Australian Journal of Basic and Applied Sciences, 7(7): 928-937, 2013
ISSN 1991-8178

Improved Models of Internet Charging Scheme of Multi bottleneck Links in Multi QoS Networks

[1]Fitri Maya Puspita, [1]Kamaruzzaman Seman, [1]Bachok M. Taib and [2]Zurina Shafii

[1]Faculty of Science and Technology, Universiti Sains Islam Malaysia, Nilai, 71800 Negeri Sembilan, Malaysia.
[2]Faculty of Economics and Muamalat, Universiti Sains Islam Malaysia, Nilai, 71800 Negeri Sembilan, Malaysia.

Abstract: This paper will seek new proposed pricing plans to develop new pricing scheme that serve both customers and maximize the supplier profit as nowadays Internet Service Providers (ISPs) deal with high demand to promote good quality information but only a few pricing plans involve QoS networks. We are going to solve multi bottleneck links in multi QoS Network scheme as an optimization model by comparing two models in multi QoS networks by taking into consideration decision whether to set up base price to be fixed to recover the cost or to be varied to compete in the market and quality premium to be fixed to enable user to choose classes according to their preferences and budget or to be varied to enable ISP to promote certain service. The results were obtained by aid of LINGO 13.0 software application. The results show that our two modified models slightly yield better solution rather than in original problem but with advantages that ISP has options to choose which of two models to be adopted depending on ISP goals in achieving the profit maximization.

Key words: charging scheme, multi bottleneck links, multi QoS networks, profit maximization.

INTRODUCTION

The pricing schemes of the past are mainly responsive pricing that is only charging extra when network congestion indicates that the users have QoS degradation, with size of changes related to degree of congestion by comparing three different schemes for allocating a simple network resource. Firstly, use no feedback and user adaptation to the network state. Secondly, use of a closed-loop form of feedback and adaptation and lastly is a closed loop variation or tight loop as it shortens the delay in the control loop (MacKie-Mason *et al*., 1996).

Other scheme is congestion avoidance algorithm (Jacobson, 1988) and also scheme that combines congestion avoidance algorithm and one type of responsive pricing scheme that is smart market mechanism by Network Protocol (Kelly *et al*., 1998; Henderson *et al*., 2001). One important thing why we want to create pricing mechanism is due to reducing congestion. What happens if we cannot avoid congestion? Karp (2005) explained problems related to congestion and how to control it. If, for instance, there is single flow which is sending packets from source to destination, if it transmits at certain rate, it get dropped packet, but if it chooses to send other rate, it can reach destination. It gets acknowledgment from destination about the received packet. But how do we know how much. How can go through? How can the source A, for instance, know and manage its flow over continuing certain time, meaning that time is divided into duration length of time (Fulp & Reeves, 2002; Yuksel *et al*., 2002).

Others dealing with analysis of pricing strategy are to optimize profits, do not raise profits by guiding us to efficient pricing strategy which can control the congestion. Tuffin (2003), Ros and Tuffin (2004) and Odlyzko (1998) also proposed Paris metro pricing scheme for charging the network. In this case, the different service class will have different price. The user has choice to choose channels to travel and price to pay. The scheme basically makes use of user to partition into classes and move to other class it found same service from other class with lower unit price. But still, they only consider with the case of single network which is not suitable with current internet. Meanwhile, Altmann and Chu (2001) offer new pricing plan that gives benefit to ISP and users. This plan is combination of flat rate and usage based pricing. In this plan, user will get benefit from unlimited access by choosing higher QoS and at the same time ISP is able to reduce its peak load. The drawback is still due to lack of information how that plans can be adopted into multiple route networks. For the next generation internet, the availability of fast transportation of data is required. The multicast communication can decrease due to limitation of bandwidth. So we need QoS specification and compute optimal routes to a multi-constrained problem, by using greedy algorithm such as meta-heuristics algorithm like proposed by Ali *et al*. (2008).

Recent works on pricing scheme of QoS networks is due to Yang *et al*. (2003), Yang (2004), Yang *et al*. (2004) and Yang *et al*. (2005). They described the pricing scheme based auction to allocate QoS and maximize

Corresponding Author: Fitri Maya Puspita, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Nilai, 71800 Negeri Sembilan, Malaysia.
E-mail: pipit140201@yahoo.com.au

ISP's revenue. The auction pricing scheme is actually scalability, efficiency and fairness in sharing resources. 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 paper, they used single QoS parameter-bandwidth. They basically formulate pricing strategy for differentiated QoS networks. In their discussion, they focus on auction algorithm to find the optimal solution. Based on their idea, we proposed to modify and improve their mathematical formulation and combine it with mathematical formulation discussed by Byun and Chatterjee (Byun & Chatterjee, 2004)(see in Puspita *et al*.(2011a) and Puspita *et al*. (2011b)).

