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QoS State Information Aggregation for Inter-domain Routing

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Abstract

Quality of Service (QoS) parameter aggregation is essential to Inter-domain QoS routing. It is the goal that how to aggregate Intra-domain QoS state with less data and less information losses. This Paper proposed a geometry-based approach to represent the QoS state information of delay and bandwidth for a subnetwork. We use regular polyline to approximate the service support area and just six tuples are needed to represent the aggregated information in our scheme. Both of the processes of aggregation and restore are introduced. Simulations and comparisons show that our scheme has the lower aggregation error ratio than existing approaches.

1. Introduction

QoS routing is considered as one of the most significant and fundamental techniques toward QoS provisioning in internet. However, the increasing internet size makes the execution time and the space requirement of a routing algorithm suffer from the scalability problem and the complexity problem. To alleviate such problems, large networks are structured hieratically through grouping nodes into many different domains [1] [2]. To provide end-to-end QoS guarantee, it need to find a QoS-supported path through several domains from source to destination according to QoS state information of networks.

However, it is impractical for a router to acquire and record whole topology information and QoS state in such a large network of Internet, thus the amount of topology advertising information has to be reduced to hide the internal topology of sub-networks for inter-domain routing. Topology Aggregation (TA) is introduced to done above in each domain before topology advertisement to the other domains [1~8].

TA may be defined as a series of processes that summarizes or abstracts the topological details into a compact and succinct description of the underlying subnetwork in terms of the representative network nodes and the transmission links for routing algorithms.

TA has two main processes, one is the aggregation of connectivity and the other is the aggregation of the resources availability in a domain [2]. With TA, routers only need to disseminate smaller updates to the other nodes and the storage cost can be effective reduced, too. Because of the summarization and abstraction of TA, a part of information tends to be lost. Hence, both of the processes of TA affect the performances of QoS-routing to a high degree. The objective of TA is to represent the topology information as accurate as possible with fewest data.

This paper focused on the aggregation of resources availability, i.e. delay and bandwidth. We proposed an approach to represent the delay and bandwidth state of an intra-domain with only six tuples. The simulation results show that our scheme has lower information distortion than existing approaches.

The rest of our paper is organized as follows: Section 2 will introduce the problem and related work. Section 3 will introduce our approach. Both the processes of information aggregation and information restore will be expounded. Section 4 compares our approach with the existing ones through simulations. Finally, we conclude with summary in section 5.

2. Problem statement & Related work

Typically, a large network is structured by several domains connected together through some inter-domain links and the nodes within each domain are connected by some intra-domain links. Each link is associated with a group of QoS parameters. In this paper, we only pay attention to delay and bandwidth. A service request with a requirement of delay d_r and a bandwidth requirement b_r is likely to be accepted by a

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physical path P with a set of nodes and links, if $b_r \le B$ and $d_r \ge D$, Where B is the bandwidth of P calculated in terms of $B = \min\{b_{u,v} \mid \forall(u,v) \in P\}$ and D is the delay of P calculated according to $D = \sum_{\forall(u,v)\in P} d_{u,v}$. That is to say, all service requests supported by P are ensured to be inside a region on *delay-bandwidth* plane. Such region is called Service Supported Area (SSA), represented as [3]:

$$SSA(P) = \{(d,b) \mid d \ge D \ and \ b \le B\} \qquad (1)$$

Given two border node x and y of a domain G , there are often several paths between them inside G . The Service Supported Area (SSA) of these paths between x and y on delay-bandwidth plane can be calculated like this:

$$SSA(x,y) = \{\bigcup SSA(P) \mid for\ all\ Ps\ \ from\ x\ to\ y\} \qquad (2)$$

In TA model, these paths are aggregated, and a node outside G knows them as a single one path (x, y) .

