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Improved Models of Internet Charging Scheme of Single Bottleneck Link in Multi QoS Networks

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Abstract: Internet Service Providers (ISPs) nowadays deal with high demand to promote good quality information. However, the knowledge to develop new pricing scheme that serve both customers and supplier is known, but only a few pricing plans involve QoS networks. This study will seek new proposed pricing plans are offered with QoS networks involved. The single link multi QoS Networks scheme is solved as an optimization model by comparing two models in multi QoS networks. The decisions whether to set up base price to be fixed to recover the cost or to be varied to compete in the market are considered. Also, the options of 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 are set up.

Key words: Charging scheme, multi QoS networks, profit maximization, single bottleneck link, recover cost, market competition

INTRODUCTION

Past researches mainly showed the extra pricing occurs when there exists congestion that causes degradation of QoS. Three stages proposed by MacKie-Mason *et al.* (1996) consisted of no use of feedback and user adaptation, use of feedback of closed-loop and one kind of variation of closed loop forms.

Also, scheme named congestion avoidance was also proposed by Jacobson (1988) and scheme of smart market (Kelly *et al.*, 1998; Henderson *et al.*, 2001). Karp (2005) then discussed problem of congestion. Problem occurring when sending packet in a flow can be dropped if there exists congested flow. In order to reach destination, the packet should be transmitted again in other rate. But it is obvious that how much for the retransmission rate. 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 like suggested by Fulp and Reeves (2002) and Yuksel *et al.* (2005).

Odlyzko (1999) and Tuffin (2003) 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. Their strategy basically attempted to optimize the profits not just increasing the profits but rather more on controlling the congestion to gain maximum profit. They proposed scheme by using partition to show different class has different services. The drawback is still due to unknown idea whether this scheme is applicable for current network or not. 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 QoS specification and compute optimal routes are needed to a multi-constrained problem, by using greedy algorithm such as meta-heuristics algorithm (Ali *et al.*, 2008).

Recent works on pricing scheme of QoS networks is due to Yang (2004), Yang *et al.* (2004, 2005). They described the pricing scheme based auction to allocate QoS and maximize ISP's revenue. The auction pricing scheme is actually scalability, efficiency and fairness in sharing resources. The solution of the

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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. 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, it is attempted to improve and modify their mathematical formulation and combine it with mathematical formulation discussed by Byun and Chatterjee (2004) and Puspita *et al.* (2011a, b).

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, b) discussed the new approach and new improved model of Sain and Herpers (2003), 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 proposed by Byun and Chatterjee (2004), it only applies simple network involving one single route from source to destination.

So, small scale contribution is created by improving the mathematical formulation of Byun and Chatterjee (2004), 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. The problem of internet charging scheme is considered as Mixed Integer Nonlinear Programming (MINLP) to obtain optimal solution by using Lingo 13.0 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 vary the quality premium parameters and see what decision can be made by ISP by choosing this parameter.

RESEARCH METHOD

Optimization techniques are applied in solving the problem in this study. Like in Sain and Herpers (2003), this study also consider the optimization problem as MINLP that can be solved by using optimization tools, LINGO 13.0. The problem of pricing the internet in multi service networks is transformed into optimization model and is solved to get optimal solution. This solution will help to interpret the current issues involving pricing, network share, base price, quality premium and also QoS level. Figure 1 shows the model that is described in next section.

RESULTS AND DISCUSSION

Mathematical formulations: The idea basically generates from Byun and Chatterjee (2004), Yang *et al.* (2004), Yang (2004) and Yang *et al.* (2005) for single QoS network (Puspita *et al.*, 2011a, b).

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 Yang (2004) pointed out, there are 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 revenue subject to constraints based on system' available resources.

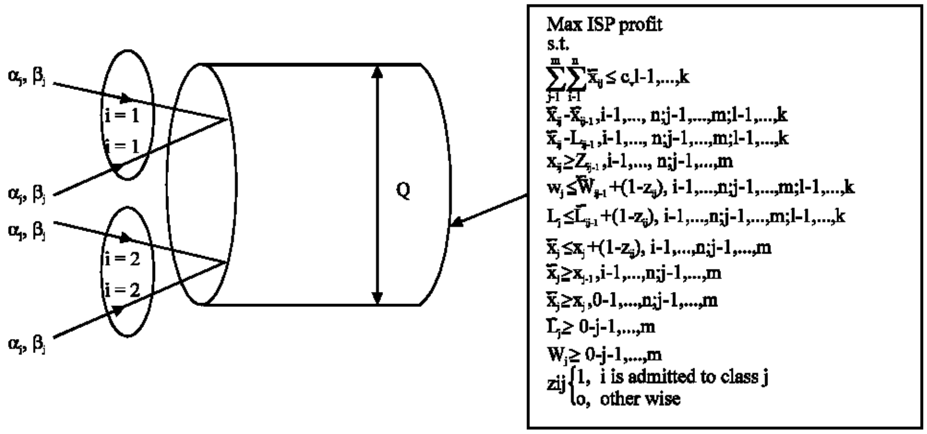

Fig. 1: Research Model Proposed in single link Multi QoS Networks

Model 1 original:

α_j = Base price for class j
Q = Total bandwidth
V_i = Minimum bandwidth required by user i
Decision variables are as follows:

$$z_{ij} = \begin{cases} 1, \text{if user i is admitted to} \\ 0, \quad \text{otherwise} \end{cases}$$

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j
L_{mj} = Minimum bandwidth for class j
W_j = Price sensitivity for class j
Xj = Bandwidth assigned to each individual user in class j
$\tilde{w}_{ij}$ = Price sensitivity for user i in class j

Model 1 original will be:

$$\text{Max profit} = \sum_j \sum_i \left(a_j.Z_{ij}\right) + w_j \log \frac{\tilde{X}_{ij}}{L_{mj}} \tag{1}$$

Subject to:

$$\left(\sum_j \sum_i X_{ij}\right) \leq Q \tag{2}$$

$$\tilde{X}_{ij} \geq L_{mj} - \left(1 - Z_{ij}\right), i=1,\ldots,n; j=1,\ldots m \tag{3}$$

$$W_j \leq \tilde{W}_{ij} + \left(1 - Z_{ij}\right), i=1,\ldots,n; j=1,\ldots m \tag{4}$$

$$\tilde{X}_{ij} \geq V_i - \left(1 - Z_{ij}\right), i=1,\ldots,n; j=1,\ldots m \tag{5}$$

$$\tilde{X}_{ij} \geq X_j - \left(1 - Z_{ij}\right), i=1,\ldots,n; j=1,\ldots m \tag{6}$$

$$\tilde{X}_{ij} \geq Z_{ij}, i=1,\ldots,n; j=1,\ldots m \tag{7}$$

$$\tilde{X}_{ij} \geq 0, i=1,\ldots,n; j=1,\ldots m \tag{8}$$

$$L_{mj} \geq 0, j=1,\ldots m \tag{9}$$

$$W_j \geq 0, j=1,\ldots m \tag{10}$$

$$\tilde{X}_{ij} \leq X_j, i=1,n; j=1,\ldots m \tag{11}$$

$$Z_{ij} = \begin{cases} 1, \text{if user i is admitted to class j} \\ 0, \quad \text{otherwise} \end{cases} \tag{12}$$

$$0 \leq \tilde{W}_{ij} \leq c, i=1,\ldots,n; j=1,\ldots m, c \in [0,1] \tag{13}$$

where, c is predetermined value of upper bound price sensitivity for user i at class j, respectively.

Model 1 modified: The parameters are as follows:

α_j = Base price for class j
Q = Total bandwidth
V_i = Minimum bandwidth required by user i
β_j = Quality premium of class j that has I_j service performance
Decision variables are as follows:

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

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j
L_{mj} = Minimum bandwidth for class j
W_j = Price sensitivity for class j
X_i = Bandwidth assigned to each individual user in class j
$\tilde{w}_{ij}$ = Price sensitivity for user i in class j
I_j = Quality index of class j

Model 1 modified 1 is as follow:

$$\text{Max profit} = \sum_j \sum_i \left(\left(a_j.Z_{ij} + \beta_j.I_j\right) + w_j \log \frac{\tilde{X}_{ij}}{L_{mj}} \right) \tag{14}$$

Subject to:
Eq. 2-13 and additional constraints as follow:

$$\alpha_j + \beta_j.I_j \geq \alpha_{j-1} + \beta_{j-1}.I_{j-1}, j > 1 \tag{15}$$

$$0 \leq I_j \leq d, j=1,\ldots m, d \in [0,1] \tag{16}$$

Model 1 modified 2: The parameters are as follows:

α_j = Base price for class j
Q = Total bandwidth
V_i = Minimum bandwidth required by user i
Decision variables are as follows:

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

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j
L_{mj} = Minimum bandwidth for class j
W_j = Price sensitivity for class j
X_i = Bandwidth assigned to each individual user in class j
$\tilde{w}_{ij}$ = Price sensitivity for user i in class j
I_j = Quality index of class j
β_j = Quality premium of class j that has I_j service performance

