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Research Paper

Improved Multi-Service-Reverse Charging Models for the Multi-link Internet wireless Using Bit Error Rate QoS Attribute

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Abstract
In this article, a improved multi-link internet reverse charging scheme (IRC) model on a multi-service network is proposed. The previous research seldom discussed the reverse charging scheme on multi-link and multi-service network. This pricing scheme is designed with the aim of maximizing internet service provider (ISP) profits. Base costs (α) and the level of service satisfaction (β) provided by the ISP are focused on this attempt. This optimization problem can be solved using LINGO 13.0 software. This problem was made and then was divided into several cases. Thus, the results obtained can be a consideration for ISPs in determining the price of services that can support an ISP. The improved models that produce the maximum solution show the same value as original model previously discussed by previous research, but ISPs reach some goals to be adopted i.e. promote certain class, recover class and have market competition by adopting the improved IRC. Moreover, in improved model when base cost and quality premium as parameter, the analysis of model shows that the objective function is also more feasible than original model.

Keywords
multi-link, multi-service, improved IRC, LINGO 13.0, ISPs

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1. INTRODUCTION

Consumptive to the internet every year is always increasing. This condition is exploited by the Internet Service Provider (ISP) (Petrova, 2003; Wu et al., 2010) to maximize profits by taking into account also the level of customer satisfaction. Internet pricing is a global economic problem. Because of this, ISPs are required to provide appropriate internet cost planning mechanisms so that they can benefit ISPs as service providers and users as internet users.

Some research on the pricing of wireless internet have been discussed. One involvement is for internet pricing schemes that focus on nonlinear wireless network (Wallenius and Hamalainen, 2002). Others are wireless internet pricing schemes on the attributes of QoS of bandwidth, bit error rate (BER), end to end delay (Puspita et al., 2018), wireless internet pricing scheme by applying the improved C-RAN (Cloud Radio Access Network) model (Mostafa and Lampe, 2018) to the QoS attributes. The Internet Reverse Charging (IRC) model (Sprenkels et al., 2000) focuses on changing 3G and 4G (Fagbohun, 2014) when conducting the host. IRC model works for the charging the subscriber who utilizes other network not in his/her own provider.

Some research, in fact rarely discuss how to model wireless internet pricing schemes of reverse charging model for Bandwidth QoS (Eltarjaman et al., 2007) by using IRC models as mathematical programming problem. So far, recently the focus of reverse charging model is in single link network (Puspita et al., 2018).

To obtain results that are in accordance with the real situation on the network, the conditions for more complex modifications for multi-service (Paschalidis and Liu, 2002; Puspita et al., 2014) and multi-link networks (Kántor and Bitó, 2010; Odarchenko et al., 2018; Puspita et al., 2015) are critically needed because in the real network there is not only a single link existed. Based on this situation, it was critical to develop and modify from previous research so that it can be modified using multi-service and multi-link. The numerical example form the data obtained from local server is processed using the LINGO program, by modeling it as Mixed Integer Non-Linear Programming (MINLP) (Benson, 2011; Leyffer et al., 2009; Sitepu et al., 2017). The MINLP model is one of the approaches used to formulate optimization (Bussieck et al., 2003; Kennington et al., 2010; Schrage, 2009)

2. EXPERIMENTAL SECTION

2.1 Data

The data used in this study are secondary data, obtained from a local server in Palembang for one month (February 27, 2019 - March 27, 2019). Data comprises the inbound and outbound data of bandwidth usages for file data traffics like stated in Table 1 as follows.

Table 1. File Data Traffic in One of Local Server in Palembang for February 27, 2019 - March 27, 2019

