Proceedings of IC-NIDC2009

PRE-CONFIGURATION BASED QOS ROUTING IN GMPLS-BASED OPTICAL NETWORKS

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Abstract

Generalized Multi-Protocol Label Switching (GMPLS) based optical networks are viewed as a promising network infrastructure for the next generation network (NGN) development. By pre-configuring the resources of dynamic optical networks, we can reconstruct the physical topology, thus increase the number of direct routes between potentially heavily loaded physical node pairs and optimize the performance of the optical networks. This article presents the introduction to the optical network topology pre-configuration schemes and verifies the effectiveness of the QoS (Quality of Service) routing algorithm in the pre-configured topology of GMPLS-based optical networks. Simulation results show that the implementation of the QoS routing algorithm in the pre-configured GMPLS-based optical networks is instrumental in shortening the average establishing time of the control plane whilst maintaining the low block probability.

Keywords: GMPLS; Pre-configuration; QoS routing; Optical networks

1 Introduction

In the context of dynamic service requests, GMPLS protocol suite is one of the deployment strategies for the control plane in intelligent optical networks to facilitate the automatic establishment and teardown of Label Switched Paths (LSPs) based on the network conditions (resources and topology). Thus, a dynamically changing virtual topology according to the arrival and departure of the dynamic traffic is built up based on the physical topology. The two topologies have distinctive differences: the former represents the services distribution among different nodes while the latter depicts the physical connection relationships between each node pair in the optical networks. Upon a connection request between a specific pair of nodes, it is mapped onto the physical topology by the RWA (Routing and Wavelength Assignment) algorithms and a lightpath is thus set up using signalling protocols such as RSVP-TE (ReSource reserVation Protocol-Traffic Engineering) or CR-LDP (ConstRaint-based Label Distribution Protocol) according to the calculated route [1, 2].

Most of the research in this area is either focused on optimal design of the physical resource [3, 4] or improving the related protocols to obtain better network performance [5, 6, 7]. As the previous work [8, 9] states, the concept of a pre-configured topology is proposed for two reasons: (1) the poor match between the virtual and physical topologies, and (2) the complexity and difficulty in optimizing routing and path establishment process. The simulation results given in previous works show that routing based on a pre-configured network topology has the advantage of a large reduction in the average hops perceived by the control plane as compared with that based only on the physical topology. Thus, it can improve the performance by reducing the average connection establishment time. However, the performance improvement is gained at the cost of higher blocking probability, which has negative effect on the performance of the intelligent optical networks. In this paper, we propose a novel pre-configured based routing algorithm by incorporating a QoS routing method in the pre-configured GMPLS-based optical networks and simulations are carried out based on the proposed algorithm to verify its effectiveness in shortening the average service connection hops whilst maintaining low blocking probability.

The structure of this paper is as follows. The idea of network topology pre-configuration methods is explained briefly in Section II; then, QoS routing algorithms are introduced and the novel QoS Routing Algorithms based on Pre-Configured GMPLS-based optical networks (PC-QRA) is analyzed and described in detail in Section III; Section IV presents the simulation results and analysis. Finally, conclusions and ongoing work are given in Section V.

2 Topology Pre-configuration Schemes

2.1 Assumptions

The assumptions for the pre-configuration mechanisms implementation in GMPLS-based optical networks are listed as below:

1. No knowledge of ingress-egress pairs information is considered; thus, it is assumed that every node pair can be a (src, dest) pair candidate for each dynamic connection request;
2. In the routing process, traffic engineering is incorporated, and it is assumed that the residual available wavelength (RAW) information is distributed across the network either through routing-based or signalling-based methods in GMPLS-based networks;
3. Only a path with two hops will be pre-configured to balance the extra cost that the pre-configuration schemes introduce and the connection establishing time reduction;
4. The weight of link is inversely proportionally to the residual bandwidth and is defined as: W_{mn} = C (Capacity) / RAW;
5. It is assumed that all nodes in the network have Wavelength Conversion (WC) capabilities.

2.2 Notations

1. Q = Max(q_{mn}), it is the maximum number of lightpaths routed in the network while q_{mn} is the number of lightpaths between the (m, n) node pair;
2. $f_{ij}(k) = t_{ij}(k)/Q$, it is the distribution factor used to decide the percentage of pre-configuration resource; while $t_{ij}(k)$ represents the number of lightpaths on the node pair (i, j) that goes through node k;
3. T_{pc} is the threshold defined to decide whether one two-hop path should be pre-configured or not. If one two-hop path meets the criteria, namely its distribution factor is bigger than T_{pc}, then $f_{ij}(k)$*C resource will be preconfigured.

