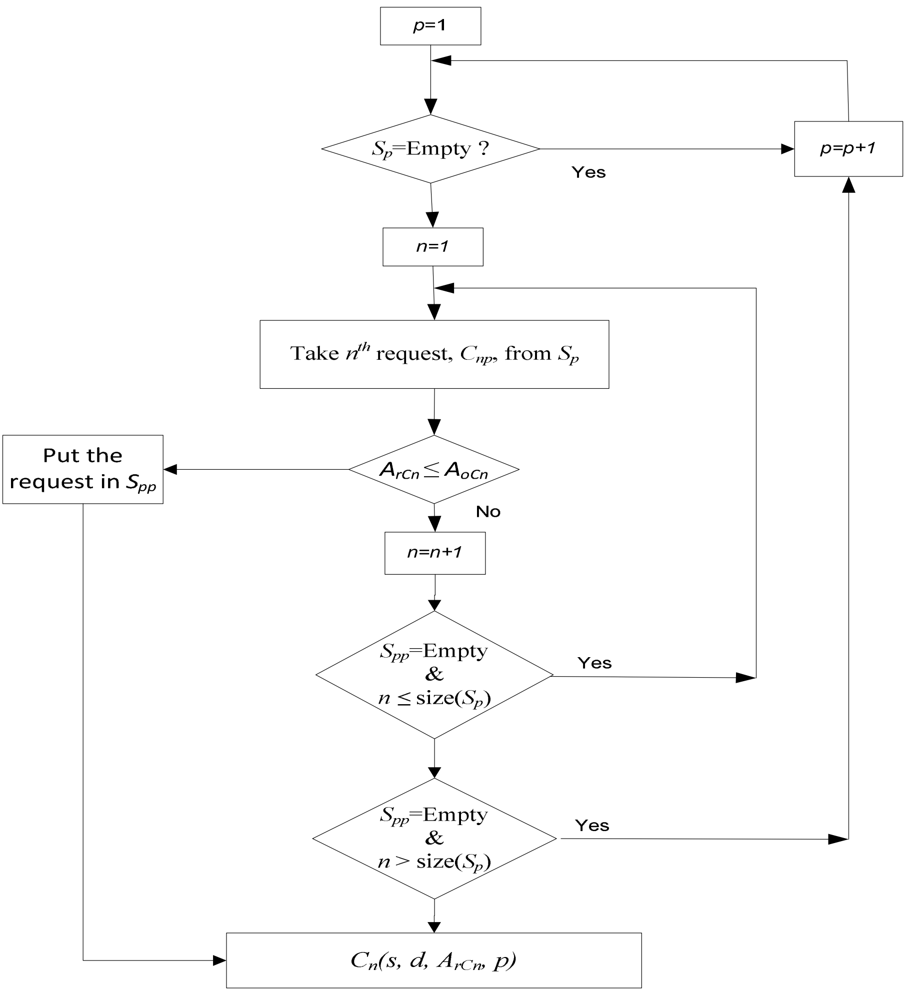

Fig. 3. Connections prioritizing module of SMPA algorithm

Following this step the wavelengths are assigned to the path based on a per-link basis, and the wavelength usage matrix is updated in this step. If the path computation finds no way from *s* to *d*, the request is said to be blocked. The wavelength assignment of the primary paths follows the First-Fit (FF) algorithm [14]. In the FF technique, the wavelengths are numbered and the lowest numbered free wavelengths are selected.

Before the RWA module calculates the backup path, the cost of the links of the graph are changed one more time based on (2) [7]. The cost function based on the logarithmic formula has been discussed in detail in [15].

$$C_{b(i,j)} = \begin{cases} \infty & \omega_{ij} = 0 \\ -ln(a_{(i,j)}) * \omega_{ij} & \omega_{rsvd} > \omega_B \\ -ln\left(a_{(i,j)}\right) * \omega_{ij} + 1 & \omega_{rsvd} \le \omega_B \end{cases} \quad (2)$$

where $C_{b(i,j)}$ is the cost of the link between nodes *i* and *j* for a backup path, ω_{rsvd} is the number of the reserved wavelengths on the link for the shared backup paths, and ω_B is the number of required wavelengths if the primary path fails.

