Lecture Notes in Electrical Engineering 315

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Chapter 81
Improving the Models of Internet Charging in Single Link Multiple Class QoS Networks

Irmeilyana Saidi Ahmad, Indrawati, Fitri Maya Puspita and Lisma Herdayana

Abstract In this paper, an improved internet charging scheme in multiple QoS networks will be discussed. The objective is to obtain better solution than previous results conducted by previous research. ISPs need a new charging scheme to maximize the revenue and provide better services to customers. The model is set up by fixing the fixed base price, varying the quality premium and fixing the sensitivity price for user in each class. The model is considered as Mixed Integer Nonlinear Programming (MINLP) and that can be solved by LINGO 11.0 to obtain the optimal solutions. We compare three cases of original, modified one and modified two models depending with the fixing or varying parameters or variables. The results show that by improving the pricing scheme model, the user' sensitivity price in modified two cases will yield maximum profit for ISPs.

81.1 Introduction

Previous works on pricing scheme of QoS networks is due to [1–4]. They described the pricing scheme based auction to allocate QoS and maximize ISP's revenue. The solution of the optimization problem goes from single bottleneck link in the network and then they generalized into multiple bottleneck links using

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heuristic method. In their study, they used single QoS parameter-bandwidth. In their discussion, they focus on auction algorithm to find the optimal solution. Based on their idea, it is attempted to improve their mathematical formulation and combine it with mathematical formulation discussed by Byun and Chatterjee [5] (see in [6–11]) to show that by improving the models, ISP improve the profit, with the advantages of availability of base price, quality premium and quality premium to be measured.

Recent studies have also been conducted to address problem of multiple service network, other kind of pricing scheme in network. Sain and Herpers [12] discussed problem of pricing in multiple service networks. They solve the internet pricing by transforming the model into optimization model and solved using Cplex software. Also, [13–15] discussed the new approach and new improved model of and got better results in getting profit maximization of ISP.

Although QoS mechanisms are available in some researches, there are few practical QoS network. Even recently a work in this QoS network proposed by [1–4], it only applies simple network involving one single route from source to destination.

So, the contribution is created by improving the mathematical formulation of to be simpler formulation in single link by taking into consideration the utility function, base price as fixed price or variable, quality premium as fixed prices and variable, index performance, capacity in one link, bandwidth required and also the user price sensitivity. The problem of internet charging scheme is considered as Mixed Integer Nonlinear Programming (MINLP) to obtain optimal solution by using LINGO 11.0 software. In this part, the comparison of two models is conducted in which whether decision variable is to be fixed of user admission to the class or not. This study focuses to fix the user's price sensitivity in each class. We consider cases of base price to be fixed and the quality premium to be fixed or vary depends on what target ISP would achieve. The Objective of ISP is to obtain maximum profit.

81.2 Research Method

The idea basically generates from [1–5] and are improved in single link multi class QoS networks. We attempt to improve the models when we consider the cases to fix the user price sensitivity in each class.

The steps are taken as follows.

1. Determine the parameters and decision variables for original and modified models.
2. Determine the constraints for the models.
3. Determine the model formulation of Steps 1 and 2.
4. Form the model formulation of base price and quality premium as the constant value and base price as the constant and quality premium as the variable.
5. Analyze the results and conclude the results.

81.3 Results and Discussion

81.3.1 Assumptions

Assume that there is only one single network from source to destination since concentrate on service pricing scheme. Assume that the routing schemes are already set up by the ISP. As [2] pointed out, we have 2 parts of utility function namely, base cost which does not depend on resource consumption and cost which depends on resource consumption. The parameters and decision variables we set up are presented in Tables 81.1 and 81.2.

81.3.2 Model Formulation

The model formulation follows from [10] except for $\tilde{W}_{ij}$ and W_j we modify by varying or fixing the prices, for each case of original, modified and modified 1 with additional constraints if we set up $\tilde{W}_{ij}$ and W_j as the parameters as follows.

$$\tilde{W}_{ij} = k, k \in R \tag{81.1}$$

$$W_j = 1 \tag{81.2}$$

81.3.3 The Solution for Original Model

In Table 81.3, the values of decision variables are given for original model. Final bandwidth ($\hat{X}_{ij}$) of user i is 1.234568. Minimum bandwidth for $L_{M_1}$and L_{M_2} is 1.234568 kbps. Sensitivity prices for class 1 and class 2, respectively (W_1 dan W_2) are 1.234568. We varies the base price 0.2/kbps and 0.3/kbps for all cases to promote the ISP goal to compete in market. Table 81.4 presents the solver status of the solver. Best objective is reached on value of 1.