Recent studies have also been conducted to address problem of multiple service network, other kind of pricing scheme in network. Sain and Herpers (2003) 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, Puspita *et al*. (2012a) and Puspita *et al*. (2012b) discussed the new approach and new improved model of Sain and Herpers (2003) and Byun and Chatterjee (2004) 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 (Byun & Chatterjee, 2004), it only applies simple network involving one single route from source to destination.

So, we would like to give small scale contribution by modifying the mathematical formulation of Byun & Chatterjee (2004) and Yang (2004) to be simpler formulation in multi links 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. Next we consider the problem of internet charging scheme as Mixed Integer Nonlinear Programming (MINLP) to obtain optimal solution by using LINGO 13.0 (2011) software. In this part, we also would like to compare two models in which whether we fix decision variable of user admission to the class or not. We focus to vary the quality premium parameters and see what decision can be made by ISP by choosing this parameter.

Research Method:

We attempt to apply optimization techniques in solving the problem in this paper. Like in Sain and Herpers (2003), we also consider the optimization problem as MINLP that can be solved by using optimization tool LINGO 13.0. We transform the problem of pricing the internet in multi service networks into optimization model and attempt to solve it to get optimal solution. This solution will help us interpreting the current issues involving pricing, network share, base price, quality premium and also QoS level.

Below is the figure showing the problem and how to transform into optimization problem.

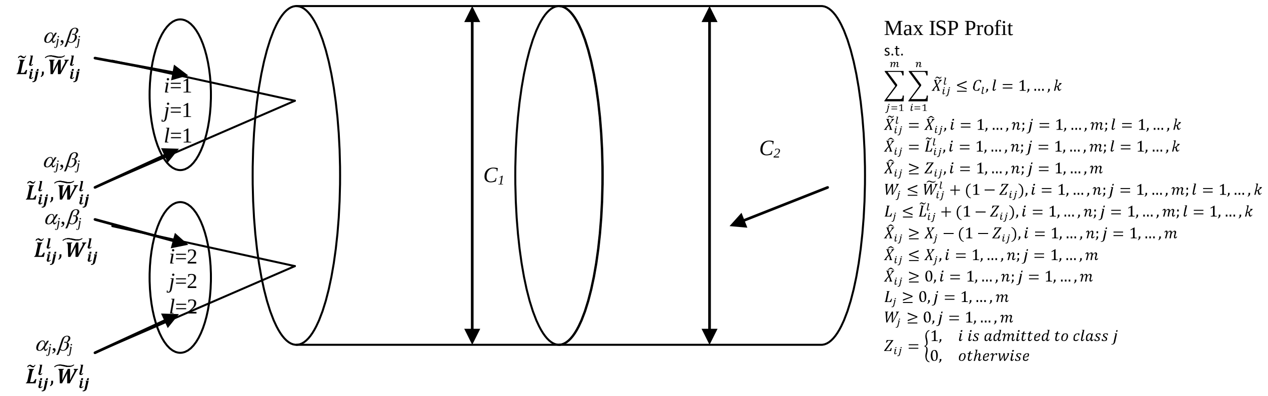

Fig. 1: General Research Model of Internet Charging Scheme.

RESULTS AND DISCUSSION

The idea basically generates from Yang (2004) and Byun and Chatterjee (2004) for single QoS network. We assume that the routing schemes are already set up by the ISP. As Yang (2004) pointed out, we have 2 parts of utility function namely, base price which does not depend on resource consumption and cost which depends on resource consumption. The utility function has characteristics as marginal profit as function of bandwidth decreasing with increasing bandwidth. The Objective of ISP is to obtain maximized profit subject to constraints based on system' available resources.

Mathematical Model:

Model 1 for Original Problem:

Parameters for model 1 original problem:

C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.
α_j : Base price of a network service *j*, since the internet cannot guarantee its level of service quality so α could be equivalent to price of best effort service in current internet architecture.
$\tilde{L}_{ij}^l$: Minimum bandwidth for user *i* in class *j* on link *l*.
$\widetilde{W}_{ij}^l$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.

Variables are as follows.
$\tilde{X}_{ij}^l$: Bandwidth obtained by user *i* in class *j* on link *l*.
$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.
$Z_{ij} = \begin{cases} 1, & i \text{ is admitted to class } j \\ 0, & otherwise \end{cases}$
W_j : Price sensitivity for class *j*.
L_j : Bandwidth for class *j*.
X_j : Bandwidth assigned to each individual user in class *j*.

So, the mathematical model of model 1 original is as follow.

