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Generalized MINLP of Internet Pricing Scheme under Multi Link QoS Networks

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***Abstract*-In this paper, we will generalize the multi link internet charging scheme in multi class QoS network. This scheme is designed according to the base price, quality premium and quality of service to help the service provider to set up the parameters to optimize the service provider's profit and to serve better quality of service. The objective function is formed by setting up the base price as a constant and setting up quality premium as a parameter and a variable. Models are in form of Mixed Integer Nonlinear Programming Problem and are solved by using LINGO 13.0 to obtain the optimal solutions. The results show that in case when we set up the base price as a parameter with varying the quality premium, fixing the sensitivity price of user I in class j and also varying the sensitivity of class j, the highest optimal solution was achieved. The modified model also gives better optimal solution compared to original model. It means that by fixing base price, ISP is able to goal its objective by recovering cost and promoting certain services.**

I. INTRODUCTION

The challenge to provide better quality of internet is essential for ISP. The network service quality is determined by the users' satisfactoriness. ISPs have a task to offer better and different QoS to the users to reach the best information quality and also to gain the profit from the available resources. The knowledge to develop the new pricing scheme under user willingness and the providers are provided but only few involve QoS network [1-4].

Yang [5] and Yang et al.[5-8] have conducted the research focused on internet pricing on multi class QoS by describing the auction scheme in obtaining the optimal solution. In fact, there exist some parameters affected QoS which can be considered.

This paper basically attempts to offer the generalized optimal solution of by applying the improved models for internet pricing in multi link with more classes based on [9] models. The results obtained can assist ISP to choose the best pricing scheme satisfying the users. So, the contribution is created by improving the mathematical formulation of [5, 9, 10] into new formulation 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 more than one link and also bandwidth required. The problem of internet charging scheme is considered as Mixed Integer Nonlinear Programming (MINLP) to obtain optimal solution by using LINGO 13.0 [11] software. In this part, we generalize the model proposed previously by [1,2] with the extension for multi link network then the comparison of the models is conducted in which whether decision variable is to be fixed of user admission to the class or not. This study focuses to vary the quality premium parameters and see what decision can be made by ISP by choosing this parameter.

II. LITERATURE REVIEW

Table I and Table II below present the several past research focusing on internet pricing and current research on wired internet pricing under multiple QoS network.

TABLE I
SEVERAL PAST RESEARCH ON INTERNET PRICING

Pricing Strategy	How it Works
Responsive Pricing [12]	Three stages proposed consist of not using feedback and user adaptation, using the closed-loop feedback and one variation of closed loop form.
Pricing plan [13]	It Combines the flat rate and usage based pricing. Proposed pricing scheme offers the user a choice of flat rate basic service, which provides access to internet at higher QoS, and ISPs can reduce their peak load.
Pricing strategy [10]	Based on economic criteria. They Design proper pricing schemes with quality index yields simple but dynamic formulas'. Possible changes in service pricing and revenue changes can be made
Optimal pricing strategy [14]	The schemes are Flat fee, Pure usage based, Two part tariff. Supplier obtains better profit if chooses one pricing scheme and how much it can charge. Two part of analysis homogenous and heterogeneous.
Paris Metro Pricing [15, 16]	Different service class will have a different price. The scheme makes use of user partition into classes and move to other class it found same service from other class with lower unit price.
Internet pricing proposed by [17]	Internet pricing according to cost analysis. The categories are flat pricing, where ISPs use one price to charge users based on a specified time and users have equal speed access and equal price. The second category is based on usage pricing, where the pricing scheme charges the amount of traffic uploaded and downloaded.
Pricing schemes proposed by [18]	Pricing schemes based on QoS levels in different allocations that control congestion and load balance. Multiple class QoS networks require differentiated pricing schemes for allocations of different levels of service traffic.

This model is was improved from by taking the case of a base price (α) as a constant and quality premium (β) as constants and variable. The modified model can be divided into two type , namely W_{ij} as a parameter and W_j as parameter, and W_{ij} as parameter W_j as variable. The generalized model is solved by LINGO 13.0 super version for educational purpose is only for 2 users, 2 classes and 2 links.

