

# Fair Network Optimization with the Cellular Network Traffic Management Model Using Lingo 13.0

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## ABSTRACT

This study aims to analyze the optimal internet pricing scheme model using the Cloud Radio Access Network (C-RAN) model by involving the Fair Network. C-RAN is a centralized radio access network, where the equipment used is connected to a cellular antenna to process signals and send them to the core network. This problem is solved optimally as a Mixed Integer Nonlinear Programming (MINLP) problem. The optimal financing scheme is applied to a local data server, including data hotspot traffic. The C-RAN model is modified into 2 cases and the maximum profit is obtained in case 1. The C-RAN model is formed by establishing initial consumption ( $P^M$ ) and maximum bandwidth consumption ( $B_0$ ). The model was completed with the help of the LINGO program. Based on the analysis that has been done, the results of this study indicate that the C-RAN model can be utilized by the Internet Service Provider (ISP) to produce the maximum solution.

**Keywords:** *Cloud Radio Access Network, Mixed Integer Nonlinear Programming, Fair Network*

## INTRODUCTION

The global telecommunications system that is growing rapidly now has brought people to the world of communication and information technology (information society). People are starting to become aware of the increasingly sophisticated development of communication and information technology. As a telecommunications facility, the use of telecommunications networks and services for daily activities is already a basic necessity [1] for most Indonesian people. The use of telecommunications networks and services is inseparable from the existence of telecommunications operators which are referred to as telecommunications service providers [2]. Everyone needs the internet to get information and to communicate with each other; with the increasing number of internet users, it will also affect the speed of the network itself. Therefore, that between users with each other has a different network speed. The server needs to improve fair between users [3]. ISPs as provider companies must be able to provide the best quality services or Quality of Service (QoS) to users [4-6]. Some research has introduced the notion of fair network [7-10], network optimization [11], resource management in network [12] to seek the possibility to extend some issue in network.

To overcome the above, there are a number of initiatives for architectural design of new cellular networks. Decoupling of uplink and downlink has been well studied over the past few years [13-15] and the pros and cons are discussed in the community. Decoupling from the field of control and data is another topic that is well investigated which is mostly studied in the context of networking-defined networking (SDN) [16, 17]. According to the Cisco Visual Networking Index [18], global cellular data traffic

reaches 2.5 exabytes per month at the end of 2014, and this figure will exceed 24.3 exabytes in 2019. With increasing data traffic on cellular networks, traffic management [15] and maintaining QoS more than ever before is a challenge. Recently, some research have been extensively conducted regarding with Cloud Radio Access Network (C-RAN). C-RAN is a radio access network centrally, where the equipment used is connected to cellular antenna to process the signal and transmit it to core network. Some literatures, recently attempt to solve C-RAN problem optimally using algorithm that combines line search and convex optimization to obtain better performance compared to non-hybrid optimization [19] or as game theory model. On the other hand, the C-RAN model is expected to be one key technology in 4G wireless network development and the future with a pricing scheme proposed. Then, a model involving C-RAN combined with bandwidth efficiency model [20, 21] solved as mathematical modelling problem were designed to seek for best performance both for networks and ISP.

Based on research proposed by Menglang and Jiang [22] modelling of network traffic management is done by using simulation annealing. Based on that issue proposed earlier by past literature, the discussion to solve the network traffic management can also be extended to be solved as mathematical programming problem that can be solved by LINGO 13.0 program as Mixed integer nonlinear programming problem (MINLP) [23-26] for such network traffic management. Such device-driven decision-making mainly focuses on user QoS requirements and is a fully "selfish" decision. Here, we expand traffic management-controlled devices that were designed beforehand to address equity issues, e.g. while users maximize their own interests, networks maintain fairness among users [22] by

utilizing games theory problem such as Nash equilibrium [27].

Therefore, we attempt to contribute new model that consider C-RAN network, in managing the traffic network by utilizing fairness of network combined with the pricing scheme. Scarce research focus on optimization problem-based network traffic management involving bandwidth efficiency model occurred so far. That is why some issues regarding to apply mathematical model of network traffic management as mathematical programming problem will be formulated. This model has benefit to maximize ISP revenue, if ISP agree to adopt since the involvement of fairness of the network, while seeking the user satisfaction to subscribe the network

**RESEARCH METHOD**

The research starts from searching for materials and studying material related qos and network traffic management and fair network. The bandwidth data obtained from local server in Palembang were described to simulate the model.

The model then is designed by making new parameter and variable involvement such as initial consumption (pm) and maximum bandwidth consumption (b0),  $C_j^{min}$  which is the need for qos in this case the minimum throughput received by user j.  $X_j = \sum_i c_{ij}$  means that total throughput received by user j, existing in cran network, traffic management network utilizing fairness network that described previously in past research [20, 22].

