Science and Technology Indonesia
e-ISSN:2580-4391 *p*-ISSN:2580-4405
Vol. 5, No. 2, April 2020

Research Paper

Selfish User Network Optimization with Cellular Network Traffic Management Model Using Lingo 13.0

Indrawati[1], Fitri Maya Puspita[1]*, Bela Olivia Mareta Silaen[1], Evi Yuliza[1], Oki Dwipurwani[1]

[1]*Mathematics Department, Faculty of Mathematics and Natural Science, University of Sriwijaya, Indralaya, South Sumatera, Indonesia*
***Corresponding author**: fitrimayapuspita@unsri.ac.id

Abstract
This paper discusses the management of traffic of cloud-based cellular networks. Well-designed traffic management will allow network operators to draw maximum value from available resource where cloud-based traffic management is called the UE (User Equipment). Running traffic management on the side of the UE allows decision making in the UE. Users can reach the level of QoS to increase the speed of data received and communication latency so they reduce their power consumption. Each UE maximizes its utility function, which is modeled based on the parameters of QoS, selfishly, at the network side. Therefore, the attempt is to maximize fairness among all users' flows by designing new improved model of traffic management cloud based of pricing internet involving the energy consumption. Also in this paper, quality premium parameter (β) as UE parameter value and base price (α) parameter as range value parameter are used. The results show that the improved model is better than the original one proposed by previous research in terms of maximum value reached although it takes more time for improved model to complete the iterations.

Keywords
5G mobile, QoS,traffic management, User Equipment

Received: 17 December 2019, Accepted: 30 January 2020
https://doi.org/10.26554/sti.2020.5.2.53-58

1. INTRODUCTION

Technological developments in this era are very rapid, especially in the field of communication technology. The high internet users are increasing every year which give a positive impact to the Internet service provider (ISP) (Petrova, 2003; Wu et al., 2010) to develop in each feature internet. ISP are partners or producers who provide internet access or communication and information media services based online. ISP has an extensive network, both domestically and internationally so that its users can connect to global internet networks.

ISP as a provider company should be able to provide the best quality service or Quality of Service (QoS) Audah et al. (2017); DaSilva (2000); Gu et al. (2011); Eltarjaman et al. (2007) to the user. The service price and good quality certainly affect ISP in order to maximize profits. The service should pay attention to the level of satisfaction on the service consumption, utility function (Puspita and Oktaryna, 2017; Sitepu et al., 2017) is associated with the consumption level of satisfaction with the service to achieve maximum profit. The utility function also describes the level of satisfaction in consuming a certain amount of goods or services (Wang and Schulzrinne, 2001). This situation will be replaced automatically by the distance of the user to the main connection. To adjust the price, ISPs must fully understand that the QoS affects the willingness of users to use the product. Therefore, ISPs cannot improve the QoS indefinitely because of limited network resources such as bandwidth, capacity, delay, jitter and utilization (Barth et al., 2004).

QoS is a network mechanism that allows applications or services to operate as expected. QoS is an efficient way to share internet bandwidth on computer networks with the promised quality of internet services (Bouras and Sevasti, 2004; Byun and Chatterjee, 2004). In this case, network architecture has been listed as a solution to address QoS problems for users. To achieve a level of satisfaction with cellular network traffic management, users can reach the level of QoS as desired, namely increasing the speed of data received and communication latency or reducing their power consumption. In this model, the UE can communicate with the Network Discovery and Selection Function (ANDSF) Access Server (Jiang and Mahmoodi, 2016).

To this end, the attempt to design improved model that enhances the selfishness of the user in traffic network management is critically needed. Few research exist in terms of pricing scheme focused on selfishness of users and C-RAN model (Indrawati et al., 2017, 2019). Previous research on selfish users also are found in some literature involving network routing problem

(Barth et al., 2005; Qiu et al., 2006; Roughgarden, 2001; Sandeep and Nuggehalli, 2006) and a bit more of statistical simulation to show the computation and never explain how pricing schemes have effects on networks (Puspita et al., 2014; Puspita and Oktaryna, 2017). That is the important issue to be explored more to how to create such mathematical formulation. The improved model proposed is to maximize the revenue of ISP by regarding the user' satisfaction. in this traffic management, the EU aims to maximize QoE (quality of experience) (Liotou et al., 2016; Reichl et al., 2015) . QoE as a utility function (Harks and Poschwatta, 2005; Kuo and Liao, 2005; La and Anantharam, 2002) based on the throughput received (Tsiaflakis et al., 2012; Varade et al., 2018) and consumed by energy.

