Modification of Wireless Reverse Charging Scheme with Bundling Optimization Issues

Fitri Maya Puspita*
Mathematics Department
Mathematics and Natural Sciences Faculty
Sriwijaya University, South Sumatra Indonesia
*fitrimayapuspita@unsri.ac.id

Ayu Wulandari
Mathematics Department
Mathematics and Natural Sciences Faculty
Sriwijaya University, Indonesia
nailaah952@gmail.com

Evi Yuliza
Mathematics Department
Mathematics and Natural Sciences Faculty
Sriwijaya University, Indonesia
evibc3@yahoo.com

Robinson Sitepu
Mathematics Department
Mathematics and Natural Sciences Faculty
Sriwijaya University, South Sumatra Indonesia
robinsonsitepu14@gmail.com

Yunita
Informatics Department
Faculty of Computer Science
Sriwijaya University, South Sumatra Indonesia
yunita.v1t4@gmail.com

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Abstract— This paper attempts to modify the Internet Reverse Charging (IRC) model by adding a bundling optimization model by considering the Cobb-Douglas utility function to manage homogeneous consumer satisfaction and by using the end-to-end delay QoS attribute. The model formed is expected to achieve maximum revenue for the ISP to maximize ISP profits by minimizing internet usage costs for customers and by providing the best quality information services. Previous research focused only on reverse charging scheme without offering bundling strategy to attract the consumers. In fact, the consumer' choices would be the first priority to be taken in designing the good model. Then, modified model is designed based on the usage-based pricing scheme, that charges the amount of internet access by its usage. The modified model is intended to be designed to show that the improvement in previous model with no use of bundling schemes can reduce the profit the ISP. The step taken for designing is then to be formulated into The Mixed Integer Nonlinear Programming (MINLP) problem by using LINGO 13.0 software. The model is then implemented using bandwidth usage data collected in one of the local server. This issue is divided into two cases, namely the case of α (base price) as a parameter and β(quality premium) as parameters and variables with sub-case PQ_{ij} (cost changes due to QoS changes) decreases in the usage based pricing scheme. The modification results show that maximum revenue for the ISP is obtained in Case 1 (α and β, as parameters) and Case 2 (α as parameter and β variable), which are divided into 2 sub-cases with the same objective value obtained. It means that by setting α and β to be varied when PQ_{ij} decreases, are able to maximize the total cost.

Keywords—*modification of internet reverse charging (IRC) model, Quality of Service (QoS), mixed integer nonlinear programming (MINLP), end –to-end delay, Cobb-Douglas*

I. Introduction

The existence of the internet is very important for life in modern and sophisticated times today. The emergence of the internet is a form of integration between computer technology and communication technology (information technology) which has a large and wide reach and does not limit the time, place, or users. The use of internet technology as a computer network connection for increasing information needs [1] should get serious attention.

In an effort to keep the feasibility of internet services, the service provider of internet or commonly called ISP(Internet Service Provider) competes to provide quality of service (QoS) of the internet that is the best condition in network traffic [2], [3] as well as to maximize its profits [4][5]. Utility functions[6], fixed-cost pricing[7],[8], usage-based pricing[7] with or without subscription fees[9], multiple QoS networks [10], [11] and multi-service networks[12] can generate maximum revenue for ISPs [13] - [14]. Sitepu et al. [15], explained that Cobb-Douglas utility function can be utilized to obtain maximum benefits for the ISP by considering a homogeneous consumer usage-based pricing scheme with monitoring costs and marginal costs.

Internet reverse charging(IRC) is a model that utilizes QoS and user access speed that focuses on network changes that can only be done by one ISP to other ISP' customers so that it does not allow others to charges back the users [16]. This scheme enables the ISP to get benefit from the ISP's own customers [17]. The improved IRC scheme proposed in the study [18] which uses the end-to-end delay QoS attribute with the choice of a base price (α) and premium quality and (β) to be variables can provide the highest profit for the ISP. In a study conducted by [19], IRC was carried out based on internet data usage which focused on changing the use of 3G and 4G networks.

