A New Service Level Agreement Model for Best-effort Traffics in IP over WDM

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Abstract

In this paper, we propose a new SLA model for best effort IP traffic over WDM networks. This model jointly considers two QoS metrics, workable traffic volume and availability, as SLA parameters. We devise an algorithm of integer programming to minimize operation cost for the incremental traffic.

1. Introduction

Wavelength Division Multiplexing (WDM) has become one of the most important technologies in the optical network. With the WDM technology, a large volume of data can be transmitted over considerably long distance in a single fiber [1].

To make the WDM technology practical to operate, routing and wavelength assignment (RWA) is a critical procedure for assigning the incoming traffic to a lightpath that is a transparent channel for end-to-end connections. A lightpath could traverse multiple fiber links from source node to destination node. However, the lightpath must conform to the constraint that only one wavelength is used along the path. This constraint, namely *wavelength continuity constraint*, causes the problem of lightpath routing as NP-hard. To address this issue, researchers have proposed a model of Integer Linear Programming (ILP). However, ILP method is not scalable to large networks since the complexity increases exponentially. Accordingly, many heuristic algorithms are proposed to improve the scalability of lightpath routing for WDM. One may refer to [2] for a good survey for RWA.

In addition to the problem of lightpath routing, another problem would be the link faults on WDM networks, which would cause a large amount of data loss. Many research papers have been proposed for several mechanisms, e.g. path restoration and protection to address this issue [3]. In general, both mechanisms rely on fault-free backup paths when faults occur. The main difference between link restoration and protection is that the protection method allocates network resources at the same time of provisioning the primary path while the restoration method allocates network resources after the primary path is faulty.

Recently, the issue for quality of service (QoS) on WDM networks is getting more and more attentions [3]. The major application of QoS would be service level agreement (SLA) which is a contract between customers and service providers. SLA defines the revenue and penalty depending on the condition of the customer's service QoS. While there are many evaluation metrics in SLA, *availability* would be the most important one for service survivability [4]. The availability of a connection is defined as the probability that the connection is operational at any instant in the future. For the service providers, satisfying the customer's various QoS requirements while reducing the operation cost is a very important issue for both network services and network management. However, to our best knowledge, there is no research papers to deal with the SLA issue for the

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best effort (BE) traffic. In this paper, we propose a SLA model for BE traffic over WDM networks. The model is based on the following observations:

1. Most traffic flows are circuit-switched on WDM networks. The QoS of these lightpaths can be evaluated by some traffic metrics like availability, delay, BER, and so on [6].
2. Most IP flows are BE traffic that means no QoS are ensured in these flows. Hence, no SLA penalty would be incurred to the service provider when these customer's connections is disconnected.
3. Many applications, like Skype, rely on the functionality of the application layer in end-to-end fashion. Only BE service might be sufficient to the most customers.
4. Traffic engineer and grooming are getting mature in Data over SDH (DoS) [7], which may be in turn over WDM as well as MPLS over WDM.
5. Internet service providers (ISPs) offer more and more varieties of services to their customers. The differential services will help ISPs in customer acquisition, retention, loyalty, and profitability.
6. The cost optimization solution for minimizing capital expenditure (CAPEX) is not enough. The operating expenditure (OPEX) should also be considered as an important metric [5].

Therefore, we are motivated to propose a SLA model for BE flows in IP over WDM networks. This model jointly considers two important QoS metrics, workable traffic volume and availability, as SLA parameters. Given a **t**-Mbps (or SDH VCs) BE traffic from the source node to the destination node, it is trivial to derive the availability of the lightpath if the individual availability of each node and link along the lightpath is already known. In addition, our model tries to answer the following question: Can we provide an SLA choice like "When the traffic volume of the customer's flow is at least 1/2 **t**, the flow availability is 0.99999. "? We use an example to explain our idea. Consider a simple network topology as shown in Fig. 1. Since there is only one path for all traffic, the answer of the question is **a** which is equal to the availability of the whole volume.

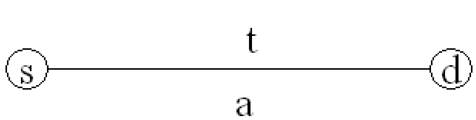

Figure 1. A connection of volume **t** over a lightpath with availability **a**

However, if the traffic is divided into two disjointed paths as shown in Fig. 2. We denote these two paths as $\mathbf{p}_1$ and $\mathbf{p}_2$ and their availability as $\mathbf{a}_1$ and $\mathbf{a}_2$, respectively. Assume that each lightpath carries half volume of whole traffic, **t**/2. We can provide the traffic flow with service availability as $1-(1-\mathbf{a}_1)(1-\mathbf{a}_2)$, which might be more available than the traffic flow in Fig. 1 when the transmitted traffic volume is only equal to half of the maximal allowable rate.