As (2) denotes, to setup a backup path, the algorithm looks for the paths with the highest available bandwidth and lowest number of shared paths on each link. The algorithm checks if the backup path can share any wavelength considering link-disjointness constraint. Then, it follows FF technique [14] to allocate a wavelength to the links forming the path.

After calculating the primary path and finding totally link-disjoint primary-backup paths pair, the wavelength and graph update module modifies the graph topology matrix by removing the links forming the primary path. The graph topology matrix is an *m* x *m* matrix of zeros and ones showing which nodes are connected to each other.

The MPA module of SMPA algorithm is an algorithm by itself. The module is responsible for calculating the highest path availability offered by the service providers for any certain source and destination pairs. The parameters advertised in the dynamic SLA mechanism is the availability of the links forming the graph. However, proper SLA negotiation needs the information about availability of all possible paths for any pair of source and destination. This is accomplished by applying the MPA module**.** After cost modification, the MPA module calculates the best possible availability offered by the service providers. MPA algorithm uses (3) and (4) to calculate the path availability of the primary and backup paths respectively.

$$A_{pC_n} = \prod_{(i,j) \in C_{n(primary-path)}} a_{(i,j)} \quad (3)$$

$$A_{bC_n} = \prod_{(i,j) \in C_{n(\ backup-path)}} a_{(i,j)} \quad (4)$$

where A_{pCn} and A_{bCn} are the availability of the primary and backup paths for the n^{th} connection request respectively.

Equation (5) results in the maximum offered path availability between any requested pair of source and destination using path availabilities for primary and backup paths. If the value of $MPA_{(s,d)}$ is zero, this means the network has no capacity at that time for serving the request and the request is not sent to the service providers and considered blocked.

$$MPA_{(s,d)} = A_{pC_n} + A_{bC_n} - A_{pC_n}.A_{bC_n} \quad (5)$$

where A_{pCn} and A_{bCn} are the path availabilities of the primary and backup paths respectively, $MPA_{(s,d)}$ is the maximum offered path availability for a source-destination pair in the n^{th} connection request.

Table 1 shows the pseudo code describing the algorithm used in MPA module. The MPA algorithm calculates an m x m matrix, the MPA matrix, for a network topology of m nodes.

Table 1. MPA calculation algorithm

1. If $s=d$, $MPA_{(s,d)}=0$ Else source=s & destination=d for all values $s\in\{1,2,3,\ldots,m\}$, $d\in\{1,2,3,\ldots,m\}$
2. Modify cost of the links of the graph through (1) for all values of i & $j=1,2,\ldots,m$
3. Run *Dijkstra's* algorithm to calculate the primary path for the given source, destination, and the pre-calculated cost function in 3
4. If no primary path found, $MPA_{(s,d)}=0$ Else go to 5
5. For all links forming primary path, link-wavelength usage matrix is updated and saved as a new matrix
6. If any elements of new link-wavelength matrix are zero, same elements on the link-availability matrix becomes zero. The modified link-availability matrix is saved in a new matrix
7. Repeat steps 2&3 with the new link-availability matrix to find the backup path
8. Calculate the path availabilities through (3) & (4) for all links forming primary and backup paths
9. Compute $MPA_{(s,d)}$ for a specific pair of source-destination in the n^{th} connection request through joint-availability function [12] presented in(5)
10. Repeat steps 1-9 for all values $s\in\{1,2,3,\ldots,m\}$, $d\in\{1,2,3,\ldots,m\}$ to build entire MPA matrix

4.2 Dynamic Maximum Path Availability Algorithm

In dynamic traffic, only one request is processed at a time in the order they are received, and the algorithm has no knowledge of the next request. After each request is processed, the graph topology and wavelength usage matrices are updated. Each request is established, blocked, or buffered for further process. The n^{th} connection request is in form of C_n (s, d, A_r, p) with the requested parameters source, s, destination, d, requested availability, A_{rn}, and the requested priority level, p, respectively. Since each established connection changes the link-wavelength usage matrix and consequently it may change the graph topology matrix, after processing any request, the cost matrix of the entire network is updated through (1).