No.	Date	Traffic (byte/sec) Inbound	Outbound
1	27/2/2019	2,482,687.87	268,149,429.75
2	28/2/2019	12,775,304.92	228,136,046.61
3	1/3/19	12,280,671.23	154,675,682.17
4	2/3/19	8,859,715.13	132,043,814.01
5	3/3/19	38,276,957.40	25,594,601.52
6	4/3/19	10,257,940.56	245,663,287.21
7	5/3/19	13,060,270.04	278,553,499.00
8	6 /3/019	8,311,188.82	146,093,050.35
9	7/3/19	9,360,633.43	273,944,919.83
10	8/3/19	8,656,810.14	395,028,328.99
11	9/3/19	8,580,837.99	24,433,116.49
12	10/3/19	27,350,992.07	17,070,722.75
13	11/3/19	11,137,696.09	363,913,727.14
14	12/3/19	11,054,865.65	105,476,390.54
15	13/3/2019	21,095,996.10	347,348,827.40
16	14/3/2019	45,530,800.63	295,608,550.63
17	15/3/2019	10,326,661.84	126,610,690.74
18	16/3/2019	6,314,701.98	15,694,652.33
19	17/3/2019	15,350,769.46	12,971,124.44
20	18/3/2019	10,410,520.91	54,867,388.75
21	19/3/2019	7,530,557.98	48,273,720.65
22	20/3/2019	12,356,128.78	198,621,622.83
23	21/3/2019	9,988,785.79	144,776,356.35
24	22/3/2019	7,146,314.36	24,651,270.02
25	23/3/2019	10,373,278.29	115,476,190.03
26	24/3/2019	21,872,985.50	5,750,067.80
27	25/3/2019	9,306,907.92	129,884,979.57
28	26/3/2019	10,354,598.49	130,556,557.53
29	27/3/2019	7,876,604.68	18,447,539.66
Demand		388,282,184.05	4,328,316,155.09
Demand kb/sec		287,878.32	

2.2 Methods

Following are the research steps:

1. Data is carried out at Palembang City at the beginning of the semester with non-primary data for one month (February 27, 2019 - March 27, 2019). The data used in the study includes file data traffics.
2. Describe data that has been grouped based on capacity usages.
3. Describe parameter and decision variables used in the Reverse Charging model for bandwidth consumption on the network
4. Determine of the improved IRC model for BER consumption in the network based on four cases.
5. Complete of the solution from in Step 4 using the LINGO 13.0 application software.
6. Analyze the results obtained.

3. RESULTS AND DISCUSSION

3.1 Original Model

Wallenius (2005) divides the model into two cases as in Model (1) as original Model.

Table 2. Solution to Original Model

Solver Status	Case PQ_{ik} and x increase	decrease
Model Class	MINLP	MINLP
State	Local Optimal	Local Optimal
Objective	2.82096×10^{7}	2
Infeasibility	9.31323×10^{-10}	2.74918×10^{-13}
Iterations	17	14
GMU	28K	28K
ER	1s	0s

Table 3. Decision Variable Values for Original Model

Solver Status Variable	Case PQ_{ik} and x increase	decrease
PQ_{11}	6,206,122	0
PQ_{21}	6.770,315	0
PQ_{12}	7,334,508	0
PQ_{22}	7,898,701	0
PB_{11}	2.612801	1.718283×10^{-2}
PB_{12}	2.850328	3.436566×10^{-2}
PB_{21}	3.087855	5.154848×10^{-2}
PB_{22}	3.325383	9.450555×10^{-2}
x	1	1×10^{-6}
Lx	2.375273	1.718283
Tl	1,000	50
B	1.07	0.935
a11	0.11	0.02
a12	0.12	0.04
a21	0.13	0.06
a22	0.14	0.11

$$MaxR = \Sigma_{k=1}^{2}\Sigma_{i=1}^{2}(PR_{ik} \pm PQ_{ik}) \quad (1)$$

Table 4. Parameters for Each Case on Improved IRC Model For α and β are Constants

Parameter	Description
α	The base price each service
β	Premium quality for each service
C	The total capacity contained in the link
PR_{ik}	The cost to connect to the QoS provided
p_{ik}	The price of the service i at the link k
m_i	Minimum QoS for Service i
n_i	The number of users of the service i
d_{ik}	The capacity required to service I at the link k
f_i	Limit values specified for the service provider
h	Limitation of traffic load this is allowed to Tl
k	Limitation of traffic load this is allowed to Tl
g_i	Limit values specified for the service provider

Table 5. Variables for Each Case on Improved Model Reverse Charging

Variable	α and β are constant
PR_{ik}	Cost change along with QoS change
x_{ik}	The number of users of the service i at link k
PB_{ik}	The base fee for the connection with the service i and k link
a_{ik}	Linear cost factor in the service i and link k
I_i	The base price of the minimum required for the service i
T_l	Traffic load
L_x	Linearity factor
x	Some of the increase of decrease in the value of QoS
B	Parameter Linear set

$$MaxR = (PR_{11} + PQ_{11}) + (PR_{21} + PQ_{21}) + (PR_{12} + PQ_{12}) + (PR_{22} + PQ_{22})$$
$$= (0.2 + PQ_{11}) + (0.4 + PQ_{21}) + (0.6 + PQ_{12}) + (0.8 + PQ_{22})$$