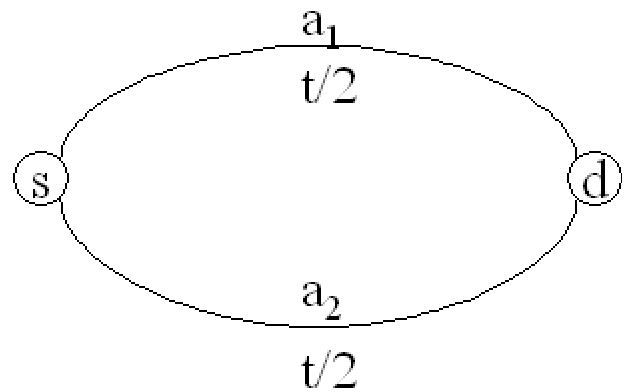

Figure 2. A connection of volume t over two disjoint lightpaths

We consider another general case. If the traffic is divided into **n** disjointed lightpaths and these lightpaths are denoted as $\mathbf{p}_1$, $\mathbf{p}_2$, …, $\mathbf{p}_n$. The volume of traffic and the availability of each lightpath $\mathbf{p}_i$ are denoted as $\mathbf{t}_i$ and $\mathbf{a}_i$, respectively. Figure 3 illustrates this scenario and the answer cannot be derived easily. To solve the problem, we have to find one of the total combinations of $\mathbf{t}_i$ such that the total traffic volume of these workable flows is greater than or equal to **t**/2 and the consequent availability is minimal of all possible combinations.

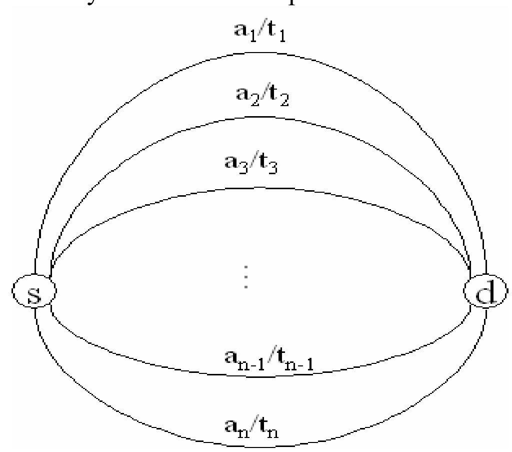

Figure 3. A connection over **n** disjoint lightpaths

The rest of this paper is organized as follows. In Section 2, we describe our SLA model. And we propose an IP for solving this problem in Section 3. Finally, simple conclusions are discussed.

2. Problem Description

To ease our explanation, we assume that the process of service provisioning is incremental, the routing algorithm is alternate-path routing [3], and lightpaths from source node *s* to destination node *d* are pre-computed and link-disjointed. Let $p^i_{s\to d}$ denote the i_{th} lightpath from node *s* to node *d* and the availability of $p^i_{s\to d}$ is denoted $a^i_{s\to d}$. The wavelength assignment algorithm can be any existing algorithm like *first fit*, *random*, and so on. Let a service request $t = (s, d, v_t, R_t)$ where v_t is the request traffic volume, and R_t is an SLA profile. For each covenant $R_t^i \in R_t$, $R_t^i = (\alpha_i v_t, a_t^i)$ for a_t^i is an availability quantity and $0<\alpha_i \le 1$. Clearly, $\alpha_0 = 1$ and α_i is a decreasing sequence. Our goal is to satisfy the request *t* while minimizing the OPEX in terms of the numbers of provisioning lightpaths.

3. Our Integer Program

To solve this problem, we devise an integer program as follows.

- Variables:
  - x_i: $x_i = 1$ if $p^i_{s\to d}$ is used for provision a service *t*; otherwise $x_i = 0$.
  - f_i: the number of free volume of $p^i_{s\to d}$ in terms of Mbps or VCs. clearly, $f_i \ge 0$.
  - a_i: the availability of $p^i_{s\to d}$ for $0 < a_i \le 1$.
  - t_i: the number of traffic volume of t using $p^i_{s\to d}$. clearly, $t_i \ge 0$ and $t_i > 0$ when $x_i = 1$.
  - a_t^i : the availability quantity of R_t^i.
  - x_i^j: $x_i^j = 1$ if $p^i_{s\to d}$ is used for provision service t and satisfies R_t^i; otherwise $x_i^j = 0$. Note x_i is the same as x_i^0.
- Objective: Minimize $\sum_i x_i^0$
- Constraints: $\sum_i x_i^j t_i \ge \alpha_j v_t$, for all j (1)

$$x_i^q \le x_i^p, \text{ for all } p < q \tag{2}$$

$$\prod_i \left[x_i^j a_i + \left(1 - x_i^j\right)\right] \ge a_t^i \tag{3}$$

$$t_i \le f_i \quad \text{for all } i \tag{4}$$

α_i, a_i , a_t^i are real numbers and $\in [0,1]$ (5)

f_i , t_i, and $v_t \in$ integers (6)

x_i^j is integers and $\in \{0,1\}$ (7)

The objective function is formulated to minimize the operation cost and subjective to constraints as explained as follows. Constraint (1) states that summation of traffic volume in each subflow is greater than or equal to the required volume in each covenant. Constraint (2) satisfies the property that each subflow used in covenant q is also used in covenant p for p > q. The availability requirement of each covenant is satisfied in constraint (3). Constraint (4) states the volume of subflow must less than or equal to the free capacity of communication paths between source node and destination node. Finally, constraints (5)-(7) represent real, integer, and binary properties of variables.

4. Conclusion

In this paper, we propose a new SLA model for BE traffic that may help operators to promote their customer acquisition, retention, loyalty, and profitability. In order to optimize the operation cost, we devise a model of integer programming for provisioning requested services with covenants of traffic volume and availability. However, as a primary study, we only consider the number of active lightpaths in operation cost. The research about IP constraint improvement and network resource optimization of SLA-aware BE traffic are in progress.

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