After the cost modification, the MPA module calculates the best possible availability offered by the service providers. As described in Section 3.1, the MPA module uses (3), (4), and (5) to calculate the path availability of the primary and backup paths and the maximum offered path availability between any requested pair of source and destination. If the value of $MPA_{(s,d)}$ is zero, this means the network has no capacity at that time for serving the request and the request is not sent to the service providers and considered blocked.

In this paper, the requests which are refused to be sent to service providers are considered blocked. Typically, in the real world scenario, such calculations take place in the customer premises and reduce the overhead of the control plane in transport networks which is one of the advantages of the proposed algorithm.

As shown in Fig. 4, if the requested availability is lower than the offered one, this means the requirements requested by the customer can be met, then the original request will be sent to the service provider for further processing including routing, wavelength assignment, wavelength usage update, and graph topology modification modules, otherwise the best availability offer from service providers will replace the requested one and the modified request is now sent to the proper service provider which is capable of fulfilling the request. The DMPA algorithm considers two availability threshold parameters at each level of priority for the customer, the lower bound availability threshold (A_{thpLB}) and the higher bound availability threshold (A_{thpHB}). Using these threshold parameters, a customer will be able to decide whether it accepts the offered parameters for a certain level of priority. The threshold parameters entirely depend on the customer and are different for any level of priorities. Some statistical research in [16] shows that the presented numerical values for the improved average availability of the different topologies can be used as threshold levels. The results presented in [16] can be a good resource for choosing thresholds that are close enough to the real world parameters.

The offered availability should be in the range of pre-defined threshold availabilities, as it is shown in (6). If (6) is fulfilled the request is modified by new parameters and is sent to the RWA module for further processing, otherwise it is blocked. The inequality (6) can be written as (7). Equation (8) presents $WMPA_{(s,d)}$ as weighted maximum path availability for a pair of source and destination, *s* and *d*. In (9), WA_{thp}, weighted availability thresholds of LB and HB for a specific level of priority, *p*, is defined. Then (7) can be summarized as (10).

$$A_{thpLB} \leq MPA_{(s,d)} \leq A_{thpHB} \tag{6}$$

$$1 \leq \frac{MPA_{(s,d)}}{A_{thpLB}} \leq \frac{A_{thpHB}}{A_{thpLB}} \tag{7}$$

$$WMPA_{(s,d)} = \frac{MPA_{(s,d)}}{A_{thpLB}} \tag{8}$$

$$WA_{thp} = \frac{A_{thpHB}}{A_{thpLB}} \tag{9}$$

$$1 \leq WMPA_{(s,d)} \leq WA_{thp} \tag{10}$$

Since the connections are determined with and treated based on their priority levels, p, A_{thpHB} can be considered 1 for all priority level traffic. With this assumption, for all values of s and d, $MPA_{(s,d)} \leq 1$.