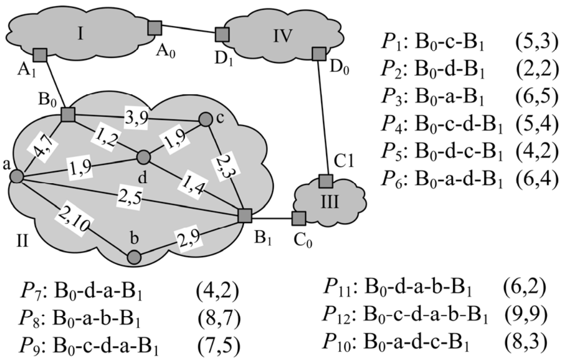

Fig. 1 The structure of inter-network

Consider an inter-network shown in Fig. 1, which has four domains I, II, III, and IV, with internal structure of domain II. B_0 and B_1 are border routers of domain II. The numbers associated with each link of domain II represent the QoS parameter tuple (*delay*, *bandwidth*). In Fig. 1, there are twelve paths i.e. P_1 to P_{12}, between B_0 and B_1.

Fig. 2 shows $SSA(B_0, B_1)$ on the delay-bandwidth plane, which is the staircase region I filled with grey bias and can be easily represented by the nodes on the convex corners of the stair. These nodes are called represent nodes [3]. For example, $SSA(B_0, B_1)$ tends to be represented by nodes (2,2), (5,4), (6,5), (8,7), (9,9). However, a service request which is likely to be supported by P_{11} is able to be supported by path P_2 , P_1 and P_6 . That is to say, domain II need not to advertise the QoS state information of P_{11} to other domains.

Dominate path: P_1 and P_2 are two different paths between a given node pair. (D_1, B_1) and (D_2, B_2) are QoS state of P_1 and P_2 respectively. If $D_1 \le D_2$ and $B_1 \ge B_2$, P_2 is dominated by P_1 . For instance, P_5 and P_{11} can be dominated by P_2 .

Non-dominated path: Suppose there are n different paths between two border nodes of a domain. If P is unable to be dominated by the other n-1 paths, P is called non-dominated path.

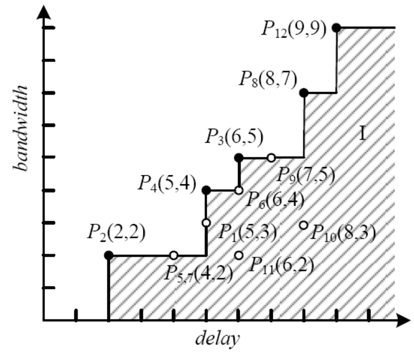

Fig. 2 *SSA* on delay-bandwidth plane

Obviously, non-dominated paths are the paths represented by the nodes of convex corners of the staircase. In Fig. 2, P_2 , P_4 , P_3 , P_8 and P_{12} are non-dominated paths.

Suppose there are n varied paths between two border routers with k non-dominated paths of them in a domain, it is true that $k \le n$. Although the *SSA* can be represented by the k representative points, on account of informing all k representatives of staircase may have substantial traffic load and memory usage overhead, especially in dense networks, it is not scalable to advertise the whole staircase to others for routing. Thus, approximation methods are needed to estimate staircase in a more efficient and cost-effective way.

So far as we known, geometry-based approaches towards this goal are so effective and there are four reported schemes in this category: line fitting, curve fitting, polyline, and cubic spline [1]. Lui *et al* [4] proposed a line fitting scheme with a Line Segment (LS) to represent the efficient frontier on the delay-bandwidth plane for a logical link. Korkmaz *et al* [5] proposed a curve fitting approach based on *stretch-factor* reflecting the deviation of the parameters of a path from the best parameters possible. Tang and Chen [6][7] proposed another curve fitting approach to fit a least-square polynomial of degree n given m data points, and at least n+5 float number are needed for this approach. A cubic spline scheme with g+5 float numbers was proposed by them too[6][7], g piecewise cubic polynomials was used to approximate the data set, which is broken up into g even ranges in terms of the restrictive parameter. In addition, they proposed a polyline scheme to represent staircase using several line segments instead of one [6] [7]. Lu *et al* [8] proposed a Regular Virtual Stair (RVS) to approximating the staircase region.