Model 1 modified 2 as follow:

Subject to Eq. 2-13, Eq. 15-16 and additional constraints as follow:

$$\beta_j \le \beta_{j-1}, j > 1 \tag{17}$$

$$f \le \beta_j \le g, j=1,...m, [f,g] \in [0,1] \tag{18}$$

Model 2 original: The parameters are as follows:

Q = Total bandwidth

V_i = Minimum bandwidth required by user i

Decision variables are as follows:

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

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j

L_{mj} = Minimum bandwidth for class j

W_j = Price sensitivity for class j

X_i = Bandwidth assigned to each individual user in class j

$\tilde{w}_{ij}$ = Price sensitivity for user i in class j

I_j = Base price for class j

Next, Model 2 original is below:

$$\text{Max profit} = \sum_j \sum_i \left(a_j + w_j \log \frac{\tilde{X}_{ij}}{L_{mj}} \right) Z_{ij} \tag{19}$$

Subject to Eq. 2-13 and additional constraints as follow:

$$\alpha_j \le \alpha_j \le b, j=1,...m, [a,b] \in [0,1] \tag{20}$$

$$\alpha_j \le \alpha_{j-1}, j > 1 \tag{21}$$

where, a and b are predetermined value of lower bound and upper bound base price respectively.

Model 2 modified 1: The parameters as follows:

Q = Total bandwidth

V_i = Minimum bandwidth required by user i

β_j = Quality premium of class j that has I_j service performance

Decision variables are as follows:

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

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j

L_{mj} = Minimum bandwidth for class j

W_j = Price sensitivity for class j

X_i = Bandwidth assigned to each individual user in class j

$\tilde{w}_{ij}$ = Price sensitivity for user i in class j

a_j = Base price for class j

I_j = Quality index of class j

Model 2 modified 1 is:

$$\text{Max profit} = \sum_j \sum_i \left(\left(a_j + \beta_j . I_j \right) + w_j \log \frac{\tilde{X}_{ij}}{L_{mj}} \right) Z_{ij} \tag{22}$$

Subject to 2-13, 15-16 and Eq. 20-21.

Model 2 modified 2: The parameters as follows:

Q = Total bandwidth

V_i = Minimum bandwidth required by user i

Decision variables are as follows:

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

$\tilde{x}_{ij}$ = Final bandwidth obtained by user i for class j

L_{mj} = Minimum bandwidth for class j

W_j = Price sensitivity for class j

X_i = Bandwidth assigned to each individual user in class j

$\tilde{w}_{ij}$ = Price sensitivity for user i in class j

α_j = Base price for class j

I_j = Quality index of class j

β_j = Quality premium of class j that has I_j service performance

So, model 2 modified 2 is as follow:

- Max objective function (22)
- Subject to 2-13, 15-18 and Eq. 20-21

Next, the model descriptions are described. Objective function (1) basically states that ISP wants to maximize its profit by maximizing its utility function with base price α_j to be fixed to recover cost. Equation 2 tells that total final bandwidth of all users cannot exceed the total bandwidth available. Equation 3 states that bandwidth obtained by user i should exceed minimum bandwidth for class j if user i is admitted to class j or otherwise. Equation 4 tells about price sensitivity for class j should be less than the price sensitivity for user i in class j if user i is admitted to class j. Equation 5 gives the information about bandwidth obtained by client i for class j should exceed minimum bandwidth required by user i if user i is admitted to class j. Equation 6 tells that 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. Equation 7 shows that bandwidth obtained by user i in class j should be greater than the availability of user i in class j and should be nonnegative (8). Nonnegativity requirement occurs in price sensitivity (10) and minimum bandwidth for class j in (9). Equation 11 shows that bandwidth obtained by user i in class j should not exceed bandwidth assigned to each individual user in class j. Equation 12 tells the value of whether the user i is admitted to class j or not. Equation 13 states the price sensitivity of user i in class j lies between range of 0 and predetermined value (c) of price sensitivity for user i.

Objective function (14) basically states that ISP wants to maximize its profit by maximizing its utility function with base price α_j to be fixed to recover cost and quality premium also to be fixed to enable user to choose the class based on their budget and preferences with chosen QoS level. Equation 15 shows that the summation of price and quality premium to yield perfect service for j class should exceed the one in (j-1) class with j>1. Equation (16) shows that the range of index quality should lie between 0 and 1 with predetermined d value set up by ISP. Equation 17 shows that quality premium in class j should not exceed the quality premium in previous class. Eq.(18) shows that the range of quality premium lies in [f,g] with $f \geq 0, g \geq 0$ and both are predetermined value set up by ISP.

