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A Comparison of Optimization of Charging Scheme in Multiple QoS Networks

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Abstract. As internet is becoming critical in economics life, Internet Service Providers (ISPs) now deal with high demand to promote good quality information. However, the knowledge to develop new pricing plans that serve both customers and supplier is known, but only a few pricing plans involve QoS networks. This paper will analyze the dynamical situation in network where new proposed pricing plans are offered with QoS networks involved. The plan is attempt to solve multiple QoS Networks scheme as an optimization model by comparing two models in multiple QoS networks by taking into consideration decision whether the user is admitted to the class or not to obtain profit maximization.

Keywords: charging scheme, multiple QoS networks, profit maximization

1.0 Introduction

Recent work on multiple service networks is due to [1]. She described the pricing scheme based auction to allocate QoS and maximize ISP's revenue. According to her, the auction pricing scheme is scalability, efficiency and fairness in sharing resources. The solution of the optimization problem goes from single bottleneck link in the network and then we generalize into multiple bottleneck links using heuristic method. In this paper, she used only single QoS parameter- bandwidth, while in networks, there are many parameters affect QoS that can be considered.

Although QoS mechanisms are available in some researches, there are few practical QoS network. Even recently a work in this QoS network [2], it only applies simple network involving one single route from source to destination.

Yang [1] and Yang et al. [3, 4] formulate pricing strategy for differentiated service networks. In their discussion, they focus on auction algorithm to find the optimal solution. We apply their mathematical formulation and combine it with mathematical formulation discussed by Byun and Chatterjee [2].

Basically, we would like to modify the mathematical formulation of [2, 3] since it could also be combined into simpler formulation by taking into consideration the utility function, base price, quality premium, index performance, capacity and also bandwidth required. Next we consider the problem of internet charging scheme as Mixed Binary Integer Nonlinear Programming (MBINLP) to obtain optimal. 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.

2.0 Material and methods

We attempt to apply optimization techniques in solving the problem in this paper. Like in [5], we also consider the optimization problem as MBINLP that can be solved by using optimization tools. 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.

3.0 Theory/calculation

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 [5].

Other scheme is congestion avoidance algorithm proposed by [6] and also scheme that combines congestion avoidance algorithm and one type of responsive pricing scheme that is smart market mechanism by Network Protocol proposed by [7] and [8]. One important thing why we want to create pricing mechanism is due to reducing congestion. What happens if we cannot avoid congestion? Karp [9] explains 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? The problem can be formulated as follows. 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 explained in [10] and [11].

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 [12], Ros & Tuffin [13] and Odlyzko [14] 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 & Chu [15] 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 suggested in [16].

4.0 Results and Discussions

The idea basically generates from [1, 2, 3, 4] for single QoS network and also we also use utility function adopted by [1, 3, 4] (see in [17]).

4.1 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 [1] 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 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.

4.2 Mathematical Formulation

We have parameters as follows:

α_j : base price for class *j* can set up as fixed price or varies.

β_j : quality premium of class j that has I_j service performance

Q : total bandwidth

V_i : minimum bandwidth required by user *i*

Decision variables are as follows:

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

X_{ij} : Final bandwidth obtained by user i for class j

L_{m_j} : Minimum bandwidth for class j

W_j : Price sensitivity for class j

I_j : Quality index of class j

X_j : Bandwidth assigned to each individual user in class j

W_{ij} : Price sensitivity for user i in class j

The first mathematical model will be

$$Max\ P_{ij}.U_{ij} = \sum_j \sum_i (\alpha_j + \beta_j \,.\, I_j) w_j log \frac{X_{ij}}{L_{m_j}} . Z_{ij} \tag{4.1}$$

Subject to

$$\left(\sum_j \sum_i X_{ij}\right) \leq Q \tag{4.2}$$

$$X_{ij} \geq L_{m_j} - (1 - Z_{ij}) \tag{4.3}$$

$$W_j \leq W_{ij} + (1 - Z_{ij}) \tag{4.4}$$

$$X_{ij} \geq V_i - (1 - Z_{ij}) \tag{4.5}$$

$$X_{ij} \geq X_j - (1 - Z_{ij}) \tag{4.6}$$

$$X_{ij} \geq Z_{ij} \tag{4.7}$$

$$X_{ij} \geq 0 \tag{4.8}$$

$$L_{m_j} \geq 0 \tag{4.9}$$

$$W_j \geq 0 \tag{4.10}$$

$$X_{ij} \leq X_j \tag{4.11}$$

$$Z_{ij} = \begin{cases} 1, if\ user\ i\ is\ admitted\ to\ class\ j \\ 0, otherwise \end{cases} \tag{4.12}$$

$$\alpha_j \geq \alpha_{j-1}, j > 1 \tag{4.13}$$

$$a \leq \alpha_j \leq b \tag{4.14}$$

$$0 \leq W_{ij} \leq c \tag{4.15}$$

$$\alpha_j + \beta_j . I_j \geq \alpha_{j-1} + \beta_{j-1} . I_{j-1}, j > 1 \tag{4.16}$$

$$0 \leq I_j \leq d \tag{4.17}$$

Where a and b are predetermined value of lower bound and upper bound base price respectively, c is predetermined value of upper bound price sensitivity for user i at class j respectively. Also, the value of d is as the upper bound of quality index.

We also have the second mathematical model that is

$$Max\ P_{ij} . U_{ij} = \sum_j \sum_i (\alpha_j . Z_{ij} + \beta_j . I_j) w_j log \frac{X_{ij}}{L_{m_j}} \tag{4.18}$$

subject to (4.2)-(4.12) and (4.15).

