QoS Route Optimization Algorithm Based on Legend Transformation

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Abstract. In this paper, transforming the convolution to the (+,-) in legend domain is proposed. Based on the transformation, the Legend Transformation of service curve and arrive curve in the case of independent cross traffic is given, and obtain the closed expression of stochastic delay and stochastic backlog. For the case of non-independent cross traffic, we get the relationship expression of different traffic. And simulation proves that the route optimization algorithm is correct.

Keywords: QoS Route, Legend Transformation, Service Curve, Arrive Curve

1 Introduction

To achieve route optimization in dynamic network, we need to model dynamic network firstly. Assume the end-to-end matrix of traffic QoS is delay, and the other traffic is called cross traffic, the QoS parameters is decided by traffic and service provided by network, and service curve is influenced by cross traffic and the interaction between cross traffic and current traffic. In this paper, the independent situation between current traffic and cross traffic is mainly studied, simultaneously we present the QoS route optimization algorithm in the simplest case.

When current traffic is independent of cross traffic, that is cross traffic doesn’t have effect on current traffic, the simplest case is that cross traffic goes through only on network node, the case is shown in figure 1. In the figure, the dashed line represents the route of cross traffic, the solid line represents the route of traffic f. To Study the QoS route problem in the extreme case, we explore the computing problem of QoS route selection using Network Calculus and Legend Transformation.

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2 Network Model

First of all, we study the case of cross traffic independent each other and we know that the current traffic is \( F \). Take the simplest case as example, each cross traffic goes through only one network node, that is the cross traffic \( f_i \) goes through only one node of path \( p_i \), and the arrive curve of traffic \( f_i \) is \( \langle \alpha_i, \varepsilon_i \rangle \) is obtained.

The network is represented by the directed graph \( G = (V, A) \), and the service curve of each node in the network is \( \langle \beta_i, \varepsilon_i \rangle_{i \in V} \). The arrive curve of traffic \( f \) is \( \langle \alpha, \varepsilon \rangle \), the traffic \( f \) enter the network in the node \( v_{in} \), and leave the network in the node \( v_{out} \). Now we find a path \( p = (v_0, v_1, \ldots, v_l) \) for traffic \( f \), in which \( v_0 = v_{in}, v_l = v_{out} \), and stochastic delay of the traffic \( f \) in the path satisfies \( \langle D_{\max}(f, p), \varepsilon \rangle \) of the stochastic backlog is \( \langle B_{\max}(f, p), \varepsilon \rangle \).

According to [2], the arrive curve of \( f \) and the service curve provided to the traffic \( f \) by the network is need to be known to get the stochastic delay \( \langle D_{\max}(f, p), \varepsilon \rangle \). At present it is known that the arrive curve of traffic \( f \) is \( \langle \alpha, \varepsilon \rangle \), and yet we need to get the service curve provided to traffic \( f \) by the network. It is assumed that the current traffic is independent of the cross traffic, the hypothesis lead to the process of getting the service curve provided to traffic \( f \) by the network is becoming easy. According the left service curve thermo[3], the service provided to the traffic \( f \) by the network is called left service curve, the gain of left service curve depends on the estimation of cross traffic. Comparing with the interdependent case of cross traffic, the estimation of left service curve is easy in the independent case of cross traffic. It is assumed that the route of traffic \( f \) in the network is \( p \) represented by dashed line, and the path \( p_i \) represented by the solid line is route of cross traffic \( f_i \). According to the left service curve theorem[3], the service curve provided to the traffic \( f \) by the each node in the path \( p \) is respectively \( \beta_{i,p}^1 = \beta_i - \alpha_i \), \( \beta_{i,p}^4 = \beta_i \), \( \beta_{i,p}^3 = \beta_i - \alpha_i \), \( \beta_{i,p}^5 = \beta_i - \alpha_i \), and the error function is \( \varepsilon \). According to the \((\min,+)\) convolution, the service curve provided to the traffic \( f \) by the path \( p \) is \( \beta(p) = \beta_i \otimes \beta_i \otimes \cdots \otimes \beta_i \), without circle.

Assume the arrive curve \( E(t) = \alpha \) of traffic \( f \) is convex, and the service curve \( \beta_i \) in the network node is concave. And according to the Legend Transformation, the transformation of service curve provided to the traffic \( f \) is

\[
\overline{L}_E(e, \alpha) = \sup_{t \geq 0} \{ct - \alpha\}
\]
For the \((\min, +)\) function \(x(t), y(t)\), their Legend Transformation is 
\[ L(x \otimes y) = L(x) + L(y) \quad [4,5], \]
the transformation of service curve provided by the path \(p\) is 
\[ L_\beta(c, \beta) = L_\beta(c, \beta_1) + L_\beta(c, \beta_2) + \cdots + L_\beta(c, \beta_n) \quad (2) \]

3 The QoS Route Optimization Algorithm Based on Legend Transformation

According to [5], we can get the delay and backlog parameter of the traffic \(f\) through the path \(p\), the step of QoS route optimization algorithm is presented using (1) and (2), and process of the algorithm includes the following four steps:

1. Perform the Legend Transformation of service curve provided to the traffic \(f\) by the path \(p\) and Legend Transformation of arrive curve of the traffic \(f\).
2. Calculate the service curve of path \(p\) through by traffic \(f\) according to formula (5-27).
3. Calculate the stochastic delay or stochastic backlog according to [6].
4. Compare the calculated QoS parameter with the demand of QoS parameter of traffic \(f\), if the result meets the demand, the path can be the route of traffic \(f\), if not, go to the step (1) and recalculate.