ISPs usually use a bundle pricing strategy to attract customer attention in product marketing [20] and are considered capable of increasing profits for ISPs [21] and minimizing internet usage costs [22]. Bundling will benefit much higher by offering one or more bundles of informational goods than by offering the same goods separately [23].

So, the modified IRC model [18] by adding a bundling problem model [24] and recent study explained on bundling [25] in wired network will be proposed in this design. This model is designed by taking reality that lack of research focusing on modifying the model of IRC to provide consideration for ISPs in obtaining greater benefits by maximizing customer satisfaction levels, minimizing internet usage costs, and making it easier to manage basic costs and premium quality. The modified model will be in form of Mixed Integer Non-Linear Programming (MINLP) model [26]–[28] which is a natural approach in formulating optimization [29] problem to maximize the objective function That mathematical programming designs are seldom discussed in previous research discussing about charging network. There exist research on the utilization of charging network, but the attempt of model as mathematical programming (MINLP) rarely discussed to be applied to optimization problem of reverse charging network. Therefore, this attempt to design the modified model of IRC will be our main contribution to this research.

The design of the improved model is conducted by assigning the models with utilization of 2 cases, namely case 1 (α, base price and β, quality premium as parameters) and case 2 (α as parameter and β as variable) with sub-cases of changes in costs as long as changes in QoS (PQ_{ij}) are considered to be decreasing.

II. Research Method

The data used in this research is bandwidth usage data for evaluating the model designed. Data is shown that model can work in the environment of wireless network. The price scheme used is usage based on the Cobb-Douglas utility function and the QoS attribute used is end-to-end delay. This data is secondary data obtained from the server local in the city of Palembang in early units of bits per second, which is then converted into kilobytes per second (kbps). The data consists of inbound and outbound which are divided into 2 sessions, namely the first session from 07.00 AM to 16.59 PM which is the peak hour data, while the second observer session starts at 17.00 PM to 06.59 AM which is the off-peak hour data. The internet pricing scheme is completed by the LINGO 13.0 software to get the optimal solution. After obtaining the optimal solution for the improved IRC model, we will then compare the results with the model designed in study [18]. Fig. 1 explains the framework of designing the model.

In Fig. 1, the design begins with the previous model of IRC, bundling strategy, utility function used, 3 pricing schemes namely flat fee, usage based and two part tariff schemes and strategy in considering the base price and quality premium to be fixed or varied to complete the ISP' goal in achieving the profit.

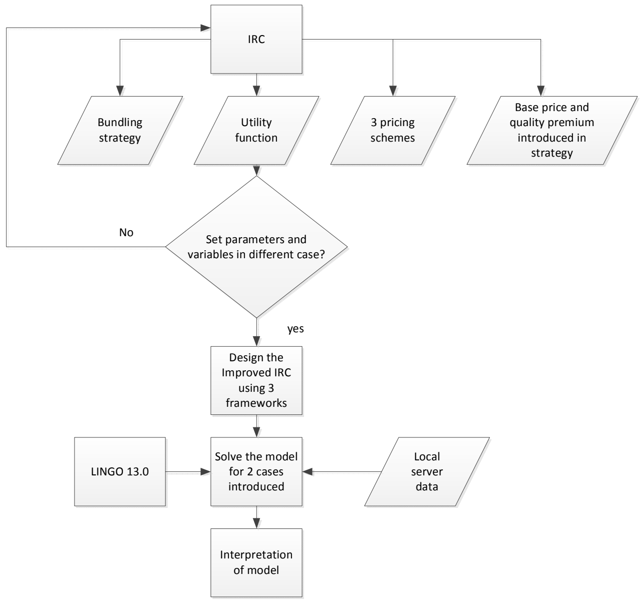

Fig. 1. Framework of Designing Improved IRC Using Bundling Strategy and Pricing Strategy.

III. Result and Analysis

In this section, a modification of IRC model based on the Cobb-Douglas utility function and the QoS end-to-end delay attribute is described for networks in wireless environment in a QoS multi-service network. The description of the IRC wireless network-pricing scheme which is modified with the end-to-end delay QoS attribute and the Cobb-Douglas utility function is described in Table I-III. Table I represents the parameters used for each case in the modification of IRC model and notations required in each case. Table II presents the decision variables used for each case, while Table III has shown the parameter values in the model.