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

Subject to

$$\sum_{j=1}^{m} \sum_{i=1}^{n} \tilde{X}_{ij}^l \leq C_l, l = 1, \ldots, k \quad (2)$$
$$\tilde{X}_{ij}^l = \hat{X}_{ij}, i = 1, \ldots, n; j = 1, \ldots, m; l = 1, \ldots, k \quad (3)$$
$$\hat{X}_{ij} = \tilde{L}_{ij}^l, i = 1, \ldots, n; j = 1, \ldots, m; l = 1, \ldots, k \quad (4)$$
$$\hat{X}_{ij} \geq Z_{ij}, i = 1, \ldots, n; j = 1, \ldots, m \quad (5)$$
$$W_j \leq \widetilde{W}_{ij}^l + (1 - Z_{ij}), i = 1, \ldots, n; j = 1, \ldots, m; l = 1, \ldots, k \quad (6)$$
$$L_j \leq \tilde{L}_{ij}^l + (1 - Z_{ij}), i = 1, \ldots, n; j = 1, \ldots, m; l = 1, \ldots, k \quad (7)$$
$$\hat{X}_{ij} \geq X_j - (1 - Z_{ij}), i = 1, \ldots, n; j = 1, \ldots, m \quad (8)$$
$$\hat{X}_{ij} \leq X_j, i = 1, \ldots, n; j = 1, \ldots, m \quad (9)$$
$$\hat{X}_{ij} \geq 0, i = 1, \ldots, n; j = 1, \ldots, m \quad (10)$$
$$L_j \geq 0, j = 1, \ldots, m \quad (11)$$
$$W_j \geq 0, j = 1, \ldots, m \quad (12)$$
$$Z_{ij} = \begin{cases} 1, & i \text{ is admitted to class } j \\ 0, & otherwise \end{cases} \quad (13)$$

Model 1 for Modified Problem with β_j Fixed:
Parameters for model 1 modified with β_j fixed
C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.
α_j : Base price of a network service *j*, since the internet cannot guarantee its level of service quality so α could be equivalent to price of best effort service in current internet architecture.
$\tilde{L}_{ij}^l$: Minimum bandwidth for user *i* in class *j* on link *l*.
$\widetilde{W}_{ij}^l$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.
β_j : Quality premium of service class *j* that has I_j service performance.

Variables
$\tilde{X}_{ij}^l$: Bandwidth obtained by user *i* in class *j* on link *l*.
$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.
$Z_{ij} = \begin{cases} 1, & i \text{ is admitted to class } j \\ 0, & otherwise \end{cases}$
W_j : Price sensitivity for class *j*.
L_j : Bandwidth for class *j*.
X_j : Bandwidth assigned to each individual user in class *j*.
I_j : Quality index of class *j*.

Then we have mathematical model of model 1 modified with β_j fixed

$$\max \sum_{j=1}^{m} \sum_{i=1}^{n} ((\alpha_j Z_{ij} + \beta_j I_j) + W_j \log \frac{\hat{X}_{ij}}{L_j}) \quad (14)$$

Subject to
Constraint (2)-(13) and additional constraint as follows.

$$0 \le I_j \le d,\ d \in [0, 1]. \quad (15)$$

Model 1 for Modified Problem with β_j Variable:

Parameters for model 1 modified with β_j variable

C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.

α_j : Base price of a network service *j*, since the internet cannot guarantee its level of service quality so α could be equivalent to price of best effort service in current internet architecture.

$\tilde{L}_{ij}^{l}$: Minimum bandwidth for user *i* in class *j* on link *l*.

$\tilde{W}_{ij}^{l}$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.

Variables:

$\tilde{X}_{ij}^{l}$: Bandwidth obtained by user *i* in class *j* on link *l*.

$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.

$Z_{ij} = \begin{cases} 1, & i \text{ is admitted to class } j \\ 0, & otherwise \end{cases}$

W_j : Price sensitivity for class *j*.

L_j : Bandwidth for class *j*.

X_j : Bandwidth assigned to each individual user in class *j*.

I_j : Quality index of class *j*.

β_j : Premium quality of class *j*.

Next, we also have optimization problem of internet charging when we have β_j as variable:

Max Objective function (14)
Subject to
Constraints (2)-(13), (15) and additional constraints as follows.

$$\alpha_j + \beta_j I_j \ge \alpha_{j-1} + \beta_{j-1} I_{j-1}, j > 1 \quad (16)$$

$$\beta_j \le \beta_{j-1}, j > 1 \quad (17)$$

$$f \le \beta_j \le g,\ f, g \in [0, 1]. \quad (18)$$

Model 2 Original Problem:

Parameters for model 2 original problem:

C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.

$\tilde{L}_{ij}^{l}$: Minimum bandwidth for user *i* in class *j* on link *l*.