2.3 Pre-configuration Principle

As shown in figure 1, the basic principle of the pre-configuration schemes is that with the help of pre-establishing certain amount of paths, the physical topology will be shaped (i.e. to form a pre-configured virtual topology) to bridge the gap between the physical topology and the dynamically coming connection request matrix. Specifically speaking, if the amount of resource on certain two-hop segment that is consumed to set up paths for

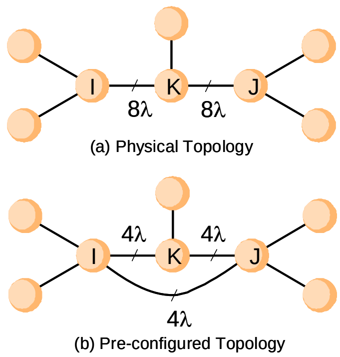

Figure 1 Pre-configuration Principles

connection requests goes across the limit (i.e. T_{pc}), then the 2-hop paths will be pre-established and proper amount of resource will be allocated. Thus, the pre-configured virtual topology is built up and will be used during the path set-up process upon each connection request. It can be easily inferred from figure 1(a) that the two-hop path I-K-J is the potential bottleneck for the traffic routed between the edge nodes of I and J separately. Thus, it will be selected as the two-hop path to be set up in this topology, which is shown in figure 1(b). The resulted pre-configured topology can better adapt to the dynamic traffic requests as it requires shorter connection setup time for the traffic routed across the sub-path I-K-J.

The Pre-Configuration Algorithms (PCA) are depicted in Figure 2. Detailed explanations about the three pre-configuration schemes are given in [8, 9].

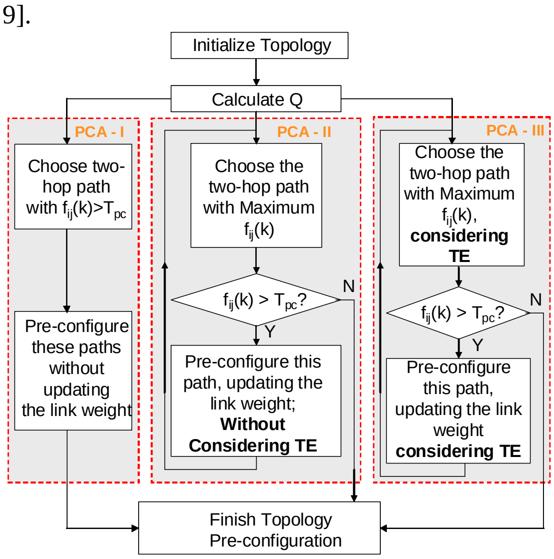

Figure 2 Pre-configuration algorithms workflow

3 Design of Pre-configuration based QoS Routing Algorithms

3.1 Introduction to QoS Routing

QoS Routing is introduced to provide the network with the routing algorithms that are able to identify QoS-satisfied paths so as to accept as many service requests as possible whilst meeting specified QoS constraint(s). Metrics such as link bandwidth, delay and packet loss are examples of QoS constraints. Usually, bandwidth is considered as the main requirement in QoS Routing algorithm exploration and other metrics can be converted into bandwidth requirements if necessary [10].

There are many QoS Routing algorithms proposed till now and most of them are proposed to be deployed in MPLS (Multi-Protocol label Switching) networks. Usually, the source and destination node set are assumed to be known in the simulation verification [10, 11, 12]. Three typical QoS routing algorithms are listed in table I and a complete introduction can be found in [13].

Table I Three typical QoS Routing Algorithms

Objective	Typical Algorithm(s)
Minimizing the network cost	WSP[12] with the second objective of balancing the network load
Balancing the network load	SWP[12] with the second objective of minimizing the network cost
Minimizing blocking probability	MIRA[10] WSS[11]

3.2 Pre-configuration based QoS routing Algorithms

As we can conclude from the principle of pre-configuration methods that the number of direct connection between certain node pairs is increased thus the number of equal hops between those node pairs also goes up. So the WSP routing algorithm can take advantage of the increasing number of equal-hop paths in the pre-configured topology while choosing the one with maximum residual bandwidth so as to reduce the interference with other requests.

A novel algorithm is proposed for deployment in pre-configured optical networks by incorporating WSP routing algorithm. Here, only bandwidth requirement is used in this paper as the QoS metric in the process of the path selection process and the algorithm is explained in Figure 4.