3. Our Approach

In this paper, we proposed a new geometry-based approach to approximate the *SSA* staircase. The main objective of our scheme is to minimize the area between the staircase function and the approximating geometric representation.

3.1 The aggregation process

We use a Regular polyLine (RPL) to approximate the staircase as shown in Fig. 3. The number of inflexion points on the polyline is determined by the number of non-dominated paths k and the polyline is formed by the secants of the arc. We use the area surround by the regular polyline and *delay*-axis to approximate the region of the staircase.

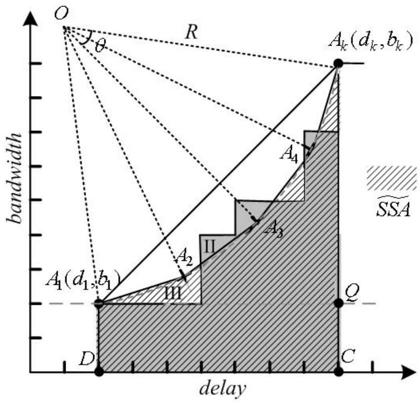

Fig. 3 The calculation of polyline

$$\theta^* = \arg_{\theta\in(0,\frac{\pi}{2}]} \min\left\{\left|S_{\text{Diamond}}(\theta) - S_\Delta(\theta) - \left|S_{stair} - S_T\right|\right|\right\} \tag{3}$$

Where θ^* is the optimal value of θ, S_{Diamond} represent the area of $OA_1A_2...A_k$,which is a diamond-like shape, S_Δ represent the area of the isosceles triangle, which is enclose by $O\overset{\frown}{A_1A_k}$, S_{stair} represent the area of the staircase as region I shown in Fig. 2, which is a actual service support region, and S_T represent the area of the right-angle trapezoidal region enclosed by A_1A_kCD , S_{Diamond} , S_Δ and S_T can be calculated as follows:

$$S_{\text{Diamond}} = \frac{1}{8} l^2 \frac{(k-1)\sin\left(2\theta/_{k-1}\right)}{\sin^2\theta} \tag{4}$$

$$S_\Delta = \frac{1}{4} l^2 \frac{\cos\theta}{\sin\theta} \tag{5}$$

$$S_T = \frac{1}{2}(d_k - d_1)(b_k + b_1) \tag{6}$$

Where, $$l = \sqrt{(d_k - d_1)^2 + (b_k - b_1)^2} \tag{7}$$

Thus the aggregated information can be expressed by $(d_1, b_1, d_k, b_k, \theta^*, k)$, which is called six tuples. After aggregation, a domain only needs to advertise these six tuples to other domains for routing. So, both the storage cost and traffic load can be reduced.

3.2 The restore process

When the other domains receive the aggregated QoS information, they will restore the approximate *SSA* in terms to $(d_1, b_1, d_k, b_k, \theta^*, k)$ to decide whether domains II can satisfy the QoS request or not and to do routing. This restore work is transferred to calculate out all coordinates of the inflexion points on the RPL. After getting these coordinates, the approximating *SSA* formed by the RPL is able to be achieved.

As shown in Fig. 3, let $\angle OA_1Q = \alpha$, $\angle OA_1A_k = \beta$ and $\angle A_kA_1Q = \omega$, so

$$\alpha = \beta + \omega \tag{8}$$

We can obtain β and ω easily by:

$$\beta = \frac{\pi}{2} - \theta^* \ , \ \omega = \arg tg \frac{b_k - b_1}{d_k - d_1} \tag{9}$$

Thus, the coordinate of the centre of the circle O can be obtained by (10), where $R = l/(2\sin\theta^*)$.

$$\begin{cases} d_o = d_1 + R\cos\alpha \\ b_o = b_1 + R\sin\alpha \end{cases} \tag{10}$$

$$\angle OA_1A_i = \frac{\pi}{2} - \frac{\theta^*}{2(k-1)}(i-1), \ i = 2,...,k-1 \tag{11}$$

$$A_1A_i = 2R\cos\angle OA_1A_i \tag{12}$$

Then, the coordinate of A_i is able to be calculated as:

$$\begin{cases} d_i = d_o + R\sin(\omega + \frac{i-k}{k-1}\theta^*) \\ b_i = b_o + R\cos(\omega + \frac{i-k}{k-1}\theta^*) \end{cases} \tag{13}$$

In terms of the formulas above, the other domains can restore the RPL and its approximating *SSA*.