$\tilde{W}_{ij}^{l}$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.

Variables

$\tilde{X}_{ij}^{l}$: Bandwidth obtained by user *i* in class *j* on link *l*.

$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.

$Z_{ij} = \begin{cases} 1, & i \text{ is admitted to class } j \\ 0, & otherwise \end{cases}$

W_j : Price sensitivity for class *j*.

L_j : Bandwidth for class *j*.

X_j : Bandwidth assigned to each individual user in class *j*.

Mathematical formulation for model 2 original is as follows.

$$max \sum_{j=1}^{m} \sum_{i=1}^{n} (\alpha_j + W_j \log \frac{\hat{X}_{ij}}{L_j}) Z_{ij} \quad (19)$$

Subject to
Constraint (2)-(13) and additional constraints as follows.

$$\alpha_j \ge \alpha_{j-1}, j > 1 \quad (20)$$

$a \le \alpha_j \le b$, a, b $\in$[0, 1]. (21)

Model 2 for Modified Problem with β_j Fixed:
Parameters for model 2 modified problem:
C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.
$\tilde{L}_{ij}^{l}$: Minimum bandwidth for user *i* in class *j* on link *l*.
$\widetilde{W}_{ij}^{l}$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.
β_j : Quality premium of service class *j* that has I_j service performance.

Variables:
$\tilde{X}_{ij}^{l}$: Bandwidth obtained by user *i* in class *j* on link *l*.
$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.
$Z_{ij} = \begin{cases} 1, & i\ is\ admitted\ to\ class\ j \\ 0, & otherwise \end{cases}$
W_j : Price sensitivity for class *j*.
L_j : Bandwidth for class *j*.
X_j : Bandwidth assigned to each individual user in class *j*.
I_j : Quality index of class *j*.

Mathematical formulation for model 2 modified 1 is as follows.
$$max \sum_{j=1}^{m} \sum_{i=1}^{n} ((\alpha_j + \beta_j I_j) + W_j log \frac{\hat{X}_{ij}}{L_j}) Z_{ij} \quad (22)$$
Subject to
Constraint (2)-(13), (20)-(21).

Model 2 for Modified Problem with β_j Variable:
Parameters for model 2 modified 2 are as follows.
C_l : Bandwidth capacity of link *l* that represents the set of links that flow *i* of class *j* crosses in the network.
$\tilde{L}_{ij}^{l}$: Minimum bandwidth for user *i* in class *j* on link *l*.
$\widetilde{W}_{ij}^{l}$: Price sensitivity for user *i* that shows the satisfaction of the user *i* by receiving the bandwidth in class *j* on link *l*.

Variables for model 2 modified 2 are shown below.
$\tilde{X}_{ij}^{l}$: Bandwidth obtained by user *i* in class *j* on link *l*.
$\hat{X}_{ij}$: Final bandwidth obtained by user *i* in class *j*.
$Z_{ij} = \begin{cases} 1, & i\ is\ admitted\ to\ class\ j \\ 0, & otherwise \end{cases}$
W_j : Price sensitivity for class *j*.
L_j : Bandwidth obtained by user *i* in class *j*.
X_j : Bandwidth assigned to each individual user in class *j*.
I_j : Quality index of class *j*.
β_j : Premium quality of class *j*.

Mathematical Formulation for model 2 modified 2 is as follows.
Max objective function (2)
Subject to
Constraint (2)-(13), (15)-(18), (20)-(21).

In objective function (1), ISP wants to maximize its profit by maximizing the total sum of base price for bps of *j*th class and utility function as a function of bandwidth diminishes with increasing bandwidth which shows the user satisfaction when receiving a bandwidth $\hat{X}_{ij}$. Since the base pice is already set up by ISP then we have fixed α_j. In objective function (14), ISP wants to maximize its profit by maximizing the total sum of base price for bps of *j*th class and utility function as a function of bandwidth diminishes with increasing bandwidth which shows the user satisfaction when receiving a bandwidth $\hat{X}_{ij}$. Since the base price is already set up by ISP at least to make ISP is at no loss, then ISP have fixed α_j but ISP has choices to fix quality premium β_j or to make β_j as a variable. Objective function (19) tells us that ISP wants to maximize its profit by maximizing the total sum of varying base price for bps of *j*th class and utility function as a function of bandwidth diminishes with increasing bandwidth which shows the user satisfaction when receiving a bandwidth $\hat{X}_{ij}$. ISP will vary the base price α_j to see whether in certain class ISP is able to have market competition and ISP has choices to fix quality premium β_j with the purposes to enable users to choose the class based on their budget or to make β_j as a variable with the objective to promote certain services in the network.

