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Improved cloud radio access network based fair network model in internet pricing

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ABSTRACT

In this study, the pricing scheme that will be formed is a model from the previous research model involving model of cloud-radio access network (C-RAN) and fair network management models. This model combines the benefits of internet service provider (ISP) and service quality (QoS) obtained by internet users, one of which is fair network factors. The model used is a nonlinear equation and is solved by the LINGO 13.0 program to get the optimal solution. The results show that the pricing scheme with regard to service quality generates maximum revenue for ISPs. Based on the improved C-RAN model that are classified into 2 cases, the optimal results in the improved model, the optimal value is found in the pricing scheme in case 1 of by conducting numerical computation using hotspot traffic from local server.

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1. INTRODUCTION

Internet now a days is every human needs. Internet service providers (ISPs) [1], [2] must attempt the best way to promote their service to encourage customers to use it. Some strategies conducting by ISPs are to minimize costs and maximize profits by designing the customization, bundling, and versioning [3]. The increasing internet users, the greeter the demand for quality of services (QoS) [4]-[8] that is better and different with others. Utility function [5], [9]-[10] as measurement for consumer's satisfaction should also be considered by ISP in determining the pricing scheme. Using utility function appropriately helps ISP in obtaining the right choice in maximizing the profit [11], [12].

Previous research on internet pricing based mathematical programming problem model was initially put forward in optimizing-based networks [13]-[15]. The models begin from pricing scheme-based wired network, then for wireless network, involving bundling strategy and utility function. Cloud-radio access network (C-RAN) scheme is a scheme based on long term evolution (LTE) management [16], [17] that works under a wireless network cloud. C-RAN is a new enhancement in digital technology. Cloud radio computing or C-RAN is part of the cloud [18]-[20] where C-RAN focuses on sending data using a base station that are centralized and then data are connected to a cellular antenna and forward the data to the radio antenna tower.

Fair network management [21]-[23] is one issue dealing with consumption of bandwidth in networks, nowadays. How to divide appropriate networks fairly among users [24] are still big issue for ISP to conduct. One instance when dealing with network utility is addressing multiple resources allocation [9], [25], other is by conduction active queue management (AQM) [24], [26], [27] for increasing network efficiency.

It is a necessity to develop improved model C-RAN-based fair network that is enable to enhance the pricing scheme based C-RAN proposed by ISP in fair networks. Scarce research that focus on determining model as mathematical programming model. The mathematical programming model has some advantages due to its simplicity in looking for solution optimally and ability to identify the parameter and decision variables clearly in the model [28]. Based on criteria stated before, the C-RAN based fair network will be developed.

2. RESEARCH METHOD

The research starts from searching for material and studying material related to C-RAN and fair network models from various literatures. Then, the bandwidth data obtained is processed and divided into 2 categories, namely data during peak hours and data during off-peak hours, and then the data is classified based on average bandwidth usage per day of 10,000 kbps. The modified C-RAN-based fair network model will be solved optimally using the LINGO program. Parameters and variables are used to solve optimization problems based on the model being formed.

The idea of designing the improved model of C-RAN is explained in flowchart as Figure 1 displayed as follows. C-RAN model will be designed by utilizing the fair network that assists users in applying network fairly. The new improved model is designed to give benefit to ISP by regulating fair and proper network based on C-RAN. Improved model will be tested numerically for local data Hotspot 3 and Hotspot 4 in Public University in Palembang.