4. Comparision

Most of current approaches use the success ratio [3] to evaluate the performance of TA schemes. However, the successful ratio is also affected by other factors, i.e. the performances of routing algorithm and connectivity aggregation, etc. Thus, we define the *aggregation error ratio Er* to evaluate distortion factor of the geometric-based QoS information aggregation schemes more effectively.

$$Er = \frac{\sum S_{IRR} + \sum S_{IAR}}{S_{stair}} \tag{14}$$

Where, $\sum S_{IRR}$ represents the total area of the *Incorrectly Rejected Region*, as the region II in Fig. 3. $\sum S_{IAR}$ represents the total area of the *Incorrectly*

Accepted Region, as the region III in Fig. 3. Obviously, *aggregation error ratio* can reflect the performances of geometry-based schemes exactly.

Lu *et al* [8] compared RVS approach with the LS approach and the *stretch-factor* approach and got the result that RVS is better than the others. Thus, this compared our scheme RPL with the RVS. We input varied numbers of paths from 10 to 100 respectively, and run these two schemes to do aggregation. After that, restored the approximating *SSA* by the aggregated information and calculated the *Er*s. On each number of paths we ran the simulations 10000 times and calculated the average of *Er* of them.

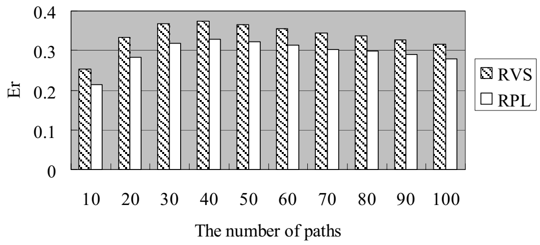

Fig. 4 ($5 \le d \le 55$ and $5 \le b \le 55$)

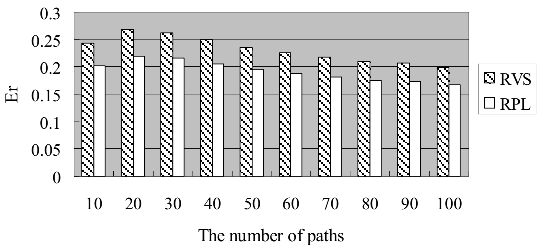

Fig. 5 ($5 \le d \le 15$ and $5 \le b \le 55$)

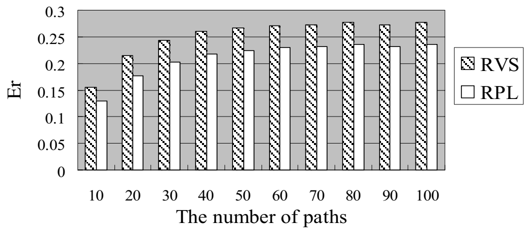

Fig. 6 ($5 \le d \le 55$ and $5 \le b \le 15$)

Fig. 4 shows the result when the delay and bandwidth of a path uniformly distributed in [5,50] and [5,50] , respectively, i.e. the paths uniformly distributed in a square region on *delay-bandwidth* plane. Fig. 5 shows the delay and bandwidth of a paths uniformly distributed in [5,15] and [5,55], respectively, i.e. a longitudinal rectangle region. Fig. 6 shows the result when the delay and bandwidth of a path uniformed distributed in [5, 55] and [5, 15], respectively, i.e. a horizontal rectangle.

From the simulations result above, we can conclude that our approach can achieve the lower aggregation error ratio than existing schemes.

5. Conclusion

In this paper, we proposed a geometry-based approach called RPL to represent the QoS state information. Only six tuples are needed to represent the aggregated information. Simulations and comparisons show that our scheme is able to obtain lower aggregation error ratio than existing approaches.

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