Constraint (2) explains that total bandwidth obtained by user *i* in each link cannot exceed the bandwidth available in each link. Constraint (3) tell us that bandwidth obtained by user *i* in class *j* on link *l* must equal to final bandwidth obtained by user *i* in class *j*. Constraint (4) shows us that final bandwidth obtained by user *i* in class *j* must exceed the minimum bandwidth for user *i* in class *j* on link *l*, if user *i* is admitted to class *j*. Final bandwidth obtained by user *i* in class *j* should exceed 1 if user *i* is admitted to class *j* and 0, otherwise, like stated in Constraint (5). Constraint (6) states that price sensitivity for class *j* cannot exceed price sensitivity for user *i* in class *j* on link *l*, if user *i* is admitted to class *j*. Minimum bandwidth for class *j* should exceed the minimum bandwidth for user *i* in class *j* on link *l*, like stated in Constraint (7). Constraint (8) tells us that final bandwidth obtained by user *i* in class *j* should exceed bandwidth assigned to each individual user in class *j*, if user *i* is admitted to class *j*. Constraint (9) informs us that final bandwidth obtained by user *i* in class *j* cannot exceed bandwidth assigned to each individual user in class *j*. Constraint (10), (11) and (12) are nonnegativity constraints where final bandwidth obtained by user *i* in class *j*, minimum bandwidth for class *j* and price sensitivity for class *j* should be nonnegative value. Constraint (13) states that admission decision for user *i* in class *j*, if 0 than it means that user *i* is admitted to class *j*, or else 0. Constraint (15) shows that the range of index quality should be [0, *d*], d $\in$[0, 1] and this range is set up by ISP. Constraint (16) shows that summation of base price and quality premium in class *j* should exceed the summation of base price and quality premium in previous class (or in *j*-1). Constraint (17) shows that quality premium in class *j* should not exceed the quality premium in previous class. Constraint (18) shows that the range of quality premium lies in [*f*, *g*] $\in$[0, 1] and both are predetermined value set up by ISP. Constraint (20) shows that base price for class *j* should exceed base price for previous class. Constraint (21) shows that range of base price lies between [*a*, *b*] $\in$[0, 1] where *a* and *b* are predetermined value set up by ISP. Below is Table 1-4 that show the solution results of Model 1 and Model 2 using LINGO 13.0.

Table 1: Solver Status of Model 1.

Solver status	Original	Modified 1	Modified 2
Model Class	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal
Infeasibility	0	0	0
Extended Solver state			
Solver type	B & B	B & B	B & B
Active	0	0	0
Update interval	2	2	2
GMU(K)	34	36	37
ER(sec)	0	0	0
Best Objective	46.55	46.6	46.67
Objective bound	46.55	46.6	46.67
ESS	0	0	0
TSI	30	30	32

Examining the Solution Report of Model 1 and Model 2 by LINGO 13.0:

Table 1 shows the solver status of model 1. Model class for each model is Mixed Integer Nonlinear Programming (MINLP), with status of current solutions are all local optimal. Infeasibility shows us the amount constraints are violated and it is 0 for each model. Solver type is Branch and Bound solver and active field lists that 2 of subproblems remaining to be evaluated for each model. The solver must run until that number goes to 0. Generated Memory Used (GMU) shows us the amount of LINGO's model generator is currently using from its memory allocation. The highest amount for memory allocation is in Model 1 modified 2 which is 37K. Elapsed Runtime (ER) explains about total time used to generate and solve the model and maybe affected by the number of other applications running in our system. For our models, we need 0 sec time to generate and solve those models. Best objective shows us the objective value of the best solution in each model which is Model 1 modified 2 that obtain highest value of 46.67. The theoretical bound on the objective is also the same value like best objective for each model. Extended Solver Steps (ESS) depends on the certain solver that is running. Since all models have solver type Branch and Bound so ESS=0 show us that there are 0 of branches in the branch and bound tree. Lastly, Total solver iterations show the number of solver iterations for each model. In Model 1 Original there are 30 iterations to solve the model.

Table 2: Solver Status of Model 2.

Solver status	Original	Modified 1	Modified 2
Model Class	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal
Infeasibility	0	0	0.5×10^{-16}
Extended Solver state			
Solver type	B & B	B & B	B & B
Active	0	0	0
Update interval	2	2	2
GMU(K)	35	37	37
ER(sec)	0	0	0
Best Objective	0.9	0.93	0.97
Objective bound	0.9	0.93	0.97
ESS	0	0	0
TSI	5	5	5

Table 3: Results for Model 1 formulation with *i*=2, *j*=2, *l*=2.