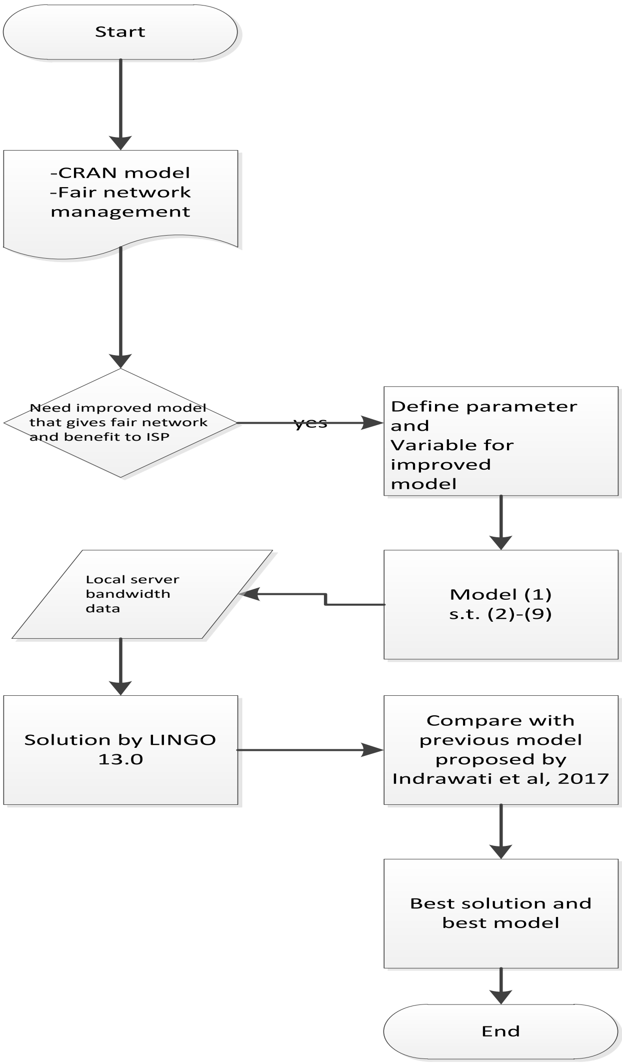

Figure 1. Flowchart of designing new improved C-RAN based on fair network management

3. RESULTS AND ANALYSIS

First step is defining the parameters and variables. Parameters and variables set up based on previous model proposed by [29] followed by fair network proposed by [30]. Table 1 is data processed that is obtained in one of local server. Tables 2-3 explain the parameters and variables, respectively.

Table 1. Internet use during busy and non busy hours

	Use of Hotspot 3 (bytes)	Use of Hotspot 4 (kbps)
$\bar{X}$=$\bar{X}_1$	7105022.145	6938.498188
$\bar{X}_2$	6976692.176	6813.175953
X_m	785924.1665	767.5040688
$\bar{Y}$=$\bar{Y}_1$	7135022.539	6967.795448
$\bar{\bar{Y}}_2$	5442395.93	5314.839775
Y_m	602.4997223	0.588378635

Table 2. The parameters for each improved model

Case 1 : B_0 as a Constanta and P^{M} as a Variable	
B_0	: Determination of bandwidth determined by the ISP
φ_{eff}	: Bandwidth pricing (IDR)
P_c^R	: Bandwidth usage limit during peak hours
P_{bh}	: Limit bandwidth usage during off peak hours
η_R	: The upper limit of QoS
η_{ER}	: The lower limit of QoS
δ_0	: The highest limit of bandwidth usage by the user
P_{max}^R	: Maximum bandwidth transfer
d_n^R	: Total consumption of Maximum and Minimum Bandwidth
$h_{n,k}^R$	: Total daily bandwidth consumption (kbps)
Case 2 : B_0 and P^{M} as Parameters	
B_0	: Determination of bandwidth determined by the ISP
φ_{eff}	: Bandwidth pricing (IDR)
P_c^R	: Bandwidth usage limit during peak hours
P_{bh}	: Limit bandwidth usage during off peak hours
η_R	: The upper limit of QoS
η_{ER}	: The lower limit of QoS
δ_0	: The highest limit of bandwidth usage by the user
P_{max}^R	: Maximum bandwidth transfer
d_n^R	: Total consumption of Maximum and Minimum Bandwidth
$h_{n,k}^R$	: Total daily bandwidth consumption (kbps)
P^M	:Initial bandwidth usage

Table 3. Decision variable for each improved model

Case 1 : B_0 as a Parameter and P^{M} as a Variable	
$a_{n,k}$	: Resource Block (RB) allocation indicator that has a value of 0 or 1
$p_{n,k}$	: Transferring bandwidth from Resource Block (RB) to Remote User Equipment (RUE)
d_k^{R2M}	: Appropriate path loss from Remote Radio Heads (RRH) in Resource Block (RB)
h_k^{R2M}	: Appropriate channel gain from Remote Radio Heads (RRH) on Resource Block (RB)
P^M	: Initial bandwidth usage
d_n^M	: Path loss from Resource Block (RB) to Remote User Equipment (RUE)
$h_{n,k}^M$	: Channel gain from Resource Block (RB) to Remote User Equipment(RUE)
N_0	: Bandwidth usage when not hosting
Case 2 : B_0 dan P^{M} as parameter	
$a_{n,k}$	: Resource Block (RB) allocation indicator that has a value of 0 or 1
$p_{n,k}$	: Transferring bandwidth from Resource Block (RB) to Remote User Equipment (RUE)
d_k^{R2M}	: Appropriate path loss from Remote Radio Heads (RRH) in Resource Block (RB)
h_k^{R2M}	: Appropriate channel gain from Remote Radio Heads (RRH) on Resource Block (RB)
d_n^M	: Path loss from Resource Block (RB) to Remote User Equipment (RUE)
$h_{n,k}^M$	: Channel gain from Resource Block (RB) to Remote User Equipment (RUE)
N_0	: Bandwidth usage when not hosting

Then, our Improved C-RAN based fair network are as follows.

