The Improved Models of Internet Pricing Scheme of Multi Service Multi Link Networks with Various Capacity Links

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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 multi service multi link networks involved. The multi service multi link Networks scheme is solved as an optimization model by comparing two models in multi QoS networks. The results showed that by fixing the base price and varying the quality premium or varying the base price and quality and setting up the equal capacity link values, ISP achieved the goal to maximize the profit.

1 Introduction

Recent works on multiple QoS networks are due to [1-4]. 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 optimization problem goes from single bottleneck link in the network and then she generalized 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 [5], it only applies simple network involving one single route from source to destination.

In previous discussion works on multiservice network proposed by [6-8], we work on single and multiple link networks to solve the internet pricing scheme. This work on multiple link multiservice networks can also be improved by considering all cases of capacity needed in the networks. The results show our improved method results in better optimal solution than previously conducted by other research.

So, we intend to improve the mathematical formulation of [5, 9] to be simpler formulation by taking into consideration the utility function, base price as fixed price or varies, quality premium, index performance, capacity and also bandwidth required by looking at all possibility of capacity needed in the network. Next we consider the problem of internet charging scheme as Mixed Integer Nonlinear Programming (MINLP). The solver LINGO 13.0 [10] were applied to assist the nonlinear programming solution to obtain the optimal solution.

2 Related Works

A number of related works has been listed for differentiated pricing scheme that works on multi QoS networks. In paper proposed by [11], they discussed about pricing scheme that is based on QoS level in different allocation to control congestion and load balance. Multiple class networks require differentiated pricing scheme to have allocation of different level of service traffic. The investigation of the connection between QoS characteristics at network with requirement of quality for users applying the network is proposed by [12]. The results of their findings mainly are that predictability, consistency of QoS is crucial, the pricing scheme is crucial to have QoS to be predicted, having reliable service protocols and new integrated service mechanism is to present alternative in solving the problem. There exist direct connection between QoS profile application identification in packet and users requesting the QoS. Models proposed by [13] viewed the relationship between congestion control, routing and scheduling of wired network as fair resource allocation. In the research explained in [14], they discussed the flat fee pricing scheme, and as the simplicity price is maximum revenue. The drawback of the rule is due to nonlinearity and does not reflect the price observed in reality.

Models proposed by [15] stated that in network, it is assumed that n users can be split into k categories. Each category can apply the same service offered by application server in a shared link with total bandwidth C_{tot} but has different demand framework and also difference price sensitivity. Alderson et al. [16] discussed issues related to ISP problems dealing with topology of the networks such as link cost, router technology which impact on availability of topology to network creator then dealing with equipment of routing adopted to tackle network traffic flow.

Other research proposed by [17] stated about ways to solve internet optimization that includes system definition as an interest function and view it as different via points and system mathematical definition. Problem proposed by [18] focused on problem of arrangement of web services and explained about model of multi-dimension QoS. Framework presented by [19] analyzed the pricing problem in integrated service network having guaranteed QoS. The Method proposed by [20] define terms for performance prediction of service-base system that consist of performance showing the how fast completion time to finish a service request, time interval showing the time period to complete service request, dependability showing the capability of web service to conduct conditional required function, price setting up by ISP and reputation showing that user perception to the service. The method proposed by [21] explained about monopoly in pricing model strategy based on pay-per-volume and pay-per-time of network. They conclude that ISP will gain more benefit by providing pricing scheme based volume since this scheme is an alternative to numerous users and scheme of pay-per volume will benefit the network provider and can prevent from bursting the networks.

Study on multiservice was investigated by [9] which discussed problem of pricing of internet by considering network share, availability capacity in each service, the number of users available for the service and the QoS level. They solved the internet pricing by transforming the model into optimization model and solved using Cplex software. Recent works conducted by [22-27] also discussed internet charging scheme under multiple class QoS networks by comparing two models that involve base price as a fixed and variable set up by ISP. The model created by setting up base price as fixed price will yield higher optimal solution if ISP intended to recover the cost. But if ISP would like to compete in market, then the choice of model involving base price as variable price would be the best option to choose.