III. RESULTS AND DISCUSSIONS

A. *Original Model*

Original model was adopted from .

$$\max R = \sum_{j=1}^{m}\sum_{i=1}^{n} \alpha_j \cdot Z_{ij} + W_j \cdot \log\frac{\hat{X}_{ij}}{L_j} \quad (1)$$

dengan kendala

$$\sum_{j=1}^{m}\sum_{i=1}^{n}\hat{X}_{ij}^{k} \le C_k, \quad k = 1,\dots,r \quad (2)$$

$$\tilde{X}_{ij}^{k} = \hat{X}_{ij} \quad (3)$$

$$\hat{X}_{ij} = \tilde{L}_{ij}^{k} \quad (4)$$

$$\hat{X}_{ij} \ge Z_{ij} \quad (5)$$

$$W_j \le \widetilde{W}_{ij}^{k} + (1 - Z_{ij}) \quad (6)$$

$$L_j \le \tilde{L}_{ij}^{k} + (1 - Z_{ij}) \quad (7)$$

$$\hat{X}_{ij} \ge X_j - (1 - Z_{ij}) \quad (8)$$

$$\hat{X}_{ij} \ge X_j \quad (9)$$

$$\hat{X}_{ij} \ge 0 \quad (10)$$

$$L_j \ge 0 \quad (11)$$

$$W_j \ge 0 \quad (12)$$

$$Z_{ij} = \begin{cases} 1, & if\ user\ i\ in\ allowed\ in\ j \\ 0, & otherwise \end{cases} \quad (13)$$

with $i = 1,\dots, n$; $j = 1,\dots, m$; $k= 1,\dots, r$.

c_j is determined as the upper bound value of sensitivity price for each user i in class j of link k.

B. *Model by fixing α_j and β_j*

The model was adapted from .

$\widetilde{W}_{ij}$ as parameter and W_j as variable

$$maks\ R = \sum_{j=1}^{m}\sum_{i=1}^{n}((\alpha_j \cdot Z_{ij} + \beta_j \cdot I_j) + w_j log\frac{\hat{X}_{ij}}{L_{m_j}}) \quad (14)$$

Subject to Eq (2) -Eq (12) and

$$\alpha_j + \beta_j \cdot I_j \ge \alpha_{j-1} + \beta_{j-1} \cdot I_{j-1} \quad (15)$$

$$0 < I_j < d_j. \quad (16)$$

$$\widetilde{W}_{ij} = c_j \quad (17)$$

$\widetilde{W}_{ij}$ parameter dan W_j parameter

Add new constraint as follows.

$$W_j = d_j \quad (18)$$

With d_j as the upper bound of quality index in class j.

C. *Model by fixing α_j and varying β_j*

The model was adapted from .

$\widetilde{W}_{ij}$ parameter dan W_j variable

Max the objective function (14) subject to Eq (2-Eq (13) and Eq (15) to Eq (18). Adding the new constraints, we have

$$\beta_j \le \beta_{j-1} \quad (19)$$

$$f \le \beta_j \le g \quad (20)$$

$\widetilde{W}_{ij}$ parameter dan W_j parameter

Max the objective function (14) subject to Eq (2) to Eq (13), Eq (15) to Eq (20).

with

- α_j : Base price for class j.
- Z_{ij} : $\begin{cases} 1, \text{if user i in allowed in j} \\ 0, \quad \text{otherwise} \end{cases}$
- W_j : Sensitivity price for class j.
- $\tilde{X}_{ij}^{k}$: Final bandwidth obtained by user i in class j of link k.
- $\tilde{L}_{ij}^{k}$: Minimum bandwidth for user i in class j of link k.
- L_j : Minimum Bandwidth for class j.
- Q : Total bandwidth.
- $\widetilde{W}_{ij}$: Sensitivity price for user i in class j.
- V_i : Minimum bandwidth needed for user i.
- X_j : Bandwidth for each user in class j.
- β_j : Premium quality of class j having service performance I_j
- I_j : Quality index of class j.
- r : Number of link
- f : Floor value for quality premium in class j
- g : Ceiling value for quality premium in class j

The solution of the mixed integer nonlinear programming problem solved using LINGO 13.0 to obtain the optimal solution. Table III and Table IV present the results.

TABLE III
SOLVER STATUS OF ORIGINAL MODEL, MODEL BY FIXING BASE PRICE AND QUALITY PREMIUM AND ALSO MODEL BY FIXING BASE PRICE AND VARYING THE QUALITY PREMIUM

	Original
Model Class	MINLP
State	Local Optimal
Objective	176.768
Infeasibility	0
Iterations	14
Solver Type	Branch and Bound
Steps	0
Active	0
GMU	32K
ER	1s

In Table III and Table IV, the solver status of each case was shown. All models are solved by using LINGO 13.0. the model is mixed integer nonlinear programming with status of local optimal. The solver type is branch and bound with the number of memory used between 32K-35K.

