

An Improved Optimization Model of Internet Charging Scheme in Multi Service Networks

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Abstrak

Pada artikel ini akan dianalisa skema baru pembiayaan yang diperbaiki yang didasarkan atas biaya dasar, premium kualitas dan jaringan QoS. Sain dan Herpers [5] telah berupaya mendapatkan maksimisasi pendapatan dengan membentuk skema pembiayaan internet. Dalam artikel ini, dicoba menyelesaikan skema jaringan banyak layanan sebagai model optimasi untuk memperoleh maksimisasi pendapatan dengan menggunakan model perbaikan yang didasarkan atas Byun and Chatterjee [2] dan Sain dan Herpers [5]. Hasil optimasi menunjukkan bahwa model yang diperbaiki dapat diselesaikan secara optimal dengan menggunakan software aplikasi optimasi LINGO untuk mendapatkan maksimisasi pendapatan yang lebih baik. Hasil yang lebih baik diperoleh jika dibandingkan dengan [5] dalam semua kasus dengan harga biaya dasar dan premium kualitas yang berbeda sesuai dengan kehendak penyedia layanan internet (ISP). Kelebihan model yang diperbaiki ini adalah kemudahan bagi ISP untuk mengatur biaya dasar dan premium kualitas. Untuk beberapa kasus yang diselesaikan untuk memperoleh maksimisasi pendapatan, tidak ditawarkan semua layanan dan hanya menawarkan beberapa layanan saja

Kata kunci: jaringan banyak layanan, model optimasi, skema pembiayaan

Abstract

This article will analyze new improved charging scheme with base price, quality premium and QoS networks involved. Sain and Herpers [5] already attempted to obtain revenue maximization by creating charging scheme of internet. The plan is attempted to solve multi service networks scheme as an optimization model to obtain revenue maximization using our improved model based on Byun and Chatterjee [2] and Sain and Herpers [5]. The results show that improved model can be solved optimally using optimization tool LINGO to achieve better revenue maximization. Better results are obtained in all cases rather than in [5]. The advantage of our new model is that ISP also can set up their base price and quality premium based on ISP preferences. For some cases for getting revenue maximization, we do not offer one service and just utilize some of the services.

Keywords: charging scheme, multi service networks, optimization model

1. Introduction

Yang [1], Byun and Chatterjee [2] and Yang et al. [3, 4] formulate pricing strategy for differentiated service networks. In their discussion, [1, 3, 4] they focus on auction algorithm to find the optimal solution. Byun and Chatterjee [2] discussed about designing pricing models for internet services at various levels of quality which focus on usage based pricing scheme since that scheme reflects congestion level in details. The parameter involved is basically based on bandwidth and by creating suitable formula these parameters are to be set up to obtain pricing formula that can be used to develop research on pricing model. The model was tested on OPNET simulation program and the results show that by designing proper pricing scheme with quality index is in pricing formula yields simpler formula but of course it is also dynamic. The possible changes in service pricing and revenue changes can also be made. The disadvantage of their result is actually only can be applied in theoretical situations since they only consider single route from the source application where in real situation, we deal with multiple routes from source to reach destinations.

Sain and Herpers [5] also try to formulate the network charging scheme into optimization model and solve it to obtain maximum profit by considering the price, total network capacity to services offered and QoS levels for each service offered. In their paper, ISP obtains profit with two services offered. The model is processed by OPL studio by use of Cplex solver. We attempt to compare [5] with our result and our new improved model to show that we gain better result with additional parameters, decision variables and constraints. We intend to modify their model by also considering the base price and quality premium of service.

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 [6]. Other scheme is congestion avoidance algorithm proposed by [7] 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 [8, 9].

Karp [10] 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 [11] and [12].

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 [13], Ros and Tuffin [14] and Odlyzko [15] 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 [16] 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 [17].

So, basically, we would like to describe that we would like to modify the model used in [5] by giving some additional constraints based on [2]. Secondly, we would like to give our point of view in dealing with result of [5].

2. Research Method

We attempt to apply optimization techniques in solving the problem in this paper. Like in [5], we also consider the optimization problem as Mixed Integer Nonlinear Programming (MINLP) 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.

The idea basically generates [5] and [2] and we seek to analyze their results by comparing with our results. We also focus on ISP's point of view to get revenue maximization by gaining prices for services available, capacity allocation for each service, determination of base price and quality premium for each service and QoS level for services offered.