The work discussed on the botnet attacks detection by using nepenthes honeypots [28] is also crucial to be issued for problems increasing if we are dealing with security problem in multiservice networks.

3 Research Method

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

3.1 Model Formulation

The idea basically generates from [5, 8, 9] and is improved in multilink multi service networks by considering various cases where we can set up requirements for the capacity link.

3.2 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 [1-4] 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, decision variables and the models are adopted in [7, 8] and are described as follows.

The parameters are as follows.

α_j : base price for class j, can be fixed or variables
β_j : quality premium of class j that has I_j service performance
C_l : total capacity available in link l
p_{il} : price a user willing to pay for full QoS level service of i in link l

The decision variables are as follows.

x_{il} : number of users of service *i* in link *l*

a_{il} : reserved share of total capacity available for service *i* in link *l*

I_i : quality index of class *i*

Formulation when we assign α and β fixed is as follows.

$$\text{Max} \sum_{l=1}^{L} \sum_{i=1}^{S} (\alpha + \beta I_i) p_{il} x_{il} \tag{1}$$

Such that

$$I_i\, d_{il}\, x_{il} \leq a_{il}\, C_l,\ i = 1, \ldots S,\ l=1, \ldots, L \tag{2}$$

$$\sum_{l=1}^{L} \sum_{i=1}^{S} I_i d_{il} x_{il} \leq C_l, i = 1, \cdots, S; l = 1, \cdots, L \tag{3}$$

$$\sum_{l=1}^{L} a_{il} = 1, i = 1, \cdots, S \tag{4}$$

; **(5)**

(6)

$$0 \leq x_{il} \leq n_i, i = 1, \cdots, S;\ l = 1, \cdots, L \tag{7}$$

With m_i and n_i are prescribed positive integer numbers.

$$\{x_{il}\}\text{integer} \tag{8}$$

Formulation when we assign α fixed and β vary is as follows.

$$\text{Max} \sum_{l=1}^{L} \sum_{i=1}^{S} (\alpha + \beta_i I_i) p_{il} x_{il} \tag{9}$$

Subject to Eq.(2)- Eq.(8) with additional constraints as follows.

$$\beta_i I_i \geq \beta_{i-1} I_{i-1}, i > 1, i = 1, \cdots, S \tag{10}$$

$$k \leq \beta_i \leq q, [k, q] \in [0,1] \tag{11}$$

Formulation we have when α and β vary

$$\text{Max} \sum_{l=1}^{L} \sum_{i=1}^{S} (\alpha_i + \beta_i I_i) p_{il} x_{il} \qquad (12)$$

Subject to Eq. (2)-(8) and (10) with additional constraints

$$\alpha_i + \beta_i I_i \geq \alpha_{i-1} + \beta_{i-1} I_{i-1}, i > 1, i = 1, \cdots, S \qquad (13)$$

$$y \leq \alpha_i \leq z, [y, z] \in [0,1] \qquad (14)$$

Formulation when we have α vary and β fixed

$$\text{Max} \sum_{l=1}^{L} \sum_{i=1}^{S} (\alpha_i + \beta I_i) p_{il} x_{il} \qquad (15)$$

Subject to Eq.(2)-(8) and (13)-(14).