	Original	Modified 1	Modified 2
α_1	0.2 fixed	0.2 fixed	0.2 fixed
Z_{11}	1	1	1
W_1	8	8	8
$\hat{X}_{11}$	22.2	22.2	22.2
L_1	7	7	7
Z_{21}	0	0	0
$\hat{X}_{21}$	22.2	22.2	22.2
α_2	0.3 fixed	0.3 fixed	0.3 fixed
Z_{12}	0	0	0
W_2	10	10	10
$\hat{X}_{12}$	27.8	27.8	27.8
L_2	7	7	7
Z_{22}	1	1	1
$\hat{X}_{22}$	27.8	27.8	27.8
$\tilde{X}_{11}^{1}$	22.2	22.2	22.2
$\tilde{X}_{21}^{1}$	22.2	22.2	22.2
$\tilde{X}_{12}^{1}$	27.8	27.8	27.8
$\tilde{X}_{22}^{1}$	27.8	27.8	27.8
$\tilde{X}_{11}^{2}$	22.2	22.2	22.2
$\tilde{X}_{21}^{2}$	22.2	22.2	22.2
$\tilde{X}_{12}^{2}$	27.8	27.8	27.8
$\tilde{X}_{22}^{2}$	27.8	27.8	27.8
X_1	22.2	22.2	22.2
X_2	27.8	27.8	27.8
β_1	-	0.01 fixed	0.04
β_2	-	0.02 fixed	0.03
I_1	-	0.9	0.9
I_2	-	0.8	0.8

Table 2 shows the solver status of Model 2. Model class for each model is Mixed Integer Nonlinear Programming (MINLP), with status of current solutions are all local optimal. Infeasibility is 0 for each model. Solver type is Branch and Bound solver and active field lists that 2 of subproblems remaining to be evaluated for each model until that number go to 0. Highest GMU for memory allocation is in Model 2 modified 1 and Model 2 modified 2 which is 37K. ER for each model is 0 sec time to generate and solve those models. Best objective is Model 2 modified 2 that obtain highest value of 0.97. The theoretical bound on the objective is also the same value like best objective for each model. ESS=0 shows us that there is 0 of branches in the branch and bound tree. Lastly, for total solver iterations in Model 2 original, there are 5 iterations in solving the model.

If we further examine the result of Model 1 and Model 2, we also obtain the reduced cost, slack/surplus and dual price for every solution of models. The reduced cost for instance, in solution report of LINGO Model 1 shows the amount of penalty we would have to pay to introduce one unit of that variable into the solution. If reduced cost of -0.2 like in row 2 of Model 1 Original, Model 1 modified 1 and Model 1 modified 2, a penalty of -0.2 of units to introduce the variable into the solution. Or it can be said that the objective value would fall by -0.2 units in maximization model. Slack of 17.2 in row 14 in Model 1 Original, Model 1 modified 1 and Model 1 modified 2 shows that this row is 17.2 units from being satisfied as equality. Lastly, dual price of 0.36 in row 2 in Model 1 Original, Model 1 modified 1, Model 1 modified 2 means adding one more unit of 0.36 would cause objective function to improve by 0.36 to a value of 46.91. In Model 2, the reduced cost in row 7 is -0.3 shows that amount penalty of -0.3 of units to introduce the variable into the solution. Slack of 74 in row 2 in Model 2 original, Model 2 modified 1, Model 2 modified 2 explains that this row is 74 units from being satisfied as equality. Dual price of -0.3 in row 34 in Model 2 original, Model 2 modified 1 and Model 2 modified 2 means that adding one more unit of -0.3 would cause objective function to improve by -0.3 to a value of 0.96.

Table 4: Results for Model 2 formulation with *i*=2, *j*=2, *l*=2.

	Original	Modified 1	Modified 2
α_1	0.3	0.3	0.29
Z_{11}	1	1	1
W_1	0	0	0
$\hat{X}_{11}$	6	6	6
L_1	6	6	6
Z_{21}	1	1	1
$\hat{X}_{21}$	6	6	6
α_2	0.3	0.3	0.3
Z_{12}	0	0	0
W_2	0	0	0
$\hat{X}_{12}$	7	7	7
L_2	7	7	7
Z_{22}	1	1	1
$\hat{X}_{22}$	7	7	7
$\tilde{X}_{11}^1$	6	6	6
$\tilde{X}_{21}^1$	6	6	6
$\tilde{X}_{12}^1$	7	7	7
$\tilde{X}_{22}^1$	7	7	7
$\tilde{X}_{11}^2$	6	6	6
$\tilde{X}_{21}^2$	6	6	6
$\tilde{X}_{12}^2$	7	7	7
$\tilde{X}_{22}^2$	7	7	7
X_1	6	6	6
X_2	7	7	7
β_1	-	0.01	0.04
β_2	-	0.02	0.03
I_1	-	0.9	0.9
I_2	-	0.8	0.8

