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Improved Model of Internet Pricing Incentive Mechanism based on Multi bottleneck Links in Multi QoS Networks

*Note: Sub-titles are not captured in Xplore and should not be used

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Abstract— ***This paper seeks to develop a new proposed pricing plan. We aim to address the multiple bottlenecks in the various QoS network scheme as an improved model by comparing the original model to the first and second modifications. We will achieve this by looking at the total cost that the customer will pay, the price charged for cost recovery or diversification by allowing the user to choose the QoS that best suits their budget and preference. Depending on the principle that increasing the quality leads to an increase in the price. The results obtained are from the Lingo 18 program which shows an improvement in the original problem by noting an increase in profits between the original model and the first and second modification.***

Keywords— profit maximization, multi bottleneck links, pricing incentive, multi QoS networks, ISP

I. Introduction

Most studies have indicated that information and communication technology is a major factor in the economic and social development of countries due to its positive repercussions on economic growth, productivity, and employment [1]. The volume of demand on the Internet has increased, especially with the emergence of the IOT and its multiple uses that require an Internet connection to display the results of the sensors [2] The Internet plays a big role in developing the economy and is seen as an important catalyst for restructuring business activities [3].

Quality of service in networks is defined as the mechanisms that allow distinguishing network services based on their unique service requirements [4]. The DiffServ and IntServ architectures allow the implementation and differentiation of QoS to different specifications on a given network [5]. QoS can grant specific privileges to specific traffic to reduce delays and losses [6]. The pricing works to regulate the use of the Internet by providing appropriate pricing that is equivalent to the quality of service, which is reflected in improving network performance and avoiding congestion.[7] Internet service providers should provide an appropriate internet pricing mechanism and a better and different quality of service [8]. There are three schemes used in Internet pricing, which are flat fees, usage-based tariffs, and two-part tariffs to maximize benefits for an ISP [9], or multiple links [10].

II. Literature Review

Pricing without reserving resources is less expensive compared to implementing bandwidth reservation measures [11]. The best way to prevent network congestion and distinguish its services is through usage-based pricing schemes [12]. [13] Presented the proposed pricing scheme of Single Bottleneck Link in Multi QoS Networks.

[14] Proposed a mathematical model of the Paris metro pricing Scheme for charging the packet networks. Which is based on dividing the networks into sub-networks or classes, and fees are imposed on their customers at different prices, based on the customer's choice of service quality, as each quality has a specific price and delay.

They were applied in the case of a single network and this is not appropriate with the size of development in the Internet Networks. The optimal solution is determined by the basic price, either it is a fixed price for the purpose of recovering the cost or

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the price is variable for the purpose of competition, determining the quality premium and the level of service quality to enable the user to choose the categories [15]. [16] Generalized the pricing scheme in the Internet pricing model in the multi-category QoS multi-link network for a number of users.

Their pricing scheme is based on load balancing, which means that the higher the load in the network, the more expensive it is to use the Internet. By increasing prices when demand increases, it aims to reduce the occurrence of congestion because the user will take cost price into account [17].

[18] Proposed an auction-based pricing algorithm whereby the internet service provider determines the acceptable price; level of service provided and allows customers to choose the price and service required. Fixed pricing and two-part tariff pricing realize the same level of profit and dominance pricing on the basis of use. Under marginal costs and zero control or when customers have a heterogeneous marginal willingness to pay. when customers are characterized by heterogeneous extreme consumption levels, the pricing of the two-part tariff is the most profitable [19].

III. Research Method

In this paper, we present a research contribution to the modification of the mathematical formula proposed by [17] looking at the model as an optimization problem of linear programming that can be solved using Lingo (version 18.0) optimization tool which will simulate formulas and research results.

. The idea for this research originated mainly from the works of [20],[21],[22],[23] and is improved for multi-service multi-link networks. The goal of the ISP is to get the maximum possible profit return. The optimization model is established based on parameters and variables that will be used to solve the optimization problem. The model will therefore consist of the objective function that will be maximized and the model constraints that will act as controls and limits to ensure they cannot be overridden during the solution.

We converted the problem of internet pricing in multi-link as well as multi-service networks into an improved model and attempt to get the best solution out of it. The gel will help explain the problems of pricing, quality premium, QoS level, and the load in the network.

The aim of the model as earlier stated is to maximize the profit based on the premium service quality and index of quality parameters. The total cost price is the product of multiplying the volume of bandwidth the user requests, the type of QoS required, and the volume of load in the network, which is represented by equation 1. We have two types of QoS, Class i (1,2) and 2 links j (1,2).

IV. Results and Discussion

We compared the results of the original model proposed by (18) with improved modified models 1 and 2 which were added variable premium QoS (beta)i and quality of index (i), for each of the two modifications. Where beta is fixed in the first modification and variable in the second modification.