Since ISP wants to get revenue maximization by setting up the prices chargeable for α, β and QoS level to recover cost and to enable the users to choose services based on their preferences like stated in Eq. (1). Eq. (2) shows that the required capacity of service does not exceed the network capacity reserved. Eq. (3) explains that required capacity cannot be greater than the network capacity C in link l. Eq. (4) guarantee that network capacity has different location for each service that lies between 0 and 1 (5). Eq. (6) explains that QoS level for each service is between the prescribed ranges set up by ISP. Eq. (7) shows that users applying the service are nonnegative and cannot be greater than the highest possible users determined by ISP. Eq. (8) states that the number of users should be positive integers. Eq. (9) explains that ISP wants to get revenue maximization by setting up the prices chargeable for α, β and QoS level to recover cost and to enable the users to choose services based on their preferences. Eq. (10) explains that β has different level for each service which is at least the same level or lower level. Eq. (11) states that value of β lies between two prescribed values. ISP wants to get revenue maximization by setting up the prices chargeable for α, β and QoS level to recover cost and to enable the users to choose services based on their preferences like stated in Eq. (12). Eq. (13) explains that the summation of α and β has different level for each service which is at least the same level or lower level. Eq. (14) shows that the base price should lie between predetermined α set up by ISP. ISP wants to get revenue maximization by setting up the prices chargeable for α, β and QoS level to recover cost and to enable the users to choose services based on their preferences as stated in objective function (15).

4 Optimal Solution

Table 1 and 3 below describes the solver status of model formulation in LINGO when considering base price to be fixed and model formulation when considering base price to be varied. GMU (Generated Memory Used) shows that how much the amount of memory use for generating a model. The total time used so far to generate and solve the model. In Table 1, the highest optimal solution of 811.2 is achieved when ISP sets up α to be fixed and vary β and equals the capacity link values with GMU= 32K and ER=1 sec. In Table 3, the highest optimal solution of 912.6 is achieved when ISP varies α, β and equals the capacity link values with GMU=33K and ER=1 sec.

Table 1. Solver Status and Extended Solver State of the Models by considering α to be fixed for Three Capacity Link Cases

Solver Status	**α and β fixed**			**α fixed and β vary**		
	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$
Model Class	INLP	INLP	INLP	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal	Local optimal	Local optimal	Local optimal
Objective	492.151	477.4	569.831	686.4	667.2	811.2
Infeasibility	2.7×10^{-13}	0.3×10^{-3}	1.8×10^{-7}	1.1×10^{-16}	0.1×10^{-15}	0.9×10^{-12}
Iterations	2186	259	818	614	375	181
Solver type	B & B	B & B	B & B	B & B	B & B	B & B
Best Objective	492.151	477.4	569.831	686.4	667.2	811.2
Objective Bound	492.151	477.4	569.831	686.4	667.2	811.2
Steps	51	9	20	26	8	6
Active	0	0	0	0	0	0
Update interval	2	2	2	2	2	2
GMU(K)	30	30	30	32	31	32
ER(sec)	2	0	1	1	0	1

Table 2. Solutions of Models by considering α to be Fixed for Three Capacity Link Cases

	α=0.5 and β=0.01(fixed)			**α=0.5 (fixed) and β vary**		
Var	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$
α_1	-	-	-	-	-	-
α_2	-	-	-	-	-	-
α_3	-	-	-	-	-	-
β_1	-	-	-	0.375	0.375	0.375
β_2	-	-	-	0.375	0.375	0.375
β_3	-	-	-	0.3	0.3	0.3
I_1	0.8	0.83	0.83	0.8	0.8	0.8
I_2	0.8	0.8	0.8	0.8	0.8	0.8
I_3	0.5	0.5	0.5	1	1	1
a_{11}	0.024	0.025	0.025	0.096	0	0
a_{21}	0.6	0.7	0.7	0.904	1	1
a_{31}	0.375	0.275	0.275	0	0	0
x_{11}	2	3	3	8	0	0
x_{21}	4	7	7	6	10	10
x_{31}	9	10	10	0	0	0
a_{12}	0.025	0.12	0.025	0.08	0.1	0.08
a_{22}	0.7	0.46	0.7	0.92	0.9	0.9
a_{32}	0.275	0.4	0.275	0	0	0.02
x_{12}	3	10	3	10	8	10

x_{22}	7	3	7	9	6	9
x_{32}	10	10	10	0	0	0

Table 2 and 4 depict the optimal solutions of the formulation by setting up the base price value to be fixed or vary the base price. In Table 2, when the formulation of α to be fixed and vary β, the QoS level of 0.8 is achieved by service 1 and service 2 with $C_1=C_2$. But only 10 users apply the service in service 2 on link 1 with 100% network is reserved and 9 users on link 2 with 90% network is reserved.