TABLE I. PARAMETERS FOR EACH CASE ON MODIFIED IRC MODEL FOR CASE 1

Par	Case 1: α and β Constants
α	Base price setting for each service
β	Quality premium assigned for each service
C_1	The total capacity contained at peak hours
C_2	The total capacity contained at off-peak hours
PR_{ij}	Cost to in charge with the available QoS
p_{ij}	Service price of user *i* on link *j*
m_i	Minimum number of QoS for services *i*
n_i	Number of service users *i*
d_{ij}	Capacity that is required for service *i* on link *j*
f_i	The range of values ISP has set for a_{ij}
h	The limit of traffic load allowed for T_l
k	The limit of traffic load allowed for T_l
g_i	The range of values the service provider has set for a_{ij}
B_j	Cost in bundling each service *j*
I	The number of potential consumers as a marketing target
J	The number of services the service provider provides
M	Marginal cost if you add more than one service bundle to your menu
V_{ik}	The price of the *i* customer order for each *k*-th favorite service
R_{ij}	The total order price for each *i*th customer on each *k*-th favorite service
P	Costs that will be incurred by consumers for following the service
P_X	Unit price set by the service provider during peak hours
P_Y	Unit price set by the service provider during off-peak hours
$U_{i(X_i,Y_i)}$	Consumer utility function *i* for peak and off-peak consumption levels
$\bar{X}_i$	The highest consumption level of consumer *i* in using the program during peak hour
$\bar{Y}_i$	The highest consumption level of consumer *i* in using the program during off-peak hours

In Case 2 when α as constant and β as a variable based on m_i, n_i, β, parameters, add a parameter I_i as the minimum required base price of the for the service i and b_i as the maximum required base price of the for service i.

In Case 2 when α as constant and β as variable is based on Case 1 decision variable with the exception of I_i and the β_i variable as premium quality for service i.

After determining the parameters and decision variables in each case, the next step is to determine the parameter values used in the model based on the internet usage-based pricing scheme, as shown in Table III.

TABLE II. VARIABLES FOR EACH CASE ON MODIFIED IRC MODEL

Variables	Case 1: α and β Constants
PQ_{ij}	Cost change together with QoS change
x_{ij}	The users number of the service i in link j
PB_{ij}	The fee for a connection with the service i in link j
a_{ij}	Factor of Linear cost in the service i in link j
I_i	The minimum base price required for service i
T_l	Load for Traffic
L_x	Factor to make linear
x	Some of the increase or decrease in the value of QoS
B	Parameter Linear set
P_j	The price assign to the bundle of j goods
S_i	Consumer surplus for customer i
R	Function for income
T_{ij}	The decision variable which is one if consumer i chooses to buy the bundle of j goods, and zero for the otherwise
Y_j	The decision variable, which is one if the vendor chooses to offer the bundle of j goods on the menu, and zero for the otherwise.
Xa_i	Consumer consumption level of service at peak hours
Yb_i	The level of consumer spending on services in off-peak hours
Z_i	Decision variables are worth 1 if consumers choose to join the program and be 0 if do not want to join

TABLE III. VARIOUS QOS PARAMETER VALUES IN MODIFIED IRC MODELS

Parameter	Value
PR_{11}	0.5
PR_{21}	0.6
PR_{12}	0.7
PR_{22}	0.8
p_{11}	15
p_{21}	15
p_{12}	15
p_{22}	15
α	0.1
β	0.5
C_1	350000
C_2	370000
m_1	0.01
m_2	0.01
d_{11}	207530.18677
d_{21}	207530.186
d_{12}	207530.186
d_{22}	207530.186
n_1	10
n_2	10
V_{11}	500
V_{12}	800
V_{21}	600
V_{22}	900
M	200
B_1	300
B_2	500
a	4
b	3
Xa	82641.19873
Yb	48685.84473
I_1	0.01
I_2	0.01

After determining the variables and the parameter values, the next step is that the modified IRC model by adding a bundling optimization model is formulated in order to obtain the internet pricing scheme that can maximize ISP' income. With the number of user (i) is 2 and the number of service (j) chosen is also 2. In this model, it is divided into 2 cases, which have different objective functions according to the cases that have been determined.