A. *Mathmatical Original Model Problem*

Parameters for the original model adopted in [17]

C_{ij} : Price service class i in link j at time t.

n : The numbers of links in the path.

i : Priority of the service.

Bl_j : Bandwidth capacity available in link j.

B_j : Total bandwidth capacity available in link j.

b : Bandwidth user request.

L_{ij} (t) : Load of service class i at time t for a link j..

- Variables are as follows:

P_{ij} (t): Load factor at time t for service class i at link j.

C_i total (t): Price traversing for the particular path is the sum of the price across all the links on the path.

- Mathematical Problem:

$$MAX\ R = \sum_{j=1}^{2} \sum_{i=1}^{2} (R_{ij}(t) * b * P_{ij}(t)) \quad (1)$$

Subject to:

$$P_{11} = \left(\frac{1-L_{base}}{1-L_{11}}\right)^n \quad (2)$$

$$P_{12} = \left(\frac{1-L_{base}}{1-L_{12}}\right)^n \quad (3)$$

$$P_{21} = \left(\frac{1-L_{base}}{1-L_{21}}\right)^n \quad (4)$$

$$P_{22} = \left(\frac{1-L_{base}}{1-L_{22}}\right)^n \quad (5)$$

$$C_{11} = R_{11}(t)*b*P_{11}(t) \quad (6)$$

$$C_{12} = R_{12}(t)*b*P_{12}(t) \quad (7)$$

$$C_{total1}(t) = C_{11} + C_{12} \quad (8)$$

$$C_{21} = R_{21}(t)*b*P_{21}(t) \quad (9)$$

$$C_{22} = R_{22}(t)*b*P_{22}(t) \quad (10)$$

$$C_{total2}(t) = C_{21} + C_{22} \quad (11)$$

$$U_1 >= C_{total1} \quad (12)$$

$$U_2 >= C_{total2} \quad (13)$$

$$N>1 \quad (14)$$

$$N=j \quad (15)$$

$$BC_1 = L_{11} + L_{21} + L_{base} \quad (16)$$

$$BC_2 = L_{12} + L_{22} + L_{base} \quad (17)$$

$$B_1 = BL_1 - BC_1 \quad (18)$$

$$B_2 = BL_2 - BC_2 \quad (19)$$

$$b <= B_1 \quad (20)$$

$$b <= B_2 \quad (21)$$

B. *Modified Model with βj Fixed:*

- Parameters:

C_{ij} : price service class i in link j at time t.
n: the number of links in the path.
i: priority of the service.
Bl_j : bandwidth capacity of link j .
B_j : Total bandwidth capacity available in link j.

.

b: bandwidth user request.

β_i : Quality premium of service class i that has Ii service performance.

R_{ij} (t): cost per Mbs at time t for service class i at link j.

- Variables:

P_{ij} (t): Load factor at time t for service class i at link j.

C_i total (t): Price traversing for the particular path is the sum of the price across all the links on the path

L_{ij} (t): load of service class i at time t for a link j.

I_i: Quality index of class i.

U: budget user.

- Mathematical Formula:

$$MAX\ R = \sum_{j=1}^{2}\sum_{i=1}^{2}(\beta iIi + Rij(t) * b * Pij(t)) \quad (22)$$

Subject to:

Constraints (2)- (22) and additional constraints as follow:

$0<=Ii<=d, d\in\{0,1\}$ (23)

C. Modified 2 with βj Variable:

- Parameters:

C_{ij}: price service class i in link j at time t.

n: the number of links in the path.

i: priority of the service.

Bl_j : bandwidth capacity of link j .

B_j : Total bandwidth capacity available in link j.

b: bandwidth user request.

R_{ij} (t): cost per Mbs at time t for service class i at link j.

- Variables:

Pij(t): load factor at time t for service class i at link j

Cij: price service class i in link j at time t.

Ci total (t): price traversing for particular path is the sum of the price across all the links on the path.

Ii: Quality index of class i.

βi : Quality premium of service class i.

U: budget user

- Mathematical Formula :

Max Objective function (22), subject to Constraints (2)-(21), (23) and additional constraints as follows:

$R_i + \beta_i l_i \geq R_{i-1} + \beta_{i-1} I_{i-1}, i>1$ (24)

$\beta_i \leq \beta_{i-1}, i>1$ (25)

$f \leq \beta_i \leq g, f,g \in [0,1]$ (26)

D. Examining the Solution Report of Original Model and Modification 1 and 2 by LINGO 18.0:

We compared the results of the original model proposed by (18), with the improved 1and 2 modified model, which was added variable Quality premium of service (beta) and Quality of index (i) to notice the difference in profit in each class.