2. EXPERIMENTAL SECTION

In this section, the improved model is solved by retrieving internet user data on a local server with internet usage for a month in certain hours. The data will be divided into three sections according to time usage for network daily. In this model, 6-hour division of time is used. The assumption will be 06.00-11.59, 12.00-17, 18.00-23.59, 24.00-05.59 West Indonesian Time. Because the original data uses units of bits per second, then changes all of the data into units of bytes per second is needed. Data consist of bandwidth usage in one of the hotspot area in local server in Palembang for one month.

After that, the total amount of data is in accordance with the division of time is calculated, and also the average throughput. The average value of the throughput will be used in the selfish users' formula. In this method, the battery energy is obtained from the formula that has been determined with the parameter values that have been assumed previously in previous research (Jiang and Mahmoodi, 2016). This energy value applies to all average values of throughput according to the time division. The improved formulation set up to seek for the satisfaction of the users who apply the network. Therefore, it must meet the requirement that energy consumption must be less or equal to the probability value or the residual value of energy consumption based on C-RAN that utilizes the 4G and 5G wireless network development in the future.

3. RESULTS AND DISCUSSION

The parameter and variable used in designing the improved model involving pricing scheme, traffic management based C-RAN are defined in Table 1 and Table 2 as follows.

Then the original formulation of this model is as follows (Indrawati et al., 2017) as follows.

$$Max\Omega = \frac{[\Sigma_i C_i j]^{w1} + [\Sigma_i E_i j]^{w2}}{\Sigma_i C_i j + \Sigma_i E_i j} \quad (1)$$

Subject to $\Sigma_i E_{ij} \leqslant P_j$

$$i = \{1, 2\} \quad (2)$$

Because Σ_i, so that only network i increases and j is an user. (j = 1,2). In this model i dan j are limited to the following conditions : i = 1,2 and j = 1,2.

Table 1. Parameters Used for Traffic Management 5G with Selfish Users

Parameter	Description
T	Time spent on this model (T = 120 minutes = 2 hours)
π	phi (π = 3.14)
B	Consumption of energy parameter values that vary from 0.4 − 1 where B=0.5
E	Basis of natural logarithm(e = 2.71)
D	Consumption of device energy bandwidth rations when connected. In this model the bandwidth allocation is limited to 10 Mb where 1 Mb = 10,240 Kb
H	Energy consumption per unit distance in 6 hours
N	Coefficient of propagation, $n = e = 2.71$

Table 2. Variables Used for Traffic Management 5G with Selfish Users

Variable	Description
ζ(T)	Energy usage level
E	Device energy
Ω	Utility function are based on the throughput received and consumed
C_{ij} and E_{ij}	The value of throughput and energy consumed by network i=1, 2 and users j =1,2
w_1 and w_2	Weight value
P	The remaining energy

If the general formula are in terms of i and j then the formulation will become as follows.

$$\Omega = \frac{[C_{11} + C_{21}]^{W1} + [E_{11} + E_{21}]^{W2}}{C_{11} + C_{21} + E_{11} + E_{21}} \quad (3)$$

Subject to

$E_{11} + E_{21} \leqslant P_1$

$$i = \{1, 2\} \quad (4)$$

Then Table 3 provides the information of parameter used for improved model for 5G traffic management with C-RAN while Table 4 provides the variables decided, respectively.

Based on the hotspot traffic data on local server and the parameter provisions in Table 4 , the establishment of an internet pricing scheme model in this model was modified to be 4 cases with the terms of initial usage and the amount of bandwidth consumption that has been determined.

The models are classified into two cases which is Model in Case 1 B_0 as a Parameter and P^M as a variable and B_0 and P^M as parameter. This is due to fact that bandwidth can be earned by ISP or bandwidth can be setup by ISP to control the network.