Generated Memory Used (GMU) in Table 81.4 shows that the number of allocated memory used to run the solver. For original model, we have GMU of 28 K. Elapsed Runtime (ER) explains that the total time needed to solve the models and is affected by ether application running in the system. ER is 1 s in 4 iterations. We got total profit of only 1 unit price.

81.3.4 The Solutions for Modified Model with α and β Fixed

We modified the models into 3 groups when W_j and $\tilde{W}_{ij}$ as parameters, W_j as and $\tilde{W}_{ij}$ as variable and lastly when W_j as variable with $\tilde{W}_{ij}$ as parameter. Table 81.5 explains the variable values for modified models. We obtain final bandwidth ($\hat{X}_{ij}$)

Table 81.1 Parameters for each case of internet charging scheme

Parameter for original model	
Q	Total bandwidth
V_i	Minimum bandwidth needed by user i
α_j	Base price for class j
Parameter for model modified 1 (α β constants)	
α_j	Base price for class j
β_j	Premium quality having service performance I_j
Q	Total bandwidth
V_i	Minimum bandwidth needed by user i
c_j	Upper bound value for user i sensitivity price in class j
d_j	Upper bound for quality index in class j
Parameter for model modified 2 (α constant, β variable)	
Q	Total bandwidth
V_i	Minimum bandwidth needed by user i
α_j	Base price for class j
c_j	Upper bound value for user i sensitivity price in class j
d_j	Upper bound value for quality index in class j
f_i	Lower bound for premium quality in class j
g_i	Upper bound for premium quality in class j

for each user is 400.346 kbps. Premium quality for user 1 is 0.01 and for user 2 of 0.02. Minimum bandwidth L_{M_1} and L_{M_2} is 0.01 kbps. The price sensitivity for class 1 and 2 respectively (W_1 and W_2) are 13 when W_j as variable and $\tilde{W}_{ij}$ as parameter. We obtain $W_1 = 10$ and $W_2 = 12$ when W_j and W_{ij} as parameters also W_j as variable and W_{ij} as parameter. It means that ISP can vary the base price of 0.2 unit price/kbps and 0.3 unit price/kbps, for all cases to compete in the market.

The highest GMU in this model is 29 K for each case as stated in Table 81.6. ER is 1 s when W_j and W_{ij} as parameter. Also, ER = 0 s for W_j as variable and $\tilde{W}_{ij}$ as parameter, and last case when W_j as variable and W_{ij} as parameter. ESS is 0 since the solver applies the branch and bound solver. We can see that ISP can gain the maximum profit of 551.62 unit price if ISP sets W_j as variable and $\tilde{W}_{ij}$ as parameter to enable ISP to recover cost.

81.3.5 The Solutions for Modified Model with α Fixed and β Vary

When we set up the modified model with α fixed and β vary, we group it into three categories namely when W_j and $\tilde{W}_{ij}$ as parameter, W_j as parameter and $\tilde{W}_{ij}$ as variable, dan lastly when W_j as variable and $\tilde{W}_{ij}$ as variable. Table 81.7 shows the result of decision variables when we set up the modified model with α fixed and β