Objective function (4.1) and (4.18) basically states that ISP wants to maximize its revenue from total sum of price and its utility function with α_j varies and α_j to be fixed respectively. Constraint (4.2) tells us that total final bandwidth of all users cannot exceed the total bandwidth available. Constraint (4.3) states that bandwidth obtained by user i should exceed minimum bandwidth for class j if user i is admitted to class j or otherwise. Constraint (4.4) tells us 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. Constraint (4.5) 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. Constraint (4.6) tells us 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. Constraint (4.7) 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 (4.8). Nonnegativity requirement occurs in price sensitivity (4.10) and minimum bandwidth for class j in (4.9). Constraint (4.11) shows that bandwidth obtained by user i in class j should not exceed bandwidth assigned to each individual user in class *j*. Constraint (4.12) tells us the value of whether the user *i* is admitted to class *j* or not. Constraint (4.13) shows that base price for *j* class is more than base price for *j*-1 class with *j*>1. Constraint (4.14) tells us the range of base price (*a* and *b*) is lower bound and upper bound of predetermined base price, respectively. Constraint (4.15) 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*. Constraint (4.16) 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.Constraint (4.17) shows that the range of index quality should lie between 0 and 1 with predetermined *d* value set up by ISP.

4.3 Solutions in Multiple Classes

We begin with introducing two classes and two users, so $j = 2$ and $i = 2$. We set up following conditions as shown in Table 1. Table 2 describes the parameter quantities that are used in both models. We also show the numerical result of both models for each case in Table 3.

In Model 1 and Model 2, as Table 3 shown, only one user is admitted to either class 1 or class 2. Basically it means that for 2 classes, only one user can utilize the class. That user can choose which class that more benefit for him.

In Model 1, case 1 and case 4 with $W_{11}>W_{21}$ and $W_{12}>W_{22}$ we slightly obtain higher value than in case 2 and case 3. It means that by setting up lower price sensitivity for user *i* in previous class, ISP will gain more profit.

Next, in Model 2, objective value of 250.92 is achieved for all cases. But in case 3 and case 4, there exist the very small infeasibilities showing the amount that shows the constraint violation. To have best solution ISP can either to choose case 1 or case 2 for their preferences with 0 infeasibilities.

If we compare between 2 models, it is obvious that Model 2 will utilize maximum revenue for ISP by fixing α and β values. In ISP point of view, this condition is achieved when ISP would like to recover the cost and user is still able to select the class that fulfils their preferences and budgets.

On the other side, Model 1 obtains lower revenue than Model 2. Again, if ISP chooses to apply model 1, ISP will be able to compete in the market, when there is market competition by taking α value to be varies and user can select the class that fits with their budget and preference by taking β value to be fixed.

5.0 Conclusions

The model represented shows the connection between bandwidth required, bandwidth obtained and QoS by giving the assumptions and data; we can find the optimal solution with profit maximization. ISP has choices to whether adopt Model 1 or Model 2 according their priorities. However, due to assumptions, we have limited the model into static optimal solution and cannot be dynamic solution where we should have various demands for capacity (peak and off-peak).

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TABLE 1. Conditions of the Model 1 and Model 2

Case 1	**Case 2**	**Case 3**	**Case 4**
$V_1 > V_2$	$V_1 < V_2$	$V_1 > V_2$	$V_1 < V_2$
$0 \leq W_{11} \leq 8$	$0 \leq W_{11} \leq 7$	$0 \leq W_{11} \leq 7$	$0 \leq W_{11} \leq 8$
$0 \leq W_{12} \leq 8$	$0 \leq W_{12} \leq 7$	$0 \leq W_{12} \leq 7$	$0 \leq W_{12} \leq 8$
$0 \leq W_{21} \leq 7$	$0 \leq W_{21} \leq 8$	$0 \leq W_{21} \leq 8$	$0 \leq W_{21} \leq 7$
$0 \leq W_{22} \leq 7$	$0 \leq W_{22} \leq 8$	$0 \leq W_{22} \leq 8$	$0 \leq W_{22} \leq 7$

TABLE 2. Parameter Quantities

	Model 1				**Model 2**			
	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
Q	100							
V_1	6	5	6	5	6	5	6	5
V_2	5	6	5	6	5	6	5	6
β_1	0.01							
β_2	0.02							
α_1	-	-	-	-	0.2			
α_2	-	-	-	-	0.3			

TABLE 3. Computation Results for each case of Two Models

	Model 1		**Model 2**	
	original	modified	original	modified
GMU(K)	29	30	29	29
ER(sec)	0	0	0	0
Obj val($)	126.13	126.12	250.92	250.92
Iter	7	20	30	22
α_1($)	0.3	0.3	fixed	
α_2($)	0.3	0.3	fixed	
I_1	0.9	0.9	0.9	0.9
I_2	0.8	0.8	0.8	0.8
W_1	8	8	8	8
W_2(bps)	8	8	8	8
X_{11}(bps)	25.5	24.5	25	25
X_{21}(bps)	24.5	25.5	25	25
X_{12}(bps)	25.5	24.5	25	25
X_{22}(bps)	24.5	25.5	25	25
L_{m1}(bps)	0.01	0.01	0.01	0.01
L_{m2}(bps)	0.01	0.01	0.01	0.01
Z_{11}	1	0	1	0
Z_{12}	1	0	1	0
Z_{21}	0	1	0	1
Z_{22}	0	1	0	1
W_{11}	8	8	8	8
W_{12}	7	7	7	7
W_{21}	8	8	8	8
W_{22}	7	7	7	7
Infeasibilities	0	0	0	