A. Case 1: α and β Constants

The two subcases are explained as follows.

Subcases a : PQ_{ij} decreases and x increases

$$\text{Max } R = \sum_{j=1}^{2}\sum_{i=1}^{2}((PR_{ij} - PQ_{ij}) + (\alpha + \beta I_i)\, p_{ij}x_{ij}) + \sum_{i=1}^{3}\sum_{j=1}^{3}(P_j - B_j)T_{ij} - \sum_{j=1}^{3} MY_j \quad (1)$$

Subject to

$I_1 d_{11} x_{11} \leq a_1 C_1$

$I_2 d_{21} x_{21} \leq a_2 C_1$

$I_1 d_{12} x_{12} \leq a_1 C_2$

$I_2 d_{22} x_{22} \leq a_2 C_2$ (1a)

$(I_1 d_{11} x_{11}) + (I_2 d_{21} x_{21}) \leq (a_1 + a_2) C_1$

$(I_1 d_{12} x_{12}) + (I_2 d_{22} x_{22}) \leq (a_1 + a_2) C_2$ (1b)

$a_1 + a_2 = 1$ (1c)

$0.01 \leq I_1 \leq 1$

$0.01 \leq I_2 \leq 1$ (1d)

$0 \leq x_{11} \leq 10$

$0 \leq x_{21} \leq 10$

$0 \leq x_{12} \leq 10$

$0 \leq x_{22} \leq 10$ (1e)

$PQ_{11} = \left(1 + \frac{x}{350}\right) PB_{11} L_x$

$PQ_{21} = \left(1 + \frac{x}{350}\right) PB_{21} L_x$

$PQ_{12} = \left(1 + \frac{x}{350}\right) PB_{12} L_x$

$PQ_{22} = \left(1 + \frac{x}{350}\right) PB_{22} L_x$ (1f)

$PB_{11} = a_{11}(e - e^{-xB}) \frac{T_l}{100}$

$PB_{21} = a_{21}(e - e^{-xB}) \frac{T_l}{100}$

$PB_{12} = a_{12}(e - e^{-xB}) \frac{T_l}{100}$

$PB_{22} = a_{11}(e - e^{-xB}) \frac{T_l}{100}$ (1g)

$Lx = a(e - e^{-xB})$ (1h)

$0.05 \leq a_{11} \leq 0.15$

$0.06 \leq a_{21} \leq 0.14$

$0.07 \leq a_{12} \leq 0.13$

$0.08 \leq a_{22} \leq 0.12$ (1i)

$50 \leq T_l \leq 1000$ (1j)

$0 \leq x \leq 1$ (1k)

$0.8 \leq B \leq 1.07$ (1l)

$a = 1$ (1m)

$S_1 \geq (R_{11} - P_1)Y_1$

$S_1 \geq (R_{12} - P_2)Y_2$

$S_2 \geq (R_{21} - P_1)Y_1$

$S_2 \geq (R_{22} - P_2)Y_2$ (1n)

$S_1 = (R_{11} - P_1)T_{11} + (R_{12} - P_2)T_{12}$

$S_2 = (R_{21} - P_1)T_{21} + (R_{22} - P_2)T_{22}$ (1o)

$(R_{11} - P_1)T_{11} \geq 0$

$(R_{12} - P_2)T_{12} \geq 0$

$(R_{21} - P_1)T_{21} \geq 0$

$(R_{22} - P_2)T_{22} \geq 0$ (1p)

$T_{11} + T_{12} \leq 1$

$T_{21} + T_{22} \leq 1$ (1q)

$T_{11} \leq Y_1$

$T_{21} \leq Y_1$

$T_{12} \leq Y_2$

$T_{22} \leq Y_2$ (1r)

$S_1 \geq 0.1$

$S_2 \geq 0.1$ (1s)

$P_1 \geq 0$

$P_2 \geq 0$ (1t)