Table 3. Parameters Used for Traffic Management 5G with C- RAN

Parameter	Description
B_0	Determination of bandwidth usage that has been determined by the ISP
φ_{eff}	Determined bandwidth price (IDR)
P_C^R	Limit bandwidth usage during peak hours
P_{bh}	Limit bandwidth usage during off-peak hours
η_R	The upper limit of QoS
η_{ER}	QoS Lower Limit
δ_0	The highest bandwidth usage limit by the user
P_{max}^R	Maximum bandwidth transfer
d_n^R	Total consumption of Maximum and Minimum bandwidth (kbps)
$h_{n,k}^R$	Total daily bandwidth consumption (kbps)
P^M	Initial use of bandwidth
$a_{n,k}$	Resource Block (RB) allocation indicator which has a value of 0 or 1
$p_{n,k}$	Transfer of bandwidth from Resource Block (RB) to Remote User Equipment (RUE)
d_k^{R2M}	The appropriate path loss from Remote Radio Heads (RRH) on Resource Block (RB)
h_k^{R2M}	Appropriate channel gain from Remote Radio Heads (RRH) on Resource Block (RB)
d_n^M	Path loss from RB to Remote User Equipment (RUE)
$h_{n,k}^M$	Channel gain from RB to Remote User Equipment (RUE)
N_0	Bandwidth usage when not hosting
N	The use of Remote User Equipment (RUE) on the Remote Radio Heads (RRH)
M	The use of Remote User Equipment (RUE) of Resources Block (RB)
K	Server usage for Resource Block (RB) is selected as much
Ω_1	Allocation of Remote User Equipment (RUE) to the upper limit QoS
Ω_2	Remote User Equipment (RUE) allocation towards the lower limit QoS
Ω_{II}	The allocation of Remote User Equipment (RUE) to Resources Block (RB)

Table 4. The Value of Parameters Used for Traffic Management 5G with C-RAN

Parameter	Value (kpbs)
Bandwidth (B_0)	5000
Efficiency of the power amplifier (φ_{eff})	500
Circuit bandwidth (P_C^R)	4500
Consumption of bandwidth from fronthaul links (P_{bh})	4000
Upper limit of QoS (η_R)	128
Lower limit of QoS (η_{ER})	64
Predetermined limits (δ_0)	4500
Maximum bandwidth transfer (P_{max}^R)	500
Initial bandwidth usage (P_M)	150

The improved model wants to maximize the profit based on optimal usage of bandwidth from links, QoS, and energy efficiency stated in CRAN management while also utilize the level of energy usage, energy of device, utility function in measuring the user' satisfaction and energy resources, as parts of selfish user management in 5G network.

Then, our improved model to maximize the bandwidth consumption as the profit gained by ISP as stated in Eq. (5) as follows.

$$\frac{\sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{(n,k)} B_0 \log_2(1+\sigma_{n,k}P_{n,k}) + [x_{11}+x_{21}]^{W_1} + [y_{11}+y_{21}]^{W_2}}{\varphi eff \sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k}P_{n,k} + P_c^R + P_{(bh)} + x_{11} + x_{12} + y_{11} + y_{21}} \tag{5}$$

The variation will be Case 1: B_0 as a Parameter and P^M as a variable, then the improved model will be as follows.

$$\begin{aligned}
\text{Max } & \frac{\sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k} B_0 \log_2(1+\sigma_{n,k}p_{n,k}) + [x_{11}+x_{21}]^{W_1} + [y_{11}+y_{21}]^{W_2}}{\varphi_{eff}\sum_{n=1}^{N+M}\sum_{k=1}^{K} a_{n,k}p_{n,k} + P_c^R + P_{bh} + x_{11} + x_{21} + y_{11} + y_{21}} \\
= & (a_{11}5000\log_2(1+\sigma_{11}p_{11}) + a_{12}5000\log_2(1+\sigma_{12}p_{12}) \\
& + a_{21}5000\log_2(1+\sigma_{21}p_{21}) + a_{22}5000\log_2(1+\sigma_{22}p_{22}) \\
& + a_{31}5000\log_2(1+\sigma_{31}p_{31}) + a_{32}5000\log_2(1+\sigma_{32}p_{32}) \\
& + a_{41}5000\log_2(1+\sigma_{41}p_{41}) + a_{42}\,5000\log_2(1+\sigma_{42}p_{42}) \\
& + a_{51}\,5000\log_2(1+\sigma_{51}p_{51}) + a_{52}5000\log_2(1+\sigma_{52}p_{52}) \\
& + a_{61}\,5000\log_2(1+\sigma_{61}p_{61}) + a_{62}5000\log_2(1+\sigma_{62}p_{62})) + [x_{11}+x_{21}]^1 + [y_{11}+ \\
& y_{21}]^2 / \\
& 500((a_{11}\,p_{11} + 4500 + 4000) + (a_{12}\,p_{12} + 4500 + 4000) \\
& +(a_{21}\,p_{21} + 4500 + 4000) + (a_{22}\,p_{22} + 4500 + 4000) \\
& +(a_{31}\,p_{31} + 4500 + 4000) + (a_{32}\,p_{32} + 4500 + 4000) \\
& +(a_{41}\,p_{41} + 4500 + 4000) + (a_{42}\,p_{42} + 4500 + 4000) \\
& +(a_{51}\,p_{51} + 4500 + 4000) + (a_{52}\,p_{52} + 4500 + 4000) \\
& +(a_{61}\,p_{61} + 4500 + 4000) + (a_{62}\,p_{62} + 4500 + 4000)) + x_{11} + x_{21} + y_{11} + y_{21}
\end{aligned}$$