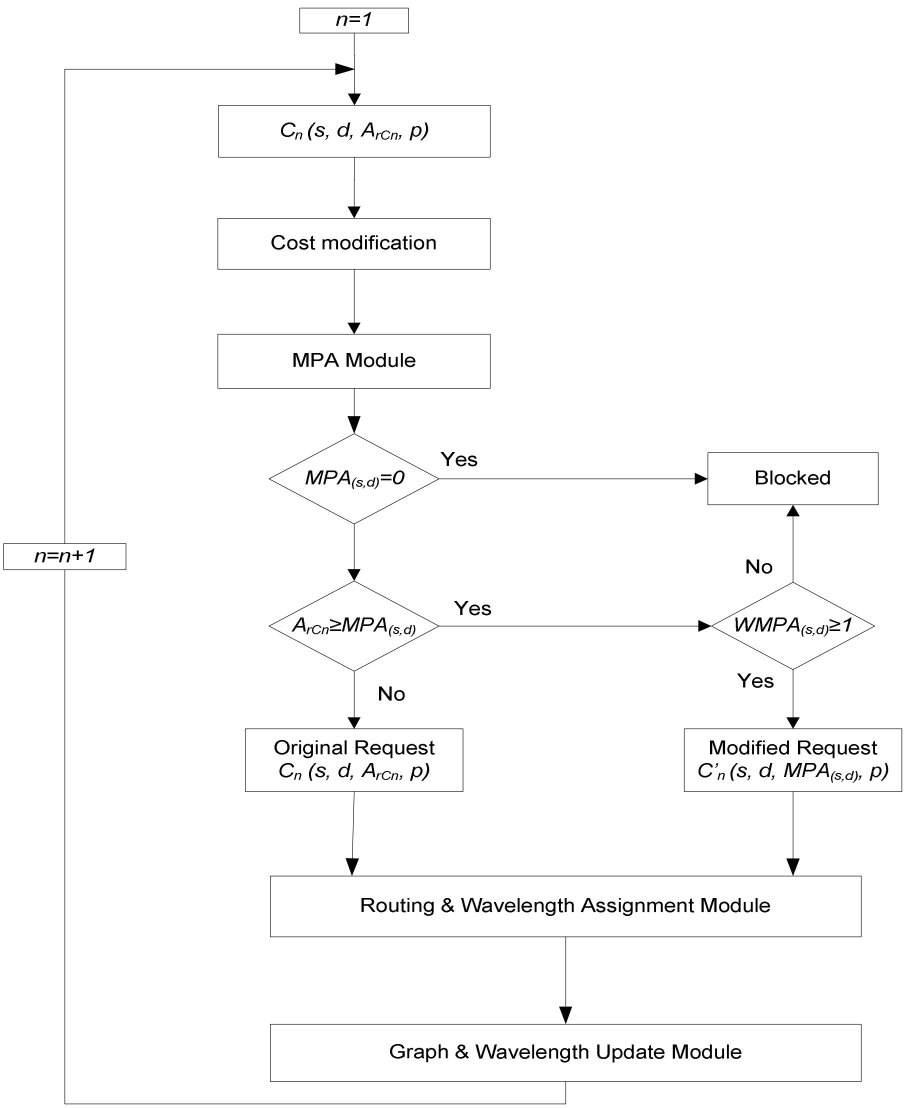

Fig. 4. DMPA algorithm flowchart

Then (10) can be simplified as (11). In fact, (11) is the final constraint for the customer to either accept or refuse the service provider's offer. If the traffic belongs to the class of Gold services and the weighted offered availability requirement presented in (11) is not met, the request is either refused or buffered for further processing. However, in this paper, for the sake of simplicity, it is assumed that no request is buffered; they are either established or blocked.

$$WMPA_{(s,d)} \geq 1 \tag{11}$$

The MPA, RWA, and graph and wavelength update modules follow the same algorithms described and discussed for the SMPA algorithm in Section 3.1. The MPA module is responsible to calculate $MPA_{(s,d)}$ for any pair of source and destination of n^{th} connection request requested in $C_n(s, d, A_r, p)$ for a network topology of m nodes. The RWA module calculates the primary and backup paths for the requested connection. The graph and wavelength update module modifies the topology and wavelength usage matrices dynamically based on the current status of the network.

5 Performance Analysis

5.1 Static Traffic Analysis

The performance in terms of blocking probability (BP) of different classes of traffic, Gold, Silver, and Bronze for static traffic case is analyzed as BP-G, BP-S, and BP-B respectively. In addition, average number of allocated wavelengths per connection for fulfilling the connection requirement (AWPC), and the percentage of high-priority provisioned requests (HPPR) are investigated by SMPA in this paper. Several protection schemes are studied in the static traffic analysis: no protection (NP), standard shared path protection (SSPP) [8] and [9], priority-aware algorithm (PAA) [10], static pre-provisioning algorithm (SPA) [7], static maximum path availability algorithm (SMPA), and SMPA and SPA algorithm from previous work together (SMPA+SPA). All existing schemes are compared with two proposed cases; SMPA and SMPA+SPA algorithms.