Finally, the numerical result will be shown to seek for the computation as minlp [10, 20] optimization model where lingo 13.0 will simulate the results. The analysis will briefly explain the results and advantages of the model designed.

**RESULTS AND DISCUSSION**

The C-RAN model used as an optimization model in this study is based on the model proposed by [28] and then modified by adding the Fair Network variable proposed by [22]. Then, the bandwidth data obtained is processed and divided into 2 categories, namely data during peak hours and data during off peak hours, then the data is classified based on average bandwidth usage per day  $\geq 1000$  kbps.

The modified C-RAN model will be solved optimally using the LINGO program. Parameter, variable used are defines in the next part while the new model designed is as follows. Objective function then can be designed as follows.

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

Subject to

$$\sum_{n=1}^{N+M} a_{n,k} = 1, \quad a_{n,k} \in \{0,1\}, \quad k = 2 \quad (1.1)$$

$$\sum_{n=1}^N C_{n,k} \geq \eta_R, \quad k \in \Omega_1 \quad (1.2)$$

$$\sum_{n=N+1}^{N+M} C_{n,k} \geq \eta_{ER}, \quad k \in \Omega_2 \quad (1.3)$$

$$\sum_{n=N}^{N+M} a_{n,k} p_{n,k} d_k^{R2M} h_k^{R2M} \leq \delta_0, \quad k \in \Omega_{II} \quad (1.4)$$

$$\sum_{n=1}^{N+M} \sum_{k=1}^K a_{n,k} p_{n,k} \leq P_{max}^R, \quad p_{n,k} \geq 0 \quad (1.5)$$

$$x_j \geq C_j^{min} \quad (1.6)$$

where

$$C_{n,k} = a_{n,k} B_0 \log_2(1 + \sigma_{n,k} p_{n,k}) \quad (1.7)$$

$$\sigma_{n,k} = \begin{cases} \frac{d_n^R h_{n,k}^R}{B_0 N_0}, & k \in \Omega_1 \\ \frac{d_n^R h_{n,k}^R}{(P^M a_n^M h_{n,k}^M + B_0 N_0)}, & k \in \Omega_2 \end{cases} \quad (1.8)$$

Then, the parameters used are shown in Table 1. Since the improved model comprises two cases, then the parameter will be divided in 2 cases namely  $B_0$  as parameter and  $P^M$  as variable, and  $B_0$  dan  $P^M$  as parameter.

**Table 1.** Parameter of Each Case

Case 1 : $B_0$ as parameter and $P^M$ as variable	
$B_0$	: Predetermined bandwidth set up by ISP
$\varphi_{eff}$	: Bandwidth price
$P_c^R$	: Bandwidth consumption in office hour
$P_{bh}$	: Bandwidth consumption in non-office hour
$\eta_R$	: QoS upper bound
$\eta_{ER}$	: QoS lower bound

$\delta_0$	: Maximum limit of user bandwidth consumption
$P_{max}^R$	: Maximum bandwidth allocation
$d_n^R$	: Number of maximum and minimum bandwidth consumption
$h_{n,k}^R$	: Number of bandwidth consumption per day (kbps)
<b>Case 2 : <math>B_0</math> dan <math>P^M</math> as parameter</b>	
$B_0$	: Predetermined bandwidth set up by ISP
$\varphi_{eff}$	: Bandwidth price
$P_c^R$	: Bandwidth consumption in office hour
$P_{bh}$	: Bandwidth consumption in non-office hour
$\eta_R$	: QoS upper bound
$\eta_{ER}$	: QoS lower bound
$\delta_0$	: Maximum limit of user bandwidth consumption
$P_{max}^R$	: Maximum bandwidth allocation
$d_n^R$	: Number of maximum and minimum bandwidth consumption
$h_{n,k}^R$	: Number of bandwidth consumption per day (kbps)
$P^M$	: Initial bandwidth consumption

For Table 2, predetermined parameter values are set up. These values are based on the values assumed in the

network and existing in local server data. Table 3 explains the decision variables for the model in each case.