Objective function (19) basically states that ISP wants to maximize its profit by maximizing its utility function with base price α_j to be variable to enable ISP to have market competition if there are chances. Equation 20 tells us the range of base price (a and b) is lower bound and upper bound of predetermined base price, respectively. Equaiton 21 shows that base price for j class is more than base price or j-1 class with j>1.

Objective function (22) basically states that ISP wants to maximize its profit by maximizing its utility function with base price α_j to be variable to enable ISP to have market competition if there are chances and quality premium to be variable to enable ISP to promote certain service.

Solutions in multiple classes: In the next part, the results of computation of the models in multiple classes are shown with introducing two classes and two users, so j = 2 and i = 2. Table 1 showed us the solver status and extended solver state of the original, modified with β fixed and β vary of model 1 then Table 2 explained solver status extended solver state of the original, modified with β fixed and β vary of model 2. And lastly, Table 3 explained the solutions of the model 1 with original, modified with β fixed and vary and model 2 with original, modified with β fixed and vary using LINGO 13.00.

Table 1: Solver status and extended solver state of model 1 original, Modified (β fixed) and modified (β vary)

Solver status	Original	Modified (β fixed)	Modified (β vary)
Model Class	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal
Objective	156.981	157.031	157.117
Infeasibility	0	0	0
Iterations	32	32	32
Extended solver state			
Solver type	B and B	B and B	B and B
Best Objective	156.981	157.031	157.117
Objective bound	156.981	157.031	157.117
Steps	0	0	0
Active	0	0	0
Update interval	2	2	2
GMU(K)	28	29	30
ER(sec)	0	0	0

INLP and B and B stand for integer nonlinear program and branch and bound, respectively. GMU refers to generated memory used and er refers to elapsed runtime

Table 2: Solver status and extended solver state of model 2 original, Modified (β fixed) and modified (β vary)

Solver status	Original	Modified (β fixed)	Modified (β vary)
Model Class	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal
Objective	79.0385	79.0635	79.0865
Infeasibility	0	1.4×10^{-14}	0
Iterations	60	78	82
Extended solver state			
Solver type	B and B	B and B	B and B
Best Objective	79.0385	79.0635	79.0865
Objective bound	79.0385	79.0635	79.0865
Steps	2	2	2
Active	1	2	2
Update interval	2	2	2
GMU(K)	28	30	31
ER(sec)	0	0	0

INLP and b and b stand for integer nonlinear program and branch and bound, respectively, GMU refers to generated memory used and er refers to elapsed runtime

In Table 1, the solver status for model 1 is obtained. The model class will be Mixed Integer Nonlinear Programming (MINLP) since in the model there is at least one nonlinear constraint. The models have one or more nonlinear constraints but the solver's local search procedure is unable to search better optimal, thus it terminate only in local optimum. For that reason, the solver will be able to find objective value for each model which is 156.981, 157.031 and 157.117, respectively. No constraints in the models are violated as the 0 infeasibility field showed. Number iterations completed by LINGO's solver vary according to models created like in our model 1 it happens to obtain the same iterations which is 32 iterations to find local optimal solution. LINGO

Table 3: Optimization solution of Model 1(Original, Modified (β fixed) and Modified (β vary) and Model 2 (Original, Modified (β fixed) and Modified (β vary)) for 2 users and 2 classes

	Model 1			Model 2		
	Original	Modified (β varies)	Modified (β fixed)	Original	Modified (β varies)	Modified (β fixed)
α_1(\$/bps)	0.2 fixed	0.2 fixed	0.2 fixed	0.3	0.3	0.288
α_2(\$/bps)	0.3 fixed	0.3 fixed	0.3 fixed	0.3	0.3	0.3
β_1(\$)	-	0.01 fixed	0.04	-	0.01 fixed	0.04
β_2(\$)	-	0.02 fixed	0.03	-	0.02 fixed	0.03
I_1	-	0.9	0.9	-	0.9	0.9
I_2	-	0.8	0.8	-	0.8	0.8
W_1 (bps)	5	5	5	5	5	5
W_2 (bps)	5	5	5	5	5	5
$\tilde{x}_{11}$ (bps)	25	25	25	25.5	25.5	25.5
$\tilde{x}_{21}$ (bps)	25	25	25	24.5	24.5	24.5
$\tilde{x}_{12}$ (bps)	25	25	25	25.5	25.5	25.5
$\tilde{x}_{22}$ (bps)	25	25	25	24.5	24.5	24.5
L_{m1} (bps)	0.01	0.01	0.01	0.01	0.01	0.01
L_{m2} (bps)	0.01	0.01	0.01	0.01	0.01	0.01
Z_{11}	1	1	1	1	1	1
Z_{12}	0	0	0	0	0	0
Z_{21}	1	1	1	1	1	1
Z_{22}	0	0	0	0	0	0
$\tilde{W}_{11}$	5	5	5	5	5	5
$\tilde{W}_{21}$	5	5	5	5	5	5
$\tilde{W}_{12}$	4	4	4	4	4	4
$\tilde{W}_{22}$	4	4	4	4	4	4
X_1 (bps)	25	25	25	25.5	25.5	25.5