For Model 1:

Table 2 shows us that for 3 cases of model 1, only user 1 and user 2 is admitted to class 1 and class 2, respectively. Bandwidth obtained by user 1 in class 1 on link 1 and on link 2 ($\tilde{X}_{11}^1$ and $\tilde{X}_{11}^2$) is 22.2 bps. Since user 1 is admitted to class 1, then price sensitivity for class 1 equals to price sensitivity for user 1 in class 1 on link 1 and user 1 in class 1 on link 2 which is W_1=$\widetilde{W}_{11}^1$=$\widetilde{W}_{11}^2$=8. Also, user 2 is admitted to class 2 since the price sensitivity of class 2 equals to price sensitivity user 2 in class 2 on link 1 and user 2 in class 2 on link 2 which is W_2=$\widetilde{W}_{22}^1$=$\widetilde{W}_{22}^2$ = 10 with $\tilde{X}_{22}^1$ = $\tilde{X}_{22}^2$=27.8 bps. Final bandwidth obtained by user 1 in class 1 ($\hat{X}_{11}$) and user 2 in class 2 ($\hat{X}_{22}$) are 22.2 bps and 27.8 bps, respectively. Minimum bandwidth for class 1 and class 2 (L_1 and L_2) are 7 bps. Lastly, bandwidth assigned to each individual user in class 1(X_1) is 22.2 bps and in class 2(X_2) is 27.8 bps. So, X_1=$\tilde{X}_{11}^1$ = $\tilde{X}_{11}^2$=22.2 bps and X_2= $\tilde{X}_{22}^1$ = $\tilde{X}_{22}^2$=27.8 bps.

In model 1 modified 1, we also obtain the quality index of each class which is I_1=0.9, and I_2=0.8. We also obtain same quality index result for model 1 modified 2 with added results of quality premium in class 1 (β_1) of $0.04 and in class 2 ($\beta_2$) of $0.03.

From the models we can see that model 1 modified 2 yields slightly better results of $46.67. So if ISP apply the option to recover cost (by fixing α) and also to promote certain service in the networks (by varying β), ISP will gain more profit.

For Model 2:

The results in Table 4 explain us that for 3 cases of model 2, user 1 and user 2 are admitted in class 1, user 2 are admitted to class 2 with bandwidth obtained by user 1 in class 1 on link 1 ($\tilde{X}_{11}^1$ and $\tilde{X}_{11}^2$) is 6 bps, $\tilde{X}_{21}^1$= $\tilde{X}_{21}^2$=6 bps and $\tilde{X}_{22}^1$ =$\tilde{X}_{22}^2$ = 7 bps. So we see that, the bandwidth assigned to each individual user in class 1 equals to final bandwidth obtained by user 1 and user 2 in class 1 and equals to bandwidth obtained by user 1 and 2 in class 1 on link 1 and 2 or $X_1 = \hat{X}_{11} = \hat{X}_{21} = \tilde{X}_{11}^1 = \tilde{X}_{11}^2 = \tilde{X}_{21}^1 = \tilde{X}_{21}^2 = 6$ bps and $X_2 = \hat{X}_{22} = \tilde{X}_{22}^1 = \tilde{X}_{22}^2 = 7\ bps$. Minimum bandwidth for Class 1 and class 2 (L_1 and L_2) are 6 bps and 7 bps respectively. Next, the price sensitivity for class 1 and class 2 (W_1 and W_2) are 0. Since ISP would choose to be able to compete in market competition, ISP varies the base price in class 1 and class 2 of $0.3/bps for all models 2.

In model 2 modified 1 and model 2 modified 2, we also obtain quality index that show QoS level I_1=0.9 and I_2 = 0.8. In addition, we also obtain premium quality in class 1 and class 2 (β_1 and β_2) of $0.04 and $0.03, respectively.

From the models, we observe that model 2 modified 2 yield slightly better results of \$0.97. So, if ISP would like to have market competition (by varying α) and also to promote certain service in the networks (by varying β), ISP are able to gain more profit.

Conclusion:

The model represented shows the connection between bandwidth required, bandwidth obtained and QoS level by giving the assumptions and data; we can find the optimal solution with profit maximization. ISP has choices to whether adopt modified model 1 or modified model 2 according their priorities. If ISP chooses to recover cost while promoting certain services then model 1 modified 1 will be the best model to adopt. Again, if ISP would like to have market competition when there is a chance to do that while promoting certain services then model 2 modified 2 will be good model to apply. Overall, our proposed models show slightly better result than previous research model.

Further research should address issue with more generalization of users and classes applying the each model. So we can give more realistic network situation.