TABLE IV
SOLVER STATUS OF MODEL BY FIXING BASE PRICE AND QUALITY PREMIUM AND ALSO MODEL BY FIXING BASE PRICE AND VARYING THE QUALITY PREMIUM

	β_j Fixed $\widetilde{W}_{ij}$ Par	β_j Fixed $\widetilde{W}_{ij}$ Par	β_j Var $\widetilde{W}_{ij}$ Par	β_j Var $\widetilde{W}_{ij}$ Par

	W_j Par	W_j Var	W_j Par	W_j Var
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	110.645	176.874	110.709	176.938
Infeasibility	0	1.1×10^{-13}	0	1.1×10^{-13}
Iterations	24	33	25	34
Solver Type	Branch and Bound	Branch and Bound	Branch and Bound	Branch and Bound
Steps	0	0	0	0
Active	0	0	0	0
GMU	35K	34K	36K	35K
ER	1s	0s	0s	1s

TABLE V
DECISION VARIABLE VALUES FOR ORIGINAL MODEL

	Original
X_1	0
X_2	0
W_1	8
W_2	10
β_1	-
β_2	-
L_1	7
L_2	7
$\hat{X}_{11}$	931.399
$\hat{X}_{12}$	931.399
$\hat{X}_{21}$	931.399
$\hat{X}_{22}$	931.399
Z_{11}	1
Z_{12}	0
Z_{21}	0
Z_{22}	1
$\tilde{X}^1_{11}$	931.399
$\tilde{X}^2_{11}$	931.399
$\tilde{X}^1_{12}$	931.399
$\tilde{X}^2_{12}$	931.399
$\tilde{X}^1_{21}$	931.399
$\tilde{X}^1_{21}$	931.399
$\tilde{X}^1_{22}$	931.399
$\tilde{X}^2_{22}$	931.399
I_1	-
I_2	-

Table V and Table VI show that all models, the bandwidth obtained ($\hat{X}_{ij}$) is 931.399 kbps which is the capacity for link 2. The minimum bandwidth for L_1 and L_2 for original case and for the case when varying the sensitivity price for class j. Price sensitivity for class 1 and 2 (W_1 and W_2) are 8 and 10 when we vary the price sensitivity. ISP obtain the highest optimal solution by setting up the base price to fixed, quality premium to be varied, sensitivity price for user I in class j to be fixed and sensitivity price for class j . The results show that the modified model in two cases share slightly better result that the original model. The advantage of the modified model that ISP is able to know its quality premium and quality index which are unavailable in original model.

TABLE VI
DECISION VARIABLE VALUES FOR MODEL BY FIXING BASE PRICE AND QUALITY PREMIUM AND ALSO MODEL BY FIXING BASE PRICE AND VARYING THE QUALITY PREMIUM

	β_j Fixed $\tilde{W}_{ij}$ Par W_j Par	β_j Fixed $\tilde{W}_{ij}$ Par W_j Var	β_j Var $\tilde{W}_{ij}$ Par W_j Par	β_j Var $\tilde{W}_{ij}$ Par W_j Var
X_1	931.399	931.399	931.399	931.399
X_2	931.399	931.399	931.399	931.399
W_1	-	8		8
W_2	-	10		10
β_1	-	-	0.05	0.05
β_2	-	-	0.05	0.05
L_1	6	7	6	7
L_2	7	7	7	7
$\hat{X}_{11}$	931.399	931.399	931.399	931.399
$\hat{X}_{12}$	931.399	931.399	931.399	931.399
$\hat{X}_{21}$	931.399	931.399	931.399	931.399
$\hat{X}_{22}$	931.399	931.399	931.399	931.399
Z_{11}	1	1	1	1
Z_{12}	1	0	1	0
Z_{21}	1	0	1	0
Z_{22}	1	1	1	1
$\tilde{X}^1_{11}$	931.399	931.399	931.399	931.399
$\tilde{X}^2_{11}$	931.399	931.399	931.399	931.399
$\tilde{X}^1_{12}$	931.399	931.399	931.399	931.399
$\tilde{X}^2_{12}$	931.399	931.399	931.399	931.399
$\tilde{X}^1_{21}$	931.399	931.399	931.399	931.399
$\tilde{X}^1_{21}$	931.399	931.399	931.399	931.399
$\tilde{X}^1_{22}$	931.399	931.399	931.399	931.399
$\tilde{X}^2_{22}$	931.399	931.399	931.399	931.399
I_1	0.8	0.8	0.8	0.8
I_2	0.9	0.9	0.9	0.9

IV. CONCLUSION

The Generalized improved models for internet pricing model in 2 link class QoS network with 2 users and 2 classes with the base price as a constant and quality premium as a constant or a variable by setting up the user i sensitivity in class j ($\tilde{W}_{ij}$) and sensitivity in class j (W_j) can be solved to obtain the better maximum profit for according to ISP' preferences. The solutions show the connections between $\tilde{W}_{ij}$ and W_j as a parameter or variable in maximizing the revenue. In the modified model, the highest maximum revenue in case where $\tilde{W}_{ij}$ as parameter and W_j as variable is achieved.

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