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Nonlinear Programming Approach of Wireless Pricing Models

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Abstract- **The pricing for wireless networks is developed to obtain surplus from subscribers. The linearity factors, elasticity price, price factors are discussed. the new approach of wireless pricing model proposed by previous research are approached by considering the model as the nonlinear programming problem that can be solved optimally using LINGO 13.0. The problem is considered to be nonlinear programming that can be solved using optimization tools. The solutions are expected to give some information about the connections between the acceptance factor and the price. The models attempt to maximize the total price for a connection based on QoS parameter. The maximum goal to maximum price is achieved when the provider set the increment of price change due to QoS change and amount of QoS value. The linearity parameter set up for most cases is obtained in ceiling value. Linear price factor ranges between the prescribed value especially cases when we increase the price change due to QoS change and increase the amount of QoS values.**

I. INTRODUCTION

The pricing scheme has been an interesting topic in network business. In supporting this business, the internet should provide best QoS which means that it has to provide the different network based on certain services [1, 2].

The research on internet pricing in multi service network in wired networks [3-6], and multi QoS network and wired networks [7, 8] have been discussed. The results mainly inform about the optimal solution that gives profit to ISP is determined by fixing the base price, quality premium and QoS level.

Recently, the development of wireless networks plays critical role in business life and so the approach can be regarded as optimization problem [9]. The volume discounts as the nonlinear pricing model is one of the tools needed in getting consumer profit. Although in some cases the nonlinear model turns out to be static, the dynamical situation of the models are still developing [10]

Past research focusing on modelling the wireless nonlinear pricing scheme is due to [11]. The pricing for wireless networks is developed to obtain surplus from subscribers. The linearity factors, elasticity price, price factors are discussed. In [10], stated that two part tariff pricing scheme can increase consumer's satisfaction. The simulation results show the connection between acceptance factor with the user price elasticity.

In this paper, the new approach of wireless pricing model proposed by [10, 11] are approached by considering the model as the nonlinear programming problem that can be solved optimally using LINGO 13.0. The problem is considered to be nonlinear programming that can be solved using optimization tools. The solutions are expected to give some information about the connections between the acceptance factor and the price.

II. LITERATURE REVIEW

Table I summarized some of those research.. The pricing models in some part do not really mention about the availability for QoS differentiation.

TABLE I
SEVERAL PAST RESEARCH ON INTERNET PRICING

Pricing Strategy	How it Works
Responsive Pricing [12]	Three stages proposed consist of not using feedback and user adaptation, using the closed-loop feedback and one variation of closed loop form.
Pricing plan [13]	It Combines the flat rate and usage based pricing. Proposed pricing scheme offers the user a choice of flat rate basic service, which provides access to internet at higher QoS, and ISPs can reduce their peak load.
Pricing strategy [1]	Based on economic criteria. They Design proper pricing schemes with quality index yields simple but dynamic formulas'. Possible changes in service pricing and revenue changes can be made
Optimal pricing strategy [14]	The schemes are Flat fee, Pure usage based, Two part tariff. Supplier obtains better profit if chooses one pricing scheme and how much it can charge. Two part of analysis homogenous and heterogeneous.
Paris Metro Pricing [15, 16]	Different service class will have a different price. The scheme makes use of user partition into classes and move to other class it found same service from other class with lower unit price.
Pricing strategy by [17]	Discussion about the measurement of QoS network service performance based on bandwidth, delay and delay jitter, throughput and loss rates.
Strategy of pricing proposed by [18]	Pointed out the importance of multiservice networks such as assisting ISPs in spending their allocations, increasing the effectiveness of network usage by giving incentives to customers, to aid well established market view since new services can gain more sustainability.

Models for internet pricing proposed by [19]	The utility function of a user can be in the form of probability of packet loss, average packet delay, probability of packet tail, delay of maximum packet and also throughput.
Pricing scheme proposed by [20]	Pricing schemes based on QoS levels in different allocations that control congestion and load balance.

Furthermore, the research on dynamic pricing models and wireless design network is summarized in Table II. The research on this pricing has been beginning in last decade and critically improves to fit in dynamical situation in wireless network

TABLE I I

SOME RESEARCH ON DYNAMIC PRICING MODEL

Pricing Strategy	**How it Works**
Pricing for 3G network proposed by [11]	By considering the linearity factor, acceptance factor, elasticity price, the provider able to maximize the price for user and class.
Pricing strategy proposed by [21]	By considering the optimal pricing strategy for specific service as function of time. Their proposed model was created then comparing with the existing approaches available. The models focus on continuous models solved heuristically
Pricing strategy proposed by [22]	the dynamic pricing scheme proposed by setting up the model as a partial differential equation (PDE) and solving it numerically. The pricing scheme proposed mainly for pricing companies. Their work utilizes the PDE background by utilizing necessary and sufficient condition of Lagrange. So by solving the boundary conditions the pricing scheme involving company debt can be calculated.
Social Optimal Pricing by [9]	Pricing strategy that is based on profit maximization of provider. The model is transformed into optimization model.
Simulation method for designing network proposed by [23]	Able to examine the schemes that are not reached by network testing and able to improve model and performance.
Concept of Dynamic pricing introduced by [24]	The process to fluctuate prices between consumer and provider. In market condition, the re -priced can often occur .
Pricing –QoS strategy proposed by [25]	utility function and cost function are proposed, and pricing mechanism is based on QoS service classes.