Table 81.2 Decision variables for each case of internet charging scheme

Variable for original model	$Z_{ij} : \begin{cases} 1, & \text{user } i \text{ is admitted to class } j \\ 0, & \text{otherwise} \end{cases}$
	$\tilde{X}_{ij}$: Final bandwidth obtained by user i in class j
	L_{Mj}: Minimum bandwidth for class j
	W_j: Sensitivity price for class j
	X_j: Final bandwidth for class j
	$\tilde{W}_{ij}$: Sensitivity price for user $i$in class j
Variable for modified model with α and β parameters	$Z_{ij} : \begin{cases} 1, & \text{user } i \text{ is admitted to class } j \\ 0, & \text{otherwise} \end{cases}$
	$\tilde{X}_{ij}$: Final bandwidth obtained by user i in class j
	L_{Mj}: Minimum bandwidth for class j
	W_j: Sensitivity price for class j
	X_j: Final bandwidth for class j
	$\tilde{W}_{ij}$: Sensitivity price for user i in class
	I_j: Quality index of class j
Variable for modified model with α parameter and β variable	$Z_{ij} : \begin{cases} 1, & \text{user } i \text{ is admitted to class } j \\ 0, & \text{otherwise} \end{cases}$
	$\tilde{X}_{ij}$: Final bandwidth obtained by user i in class j
	L_{Mj}: Minimum bandwidth for class j
	W_j: Sensitivity price for class j
	X_j: Final bandwidth for class j
	$\tilde{W}_{ij}$: Sensitivity price for user i in class
	I_j: Quality index of class j
	β_j: Premium quality of class j having service performance of I_j

Table 81.3 Decision variable values for original model proposed by [2]

Decision variables values			
α_1	0.2	$\hat{X}_{11}$	1.234568
α_2	0.3	$\hat{X}_{12}$	1.234568
β_1	–	$\hat{X}_{21}$	1.234568
β_2	–	$\hat{X}_{22}$	1.234568
Z_{11}	1	L_{M_1}	1.234568
Z_{12}	1	L_{M_1}	1.234568
Z_{21}	1	X_1	1.234568
Z_{22}	1	X_2	1.234568
$\tilde{W}_{11}$	1.234568	I_1	–
$\tilde{W}_{12}$	1.234568	I_2	–
$\tilde{W}_{21}$	1.234568	W_1	1.234568
$\tilde{W}_{22}$	1.234568	W_2	1.234568

Table 81.4 Solver status of original model proposed by [2]

Solver status	Model class	INLP
	State	Local optimal
	Infeasibility	0
	Iterations	4
Extended solver state	Solver type	Branch and bound
	Active	0
	Update interval	2
	GMU (K)	28
	ER (sec)	1
	Best objective	1
	Objective bound	1
	ESS	0
	TSI	4

Table 81.5 Decision variable values for modified model with α and β fixed

Variable	Modified model with α and β fixed		
	W_j Par $\tilde{W}_{ij}$ Par	W_j Par $\tilde{W}_{ij}$ Var	W_j Var $\tilde{W}_{ij}$ Par
α_1	0.2	0.2	0.2
α_2	0.3	0.3	0.3
β_1	0.01	0.01	0.01
β_2	0.02	0.02	0.02
Z_{11}	1	1	0
Z_{12}	1	1	0
Z_{21}	1	1	1
Z_{22}	1	1	1
W_1	10	10	13
W_2	12	12	13
$\tilde{W}_{11}$	12	10	12
$\tilde{W}_{12}$	12	12	12
$\tilde{W}_{21}$	15	10	15
$\tilde{W}_{22}$	15	12	15
$\hat{X}_{11}$	400.346	400.346	400.346
$\hat{X}_{12}$	400.346	400.346	400.346
$\hat{X}_{21}$	400.346	400.346	400.346
$\hat{X}_{22}$	400.346	400.346	400.346
L_{M_1}	0.01	0.01	0.01
L_{M_2}	0.01	0.01	0.01
X_1	400.346	400.346	400.346
X_2	400.346	400.346	400.346
I_1	0.9	0.9	0.9
I_2	0.8	0.8	0.8

Table 81.6 Solver status for modified model with α and β fixed

Solver status	W_j Par and $\tilde{W}_{ij}$ Par	W_j Par $\tilde{W}_{ij}$ Var	W_j Var $\tilde{W}_{ij}$ Par
Model class	INLP		
State	Local optimal		
Infeasibility	7.38964e-012	7.38964e-012	0
Iterations	5	5	7
Solver type	Branch and bound		
Active	0	0	0
Update interval	2	2	2
GMU (K)	29	29	29
ER (sec)	1	0	0
Best objective	467.34	467.34	551.62
Objective bound	467.34	467.34	551.62
ESS	0	0	0
TSI	5	5	7