Connection availability requests are uniformly distributed between three classes of traffic: Gold class with the availability of 0.9999, Silver class with the availability of 0.9990, and Bronze class with no availability significance. In addition, it is assumed that the primary and the backup paths in any protection scheme are totally disjoint.

Table 2 shows that SMPA algorithm improves the blocking rate of Gold requests more than 40% in comparison to the other protection schemes. The SMPA algorithm also brings 11-16% improvement for different protection schemes. Applying SPA algorithm on top of the SMPA brings 18% more improvement on preserving Gold requests, but it increases the blocking rate of Silver requests. However, the blocking rate of the SMPA+SPA algorithm for Silver class of traffic is still comparable with other existing algorithms.

This great improvement in decreasing blocking rate for Gold class of traffic does not degrade the resource utilization. Fig. 5 shows that although no improvement in bandwidth allocation is seen in either SMPA or SMPA+SPA algorithms, the average number of allocated wavelengths per connection is almost the same for different priority-aware algorithms. However, no-protection (NP) scheme has the minimum amount of bandwidth consumption which is obviously because of considering no protection paths as backup for primary paths. In addition, since standard shared mesh protection method, SSPP, does not count the link availabilities into account as a constraint in the path calculation, it has the maximum bandwidth consumption among all studied protection schemes.

Fig. 6 shows an increase on the percentage of high priority provisioned requests including Gold and Silver which are served by either SMPA or SMPA+SPA algorithms. It is indicated that 52% of high-priority requests which were blocked in other protection schemes are now provisioned by the proposed mechanism. SMPA+SPA algorithm barely improves the total number of provisioned high priority requests in comparison to SMPA algorithm, and it works well just for Gold requests. However, as Fig. 6 shows, the SMPA+SPA algorithm still has 12-28% improvement in number of provisioned high-priority requests comparing to the other existing algorithms. Since SMPA algorithm works based on the traffic priority, the Bronze traffic gets the minimum attention. From the business point of view, applying the proposed algorithm brings more money to service providers since serving the quality of service based traffic is more lucrative than low priority traffic.

The total number of Gold, Silver, and Bronze requests among all possible connection requests is dictated by the network topology presented in Fig. 7. This paper uses the same network topology used in other existing algorithms in [7], [10], [11], and [12] for the sake of consistency and fair results comparison.

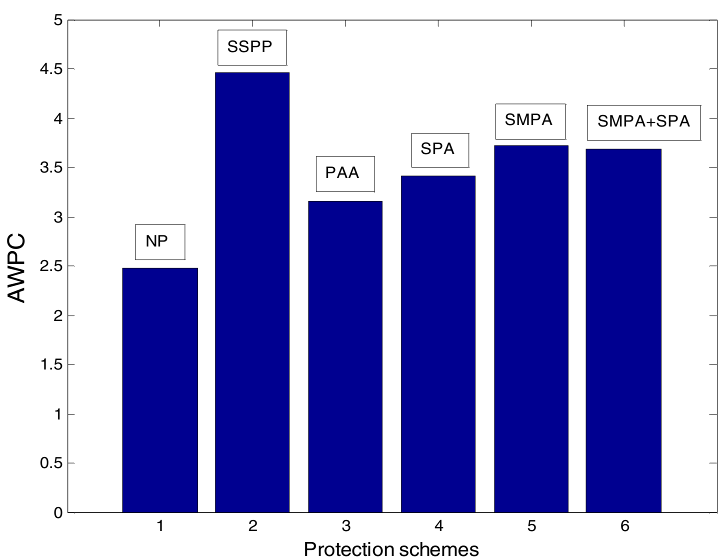

Fig. 5. Average number of allocated wavelengths per connection with respect to different protection schemes