**Table 2.** Predetermined Parameter Value

Parameters	Value (kbps)
$B_0$	5000
$\varphi_{eff}$	500
$P_c^R$	4500
$P_{bh}$	4000
$\eta_R$	128
$\eta_{ER}$	64
$\delta_0$	7000
$P_{max}^R$	500
$P_m$	150

**Table 3.** Variable for each case in the C-RAN Model

Case 1 : $B_0$ as a Parameter and $P^M$ as a Variable	
$a_{n,k}$	: Allocation indicator of Resource Block (RB) having 0 or 1 values.
$p_{n,k}$	: Bandwidth allocation of RB to Remote User Equipment (RUE)
$d_k^{R2M}$	: Suitable path loss of Remote Radio Heads (RRH) in RB
$h_k^{R2M}$	: Suitable Channel gain of RRH in RB
$P^M$	: Initial bandwidth consumption
$d_n^M$	: Path loss of RB to RUE
$h_{n,k}^M$	: Channel gain of RB to RUE
$N_0$	: Bandwidth consumption whenever no hosting
Case 2 : $B_0$ and $P^M$ as a Parameter	
$a_{n,k}$	: Allocation indicator of Resource Block (RB) having 0 or 1 values.
$p_{n,k}$	: Bandwidth allocation of RB to Remote User Equipment (RUE)
$d_k^{R2M}$	: Suitable path loss of Remote Radio Heads (RRH) in RB
$h_k^{R2M}$	: Suitable Channel gain of RRH in RB
$d_n^M$	: Path loss of RB to RUE
$h_{n,k}^M$	: Channel gain of RB to RUE
$N_0$	: Bandwidth consumption whenever no hosting

The proposed model is an optimization problem by maximizing profits, with the help of the LINGO program, numerical example for the following model is obtained.

Case 1 :  $B_0$  as a Parameter and  $P^M$  as a Variable

$$\begin{aligned} \text{Max } & \frac{\sum_{n=1}^{3+3} \sum_{k=1}^2 a_{n,k} B_0 \log_2(1 + \sigma_{n,k} p_{n,k})}{\varphi_{eff} \sum_{n=1}^{3+3} \sum_{k=1}^2 a_{n,k} p_{n,k} + P_c^R + P_{bh}} \\ = & (a_{11} 5000 \log_2(1 + \sigma_{11} p_{11}) \\ & + a_{12} 5000 \log_2(1 + \sigma_{12} p_{12}) \\ & + a_{21} 5000 \log_2(1 + \sigma_{21} p_{21}) \\ & + a_{22} 5000 \log_2(1 + \sigma_{22} p_{22}) \\ & + a_{31} 5000 \log_2(1 + \sigma_{31} p_{31}) \\ & + a_{32} 5000 \log_2(1 + \sigma_{32} p_{32}) \end{aligned}$$

$$\begin{aligned} & + a_{41} 5000 \log_2(1 + \sigma_{41} p_{41}) \\ & + a_{42} 5000 \log_2(1 + \sigma_{42} p_{42}) \\ & + a_{51} 5000 \log_2(1 + \sigma_{51} p_{51}) \\ & + a_{52} 5000 \log_2(1 + \sigma_{52} p_{52}) \\ & + a_{61} 5000 \log_2(1 + \sigma_{61} p_{61}) \\ & + a_{62} 5000 \log_2(1 + \sigma_{62} p_{62}) \\ & + (x_1 + x_2 + x_3)^2 / 500 \\ & ((a_{11} p_{11} + 4500 + 4000) \\ & + (a_{12} p_{12} + 4500 + 4000) \\ & + (a_{21} p_{21} + 4500 + 4000) \\ & + (a_{22} p_{22} + 4500 + 4000) \\ & + (a_{31} p_{31} + 4500 + 4000) \\ & + (a_{32} p_{32} + 4500 + 4000) \end{aligned}$$

$$\begin{aligned}
 &+(a_{41}p_{41} + 4500 + 4000) \\
 &\quad + (a_{42}p_{42} + 4500 \\
 &\quad + 4000) \\
 &+(a_{51}p_{51} + 4500 + 4000) \\
 &\quad + (a_{52}p_{52} + 4500 \\
 &\quad + 4000) \\
 &+(a_{61}p_{61} + 4500 + 4000) \\
 &\quad + (a_{62}p_{62} + 4500 \\
 &\quad + 4000)) + 3(x_1^2 \\
 &\quad + x_2^2 + x_3^2)
 \end{aligned}$$

Based on Constraints (1.1) then

$$a_{11} + a_{21} + a_{31} + a_{41} + a_{51} + a_{61} = 1$$

$$a_{12} + a_{22} + a_{32} + a_{42} + a_{52} + a_{62} = 1$$

Based on Constraints (1.2) then

$$C_{11} + C_{12} \geq 128$$

$$C_{21} + C_{22} \geq 128$$

$$C_{31} + C_{32} \geq 128$$

Based on Constraints (1.2), (1.7) and (1.8) then as follows.