employs branch and bound solver while dealing with integer constraints. The best possible objective value found so far in the model turns out to be the same value as in objective that highest value is achieved by model 1 modified 2. At some point, the best objective and objective bound can be very close value as Table 1 pointed out since the bound shows limit on how far the solver can improve the objective. Since the solver type is branch and bound then the number of branches in branch and bound tree is explained in steps taken by extended solver which are 0 in all model 1.The number of active subproblems remaining to be analyzed in model 1 is 2 as stated in active field that shows us that are 2 remaining open subproblems to be evaluated until goes to zero. Generated Memory Used (GMU) varies according to the model that shows us the memory generator is currently using from LINGO's memory allocation. Total time to generate and solve the models is all 0 as shown in 0 sec Elapsed Runtime (ER).

The interpretation for Table 2 is also quite similar with the one in Table 1. Model class for each model is MINLP which local optimal found so far by the solver. Objective value reach so far is highest value is achieved by model 2 modified 2. There is 0 or near 0 number of constraint violated by as infeasibility field showed. Branch and bound solver type are applied in the models. The same value of best objective and objective bound are obtained. There are 2 branches in branch bound tree taken by extended solver in each model. The number of active subproblems remaining to be analyzed is 1 in model 2 original and 2 in model 2 modified 1 and model 2 modified 2. Then the solver must run until goes to zero.

In Table 3, user 1 is allowed to take class 1 and class 2 since final price sensitivity for user 1 in class 1 (W_{11} and W_{12}) is at least greater than or equal to price sensitivity for class 1 and or class 2 (W_1 and W_2). That is why only user 1 is admitted to either class 1 or 2. Bandwidth obtained by user 1 in class 1 is 25 bps. It happens also for user 2 in class 1 or 2. Bandwidth obtained by user 1 in class 1 is at least than or equal to bandwidth for class 1. Bandwidth obtained by user 1 in class 2 also occur the same condition like in class 1. From the objective value in each model, it is obvious that the modified model yields better solution compared to original model proposed by Yang (2004).

So, the choice of whether to fix or vary the base price depends on ISP. If the choice of recovering cost would be the main goal, then, ISP should choose to fix the base price. But, if ISP chooses to have competition in market, then the choice of varying the base price will be the best choice. The choice of varying the quality premium will yield better profit for ISP while ISP is also able to compete in market competition and promote certain service. So, ISP can have two options that are choose to fix base price to recover cost and vary quality premium to promote certain service offered by ISP (model 1 modified with α fixed and β varies); secondly, ISP's option to vary base price to have market competition when there is a chance for ISP to do competition and vary the quality premium to promote certain services (model 2 modified with α varies and β varies). If the users are also becoming ISP's concern, so the choice to fix the quality premium is best but the profit is slightly lower (model 1 modified with α fixed and β varies or model 2 modified with α varies and β fixed). To sum up, the choice of model depends on ISP point of view but in all models, our proposed models yield slightly better optimal solution than model proposed by Yang (2004).

CONCLUSION

The model represented shows the connection between bandwidth required, bandwidth obtained and QoS by giving the assumptions and data; the optimal solution can be obtained with profit maximization. ISP has choices to whether adopt modified model 1 or modified model 2 according their priorities. The proposed models whether it is modified 1 model or modified model 2 show slightly better result than model proposed by Yang (2004). Other advantage of the modified models is ISP has choice to choose what plan would be adopted. It is obvious, if ISP would like to maximize its profit, ISP will choose model 1 modified 2 if ISP choose to fix the recover cost or model 1 modified 2 if ISP choose to vary to gain market competition. Further research should address issue with more generalization of users and classes applying the model proposed.

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