TABLE I. SOLVER STATUS

Solver States	*Original*	*Modified1 (Beta Fixed)*	*Modified2 (Beta Vary)*
Model Class	LP	LP	QP
Status	Global optimal	Global optimal	Local Optimal
Infisibility	0	0	0.13×10^{-5}
Objective	31.2008	31.3528	31.3714
GMU (K)	32	35	37
Elapsed R .T	0	0	0

From table 1 the solution status becomes clear to us, we find that the original model and the first modified are from the linear programming class (LP), with the status of current solutions at the global level, the second modified from the quadratic programming class (QP) with the status of current solutions is local level. The Infeasibility of the original model and the first modified is zero, while in the second modified is 0.13×10^{-5}.

Generated memory (GMU) shows how much of the LINGO model constructor is currently using from memory allocation. In the original model = 32k, modified1=35 k and modified 2 = 37 k Elapsed runtime: The time required to construct and solve the model is equal to zero in all cases.

The objective shows us the objective value of the solution in each model Where we notice that the target in the original model = 31.2008, in the first modified = 31.3528 and in the second modified =31.3714. So we notice that the second modification when beta is variable a achieved highest value is 31.3714.

TABLE II. RESULTS FOR ORIGINAL MODEL ,MODIFIED 1 AND 2 FORMULATIONS WITH, J=2, L=2.

Symbol	*Original*	*Modified1 (Beta Fixed)*	*Modified2 (Beta Vary)*
R1	0.00007	0.00007	0.00007
R2	0.005	0.005	0.005
b	5	5	5
Lbase	3	3	3
L11	40	40	40
L21	25	25	25
L12	30	30	30
L22	20	20	20
P11	1764	1764	1764
P21	729	729	729
P12	1024	1024	1024
P22	484	484	484
C11	0.6174000	0.6254000	0.6176800
C12	0.3584000	0.3664000	0.3586800

Symbol	*Original*	*Modified1 (Beta Fixed)*	*Modified2 (Beta Vary)*
Total1	0.9758000	0.9918000	0.9763600
C21	18.22500	18.24300	18.26000
C22	12.10000	12.11800	12.13500
Total2	30.32500	30.36100	30.39500
U1	0.9758000	0.9918000	0.9763600
U2	30.32500	30.36100	30.39500
BC1	68.00000	68.00000	66
BC2	53.00000	53.00000	53
B1	32	32	32
B2	47	47	47
BETA1	-	0.01	0.00035
B2TA2	-	0.02	0.04
I1	-	0.8	0.8
I2	-	0.9	0.8749836

The solution report shows us that the price of using class 1= 0.0007 /Mbps, and class2=0.005/Mbps. a load of service class1 in link1=40 Mb and class2=25Mb.Also a load of service class1 in link2 = 30 Mb and class2=20 Mb. load base factor=3 Mb, bandwidth user request (b)=5Mb.

The load factor at time 1 for service class1 at link1 (P11) =1764, load factor at time 1 for service class2 at link1 (P21) =729, load factor at time 1 for service class1 at link2 (P12) =1024, load factor at time 1 for service class2 at link1 (P21) =484.

We notice that the consumed bandwidth in the link1(BC1) =68Mb, the available bandwidth for use (B1) =32Mb, while in the second link the consumed bandwidth (BC2) =53Mb and the available bandwidth (B2) =47Mb.

In the original model, the user budget (U1) and total cost of using class1(Total1) in the network are 0.9758000, while the user budget (U2) and total cost of using class2 (Total2) in the network are 30.32500, when adding the quality premium (beta) as a fixed and quality index (i) as a variable in the modification 1, the cost of using class1=0. 0.9918, while in class2 =30.361. a quality index (i) that shows QoS level, in class1 (i1) = 0.8, while the quality index in the class2 (i2) = 0.9. quality premium (beta1) =0.01$ while quality premium (beta2) =0.02$.

In the second modified, when the beta is variable, the cost of the class1= 0.97636, and class2 = 30.395. quality index (i1) = 0.8, (i2) = 0.8749836. quality premium (beta1) = 0.00035$ quality premium (beta2) = 0.04$. From the results we can see that the objective function in the second modification is the best, as it is 31.2008, while in the first modification it is 31.3528, and in the original model it is 31.2008.

V. CONCLUSION

The model illustrates the relationship between network load size and demand volume and how to avoid congestion by increasing the cost of resource use if limited bandwidth size is available. The ISP can adopt a higher rate for using the categories on the network and also choose the first or second modified form. If he wants to recover the cost, then the modified first model is the best, but if he wants to promote a specific service, then the second is the best.

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