$$\begin{aligned}
 &a_{11}5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(3294,776782)(2681,549783)}{5000N_0} p_{11} \right) \\
 &+ a_{12}5000 \log_2
 \end{aligned}$$

$$\left( 1 + \frac{(3294,776782) (4443,802244)}{5000N_0} p_{12} \right)$$

$$\begin{aligned}
 &+ a_{13}5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(3294,776782) (3306,167067)}{5000N_0} p_{13} \right) \geq 128
 \end{aligned}$$

$$\begin{aligned}
 &a_{21}5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(3285,056531)(3409,394901)}{5000N_0} p_{21} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{22}5000 \log_2 \left( + \frac{(3285,056531) (919,4281926)}{5000N_0} p_{22} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{23}5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(3285,056531) (5292,248906)}{5000N_0} p_{23} \right) \geq 128
 \end{aligned}$$

$$\begin{aligned}
 &a_{31}5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(8,924681448)(240,8648761)}{5000N_0} p_{31} \right)
 \end{aligned}$$

$$+ a_{32}5000 \log_2$$

$$\left( 1 + \frac{(8,924681448) (2873,072649)}{5000N_0} p_{32} \right) + a_{33}5000 \log_2$$

$$\left( 1 + \frac{(8,924681448) (3726,443782)}{5000N_0} p_{33} \right) \geq 128$$

Based on Constraints (1.3) then as follows.

$$C_{41} + C_{42} \geq 64$$

$$C_{51} + C_{52} \geq 64$$

$$C_{61} + C_{62} \geq 64$$

Based on Constraints (1.3), (1.7) and (1.8), the constraint will be as follows.

$$\begin{aligned}
 &a_{44} 5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(1815,349459) (1693,077365)}{(p^M d_4^M h_{44}^M + 5000N_0)} p_{44} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{45} 5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(1815,349459) (519,7592131)}{(p^M d_4^M h_{45}^M + 5000N_0)} p_{45} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{46} 5000 \log_2 \\
 &\quad \left( 1 + \frac{(1815,349459) (4040,194734)}{(p^M d_5^M h_{54}^M + 5000N_0)} p_{46} \right) \geq 64
 \end{aligned}$$

$$\begin{aligned}
 &a_{54} 5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(1177,11349) (3405,32275)}{(p^M d_5^M h_{54}^M + 5000N_0)} p_{54} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{55} 5000 \log_2 \left( 1 \right. \\
 &\quad \left. + \frac{(1177,11349) (2339,481179)}{(p^M d_5^M h_{55}^M + 5000N_0)} p_{55} \right)
 \end{aligned}$$

$$\begin{aligned}
 &+ a_{56} 5000 \log_2 \\
 &\quad \left( 1 + \frac{(1177,11349) (885,3055146)}{(p^M d_5^M h_{56}^M + 5000N_0)} p_{56} \right) \geq 64
 \end{aligned}$$

$$\begin{aligned}
 & a_{64} 5000 \log_2 \left( 1 + \frac{(0,357273478) (428,7911)}{(p^M d_6^M h_{64}^M + 5000N_0)} p_{64} \right) \\
 & + a_{65} 5000 \log_2 \left( 1 + \frac{(0,357273478) (3587,165237)}{(p^M d_6^M h_{65}^M + 5000N_0)} p_{65} \right) \\
 & + a_{66} 5000 \log_2 \left( 1 + \frac{(0,357273478) (935,1141571)}{(p^M d_6^M h_{66}^M + 5000N_0)} p_{66} \right) \geq 64
 \end{aligned}$$

Based on Constraints (1.4) ,then

$$\begin{aligned}
 & a_{31}p_{31} d_1^{R2M} h_1^{R2M} + a_{41}p_{41} d_1^{R2M} h_1^{R2M} + a_{51}p_{51} d_1^{R2M} h_1^{R2M} + a_{61}p_{61} d_1^{R2M} h_1^{R2M} \leq 4500 \\
 & a_{32}p_{32} d_1^{R2M} h_1^{R2M} + a_{42}p_{42} d_1^{R2M} h_1^{R2M} + a_{52}p_{52} d_1^{R2M} h_1^{R2M} + a_{62}p_{62} d_1^{R2M} h_1^{R2M} \leq 4500 \\
 & a_{33}p_{33} d_1^{R2M} h_1^{R2M} + a_{43}p_{43} d_1^{R2M} h_1^{R2M} + a_{53}p_{53} d_1^{R2M} h_1^{R2M} + a_{63}p_{63} d_1^{R2M} h_1^{R2M} \leq 4500 \\
 & a_{34}p_{34} d_1^{R2M} h_1^{R2M} + a_{44}p_{44} d_1^{R2M} h_1^{R2M} + a_{54}p_{54} d_1^{R2M} h_1^{R2M} + a_{64}p_{64} d_1^{R2M} h_1^{R2M} \leq 4500
 \end{aligned}$$