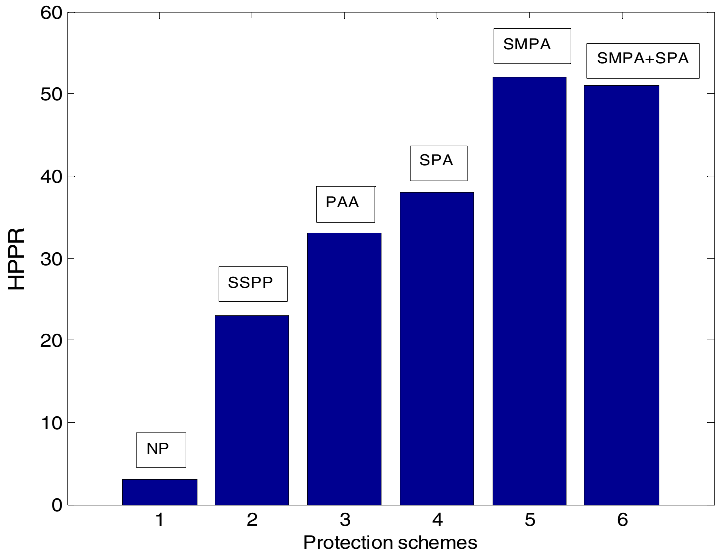

Fig. 6. Percentage of high-priority requests provisioned by different protection schemes

Table 2. Blocking rate percentage comparison for several protection schemes and algorithms

	NP	SSPP	PAA	SPA	SMPA	SMPA+SPA
BP-G	100	89	81	65.5	47	29
BP-S	97	66	61	64	50	66
BP-B	32	68	26	35	62	65

5.2 Dynamic Traffic Analysis

The lightpaths in the dynamic traffic pattern are requested dynamically with randomly generated availability requests so that the algorithm has no knowledge about the coming request. The simulation environment is similar to the previous work [7] environment. The links have wavelength conversion capability with 8 wavelengths per each link. The link availabilities are uniformly distributed between 0.99 and 0.9995. Connection availability requests are uniformly distributed between 0.99 and 1.00. A Poisson process with arrival rate of β is considered for the arrival process of connection requests. The holding time of the connections follows an exponential distribution with the mean value of μ=1. No waiting queue has been considered for this process. The primary and the backup paths are considered totally disjoint. The total number of connection requests over entire simulation period is 10^5. The topology selected for the simulation is NSFNet shown in Fig. 7 with 14 nodes and 21 bidirectional fiber connections of the same physical distance.

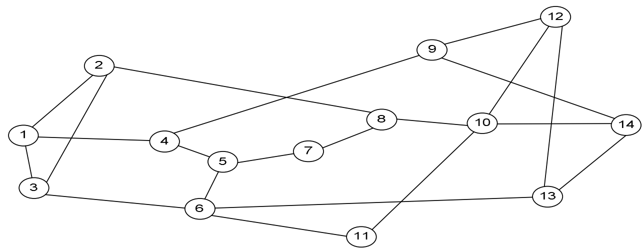

Fig. 7. Network topology, NSFNet

Based on practical values for different protection schemes and several network topologies presented in [16], for the simulation purposes A_{thpLB} has been considered 0.9997 and 0.9988 for Gold and Silver traffic respectively. However, theses marginal numbers can vary depending on the customer needs.

In dynamic traffic analysis, the availability satisfaction ratio (ASR), the blocking probability (BP), and the average number of link-wavelength per connection request (AWPC) of DMPA algorithm is compared with other existing algorithms for dynamic traffic case. ASR represents the percentage of provisioned connections whose availability requirements are met over all provisioned connections. BP denotes the percentage of blocked connection requests over all arriving requests. AWPC shows the average number of the wavelengths allocated for each connection. The performance of the proposed algorithm for the dynamic traffic is compared with the schemes in which there are either no automatic SLA negotiations (SSPP) [8] and [9] or just static negotiation (SPA) [7]. In the previous work [7], the performance of SPA has been compared with SSPP and PAA algorithms [10] and [11].