Table 3. Solver Status and Extended Solver State of the Models by Considering α being varied for Three Capacity Link Cases

Solver Status	***α* vary and *β* fixed**			***α* and *β* vary**		
	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$
Model Class	INLP	INLP	INLP	INLP	INLP	INLP
State	Local optimal	Local optimal	Local optimal	Local optimal	Local optimal	Local optimal
Objective	585.144	563.2	677.421	772.2	750.6	912.6
Infeasibility	0.0015	0.3×10^{-3}	3.7×10^{-5}	8.7×10^{-13}	0	1.7×10^{-17}
Iterations	1517	348	736	1622	462	188
Solver type	B & B	B & B	B & B	B & B	B & B	B & B
Best Objective	585.144	563.2	677.421	772.2	750.6	912.6
Objective Bound	585.144	563.2	677.421	772.2	750.6	912.6
Steps	26	16	12	25	11	6
Active	0	0	0	0	2	0
Update interval	2	2	2	2	0	2
GMU(K)	32	32	32	33	33	33
ER(sec)	1	0	2	1	0	1

Table 4. Solutions of Models by Considering α being Varied For Three Capacity Link Cases

Var	***α* vary and *β*=0.01(fixed)**			***α* and *β* vary**		
	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$	$C_1<C_2$	$C_1>C_2$	$C_1=C_2$
α_1	0.5	0.5	0.5	0.25	0.26	0.26
α_2	0.597	0.59	0.59	0.53	0.53	0.63
α_3	0.6	0.6	0.6	0.6	0.6	0.6
β_1	-	-	-	0.8	0.8	0.8
β_2	-	-	-	0.45	0.45	0.34
β_3	-	-	-	0.3	0.3	0.3
I_1	0.8	0.83	0.8	0.8	0.8	0.8
I_2	0.8	0.8	0.8	0.8	0.8	0.8
I_3	0.5	0.5	0.5	1	1	1
a_{11}	0.024	0.025	0.024	0.096	0	0
a_{21}	0.602	0.7	0.7	0.9	1	1
a_{31}	0.373	0.275	0.276	0.003	0	0
x_{11}	2	3	3	8	0	0
x_{21}	4	7	7	6	10	10
x_{31}	9	10	10	0	0	0
a_{12}	0.024	0.12	0.024	0.08	0.1	0.08
a_{22}	0.7	0.46	0.7	0.91	0.9	0.9

a_{32}	0.276	0.4	0.276	0.012	0	0.02
x_{12}	3	10	3	10	8	10
x_{22}	7	3	7	9	6	9
x_{32}	10	10	10	0	0	0

The Highest QoS level of 1 is achieved by service 3 but no users apply the service. When the formulation of varying α and β, as stated in Table 4, QoS level 0f 0.8 is achieved by service 1 and 2 also of 1 in service 3 but only in service 2, 10 users apply the service in link 1 and 9 users in link 2 with 100% network reserved for service 2 in link 1 and 90% network reserved in link 2.

To sum up, the objective of ISP to achieve the maximum profit will be reached if ISP set up the base price to be fixed and vary the quality premium or to vary the base price and quality premium with setting up the equal capacity link values ($\boldsymbol{C_1=C_2}$).

5 Conclusion

The paper [9] be more upgraded by using our new approach using other tools. We obtain slightly increasing profit in several solutions we proposed. We also save human resources by only applying few users to apply the service and also we can save energy by only promote one service rather than two services. Our solutions show better profit with less idle time and number of users applied the services.

We have shown that by considering new parameters, more decision variables and constraints, we obtain better revenue maximization. The cases shown above basically are ISP strategy to vary its preference to achieve their goals. ISP is able to adopt the cases to suit their goals. But again, like stated in since it is more theoretical point of view and assumptions, we limit our result only static result in data changes, and cost preference is just based on our discrete data. Further research should address more generalization of the model to also consider numerous services offered or generalization of more services.

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

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