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

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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.

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 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]).

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 β, the quality premium to be fixed or vary depends on what target ISP would achieve. The Objective of ISP is also to obtain maximized.

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.

3 Results and Discussion

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 Table 1 and Table 2 below.

Table 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 untuk 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

Table 2. Decision Variables for Each Case of Internet Charging Scheme

Variables		
Z_{ij}	:	$\begin{cases} 1, \text{if user } i \text{ in class } j \\ 0, \text{otherwise} \end{cases}$
$\tilde{X}_{ij}$	:	Final bandwidth for user i in class j
L_{mj}	:	Minimum bandwidth for class j
W_j	:	Sensitivity price for class j
X_j	:	Final bandwidth achieved by user i in class j
$\widetilde{W}_{ij}$	:	Price sensitivity for user i in class j
I_j	:	Quality index of class j
β_j	:	Premium quality that has service performance I_j

3.2 Model Formulation

The model formulation follows from [10] except for $\widetilde{W}_{ij}$ 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 $\widetilde{W}_{ij}$ and W_j as the parameters as follows.

$$\widetilde{W}_{ij} = k, k \in R \tag{1}$$

$$w_j = l \tag{2}$$

3 Optimal Solution

We solve the models of internet charging with LINGO 11.0 by applying file and web data traffic and we get the results as follows.

Tabel 3. Solver status for File Traffic Data

Solver status	Original	Modified		Modified 1	
		$\widetilde{W}_{ij}$ **Par** W_j **Var**	$\widetilde{W}_{ij}$ **Par** W_j **Par**	$\widetilde{W}_{ij}$ **Par** W_j **Var**	$\widetilde{W}_{ij}$ **Par** W_j **Par**
Model Class			INLP		
State			Local optimal		
Infeasibility	0	0	0	0	0
		Extended Solver state			
Solver type			Branch & Bound		
Active	0	0	0	0	0
Update interval	2	2	2	0	2
GMU(K)	28	29	29	29	29
ER(sec)	1	0	0	0	0
Best Objective	1	323.71	274.493	323.78	274.563
Objective bound	1	323.71	274.493	323.78	274.563
ESS	0	0	0	0	0
TSI	4	6	5	6	5

In Table 3, Generated Memory Unit (GMU) shows the amount of allocated memory in LINGO. The highest GMU is 30K for all cases except for original model. Elapsed Runtime (ER) shows that the total time spending to yield and solve the models that is affected by the other application running in this system. In all cases, the ER is 0 sec except for original case of 1 sec. ESS (Extended Solver Steps) depends on the certain solver running in the system. Since all models have branch and bound solver, then ESS is 0. ISP has choice to adopt modified 1 model when varying β in case of fixing $\widetilde{W}_{ij}$ and varying W_j since the model of MINLP attain the highest maximum value of 323.78.

The results in Table 4 show that the bandwidth obtained by the users for each case is 5 bps. Each minimum bandwidth for class 1 and 2 (L_1 dan L_2) is 0.01 bps. Then, the sensitivity price for class 1 and class 2 (W_1 and W_2) is 13 for the case of fixing $\widetilde{W}_{ij}$ and varying W_j; W_1 = 10; W_2 = 12 for the case of fixing $\widetilde{W}_{ij}$ and W_j. To be able to compete in the market, ISP should vary the base price of 0.2/bps and 0.3/bps for all cases.

GMU in Table 5 for web traffic data shows that the allocated memory used for LINGO. The highest GMU in this model is 29K for all cases except for original model of 28K. The ER shows that the total time used to obtain and solve the model which is affected by other application running on the system. In this case the ER is 1 sec. The ESS depends on the certain solver which is Branch dan Bound then we have ESS is 0. The best model to be adopted by ISP is by modified 1 model by varying β when we fix $\widetilde{W}_{ij}$ and varying W_j since the model reaches the highest maximum value of 323.78.