Based on Constraints stated that Resource Block (RB) allocation indicator which has a value of 0 or 1 then

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

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

With the constraints that explain the value of throughput needed should exceed the upper limit QoS, then

$C_{11} + C_{12} \geqslant 128$
$C_{21} + C_{22} \geqslant 128$
$C_{31} + C_{32} \geqslant 128$

To find the value of $C_{n,k}$ then, the formulation needed is as follows.

$$a_{11} 5000 \log_2\left(1+\frac{(26033190{,}74)\,(1932156{,}54)}{5000N_0}p_{11}\right) + a_{12}\, 5000 \log_2\left(1+\frac{(26033190{,}74)\,(68338{,}04)}{5000N_0}p_{12}\right) + a_{13}\, 5000 \log_2\left(1+\frac{(26033190{,}74)\,(10468{,}10)}{5000N_0}\,p_{13}\right) \geq 128$$

$$a_{21} 5000 \log_2\left(1+\frac{(12201846{,}44)\,(84{,}20)}{5000N_0}\,p_{21}\right) + a_{22} 5000 \log_2\left(1+\frac{(12201846{,}44)\;(84{,}49)}{5000N_0}\,p_{22}\right) + a_{23} 5000 \log_2\left(1+\frac{(12201846{,}44)\,(322089{,}23)}{5000N_0}\,p_{32}\right) \geq 128$$

$$a_{31} 5000 \log_2\left(1+\frac{(4293829{,}27)\,(141170{,}53)}{5000N_0}\,p_{31}\right) + a_{32} 5000 \log_2\left(1+\frac{(4293829{,}27)\;(155594{,}89)}{5000N_0}\,p_{32}\right) + a_{33} 5000 \log_2\left(1+\frac{(4293829{,}27)\,(85{,}26)}{5000N_0}\,p_{33}\right) \geq 128$$

For other network, then

$C_{41} + C_{42} \geqslant 64$
$C_{51} + C_{52} \geqslant 64$
$C_{61} + C_{62} \geqslant 64$

To find the value of $C_{n,k}$ then, the formulation needed for user 2 is as follows.

$$a_{44}\, 5000 \log_2\left(1+\frac{(2953653{,}97)\,(96816{,}98)}{(P^{M}d_4^{M}h_{44}^{M}+5000N_0)}\,p_{44}\right) + a_{45}\, 5000 \log_2\left(1+\frac{(2953653{,}97)\,(104633{,}35)}{(P^{M}d_4^{M}h_{45}^{M}+5000N_0)}\,p_{45}\right) + a_{46}\, 5000 \log_2\left(1+\frac{(2953653{,}97)\,(154012{,}39)}{(P^{M}d_4^{M}h_{46}^{M}+5000N_0)}\,p_{46}\right) \geq 64$$

$$a_{54}\, 5000 \log_2\left(1+\frac{(25411{,}55)\,(134467{,}09)}{(P^{M}d_5^{M}h_{54}^{M}+5000N_0)}\,p_{54}\right) + a_{55}\, 5000 \log_2\left(1+\frac{(25411{,}55)(32193{,}91)}{(P^{M}d_5^{M}h_{55}^{M}+5000N_0)}\,p_{55}\right) + a_{56}\, 5000 \log_2\left(1+\frac{(25411{,}55)\,(84{,}21)}{(P^{M}d_5^{M}h_{56}^{M}+5000N_0)}\,p_{56}\right) \geq 64$$