We consider cases of α , base price and or β , the quality premium to be fixed or vary depends on what target ISP would achieve. According to [2], ISP will gain benefit for considering the values of α and β as follows.

3. Results and Discussion

We propose our new improved model. First case is when α and β are fixed.

$$\text{Max } R = \sum_{i=1}^S (\alpha + \beta * I_i) * p_i * x_i \quad (1)$$

Subject to

$$I_i * d_i * x_i \leq a_i * C, i = 1, 2, \dots, S. \quad (2)$$

$$\sum_{i=1}^S I_i * d_i * x_i \leq a_i * C, i = 1, 2, \dots, S. \quad (3)$$

$$\sum_{i=1}^S a_i = 1, i = 1, 2, \dots, S. \quad (4)$$

$$0 \leq a_i \leq 1, i = 1, 2, \dots, S. \quad (5)$$

$$m_i \leq I_i \leq 1, i = 1, 2, \dots, S. \quad (6)$$

$$0 \leq x_i \leq n_i, i = 1, 2, \dots, S. \quad (7)$$

$$\{x_i\} \text{ integer}, i = 1, 2, \dots, S. \quad (8)$$

Second case when α is fixed and β vary.

$$\text{Max } R = \sum_{i=1}^S (\alpha + \beta_i * I_i) * p_i * x_i \quad (9)$$

with subject to constraint (2)-(8). We also add new constraints as follows.

$$\beta_i * I_i \geq \beta_{i-1} * I_{i-1}, i > 1, i = 1, 2, \dots, S. \quad (10)$$

$$l_i \leq \beta_i \leq b_i, i=1, 2, \dots, S. \quad (11)$$

Next case is for α and β vary.

$$\text{Max } R = \sum_{i=1}^S (\alpha_i + \beta_i * I_i) * p_i * x_i \quad (12)$$

with subject to constraint (2)-(8) and (10)-(11). We also add new constraints as follows.

$$\alpha_i + \beta_i * I_i \geq \alpha_{i-1} + \beta_{i-1} * I_{i-1}, i > 1, i = 1, 2, \dots, S. \quad (13)$$

$$c_i \leq \alpha_i \leq g_i, i=1, 2, \dots, S. \quad (14)$$

Last case is for α vary and β fixed.

$$\text{Max } R = \sum_{i=1}^S (\alpha_i + \beta * I_i) * p_i * x_i \quad (15)$$

with subject to constraint (2)-(8) and (14). We also add new constraints as follows.

$$\alpha_i + I_i \geq \alpha_{i-1} + I_{i-1}, i > 1, i = 1, 2, \dots, S. \quad (16)$$

Following are the descriptions of the model:

1. ISP wants to get revenue maximization by setting up the prices chargeable for a base price and quality premium and QoS level to recover cost and to enable the users to choose services based on their preferences [2] like stated in objective function (1). For constraint (2)-(7) basically we adopt from [5].
2. Constraint (2) describes that the required capacity of service does not exceed the network capacity reserved.
3. Constraint (3) explains that required capacity is not greater than total network capacity C.
4. Constraint (4) guarantees that network capacity has different allocation for each service that lies between 0 and 1 (Constraint (5)).

5. Constraint (6) states that QoS level should lie between determined QoS level for each service.
6. Constraint (7) tells us that users apply the service is nonnegative and is not greater than highest possible users determined by service provider.
7. Constraint (8) tells us that there is limitation in the number of users and it should be positive integers.
8. Objective function (9) describes that ISP set up revenue maximization the price chargeable for a base price, quality premium, a QoS level to recover cost and also promote certain services [2] and also the number of users over all service.
9. Constraint (10) explains that quality premium has different level for each service which is at least the same level or lower level.
10. Constraint (11) tells us that the quality premium does not fall out of determined quality premium set up by ISP.
11. Objective function (12) explains that ISP wants to obtain revenue maximization by setting up the price chargeable for a base price and quality premium to compete in market competition if there is a chance to do that and the meantime, ISP can also promote certain services[2] and for the number of users over all services.
12. Constraint (13) guarantees that base price and quality premium has at least same level or lower level value for each service and also that base price should lie between prescribed base price set up by ISP.
13. Objective function (15) states that ISP seek to maximize the price chargeable for a base price and quality premium, QoS level to have market competition if there is a chance and users are able to choose the service according to their budget and preference and for the number of users over all services.
14. Constraint (16) states that base price has at least the same or lower level for each service that lies between prescribed ISP base price.