Pre-Configuration based QoS Routing Algorithm (PC-QRA)

Step I: Inherit the weights updated by PCA;

Step II: When a service request arrives, execute the following steps; when a service terminates, execute **Step VII**;

Step III: Prune the links that do not have sufficient bandwidth for the request, and run Dijkstra algorithm in the pre-configured topology;

Step IV: Find all the routes with minimum number of hops;

Step V: Choose the route with Maximum Residual bandwidth;

Step VI: Allocate network resources, and go to **Step II**;

Step VII: Release network resources, and go to **Step II**;

Figure 4 PC-QRA working flow

4 Simulation Results and Analysis

In this section, the proposed QoS Routing Algorithm based on Pre-Configuration schemes (PC-QRA) are evaluated using the same topologies (NSF network and ARPA network) as presented in [9]. The traffic is distributed equally among all nodes pairs and arrives according to a Poisson distribution. For comparison purposes, the following two schemes are included:

1. WSP routing algorithm based on physical topology (QRA on physical topology);
2. The schemes with the optimal performance proposed in [9] (i.e. PCT-DRA-I over PCTGA-I and PCT-DRA-I over PCTGA-II respectively);

Figure 5 depicts the QRA routing algorithm with different PCA approaches using the NSF network topology, which again verifies the effectiveness of pre-configuration in lowering average number of hops perceived from the control plane. Moreover, QRA with the first PCA scheme (PC-QRA for short) is better in regard to both blocking probability and average number of hops, which is selected for comparison with PCT-DRA-I over the PCTGA-I scheme (PCT-I for short) under the same topology.

As shown in Figure 6, the PC-QRA scheme is superior to the PCT-I scheme, as it can reduce the average number of hops whilst maintaining lower blocking probability. However, as the traffic load becomes heavier, the average hop number with PC-QRA will be slightly higher than that of the PCT-I scheme, but still smaller than that obtained without the pre-configuration strategy. However, the average hop performance of PCT-I is lower at higher traffic loads because its blocking probability is as high as 10%. Whereas, the PC-QRA scheme has blocking probability lower than 1% under the same traffic conditions. Thus, overall, the performance of the proposed scheme is better than the previous one.

As for the verification of PC-QRA under the ARPA network topology, the similar results are shown in figure 7 and 8. Comparable conclusions can be drawn for both the performance of different pre-configuration based QoS routing schemes (QRA over PCA-III has the same performance with QRA over PCA-II so it is omitted in the figure.) and the comparison with the previous best one in [9]. However, the average hop gain in ARPA network topology can be only obtained at a comparatively lower traffic load as shown in figure 8. Possible reasons for this are two folds: one is that the blocking probability of PCT-DRA-I over PCTGA-I deteriorate much faster than that of the QRA over PCA-II; and the second one is rooting in the lower node degree of ARPA network topology which provides less equal-hop paths even the pre-configuration schemes are implemented so that the performance of QoS routing is as helpful as that in the NSF network topology.

In summary, the simulation results show the effectiveness of the pre-configuration based QoS routing in shortening the average hop number of the control plane thus lower the connection setup time in the control plane. But as we can see from the figures that as the traffic demand grows, the average hop number gain is decreasing while the performance of blocking probability is deteriorating. This issue will be addressed in the future by deploying dynamic pre-configuration which can adapt itself to the dynamic features of the traffic so as to reduce both the average hops and the blocking probability at the same time.