Subject to

$$PQ_{11} = (1 + \frac{x}{10^{-6}}) + PB_{11}Lx$$
$$PQ_{21} = (1 + \frac{x}{10^{-6}}) + PB_{21}Lx$$
$$PQ_{12} = (1 + \frac{x}{10^{-6}}) + PB_{12}Lx$$
$$PQ_{22} = (1 + \frac{x}{10^{-6}}) + PB_{22}Lx$$

Table 6. Values Of QoS Parameters In Improved IRC Models

Parameter	Value
The cost of connecting users 1 class 1	0.2
The cost of connecting users 2 class 1	0.4
The cost of connecting users 1 class 2	0.6
The cost of connecting users 2 class 2	0.8
Price of 1 class 1 service user	25
Price of 2 class 1 service user	25
Price of 1 class 2 service user	25
Price of 2 class 2 service user	25
The base price of each service	0.1
Maximum premium quality for service 1 (b_1)	0.5
Maximum premium quality for service 2 (b_2)	0.5
Service index quality 1(I_1)	0.01
Service index quality 2 (I_2)	0.01
The total capacity contained in the class 1(C_1)	400000
The total capacity contained in the class 2(C_2)	450000
Minimum QoS for service 1 (m_1)	0.01
Minimum QoS for service 2 (m_2)	0.01
Number of users of the service 1(n_1)	10
Number of users of the service 2(n_2)	10

$$PB_{11} = a_{11}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{21} = a_{21}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{12} = a_{12}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{21} = a_{21}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{11} = a_{11}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{22} = a_{22}(e - e^{-xB})\frac{T_l}{100}$$

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

$$0.02 \leq a_{11} \leq 0.11$$
$$0.04 \leq a_{21} \leq 0.12$$
$$0.06 \leq a_{12} \leq 0.13$$
$$0.08 \leq a_{22} \leq 0.14$$

$$50 \leq T_l \leq 100$$

$$0 \leq x \leq 1$$

$$0.8 \leq B \leq 1.07$$

where
PR_{ik} : The cost to connect to the QoS provided
PQ_{ik} : Cost change along with QoS change

Table 7. Optimal Solution of Improved IRC when α and β as Parameter

Solver Status	variable Values when α and β as parameter PQ_{ik} x increase	PQ_{ik} ncrease x decrease	PQ_{ik} decrease x increase	PQ_{ik} and x decrease
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	2.82098x10^7	201.499	186.442	186.737
Infeasibility	0	0	0	2.48887x10^{-3}
Iterations	84	79	70	81
		Extended Solver Status		
Solver Type	Branch and Bound	Branch and Bound	Branch and Bound	Branch and Bound
Best Objective	2.82098x10^7	201.499	186.442	186.737
Steps	3	3	3	3
Update Interval	2	2	2	2
GMU (K)	34	34	34	34
ER (Sec)	0	0	0	1

PB_{ik} : The base fee for the connection with the service *i* and *k* link

a_{ik} : Linear cost factor in the service i and link k

T_l : Traffic load

Lx : Linearity factor

x : Some of the increase of decrease in the value of QoS

a, *B* : Parameter Linear set

The optimal solution is achieved when cost change PQ_{ik} and increment in QoS value (x) occur. Next, Table 2 describes the decision variable values for original model.

The variable decision values show that in case 1 the values are higher than in case 2 as Table 3 described.

3.2 Improved model of IRC

The IRC model used in this study is based on the model proposed by Wallenius (2005) and Puspita et al. (2018) . Then, the objective function is as follows.

$$MaxR = \Sigma_{k=1}^{2}\Sigma_{i=1}^{2}((PR_{ik} \pm PQ_{ik}) + (\alpha + \beta I_i)p_{ik}x_{ik}) \qquad (2)$$

Subject to:

$$I_i d_{ik} x_{ik} \leq a_i C$$
$$\Sigma_{i=1}^{2}\Sigma_{k=1}^{2} I_i d_{ik} x_{ik} \leq a_i C$$
$$\Sigma_{i=1}^{2} a_i \leq 1 \leq 1, a_i \epsilon \{0.1\}$$
$$m_i \leq I_i \leq 1, m_i \geq 0$$
$$0 \leq x_{ik} \leq n_i, x_{ik} \geq 0$$

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

$$PB_{ik} = a_{ik}(e - e^{-xB}T_l/100)$$
$$Lx = a(e - e^{-xB})$$
$$f \leq a_{ik} \leq g$$
$$h \leq T_l \leq k$$
$$0 \leq x \leq 1$$
$$0.8 \leq B \leq 1.07$$
$$a = 1$$

The improved model (2) is designed as follows. Since the model is considered for varying or fixing the base cost (α) and quality premium (β) as parameters in proving the contribution of ISP in network, then, the models are divided in to four cases. The model is begun by introducing parameters, variables and parameter values like stated in Table 4-5 as follows.