For decision variables and parameters, we add ours in addition to [5] as follows.

Decision variables:

- α_i : Base price of network service. ISP set up differentiation of base price to allow competition in the market [2] for $i=1, 2, \dots, S$.
- β_i : Quality premium of service that has $I_i, i=1, 2, \dots, S$ service performance. ISP set up differentiation of quality premium to promote certain services [2].

Parameters:

- l_i : Minimum base price required for service $i=1, 2, \dots, S$.
- b_i : Minimum base price required for service $i=1, 2, \dots, S$.
- c_i : Minimum quality premium needed for service $i=1, 2, \dots, S$.
- g_i : Maximum quality premium needed for service $i=1, 2, \dots, S$.

We also set additional parameter values, in addition to parameter set by [5].

Table 1. Target of ISP in Adopting the Pricing Scheme [2]

Target	β fixed	β varies
α fixed	Recover cost and user can select service	Recover cost and can promote certain service
α varies	Market competition and user can select service	Market competition can promote certain service

Table 2. Additional Parameters for Our New Modified Model

Service	$i=1$	$i=2$	$i=3$
α fixed	0.5	0.5	0.5
β fixed	0.4	0.4	0.4
l_i	0.05	0.02	0.01
b_i	0.8	0.5	0.3
c_i	0	0	0
g_i	0.5	0.7	0.6

We put example to see the solution of our MINLP model adopted in [5]. By applying each case, we can see how we can gain profit. The analysis previously described in [5] can also be adopted in our result. Also, ISP can seek possibility to achieve their target by considering each case.

Table 3 basically tells us the solver status for 4 our cases using LINGO 13 [18]. Some cases take long time to finish iterations and we obtain local optimal for the solutions. Some cases also show a very small infeasibility that we can say that zero infeasibilities.

Table 3. Solver Status of Our New Modified Model

	α, β fixed	α fixed β vary	α, β vary	α vary β fixed
Solver Status				
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local opt	Local opt	Local opt	Local opt
Objective	308.628	297.6	334.8	377.23
Infeasibility	7×10^{-15}	2×10^{-14}	0	0
Iterations	528	150	128	147
Extended Solver status				
Solver Type	B & B	B & B	B & B	B & B
Best Objective	308.628	297.6	334.8	377.23
Objective bound	308.628	297.6	334.8	377.23
Steps	12	5	5	4
Active	0	1	0	3
Update interval	2	2	2	2
GMU(K)	25	27	28	26
ER(sec)	1	0	0	0

Table 4-7 show the solutions for cases. In Table 4 below, service 1 has optimal QoS level of 0.8, 1, user allows applying the service and only 0.9% of network is reserved of 48 is used. Service 2 obtain optimal QoS level of 0.807, there are 6 users apply the service and 72.64% of network is reserved of 3631.5 is used. For service 3, a QoS level of 50% is obtained, giving the chance for 8 users apply the service and 26.4% network is reserved and it use 1320. ISP is targeting to be able to recover their cost of service and also can enable the users to select the services based on their budget and preferences. If, we sum up all service we will get total revenue of 308.616 and use capacity of 4999.5 or having degree of utilization of 99.99%. We can say that for this case, there only 0.5 idle capacity that cannot be utilized for other services.

Table 4. Solution for $\alpha=0.5$ and $\beta=0.4$ (Fixed)

Service	$i=1$	$i=2$	$i=3$
Share of total network capacity(a_i)	0.0096	0.7264	0.264
QoS level(l_i)	0.8	0.807	0.5
No. of concurrent users(x_i)	1	6	8
Used capacity per service ($l_i^*d_i^*x_i$)	48	3631.5	1320
Total capacity used($\sum l_i^*d_i^*x_i$)		4999.5	
Profit per service($(\alpha+\beta^*l_i)^*p_i^*x_i$)	2.46	222.156	84
Total profit ($\sum (\alpha+\beta^*l_i)^*p_i^*x_i$)		308.616	

For case that $\alpha=0.5$ (fixed) and β varies like shown in Table 5, we come up with different solution. For reason of revenue maximization, ISP does not offer the service 3. Service 1, a QoS level of 80% is obtained with 4 users apply the service and 3.84% network is reserved of 192 is used. For service 2, a QoS level of 80% is obtained with 8 users apply the service and 96.16% network is reserved with 8 customers apply the service. Since we set up α to be fixed and β varies, ISP can target to recover cost of service and promote certain services which is service 1 and service 2 by no promoting for service 3. By summing up all revenues, we obtain revenue of 297.6 and utilization degree of 99.84%.