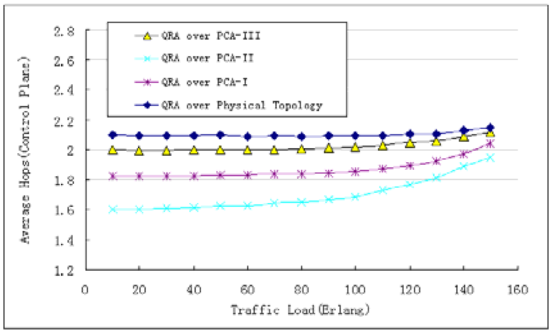

Fig. 5 (a) Average Hops

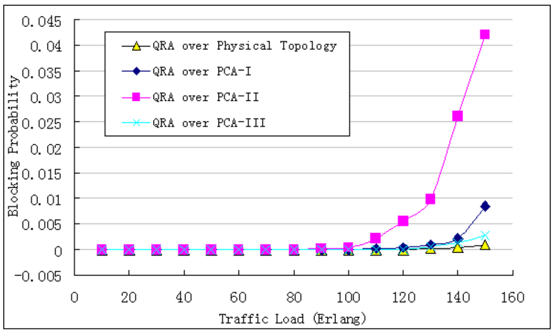

Fig.5 (b) Blocking Probability

Fig. 5 PC-QRA with different pre-configuration schemes under NSF topology

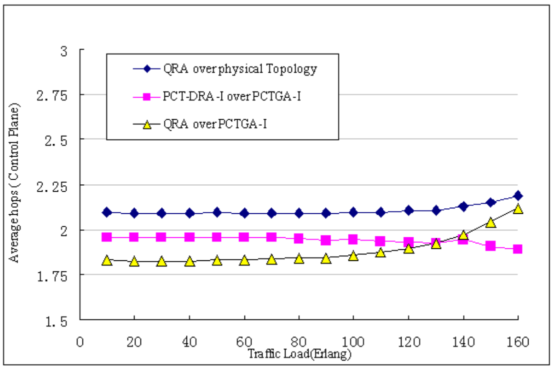

Fig. 6 (a) Average Hops

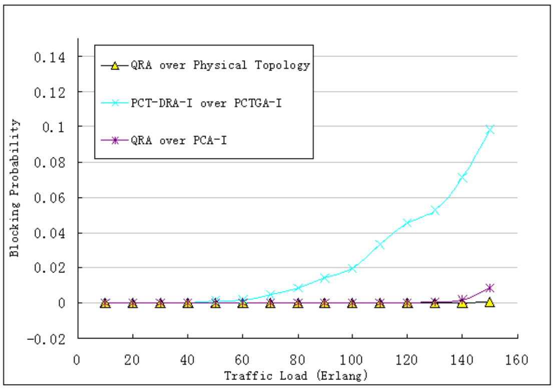

Fig. 6 (b) Blocking Probability

Fig. 6 PC-QRA compared with PCT-DRA-I over PCTGA-I schemes under NSF network topology

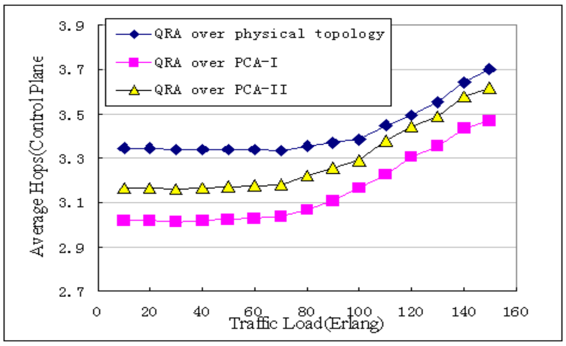

Fig. 7 (a) Average Hops

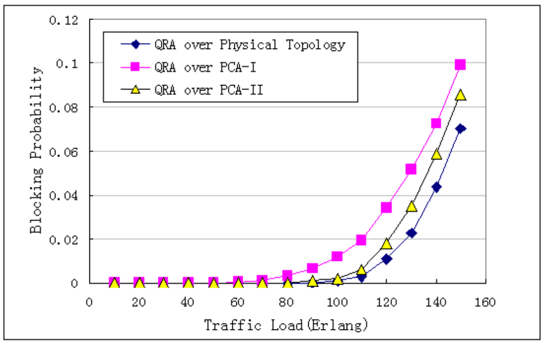

Fig.7 (b) Blocking Probability

Fig. 7 PC-QRA with different pre-configuration schemes under ARPA topology

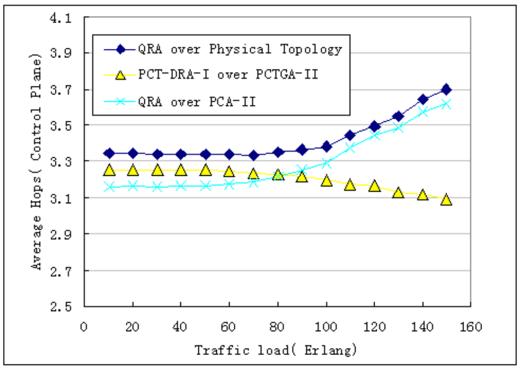

Fig. 8 (a) Average Hops

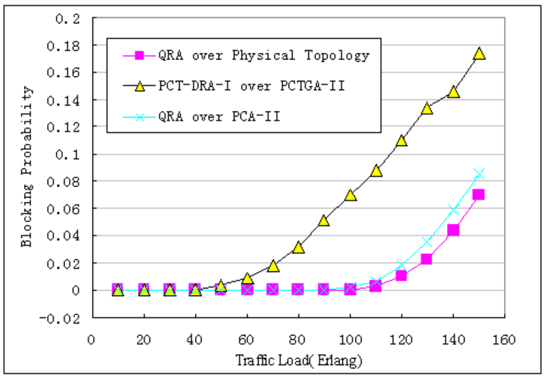

Fig. 8 (b) Blocking Probability

Fig. 8 PC-QRA compared with PCT-DRA-I over PCTGA-II scheme under ARPA network topology

5 Conclusion

In this paper, a pre-configured based QoS Routing algorithm deployed on GMPLS-based optical networks (PC-QRA) is presented. Simulation results show that the performance of the proposed algorithm is better than that of the previous ones as it can obtain lower average number of hops perceived from the control plane thus shortening the average connection setup time in the context of dynamic traffic, whilst still keeping low blocking probability.

Acknowledgement

The work is partially supported by the National Natural Science Foundation of China (No.60702005), the Hi-Tech Research and Development Program of China (Nos. 2009AA01Z218 and 2009AA01Z255), and the Major State Basic Research Development Program of China (973 Program) (No.2010CB328204).

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