ACKNOWLEDGMENT

The research leading to this paper was financially supported by Ministry of Higher Education Malaysia for support through Fundamental Research Grant Scheme 2011, Research Code: USIM/FRGS-FST-5-50811.

REFERENCES

Ali, N.B., M. Molnár and A. Belghith, 2008. Multi-constrained QoS Multicast Routing Optimization. Institut De Recherche En Informatique Et Systèmes Aléatoires, Rennes Cedex, N° RR-6500.

Altmann, J. and K. Chu, 2001. How to charge for network service-Flat-rate or usage-based? Special Issue on Networks and Economics, Computer Networks, 36: 519-531.

Byun, J. and S. Chatterjee, 2004. A strategic pricing for quality of service (QoS) network business. In Proceedings of the Tenth Americas Conference on Information Systems, pp: 2561-2572.

Fulp, E.W. and D.S. Reeves, 2002. The Economic Impact of Network Pricing Intervals. In Proceedings of the Workshop Advanced Internet Charging and QoS Technology (ICQT).

Henderson, T., J. Crowcroft and S. Bhatti, 2001. Congestion pricing paying your way in communication networks. IEEE Internet Computing, 5: 85-89.

Jacobson, V., 1988. Congestion Avoidance and Control. Proc. ACM SIGCOMM'88 Symp, Stanford, CA, 18.

LINGO 13.0.2.14, 2011. LINDO SYSTEMS Inc.Chicago, IL, 60642 USA.

Karp, R., 2005. Graph Theory, Combinatorics and Algorithms Interdisciplinary Applications. In Optimization Problems Related to Internet Congestion Control, pp: 1-16.

Kelly, F.P., A.K. Maulloo and D.K.H. Tan, 1998. Rate control for communication networks: shadow prices, proportional fairness and stability. Journal of Operations Research Society, 49: 237-252.

MacKie-Mason, J.K., L. Murphy and J. Murphy, 1996. The Role of responsive pricing in the internet. In Internet Economics, pp: 279-304.

Odlyzko, A., 1998. Paris Metro Pricing for the Internet. In Proceedings of 1st ACM Conference on Electronic Commerce, pp: 140-147.

Puspita, F.M., K. Seman and B. Sanugi, 2011a. Internet Charging Scheme Under Multiple QoS Networks. In The International Conference on Numerical Analysis & Optimization (ICeMATH 2011) 6-8 June 2011.

Puspita, F.M., K. Seman and B.M. Taib, 2011b. A Comparison of Optimization of Charging Scheme in Multiple QoS Networks. In 1st AKEPT Young Reseachers Conference and Exhibition (AYRC X3 2011) Beyond 2020: Today's Young Reseacher Tomorrow's Leader 19-20 DECEMBER 2011, pp: 704-711.

Puspita, F.M., K. Seman, B.M. Taib and Z. Shafii, 2012a. An improved optimization model of internet charging scheme in multi service networks. TELKOMNIKA, 10(3): 592-598.

Puspita, F.M., K. Seman, B.M. Taib and Z. Shafii, 2012b. A new approach of optimization model on internet charging scheme in multi service networks. International Journal of Science and Technology, 2(6): 391-394.

Ros, D. and B. Tuffin, 2004. A mathematical model of the paris metro pricing scheme for charging packet networks. The International Journal of Computer and Telecommunications Networking - Special issue: Internet economics: Pricing and policies, 46.

Sain, S. and S. Herpers, 2003. Profit Maximisation in Multi Service Networks- An Optimisation Model, Proceedings of the 11th European Conference on Information Systems. In 11th European Conference on Information Systems, ECIS 2003.

Tuffin, B., 2003. Charging the internet without bandwidth reservation: An overview and bibliography of mathematical approaches. Journal of Information Science and Engineering, 19: 765-786.

Yang, W., 2004. Pricing Network Resources in Differentiated Service Networks. In School of electrical and Computer Engineering, pp: 1-111.

Yang, W., H. Owen and D.M. Blough, 2004. A Comparison of Auction and Flat Pricing for Differentiated Service Networks. In Proceedings of the IEEE International Conference on Communications, pp: 2086-2091.

Yang, W., H.L. Owen, D.M. Blough and Y. Guan, 2003. An Auction Pricing Strategy for Differentiated Service Network. In Proceedings of the IEEE Global Telecommunications Conference, pp: 4148-4152.

Yang, W., H.L. Owen and D.M. Blough, 2005. Determining Differentiated Services Network Pricing Through Auctions. In Networking-ICN 2005, 4th International Conference on Networking April 2005 Proceedings, Part I.

Yuksel, M., S. Kalyanaraman and B. Sikdar, 2002. Effect of pricing intervals on the congestion-sensitivity network service. Telecommunication Systems, 28(1): 79-99.