Based on Table 4, the parameters and variables are introduced including base price, quality premium which were parameters that affect the ISP in whether to adopt the model or not. Table 5 depicts the decision variables used for case 1 if base cost and quality premium are fixed. Table 6 explains the values determined in the network to set up the simulation of the models. When all parameters and variables are set up, then the model designed in Eq. 2 is solved by LINGO 13.0 to obtain the optimal solution. Since the model proposed is Improved IRC, the model extend from original Model (1) to include the base price (α) and premium quality (β) for each service. The reason to extend into added parameter or variables are due to the extension to be able to make close enough to real network that involves ISP goals to achieve higher profit. Then, the model is described as follows.

First, the model is divided into four case four cases, i.e.

1. α and β as parameters
2. α as parameter and β as variable

Table 8. Optimal Solution of Improved IRC when α as Parameter and β as Variable

Solver Status	variable Values when α and β as parameter			
	PQik x increase	PQik increase x decrease	PQik decrease x increase	PQik and x decrease
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	$2.82098x10^7$	174.262	159.205	159.5
Infeasibility	$9.31323 \text{ x } 10^{-10}$	$4.44089 \text{ x } 10^{-16}$	$1.38778 \text{ x } 10^{-7}$	$2.74918 \text{ x } 10^{-13}$
Iterations	48	42	36	43
Extended Solver Status				
Solver Type	Branch and Bound			
Best Objective	2.82098x	174.262	159.205	159.5
Steps	2	2	2	2
Update Interval	2	2	2	2
GMU (K)	35	35	35	35
ER (Sec)	0	0	1	0

3. α and β as variables
4. α as variable and β as parameter

Then, for four model above, the model then subdivided into subcases, i.e.

1. When PQ_{ik} and x increase
2. When PQ_{ik} increases and x decreases
3. When PQ_{ik} and x decrease
4. When PQ_{ik} decreases and x increases

One of the improved models described in detail is when PQ_{ik} and x increase with added value stated in Table 6. Then, subcase 1 will be PQ_{ik} increase and x increase is as follows.

$$MaxR = (0.2 + PQ_{11}) + ((0.1 + 0.5I_1)25x_{11}) + (0.4 + PQ_{21}) +((0.1 + 0.5I_2)25x_{21}) + (0.6 + PQ_{12}) + ((0.1 + 0.5I_1)25x_{12}) +(0.8 + PQ_{22}) + ((0.1 + 0.5I_2)25x_{22})$$

Subject to:

$$I_1 287,878.32x_{11} \leq a_1C_1$$
$$I_2 287,878.32x_{21} \leq a_2C_1$$
$$I_1 287,878.32x_{12} \leq a_1C_2$$
$$I_2 287,878.32x_{22} \leq a_2C_2$$

$$(I_1d_{11}x_{11}) + (I_2d_{21}x_{21}) \leq (a_1 + a_2)C_1$$
$$(I_1d_{12}x_{12}) + (I_2d_{22}x_{22}) \leq (a_1 + a_2)C_2$$

$$a_1 + a_2 = 1$$

$$0.01 \leq I_1 \leq 1$$
$$0.01 \leq I_2 \leq 1$$

$$0 \leq x_{11} \leq 30$$
$$0 \leq x_{21} \leq 30$$
$$0 \leq x_{12} \leq 30$$
$$0 \leq x_{22} \leq 30$$

$$PQ_{11} = (1 + \frac{x}{2000})PB_{11}Lx$$
$$PQ_{21} = (1 + \frac{x}{2000})PB_{21}Lx$$
$$PQ_{12} = (1 + \frac{x}{2000})PB_{12}Lx$$
$$PQ_{22} = (1 + \frac{x}{2000})PB_{22}Lx$$

$$PB_{11} = a_{11}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{21} = a_{21}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{12} = a_{12}(e - e^{-xB})\frac{T_l}{100}$$
$$PB_{22} = a_{22}(e - e^{-xB})\frac{T_l}{100}$$