Table 4. Solution for the Models Using File Traffic Data

	Original	Modified		Modified 1 (β varies)	
		$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Var**	$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Par**	$\widetilde{W}_{ij}$**Par** $\boldsymbol{W_j}$ **Var**	$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Par**
α_1	0.2 fixed	0.2 fixed	0.2 fixed	0.2 fixed	0.2 fixed
α_2	0.3 fixed	0.3 fixed	0.3 fixed	0.3 fixed	0.3 fixed
β_1	-	0.01	0.01	0.04	0.04
β_2	-	0.02	0.02	0.03	0.03
Z_{11}	1	0	1	0	1
Z_{12}	1	0	1	0	1
Z_{21}	1	1	1	1	1
Z_{22}	1	1	1	1	1
W_1	1.234568	13	10	13	10
W_2	1.234568	13	12	13	12
$\hat{X}_{11}$	1.234568	5	5	5	5
$\hat{X}_{12}$	1.234568	5	5	5	5
$\hat{X}_{21}$	1.234568	5	5	5	5
$\hat{X}_{22}$	1.234568	5	5	5	5
L_1	1.234568	0.01	0.01	0.01	0.01
L_2	1.234568	0.01	0.01	0.01	0.01
X_1	1.234568	5	5	5	5
X_2	1.234568	5	5	5	5
I_1	-	0.9	0.9	0.9	0.9
I_2	-	0.8	0.8	0.8	0.8

Tabel 5. Solver Status for Web Traffic Data

Solver status	Original	Modified		Modified 1	
		$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Var**	$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Par**	$\widetilde{W}_{ij}$ **Par** $\boldsymbol{W_j}$ **Var**	$\widetilde{W}_{ij}$**Par** $\boldsymbol{W_j}$ **Par**
Model Class			INLP		
State			Local optimal		
Infeasibility	0	0	0	0	0
Extended Solver state					
Solver type			Branch & Bound		
Active	0	0	0	0	0
Update interval	2	2	2	0	2
GMU(K)	28	29	29	29	29
ER(sec)	1	0	0	0	0
Best Objective	1	323.71	323.71	323.78	274.563
Objective bound	1	323.71	323.71	323.78	274.563
ESS	0	0	0	0	0
TSI	4	6	7	6	5

Table 6. Result of the Model Using Web Traffic Data

	Original	**Modifikasi**		**Modified 1 (β varies)**	
		$\widetilde{W}_{ij}$ **Par** W_j **Var**	$\widetilde{W}_{ij}$ **Par** W_j **Par**	$\widetilde{W}_{ij}$ **Par** W_j **Var**	$\widetilde{W}_{ij}$ **Par** W_j **Par**
α_1	0.2 fixed	0.2 fixed	0.2 fixed	0.2 fixed	0.2 fixed
α_2	0.3 fixed	0.3 fixed	0.3 fixed	0.3 fixed	0.3 fixed
β_1	-	0.01	0.01	0.04	0.04
β_2	-	0.02	0.02	0.03	0.03
Z_{11}	1	0	0	0	1
Z_{12}	1	0	0	0	1
Z_{21}	1	1	1	1	1
Z_{22}	1	1	1	1	1
W_1	1.234568	13	13	13	10
W_2	1.234568	13	13	13	12
$\hat{X}_{11}$	1.234568	5	5	5	5
$\hat{X}_{12}$	1.234568	5	5	5	5
$\hat{X}_{21}$	1.234568	5	5	5	5
$\hat{X}_{22}$	1.234568	5	5	5	5
L_1	1.234568	0.01	0.01	0.01	0.01
L_2	1.234568	0.01	0.01	0.01	0.01
X_1	1.234568	5	5	5	5
X_2	1.234568	5	5	5	5
I_1	-	0.9	0.9	0.9	0.9
I_2	-	0.8	0.8	0.8	0.8

The results in Table 6 explain that the bandwidth obtained by the users for each case is 5 bps. The minimum bandwidth for class 1 and class 2 (L_1 dan L_2) is 0.01 bps. The sensitivity price for class 1 and class 2 (W_1 and W_2) is13 when we fix $\widetilde{W}_{ij}$ parameter and vary W_j and for class 2 with W_1 = 10; W_2 = 12 when we fix $\widetilde{W}_{ij}$ and W_j in modified 1 model. Two do so; ISP should vary the base price of 0.2/bps and 0.3/bps for all cases.

From results of decision variables in Table 4 and Table 6, we can examine that for all bandwidth cases of file and web traffic data, ISP is able to gain maximum profit when ISP fix the base α and vary the quality premium β when the case of fixing $\widetilde{W}_{ij}$ and varying W_j which enables ISP to recover the cost with maximum value of 323.78 bps.

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 the model of modified 1 by varying the β when fixing and varying W_{ij} and W_j to attain maximum value of 323.78 bps for each file and web traffic data.

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