$$\begin{aligned}
 & a_{35}p_{35} d_1^{R2M} h_1^{R2M} + a_{45}p_{45} d_1^{R2M} h_1^{R2M} + a_{55}p_{55} d_1^{R2M} h_1^{R2M} + a_{65}p_{65} d_1^{R2M} h_1^{R2M} \leq 4500 \\
 & a_{36}p_{36} d_1^{R2M} h_1^{R2M} + a_{46}p_{46} d_1^{R2M} h_1^{R2M} + a_{56}p_{56} d_1^{R2M} h_1^{R2M} + a_{66}p_{66} d_1^{R2M} h_1^{R2M} \leq 4500
 \end{aligned}$$

Based on Constraints (1.5) the obtained constraint is as follows.

$$\begin{aligned}
 & a_{11}p_{11} + a_{12}p_{12} + a_{21}p_{21} + a_{22}p_{22} + a_{31}p_{31} + a_{32}p_{32} + a_{41}p_{41} + a_{42}p_{42} + a_{51}p_{51} + a_{52}p_{52} + a_{61}p_{61} + a_{62}p_{62} \leq 500
 \end{aligned}$$

Based on Constraints (1.6) then

$$\begin{aligned}
 x_1 & \geq C_j^{min} \\
 x_2 & \geq C_j^{min} \\
 x_3 & \geq C_j^{min}
 \end{aligned}$$

For case 2 are  $B_0$  and  $P^M$  as a parameter, by adding the value of  $P^M$  as parameters to the LINGO syntax. Then solve the model and the solution is shown.

The original model to be compared is the model used by [5]:

$$\text{Max } \frac{\sum_{n=1}^{N+M} \sum_{k=1}^K a_{n,k} B_0 \log_2(1 + \sigma_{n,k} p_{n,k})}{\varphi_{eff} \sum_{n=1}^{N+M} \sum_{k=1}^K a_{n,k} p_{n,k} + P_C^R + P_{bh}}$$

without the constraint  $x_j \geq C_j^{min}$ .

The solutions of the original models are shown in Table 4.

**Table 4.** Solution from the Original Model Proposed by Indrawati et al [6]

Solver Status	Case 1	Case 2
Model Class	MINLP	MINLP
State	Global Optimal	Global Optimal
Objective	0.0209997	0.0209997
Infeasibility	0	0
Iterations	8	10
$P^M$	1.234568	150

Based on Table 4, the optimal value is obtained in case 1 with an objective value of 0.020997 obtained through 8

iterations with  $P^M$  of 1.234568. Next is the solution from the Improved Model shown in Table 5.

**Table 5.** Solution from the Improved Model

Solver Status	Case 1	Case 2
Model Class	MINLP	MINLP
State	Global Optimal	Global Optimal
Objective	1	1
Infeasibility	0	0
Iterations	11	11
$P^M$	1.234568	150

Based on Table 5, the optimal value is obtained in case 1 with an objective value of 1 obtained through 11 iterations with  $P^M$  of 1.234568. A comparison of solutions from the

original model with the improved model is shown in Table 6.

**Table 6.** Comparison of Original Model and Improved Model Solutions

Model	Original		<i>Improved</i>	
	Case 1	Case 2	Case 1	Case 2
Solver Status	1	2	1	2
Model Class	MINLP	MINLP	MINLP	MINLP
State	Global Optimal			
Objective	0.020999 7	0.020999 7	1	1
Infeasibility	0	0	0	0
Iterations	8	10	11	11
$P^M$	1.234568	150	1.234568	150

Based on Table 6, it is known that the solution to the improved model is more maximum compared to the original model solution even though the iteration is bigger. The initial bandwidth used is all the same value for all case 1. It means that by using case 1, the initial bandwidth used is smaller than for case 2. However, for all improved cases, the better performance are obtained by setting up the fairness parameter and variables into the model which are  $C_j^{min}$  = the need for QoS (in this case the minimum throughput received by user  $j$ ) and  $X_j = \sum_i c_{ij}$  (total throughput received by user  $j$ ).

## CONCLUSION

Based on the calculation of the original model and the improved C-RAN model using the LINGO program, the optimal value is found in the case of 1 improved model where  $B_0$  is constant and  $P^M$  as a variable with an objective value of 1 obtained from 11 iterations. The optimal cost to be paid by the user is Rp. 1 / kbps with the initial use of bandwidth incurred by the ISP of 1.234568 kbps.

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