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

$$0.02 \leq a_{11} \leq 0.11$$
$$0.04 \leq a_{21} \leq 0.12$$
$$0.06 \leq a_{12} \leq 0.13$$
$$0.08 \leq a_{22} \leq 0.14$$

$$50 \leq T_l \leq 1000$$

$$0 \leq x \leq 1$$

Table 9. Optimal Solution of Improved IRC when α and β as Variable

Solver Status	variable Values when α and β as parameter			
	PQ_{ik} x increase	PQ_{ik} ncrease x decrease	PQ_{ik} decrease x increase	PQ_{ik} and x decrease
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	2.82112×10^{7}	1524.26	1509.2	1509.5
Infeasibility	9.31323×10^{-10}	4.44089×10^{-16}	1.38778×10^{-7}	2.74918×10^{-3}
Iterations	50	45	38	46
Extended Solver Status				
Solver Type	Branch and Bound			
Best Objective	2.82112×10^{7}	1524.26	1509.2	1509.5
Steps	2	2	2	2
Update Interval	2	2	2	2
GMU (K)	36	36	36	36
ER (Sec)	0	0	0	0

$$0.8 \le B \le 1.07$$

$$a = 1$$

One of the solution is presented in detail when α and β as parameters and four subcases are also explained as Table 7-10 shown.

When setting up base price and quality premium to be parameter, the objective function values obtained has the same value. It means that the original model and improved IRC can be adopted by the ISP to recover cost by setting up the base price as parameter and quality premium as parameter to enable user in selecting the class.

In Table 8, when ISPs setup base price as parameter to recover cost and quality premium as variable to enable ISPs to promote certain service, the same value for objective function is also has the same value as original model, with some advantages for ISP to recover cost and promote certain service if ISP adopt the improved IRC. In selecting base price and quality premium as variable as Table 9 explained, it occurs that objective function value has the same value as original model. However, the advantage of this improved IRC is in adding the decision for ISPs to be made for choosing base price as variable to have market competition and quality premium as variable to enable ISPs to promote certain service. The results remain the same for the objective value for optimal solution when base price as variable to have market competition and quality premium as parameter to enable user to select class as Table 10 shown. However, ISPs has advantage of being able to have market competition and attract user to subscribe since the ability of the network to have user to choose class in network based on user's preferences.

Therefore, when original model and improved model yield the same value, it means that ISPs is still able to have other option to adopt other models, which have the same objective function values, but attract more users in applying their services. ISPs never go bankrupt as base price can handle to recover cost and users are spoiled by having the chance to select services based on their preferences. In addition, if seeking as further analysis for the solution, it happens when original model yield higher infeasibility in solving the model than improved models (when having α and β as parameter). It means that it has possibility that the original model cannot achieve optimal solution. It is still better to adopt the improved models for subcases 1 due to having invisibility of 0. Finally, the decision to adopt improved model by setting up the base price to recover cost and quality premium to user to select class can be good choice for ISPs.

4. CONCLUSIONS

As the results of improved IRC shown, the four models show the same objective function values as original model, but the added parameter in improved IRC enable ISPs to setup their goals to achieve ISP preferences while in original models.

For further research, the more extension of number of users, link and services are also critically important to have models that are more realistic rather than those models as theoretically explained above. It means that the software included should be able to handle more variables and more constraints.

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Table 10. Optimal Solution of Improved IRC when α as Variable and β as Parameter

Solver Status	variable Values when α and β as parameter PQ_{ik} x increase	PQ_{ik} ncrease x decrease	PQ_{ik} decrease x increase	PQ_{ik} and x decrease
Model Class	MINLP	MINLP	MINLP	MINLP
State	Local Optimal	Local Optimal	Local Optimal	Local Optimal
Objective	2.82112x	1524.26	1509.2	1509.5
Infeasibility	9.31323 x	4.44089 x	1.38778 x	2.74918 x
Iterations	47	42	35	20
Extended Solver Status				
Solver Type	Branch and Bound			
Best Objective	2.82112x	1524.26	1509.2	1509.5
Steps	2	2	2	0
Update Interval	2	2	2	2
GMU (K)	35	35	35	35
ER (Sec)	0	0	0	0

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