$T_{11}, T_{21}, T_{12}, T_{22} \in \{0,1\}$ (1u)
$Y_1, Y_2 \in \{0,1\}$ (1v)
$Xa \leq (82641.19873)\ Z$ (1w)
$Yb \leq (48685.84473)\ Z$ (1x)
$Xa^4 Yb^3 - P_x Xa - P_y Yb - PZ \geq 0$ (1y)
$Z = 1$ (1z)

Then the internet pricing scheme will be called by usage based pricing scheme. Pricing scheme of usage-based coupled with the additional constraints are as follows:

$P_x > 0$
$P_y > 0$
$P = 0$ (2a)

Subcases b when setting up PQ_{ij} decreases with also x decreases with maximizing the Objective function model (1) subject to Eq. (1a) - (1e), Constraints (1g) - (1z) and Constraints (2a) as a pricing scheme and adding constraints as follows:

$PQ_{11} = \left(1 - \frac{x}{350}\right) PB_{11} L_x$
$PQ_{21} = \left(1 - \frac{x}{350}\right) PB_{21} L_x$
$PQ_{12} = \left(1 - \frac{x}{350}\right) PB_{12} L_x$
$PQ_{22} = \left(1 - \frac{x}{350}\right) PB_{22} L_x$ (3a)

Then, the step to get the solution is done by LINGO 13.0 software. The optimal solution is obtained as follows for case 1 (α and β as a Constant) with a usage-based pricing scheme.

In cases α and β as a constants with sub-case 2, the optimal solution is obtained in Table IV. The model used is MINLP with the same objective value, namely IDR 1830.09, which means that the maximum revenue for ISPs is IDR 1830.09 per kbps. The variable values in sub-case 1 and sub-case 2 are the same. The number of service users 2 on link 2 is 10 users, while the number of users on service 1 on link 1 and link 2 is zero, which means there are no users on the link. The traffic load is 50. The level of consumer consumption for peak hour services is 0.8635929/kbps, while the consumption level for non-peak hours services is 0.6476946/kbps. Service providers offer a bundle of services 1 on the menu with customer 1 picks in the service bundle 1 (T_{11}) and choose the bundle in service 2 (T_{12}), while consumers do not choose bundle in services 1 and 2.

B. Case 2: α as constants and β as variable

Subcase a: PQ_{ij} decreases and x increases

Max $R = \sum_{j=1}^{2} \sum_{i=1}^{2} ((PR_{ij} - PQ_{ij}) + (\alpha + \beta_i I_i)\, p_{ij} x_{ij}) + \sum_{i=1}^{3} \sum_{j=1}^{3} (P_j - B_j) T_{ij} - \sum_{j=1}^{3} M\, Y_j$ (4)

Subject to

$\beta_2 0.01 \geq \beta_1 0.01$ (4a)
$0.01 \leq \beta_1 \leq 0.5$
$0.01 \leq \beta_2 \leq 0.5$ (4b)
and Eq.(1a)-(1z), as well as adding Constraints (2a).

For Subcase b when PQ_{ij} increases and x decreases, the objective function is (3) with the aim of maximizing and subject to Eq. (4a) - (4b), Eq. (1a) - (1e), Eq. (1g) - (1z) , Eq. (2a) , and Eq. (3a).

TABLE IV. OPTIMAL SOLUTIONS MODIFIED MODEL WITH BUNDLING SCHEME TO α AND β AS A CONSTANTS WITH USAGE-BASED PRICING SCHEME

Variables	**PQ_{ij} decreases and x increase**	**PQ_{ij} and x decrease**
Model Class	MINLP	MINLP
Obj	1830.09	1830.09
PQ_{11}	0.07381231	0.07381231
PQ_{21}	0.08857477	0.08857477
PQ_{12}	0.1033372	0.1033372
PQ_{22}	0.1180997	0.1180997
x_{11}	0	0
x_{21}	0	0
x_{12}	0	0
x_{22}	10	10
PB_{11}	0.04295705	0.04295705
PB_{21}	0.05154845	0.05154845
PB_{12}	0.06013986	0.06013986
PB_{22}	0.06873127	0.06873127
a_{11}	0.05	0.05
a_{21}	0.06	0.06
a_{12}	0.07	0.07
a_{22}	0.08	0.08
I_1	0.505	0.505
I_2	0.1782873	0.1782873
B	0.935	0.935
T_l	50	50
L_x	1.718282	1.718282
x	0	0
Xa	0.8635929	0.8635929
Yb	0.6476946	0.6476946
P_1	1299.9	1299.9
P_2	1.1	1.1
S_1	0.1	0.1
S_2	200.1	200.1
Z	1	1
T_{11}	1	1
T_{21}	0	0
T_{12}	1	1
T_{22}	0	0
Y_1	1	1
Y_2	0	0