As Fig. 8 Show, the blocking rate of DMPA algorithm is improved in comparison to two other algorithms, SSPP and SPA schemes. Results in Fig. 8 shows a 47% decrease in connection blocking probability of DMPA algorithm in comparison to SSPP and SPA algorithms.

Simulation results in Fig. 9 shows a 15% increase in ASR performance of the DMPA algorithm compared to SSPP and SPA algorithms. Fig. 8 and 9 show that although the previous work [7] could improve ASR compared to the SSPP scheme, it could not improve the BP. In contrast, the proposed algorithm, the DMPA algorithm, improves both ASR and BP.

Fig. 10 shows how much better the DMPA algorithm saves the network resources in terms of number of assigned wavelengths per connection when compared with the SSPP and SPA algorithms. The average AWPC for DMPA is around 4.0 wavelengths while it is 4.6 for SPA and 4.75 for SSPP. Since the number of connection requests is large, the DMPA algorithm saves a huge amount of network resources. In addition, Fig. 10 shows that the performance of SPA in terms of AWPC is degraded for small values of offered loads. However, the DMPA has a good performance for both small and large offered loads.

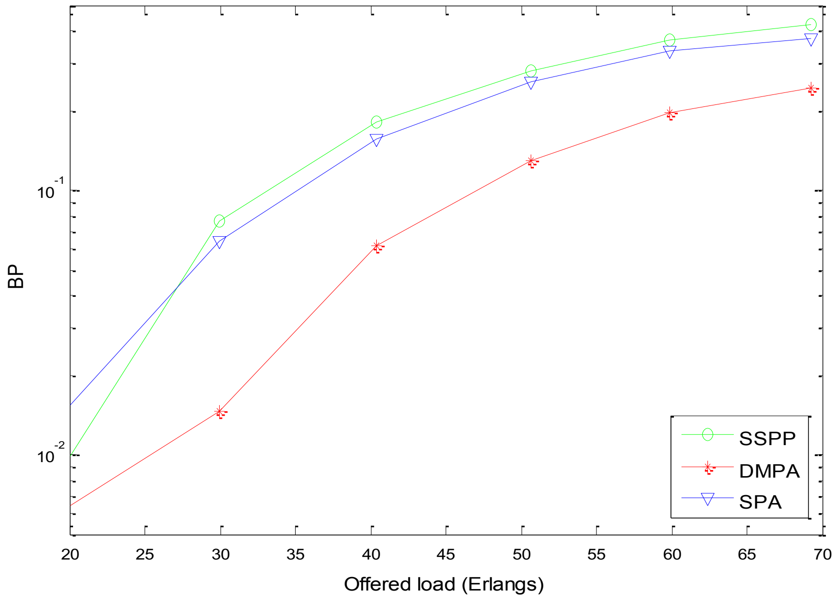

Fig. 8. Blocking rate performance of DMPA algorithm

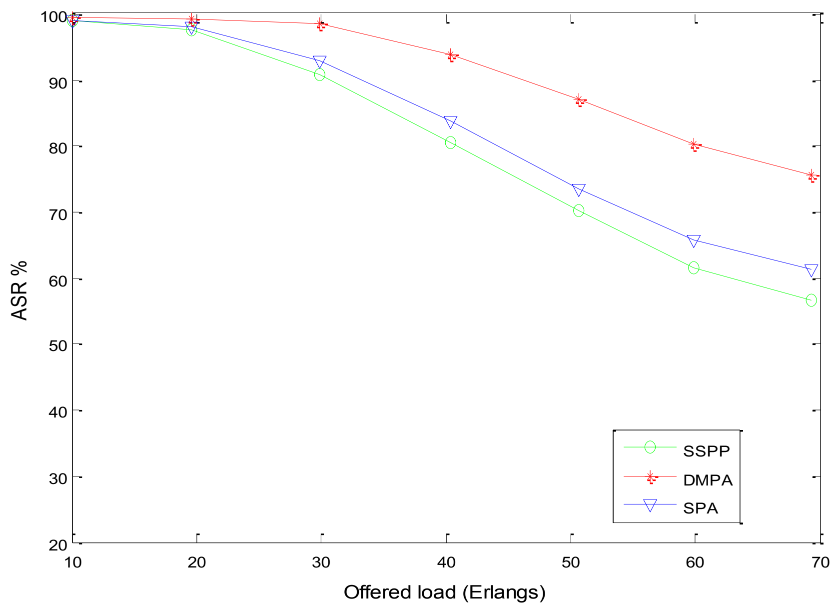

Fig. 9. Availability satisfaction rate performance of DMPA algorithm

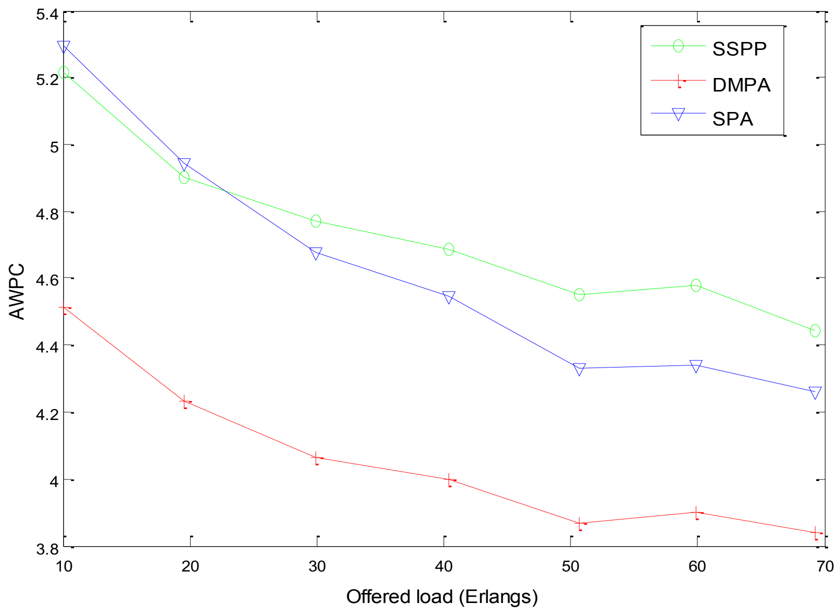

Fig. 10. Average number of allocated wavelengths per connection

6 Conclusion