Table 81.7 Decision variables for modified model with α fixed and β vary

Var	Modified Model with α Fixed and β Vary		
	W_j Par $\tilde{W}_{ij}$ Par	W_j Par $\tilde{W}_{ij}$ Var	W_j Var $\tilde{W}_{ij}$ Par
α_1	0.2	0.2	0.2
α_2	0.3	0.3	0.3
β_1	0.04	0.04	0.04
β_2	0.03	0.03	0.03
Z_{11}	1	1	0
Z_{12}	1	1	0
Z_{21}	1	1	1
Z_{22}	1	1	1
W_1	10	10	13
W_2	12	12	13
$\tilde{W}_{11}$	12	10	12
$\tilde{W}_{12}$	12	12	12
$\tilde{W}_{21}$	15	10	15
$\tilde{W}_{22}$	15	12	15
$\hat{X}_{11}$	400.346	400.346	400.346
$\hat{X}_{12}$	400.346	400.346	400.346
$\hat{X}_{21}$	400.346	400.346	400.346
$\hat{X}_{22}$	400.346	400.346	400.346
L_{M_1}	0.01	0,01	0.01
L_{M_2}	0.01	0,01	0.01
X_1	400.346	400,346	400.346
X_2	400.346	400,346	400.346
I_1	0.9	0.9	0.9
I_2	0.8	0.8	0.8

Table 81.8 Solver status of modified model with α fixed and β vary

Solver status	W_j Par $\tilde{W}_{ij}$ Par	W_j Par $\tilde{W}_{ij}$ Var	W_j Var $\tilde{W}_{ij}$ Par
Model Class	INLP		
State	Local optimal		
Infeasibility	7.38964e-012	7.38964e-012	0
Iterations	5	5	7
Extended solver state			
Solver type	Branch and bound		
Active	0	0	0
Update interval	2	2	2
GMU (K)	29	30	29
ER (sec)	0	1	1
Best objective	467.41	467.41	551.69
Objective bound	467.41	467.41	551.69
ESS	0	0	0
TSI	5	5	7

vary. Final bandwidth ($\hat{X}_{ij}$) obtained by the users is 400.346 kbps. Premium quality for user 1 is 0.04 and for user 2 is 0.03. Minimum bandwidth for $L_{M_1}$and L_{M_2} is 0.01 kbps. Price sensitivity for class 1 and 2 (W_1 dan W_2) respectively is 13 when W_j as variable and $\tilde{W}_{ij}$ as parameter while $W_1 = 10$ dan $W_2 = 12$ when W_j and W_{ij} as parameter and also when W_j as variable and W_{ij} as parameter. ISP enables to vary the base into 0.2/kbps dan 0.3/kbps to promote the available classes.

The highest GMU presented in Table 81.8 is 30 K when W_j as parameter and W_{ij} as variable, meanwhile GMU = 29 K when W_j and $\tilde{W}_{ij}$ as parameter, also when W_j as variable and W_{ij} as parameter. ER is 0 s for the case when W_j and W_{ij} as parameter, while ER = 1 s for W_j as variable and $\tilde{W}_{ij}$ as parameter, also W_j as variable and W_{ij} as parameter. ESS is 0 for all cases. ISP can obtain maximum profit of 551.69 unit price when ISP sets up the case when W_j as variable and $\tilde{W}_{ij}$ as parameter to enable ISP to recover cost.

From Tables 81.4, 81.6 and 81.8 we can check that the best objective is achieved when ISP sets up either to fix the base price and quality premium to recover cost and to let user to choose the class; or to fix the base price and vary quality premium to recover cost and ISP can promote certain services by adding the condition to the models by setting up the sensitivity price for user j to be fixed and the sensitivity price for user i in class j to be varied.

81.4 Conclusion

From the above discussion, we can see that by considering the new parameters, decision variables and the constraints, we can obtain the better maximum profit. ISP can adopt either the model of modified by fixing α and β; or fixing α and varying β for W_j as variable and fixing $\tilde{W}_{ij}$ as parameter to attain maximum value of 323.78 bps for each file and web traffic data.

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