For the independent case of cross traffic, the end-to-end service curve have been given, and for the non-independent case of cross traffic, as [7] said, the method of add node by node can’t describe the PMOO phenomenon. Figure 1 describes the case of non-independent cross traffic. The cross traffic in the path of traffic \(f\) is \(f_1\) and \(f_2\), and there is no cross path between traffic \(f_1\) and \(f_2\). Next we will give the calculation method of end-to-end service curve in the case of non-independent cross traffic in the condition of take account of the PMOO phenomenon.

Fig.1. Network Model for Non-independent Cross Flow

First, according to the left service curve theorem\([3]\), the service curve provided to the traffic \(f\) by node-one-node is calculated. In order to simplify the problem, assume there is only three nodes, and its service curve is respectively \(\langle \beta_i, \varepsilon_i \rangle, i = 1, 2, 3\), and the arrive curve of traffic \(f_1\) and \(f_2\) is...
respectively \( \langle \alpha_e, \epsilon_e \rangle \). According to the left service curve theorem \(^3\), the service curve provided to traffic \( f \) is

\[
\langle (\beta_1 - \alpha_1) \otimes (\beta_2 - \alpha_1 - \alpha_2) \otimes (\beta_3 - \alpha_2), \epsilon_e \otimes \epsilon_e \rangle
\]  

Formula (3) gives the service curve not taking account of PMOO. To study the interaction between traffics, it is assumed that the arrive function is concave, and service function is convex, the service curve is obtained for taking account of PMOO thought performing the Legend Transformation of formula (3)

\[
\begin{align*}
L \langle (\beta_1 - \alpha_1) \otimes (\beta_2 - \alpha_1 - \alpha_2) \otimes (\beta_3 - \alpha_2) \rangle \\
= \inf \{ \beta_1 - \alpha_1 - st \} + \inf \{ \beta_2 - \alpha_1 - \alpha_2 - st \} + \inf \{ \beta_3 - \alpha_2 - st \}
\end{align*}
\]

According to inequality \( \inf \{ X(s) - Y(s) \} \geq \inf \{ X(s) - \sup \{ Y(s) \} \} \), formula (4) is expressed as

\[
\begin{align*}
L \langle (\beta_1 - \alpha_1) \otimes (\beta_2 - \alpha_1 - \alpha_2) \otimes (\beta_3 - \alpha_2) \rangle \\
\geq L \langle \beta_1 \rangle + L \langle \beta_2 \rangle + L \langle \beta_3 \rangle - \{ \sup, \alpha_1 + \sup, (\alpha_1 + \alpha_2) + \sup, \alpha_2 \}
\end{align*}
\]

4 Numerical Analysis and Simulation

The calculation method of traffic QoS parameter in Legend domain is given in above section, the QoS route optimization algorithm is proposed based on the QoS parameter. The performance of the algorithm is decided by the accuracy of QoS parameter calculation. In the circumstance of NS, the simulation for the scene is performed. By monitoring the output of network node and combining the input of traffic, estimation of service in the Legend domain can be obtained according to \( H(\alpha) = L(y(t)) - L(x(t)) \), the simulation result is shown in figure 2, here \( x(t) \) is input, \( y(t) \) is output, and \( L \) is Legend Transformation.

Fig.2. Comparison between Academic Legendre Service Curve and its simulation
To verify that the theoretical model conform to the actual network situation, the result of theoretical analysis and the simulation result is shown in figure 2. The comparison proves the service curve in the case of non-independent cross traffic adapts the actual network. As the service curve is the foundation of QoS route optimization algorithm, the service curve shown in figure 2 can be used to calculate the QoS parameter accurately, then select the route based on the calculation result, and the calculated service curve can adapt the actual network. Therefore, the validity of the algorithm is proved.

5 Conclusion

For the case of independent cross traffic, transforming the convolution to the (+,-) in legend domain reduce the complexity of service curve. Through performing the Legend Transformation of arrive curve and service curve, the closed expression of stochastic delay and stochastic backlog can be obtained. For the case of non-independent cross traffic, combining the left service curve and analyzing the service curve in Legend domain, we can get the cross relations of traffic in different path and the expression of different traffic in condition of taking account the PMOO. Last, the simulation result proves the correctness the route optimization algorithm.

References