$$a_{64}\, 5000 \log_2\left(1+\frac{(5427{,}95)\,(84{,}29)}{(P^{M}d_6^{M}h_{64}^{M}+5000N_0)}\,p_{64}\right) + a_{65}\, 5000 \log_2\left(1+\frac{(5427{,}95)\,(169543{,}91)}{(P^{M}d_6^{M}h_{65}^{M}+5000N_0)}\,p_{65}\right) + a_{66}\, 5000 \log_2\left(1+\frac{(5427{,}95)\,(76304{,}32)}{(P^{M}d_6^{M}h_{66}^{M}+5000N_0)}\,p_{66}\right) \geq 64$$

Based on Constraints stated that $\sum_{n=N}^{N+M} a_{(n,k)} P_{(n,k)} d_k^{R2M}\, h_k^{R2M} \leqslant \sigma_0, k\epsilon\Omega_{II}$ then

$$a_{31}\, p_{31}\, d_1^{R2M}\, h_1^{R2M} + a_{41}\, p_{41}\, d_1^{R2M}\, h_1^{R2M} + a_{51}\, p_{51}\, d_1^{R2M}\, h_1^{R2M} + a_{61}\, p_{61}\, d_1^{R2M}\, h_1^{R2M} \leq 4500$$

$$a_{32}\, p_{32}\, d_1^{R2M}\, h_1^{R2M} + a_{42}\, p_{42}\, d_1^{R2M}\, h_1^{R2M} + a_{52}\, p_{52} d_1^{R2M} h_1^{R2M} + a_{62}\, p_{62} d_1^{R2M} h_1^{R2M} \leq 4500$$

$$a_{33}\, p_{33}\, d_1^{R2M}\, h_1^{R2M} + a_{43}\, p_{43} d_1^{R2M} h_1^{R2M} + a_{53}\, p_{53}\, d_1^{R2M}\, h_1^{R2M} + a_{63}\, p_{63}\, d_1^{R2M}\, h_1^{R2M} \leq 4500$$

$$a_{34}\, p_{34}\, d_1^{R2M}\, h_1^{R2M} + a_{44}\, p_{44}\, d_1^{R2M}\, h_1^{R2M} + a_{54}\, p_{54}\, d_1^{R2M}\, h_1^{R2M} + a_{64}\, p_{64}\, d_1^{R2M} h_1^{R2M} \leq 4500$$

$$a_{35}\, p_{35}\, d_1^{R2M}\, h_1^{R2M} + a_{45}\, p_{45}\, d_1^{R2M} h_1^{R2M} + a_{55}\, p_{55}\, d_1^{R2M} h_1^{R2M} + a_{65}\, p_{65}\, d_1^{R2M} h_1^{R2M} \leq 4500$$

$$a_{36}\, p_{36}\, d_1^{R2M}\, h_1^{R2M} + a_{46}\, p_{46} d_1^{R2M} h_1^{R2M} + a_{56}\, p_{56}\, d_1^{R2M}\, h_1^{R2M} + a_{66}\, p_{66}\, d_1^{R2M}\, h_1^{R2M} \leq 4500$$

Constraint $\sum_{n=1}^{N+M} \sum_{k=1}^{K} a_{(n,k)} \leqslant P_{max}^{R}, p_{(n,k)} \geqslant 0$ stated that

$$a_{11}p_{11} + a_{12}p_{12} + a_{21}p_{21} + a_{22}p_{22} + a_{31}p_{31} + a_{31}p_{31} +$$

$$a_{41}p_{41} + a_{42}p_{42} + a_{51}p_{51} + a_{52}p_{52} + a_{61}p_{61} + a_{16}p_{16} \leqslant 500$$

The solution of original model proposed by Indrawati et al. (2017) that describe 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 $\Sigma_i\, E_{ij} \leqslant P_j$ as the energy consumed cannot exceed the remaining energy, is explained in Table 5. Our improved models are displayed in the Table 6. Since the model is in form of mixed integer nonlinear programming, then LINGO 13.0 can be utilized to obtain the solution.