Next, Table V shows the highest values those are achieved when Sub-case a (PQ_{ij} decreases and x increases) and Sub-case b (PQ_{ij} decreases and x decreases) so that the ISP can find out which sub-case has the highest value to achieve profit.

In the case as a constant and as a variable with sub-case 1 and sub-case 2, the optimal solution is obtained in Table V. The model used is MINLP with the same objective value, namely IDR 1817.46, which means that the maximum revenue for ISPs is IDR 1817.46 per kbps. The variable values in sub-case 1 and sub-case 2 are the same. The number of service users 2 on link 2 is 10 users, while the number of users on service 1 on link 1 and link 2 is zero, which means there are no users on the link. The traffic load is 50. The level of consumer consumption for peak hour services is 0.8635928/kbps, while the level of consumer consumption for off-peak services is 0.6476947/kbps. ISP offers a bundle of service 1 on the menu with consumer 1 choosing bundle in service 1 (T_{11}) and choosing bundle in service 2 (T_{12}), while consumer 2 does not choose bundle in service 1 or 2.

Using the same data, the optimal solution of the previous research model [18] is being compared to our model. The highest objective value is obtained from the modified IRC model with the addition of bundling. Thus, this scheme is considered better than the research scheme [18] in order to gain benefits for the ISP.

TABLE V. OPTIMAL SOLUTIONS IRC MODIFIED MODEL OF OPTIMIZATION PROBLEMS BUNDLING ADDITION TO α AS PARAMETER AND β AS VARIABLE WITH USAGE-BASED PRICING SCHEME

Var	PQ_{ij} decreases and x increase	PQ_{ij} and x decrease
Model Class	MINLP	MINLP
Obj	1817.46	1817.46
PQ_{11}	0.07381231	0.07381231
PQ_{21}	0.08857477	0.08857477
PQ_{12}	0.1033372	0.1033372
PQ_{22}	0.1180997	0.1180997
x_{11}	0.5	0.5
x_{21}	0.5	0.5
x_{12}	0	0
x_{22}	0	0
PB_{11}	0	0
PB_{21}	10	10
PB_{12}	0.04295705	0.04295705
PB_{22}	0.05154845	0.05154845
a_{11}	0.06013986	0.06013986
a_{21}	0.06873127	0.06873127
a_{12}	0.05	0.05
a_{22}	0.06	0.06
I_1	0.07	0.07
I_2	0.08	0.08
B	0.935	0.935
T_l	50	50
L_x	1.718282	1.718282
x	0	0
Xa	0.8635928	0.8635928
Yb	0.6476947	0.6476947
P_1	1299.9	1299.9
P_2	0.1	0.1
S_1	0.1	0.1
S_2	200.1	200.1
Z	1	1
T_{11}	1	1
T_{21}	0	0
T_{12}	1	1
T_{22}	0	0
Y_1	1	1
Y_2	0	0

IV. CONCLUDING REMARKS

The modified IRC scheme with the added bundling problem can be used as a consideration for ISP using multiple network links if the end-to-end delay QoS attributes and utility functions for homogeneous consumer satisfaction levels are used. By setting a base price and premium quality that vary or is determined, it is proven to be able to provide maximum revenue for the ISP. In Case 1 and Case 2, which are divided into 2 sub-cases, the same objective value in each case are obtained, meaning that by setting the base price and premium quality to be set or varied in cost changes as long as changes in QoS that are deemed to decrease, then are able to maximize the total cost. to maximize profits for the ISP.

For further research, it is expected that using QoS attributes with different utility functions can be applied to find the best scheme between attributes and customer satisfaction levels.

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