This paper is a complementary study to the previous work presented in [7]. In this paper, two priority-aware algorithms have been introduced for shared mesh survivable WDM networks. The SMPA and the DMPA algorithms have been introduced to improve the network performance for static and dynamic traffic types respectively. The proposed algorithms take advantages of a dynamic negotiation mechanism of SLA parameters which can help customers to have a better picture of the entire network with respect to path availabilities. This fact can help customers to modify and process their requests before they send them out to the service providers for the further processing. The paper has also proposed a new metric, maximum path availability, by which the proposed algorithms improve the performance of high priority connection requests The algorithms reduce the blocking probability of the high priority requests, increase availability satisfaction rate, better preserve high priority connection requests, and reduce the average number of allocated wavelengths per connection. In addition, the algorithms also reduce the calculation steps done by service providers.

The performance analysis in both types of traffic, static and dynamic, shows lower blocking probability and resource consumption, higher availability satisfaction rate and resource utilization, and more preserved high priority traffic for the customer. In addition, the proposed algorithms can provide more benefits and fewer calculations and decision processes for service providers.

An automatic mechanism for SLA parameters negotiation between service providers and customers by defining new extensions to OSPF-TE opaque LSAs will be presented in future work. In addition, a buffered request service module in the DMPA algorithm which can benefit from certain algorithms to accommodate potentially blocked high priority connection requests is a potential subject for future research studies.

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