$$\text{Max } \frac{\sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k} B_0 \, log_2\left(1+\sigma_{n,k} p_{n,k}\right) + \left(\sum_{j=1}^{u} x_j\right)^2}{\varphi_{\text{eff}} \sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k} p_{n,k} + P_c^{\text{R}} + P_{\text{bh}} + u \, \sum_{j=1}^{u} x_j{}^2} \tag{1}$$

Subject to:

$$\sum_{n=1}^{N+M} a_{n,k} = 1, a_{n,k} \in \{0,1\}, k = 2 \quad (2)$$

$$\sum_{n=1}^{N} C_{n,k} \geq \eta_{\mathrm{R}}, k \in \Omega_1 \quad (3)$$

$$\sum_{n=N+1}^{N+M} C_{n,k} \geq \eta_{\mathrm{ER}}, k \in \Omega_2 \quad (4)$$

$$\sum_{n=N}^{N+M} a_{n,k} p_{n,k} d_k^{\mathrm{R2M}} h_k^{\mathrm{R2M}} \leq \delta_0 , k \in \Omega_{\mathrm{II}} \quad (5)$$

$$\sum_{n=1}^{N+M} \sum_{k=1}^{K} a_{n,k} p_{n,k} \leq P_{\max}^{\mathrm{R}} , p_{n,k} \geq 0 \quad (6)$$

$$x_j \geq C_j^{min} \quad (7)$$

With,

$$C_{n,k} = a_{n,k} B_0 \log_2\left(1 + \sigma_{n,k} p_{n,k}\right) \quad (8)$$

$$\sigma_{n,k} = \begin{cases} \dfrac{d_n^{\mathrm{R}} h_{n,k}^{\mathrm{R}}}{B_0 N_0}, k \in \Omega_1 \\ \dfrac{d_n^{\mathrm{R}} h_{n,k}^{\mathrm{R}}}{(p^{\mathrm{M}} d_n^{\mathrm{M}} h_{n,k}^{\mathrm{M}} + B_0 N_0)}, k \in \Omega_2 \end{cases} \quad (9)$$

The C-RAN network originally comes from (2)-(6) with added variable of total bandwidth for user j, x_j as model for fair network. The model then will be solved by optimization tool, LINGO 13.0 to obtain the optimal result for optimal revenue gained by ISP. The original model to be compared then, is the model used by Indrawati *et a.l* [29] that has objective to maximize $\frac{\sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k} B_0 \, log_2\left(1+\sigma_{n,k} p_{n,k}\right)}{\varphi_{eff} \sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k} p_{n,k} + P_c^R + P_{bh}}$ with constraint $x_j \geq C_j^{min}$. The parameters for original model is presented in Table 4. The solution of original model is presented in Table 5 while in Tables 6-7, the solutions for improved model proposed applied in different data traffic, which are hotspot 3 and hotspot 4.

Table 4. Parameter values used in indrawati *et al.* [29]

Parameters	Value (kbps)
(B_0)	5000
(φ_{eff})	500
(P_c^R)	4500
(P_{bh})	4000
(η_{R})	128
(η_{ER})	64
(δ_0)	7000
$(P_{\max}^{\mathrm{R}})$	500
(P_m)	150

Table 5. Original model solution

Solver Status	Case	
	1	2
Model Class	MINLP	
State	Global Optimal	
Objective	0.0209997	0.0209989
Infeasibility	0	0
Iterations	8	131
P^M	1.34568	150
Solver Type	Branch and Bound	Branch and Bound
Best Objective	0.209997	0.0209989
Steps	0	0
Update Interval	2	2
GMU (K)	64	64
ER (Sec)	0	2

As Table 5 shows, the objective function of original model shows lower value rather than the improved model. It shows us that both improved model shows better results since involving fair network management. All models are in mixed integer nonlinear programming forms, solved using branch and bound solver as LINGO 13.0 informed. Tables 6-7 show the solution in hotspot 3 and hotspot 4, respectively. Both objective value shows the same value. As Table 8 explained, all decision variables from original and improved models are displayed. However, the comparison between the three models is case 1 in an improved model that uses hotspot 4 data traffic to provide better results in terms of objective function value. Therefore, by setting up bandwidth earned and varied the initial bandwidth, ISP yields higher results of profit, which is IDR 1/kbps.