In Table 6, The ISP targets on getting market competition and promote certain services which are service 1 and 2 to gain revenue maximization. This is the reason why ISP choose to differentiate the value of α and β . For revenue reason, ISP does not offer service 3. In service 1, a QoS level of 80% is offered with 4 users apply the service and 3.84% network is reserved of 192 is used. Service 2 obtain a QoS level of 80% with 8 users apply the service and 96.16 % of network is reserved with 4800 is used. Total of revenue of 334.8 is obtained with utilization degree of 99.84%. So, there is the idle capacity of 8 only not to be used by other services.

Last case (Table 7) is when α varies, $\beta=0.4$ (fixed) ISP can gain market competition when there is chance meanwhile it can allow users to choose the service that suitable with their needs and budgets. For revenue reason, ISP does not offer service 3. Service 1 obtains a QoS levels of 80%, with 4 users apply the service, 3.84 % networks is reserved and 192 is used. In service 2, QoS level of 80.13% is offered and users of 4 is allowing to use the services, with 8 users use the service and 96.16% networks is reserved and 4808 is used. Total revenue is

77.232 which use of 4999.99 \approx 5000 of total capacity. It means that there is almost no idle capacity to waste.

Table 5. Solution for $\alpha=0.5$ (Fixed), β Vary

Service	$i=1$	$i=2$	$i=3$
Premium quality (β)	0.375	0.375	0.3
Share of total network capacity(a_i)	0.0384	0.9616	0
QoS level(l_i)	0.8	0.8	1
No. of concurrent users(x_i)	4	8	0
Used capacity per service ($l_i^* d_i^* x_i$)	192	4800	0
Total capacity used($\sum l_i^* d_i^* x_i$)		4992	
Profit per service ($(\alpha+\beta^* l_i)^* p_i^* x_i$)	9.6	288	0
Total profit ($\sum (\alpha+\beta_i^* l_i)^* p_i^* x_i$)		297.6	

Table 6. Solution for α and β Vary

Service	$i=1$	$i=2$	$i=3$
Base price(α_i)	0.26	0.6301951	0.6
Premium quality (β)	0.8	0.3372562	0.3
Share of total network capacity(a_i)	0.0384	0.9616	0
QoS level(l_i)	0.8	0.8	1
No. of concurrent users(x_i)	4	8	0
Used capacity per service ($l_i^* d_i^* x_i$)	192	4800	0
Total capacity used($\sum l_i^* d_i^* x_i$)		4992	
Profit per service ($(\alpha+\beta_i^* l_i)^* p_i^* x_i$)	10.8		0
Total profit ($\sum (\alpha+\beta_i^* l_i)^* p_i^* x_i$)		334.8	

Table 7. Solution for α Vary, $\beta=0.4$ (Fixed)

Service	$i=1$	$i=2$	$i=3$
Base price(α_i)	0.5	0.7	0.6
Share of total network capacity(a_i)	0.0384	0.9616	0
QoS level(l_i)	0.8	0.8013	0.9013
No. of concurrent users(x_i)	4	8	0
Used capacity per service ($l_i^* d_i^* x_i$)	192	4807.999	0
Total capacity used($\sum l_i^* d_i^* x_i$)		4999.999	
Profit per service ($(\alpha+\beta^* l_i)^* p_i^* x_i$)	7.92	367.391	0
Total profit ($\sum (\alpha+\beta_i^* l_i)^* p_i^* x_i$)		377.232	

Table 8. Comparison between Our Results and [5] Result

Comparison	[5] model	Our model			
		Case 1	Case 2	Case 3	Case 4
Total capacity used($\sum l_i^* d_i^* x_i$)	4980	4999.5	4992	4992	4992
Total profit	294	308.616	297.6	297.6	334.8

So to sum up, we obtain better results in all cases rather than in [5] if we compare the results like in Table 8 although it takes more time to finish the iteration like shown in Table 3. The advantage of our new model is that ISP also can set up their base price and quality premium based on ISP preferences. For some cases (like in Table 5, 6, and 7), for revenue maximization, we do not offer all services but only some services.

4. Conclusion

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 [2, 5], 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.

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