III. MODEL

Models used in this framework are adapted from [10, 11] but the approach is the nonlinear programming approach. So the model will consist of the objective function to be maximized subject to sets of constraints. Then, the models are solved using LINGO 13.0 software to obtain the optimal solutions. Based on four cases of the model by considering the increment or decrement of price change due to QoS change and increment or decrement of number of QoS needed we can set up the models required.

Basically, the models attempt to maximize the total price for a connection based on QoS parameter. The total price is the summation between basic price for a connection and the price change due to QoS change. We have *i* users and *j* class.

IV. RESULT AND DISCUSSION

The objective of the research is to obtain the revenue for the provider. The model provided by [11] and then work done by [10] are available. But here, we do not approach the method by running the simulation. We create the models by gathering all information about parameter and variables.

So, the objective function will maximize

$$\sum_{j}^{m}\sum_{i}^{n}(PR_{ij} \pm PQ_{ij})$$

which means to maximize the summation of total price that consists of the price for a connection with QoS available and the price change over that QoS. The objective function has limitation to be satisfied to obtain the revenue which is called the sets of the constraints.

The first constraint states that the price change will depends on the factor of the price, that involves the bandwidth as QoS attribute, the basic price at user *i* and class *j*, and also the factor of linearity. Gather all information, we have the sets of the constraints as follow.

$$PQ_{ij} = (1 \pm \frac{x}{2000})PB_{ij}Lx$$

Where PB_{ij} is the basic price for a connection for user *i* and the class *j* and *Lx* is the linearity factor. Then, a_{ij} which defines the linear price factor in user user i and class *j*, the linear factor $(e - e^{-Bx})$ and the traffic load t_l. So,

$$PB_{ij} = a_{ij}(e - e^{-Bx})t_l/100$$

Lx is a linearity factor that depends on the linearity parameters of a and $(e - e^{-Bx})$. Then

$$\mathrm{Lx} = \mathrm{a}(\mathrm{e} - \mathrm{e}^{-\mathrm{Bx}})$$

With *x* is assumed between 0 and 1.

The linear price factor a_{ij} is set up between prescribed values determined by the provide., say *f* and *g*. So,

$$f \le a_{ij} \le g$$

The range of allowed traffic load t_l is also determined by the providers, say *h* and *k*. Then,

$$h \le t_l \le k$$

For *x* as the amount of increment of decrement in QoS value, we range between 0 and 1 implying 0 is in best effort service case while 1 means in perfect service case. B is arranged between 0.8 and 1.07 since in this range, the best network quality occurs [11].

$$0 \leq x \leq 1$$
$$0.8 \leq B \leq 1.07$$

For parameter value PR_{ij}, the provider arrange the value to have a connection. It also happens in a as the linearity parameters that keep the ratio of the price between floor and ceiling of QoS value is not really high.

Next step, for a model described above, the optimal solution for 4 cases involving decrement or increment of price change due to change of QoS and decrement or increment of QoS value is conducted by using LINGO 13.0. Table II and III summarize the solver status for all cases and the decision variables, respectively.

TABLE III

SOLVER STATUS OF NONLINEAR PROGRAMMING MODEL OF WIRELESS PRICING SCHEME

variables	*PQij* increase *x* increase	*PQij* increase *x* decrease	*PQij* decrease *x* increase	*PQij* decrease *x* decrease
Model Class	NLP	NLP	NLP	NLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	6.21523	4.2	-1.8	-1.78477
Infeasibility	$4.4\text{x}10^{-16}$	$1.8\text{x}10^{-7}$	$1.3\text{x}10^{-17}$	0
Iterations	13	11	16	13
GMU	25K	25K	25K	25K
ER	0s	0s	1s	0

In Table III, model class for each class I defined as nonlinear programming, having local optimal state. The highest objective value to maximize the price for each user is achieved when PQ_{ij} increases with increase of *x*. Iterations involve in the highest objective value is the lower or the same value with other case.

Next, in Table IV, the decision variables for 2 users and 2 classes are presented. The price change due to QoS change for each case appears to have roughly the same values approaching to 1. In case of either price change or amount of QoS change increase or decrease, the amount of decrease will be 0.basic price for the highest objective function value got slightly lower value than the case when we increase the price change and the amount of QoS value. The value of linearity parameter *B*, in three cases is the ceiling of the requirement set up for *B*.

TABLE IV

DECISION VARIABLES OF NONLINEAR PROGRAMMING MODEL OF WIRELESS PRICING SCHEME

variables	*PQij* increase *x* increase	*PQij* increase *x* decrease	*PQij* decrease *x* increase	*PQij* decrease *x* decrease
PQ_{11}	1.004	1	1	0.995
PQ_{12}	1.0039	1	1	0.996
PQ_{21}	1.0036	1	1	0.996
PQ_{22}	1.0033	1	1	0.996
x	1	0	0	1
PB_{11}	3.5	0.128	0.04	3.56
PB_{12}	3.3	0.12	0.05	3.32
PB_{21}	3.08	0.11	0.06	3.08
PB_{22}	2.8	0.1	0.06	2.85
a_{11}	0.15	0.15	0.05	0.15
a_{12}	0.14	0.14	0.06	0.14
a_{21}	0.13	0.13	0.07	0.13
a_{22}	0.12	0.12	0.08	0.12
B	1.07	1.07	0.85	1.07

V. CONCLUSION

The maximum goal to maximum price is achieved when the provider set the increment of price change due to QoS change and amount of QoS value. The linearity parameter set up for most cases is obtained in ceiling value. Linear price factor ranges between the prescribed value especially cases when we increase the price change due to QoS change and increase the amount of QoS values.

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