Table 6. Improved model solutions hotspot 3 Traffic

Solver Status	Case	
	1	2
Model Class	MINLP	MINLP
State	Global Optimal	
Objective	1	1
Infeasibility	0	0
Iterations	11	11
P^M	1.234568	150
Solver Type	Branch and Bound	Branch and Bound
Best Objective	1	1
Steps	0	0
Update Interval	2	2
GMU (K)	66	66
ER (Sec)	0	0

Table 7. Improved model solutions for hotspot 4 traffic

Solver Status	Case	
	1	2
Model Class	MINLP	MINLP
State	Global Optimal	
Objective	1	1
Infeasibility	0	0
Iterations	8	8
P^M	1.234568	150
Solver Type	Branch and Bound	Branch and Bound
Best Objective	1	1
Steps	0	0
Update Interval	2	2
GMU (K)	65	66
ER (Sec)	0	0

Table 8. Variable values for the original model, improved hotspot 3 model, and improved hotspot 4 model

Solver Status	Value					
	Original Model		Improved Model for hotspot 3		Improved Model for hotspot 4	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
a_{11}	0	1	0	0	0	0
a_{12}	0	0	1	1	0	0
a_{13}	1	1	1	1	1	1
a_{21}	0	0	0	0	0	1
a_{22}	0	0	0	0	0	0
a_{23}	1	1	1	1	1	1
a_{33}	1	1	1	1	1	1
a_{34}	1	1	1	1	1	1
a_{35}	1	1	1	1	1	1
a_{36}	1	1	1	1	1	1
a_{41}	0	0	1	1	1	0
a_{42}	1	1	0	0	0	1
a_{43}	1	1	1	1	1	1
a_{44}	1	1	1	1	1	1
a_{45}	1	1	1	1	1	1
a_{46}	1	1	1	1	1	1
a_{51}	1	0	0	0	0	0
a_{53}	1	1	1	1	1	1
a_{54}	1	1	1	1	1	1
a_{55}	1	1	1	1	1	1
a_{56}	1	1	1	1	1	1
a_{62}	0	0	0	0	1	0
a_{63}	1	1	1	1	1	1
a_{64}	1	1	1	1	1	1
a_{65}	1	1	1	1	1	1
a_{66}	1	1	1	1	1	1
P_{11}	1.234568	249.9930	1.234568	1.234568	1.234568	1.234568
P_{12}	1.234568	1.234568	1.234568	376.4537	1.234568	1.234568
P_{13}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{21}	1.234568	1.234568	1.234568	1.234568	1.234568	268.8341
$P_{22}=P_{23}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
$P_{31}=P_{32}=P_{33}=P_{34}=P_{35}=P_{36}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{41}	1.234568	1.234568	1.234568	1.234568	222.5723	1.234568
P_{42}	249.7102	250.0070	1.234568	1.234568	1.234568	231.1659
$P_{43}=P_{44}=P_{45}=P_{46}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{51}	250.2898	1.234568	250.4597	1.234568	1.234568	1.234568
$P_{52}=P_{53}=P_{54}=P_{55}=P_{56}=P_{61}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{62}	1.234568	1.234568	1.234568	1.234568	277.4277	1.234568
P_{63}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{64}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{65}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
P_{66}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
B_0	Parameter	Parameter	Parameter	Parameter	Parameter	Parameter
P^M	1.234568	Parameter	1.234568	Parameter	1.234568	Parameter
D_4^M	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
D_5^M	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
D_6^M	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
$H_{44}^M = \ldots = H_{66}^M$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
d_1^{R2M}	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
$d_2^{R2M}=\ldots=d_6^{R2M}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568
$h_1^{R2M}=\ldots= h_6^{R2M}$	1.234568	1.234568	1.234568	1.234568	1.234568	1.234568

Case 1 of the original model when the B_0 parameter and P^M as a variable obtained, the value of P^M = 1.234568 which means that when searching for an optimal solution, the amount of bandwidth consumption that was first used was 1.234568 kbps. The transfer value bandwidth from RB to RUE P_{42}=250 means the transfer of bandwidth from the fourth RB to the second RUE is 250 kbps. In Case 2 for P_{51}=250.2898 which means for bandwidth transfer from the fifth RB at the first RUE is 250.2898 kbps.

Next, for Case 1 of improved model, when B_0 as parameter and P^{M} as variable then P^{M}=1.234568 which means that in seeking optimal value, the amount of first bandwidth consumption is 1.234568 kbps, Bandwidth transfer value from RB to RUE P_{41} =222.5723 which means that bandwidth transfer from fourth RB in first RUE is 222.5723 kbps.

4. CONCLUSION

Based on the improved C-RAN model, the optimal solution is found in case 1, namely B_0 as a parameter and P^M as a variable with price of IDR 1/kbps, with initial bandwidth usage of 1.234568 kbps. Better solution was achieved when applying improved model compared to original model. This study discusses an improved C-RAN model on the efficiency of bandwidth consumption in internet pricing which was modified into two cases. The optimal results will then be compared based on the optimal solution obtained from each case. For further research, it is recommended to develop a model by calculating optimal results involving fair network traffic management based on flat fee, usage-based, and two-part tariff pricing strategies. These strategies is best strategies that have been chosen by users, now a days.

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