Table 5. Solutions from the Original Model Proposed by Indrawati et al. (2017)

Solver Status	Value 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 5 , the optimal value is obtained in case 1 with an objective value of 0.0209997 IDR obtained through 8 iterations with P^{M} of 1.234568. Next is the solution from the improved model shown in Table 6 .

Based on Table 6 , The optimal value is obtained in case 1 with an objective value of 1.00 IDR obtained through iterations with P^{M} of 1.234568. A comparison of solutions from the original model with the improved model shown in Table 7 .

Based on Table 7, it is known that the solution to the improved model has the higher maximum value compared to the original model. The initial bandwidth use is all the same value for

Table 6. Solutions from the Improved Model

Solver Status	Value	
	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

Table 7. Comparison of Original Model and Improved Model Solutions

Solver Status	Value			
	Original		Improved	
	Case 1	Case 2	Case 1	Case 2
Model Class	MINLP	MINLP	MINLP	MINLP
State		Global Optimal		
Objective	0.02099	0.02099	1	1
Infeasibility	0	0	0	0
Iterations	8	10	11	11
P^M	1.234568	150	1.234568	150

all case. Case 1 show that initial bandwidth used is smaller than for case 2. The better performance are obtained by setting up the selfish users parameter and variables into the model which are P_j is need for QoS (as a user j) and $\Sigma_i E_{ij}$ (consumed energy by user j).

4. CONCLUSIONS

Based on the above calculation from the two methods used it can be concluded that the level of user satisfaction with internet services can be achieved from the user for 1.00 IDR; per byte every time when assess the internet. The improved model shown better value than the original model through the number of iterations involved.

Though the improved shown some progress in calculating the profit for ISP with some facts of new parameter and variables involved, the theoretical point of view is still recognized. That is why, for future work, the real network can be enhance to have better results.

5. ACKNOWLEDGEMENT

This research is supported by Sriwijaya University through Unggulan Kompetitif Research Grant Scheme, year 2019.

REFERENCES

Audah, L., Z. Sun, and H. Cruickshank (2017). QoS based admission control using multipath scheduler for IP over satellite networks. *International Journal of Electrical and Computer Engineering (IJECE)*, **7**(6); 2958–2969

Barth, D., L. Blin, L. Echabbi, and S. Vial (2005). Distributed cost management in a selfish multi-operators BGP network. In *Next Generation Internet Networks, 2005*. IEEE, pages 24–30

Barth, D., K. Deschinkel, M. Diallo, and L. Echabbi (2004). Pricing, QoS and Utility models for the Internet. *Rapport de recherche interne*, **60**

Bouras, C. and A. Sevasti (2004). SLA-based QoS pricing in DiffServ networks. *Computer Communications*, **27**(18); 1868–1880

Byun, J. and S. Chatterjee (2004). A strategic pricing for quality of service (QoS) network business. *AMCIS 2004 Proceedings*; 306

DaSilva, L. A. (2000). Pricing for QoS-enabled networks: A survey. *IEEE Communications Surveys & Tutorials*, **3**(2); 2–8

Eltarjaman, W., M. Ashibani, B. El-Jabu, and P. Box (2007). Towards optimized QoS based–charging model. In *Southern African Telecommunication Networks and Applications Conference (SATNAC 2007). Sugar Beach Resort, Mauritius*

Gu, C., S. Zhuang, and Y. Sun (2011). Pricing Incentive Mechanism based on Multi-stages Traffic Classification Methodology for QoS-enabled Networks. *Journal of Networks*, **6**(1); 163

Harks, T. and T. Poschwatta (2005). Priority pricing in utility fair networks. In *13TH IEEE International Conference on Network Protocols (ICNP'05)*. IEEE, pages 10–pp

Indrawati, F. M. Puspita, Affriyanti, Y. E. Putri, E. Yuliza, and O. Dwipurwani (2019). Cloud computing model implementation in internet pricing Schemes based on Cobb-Douglas utility function. *Journal of Physics: Conference Series*

Indrawati, F. M. Puspita, S. Erlita, and I. Nadeak (2017). Optimasi Model Cloud Radio Access Network (CRAN) pada Efisiensi Konsumsi Bandwidth dalam Jaringan. *In 3rd Annual Research Seminar on Computer Science and ICT*

Jiang, M. and T. Mahmoodi (2016). Traffic Management in 5G Mobile Networks: Selfish Users and Fair Networks. *Transactions on Networks and Communications*, **4**

Kuo, W.-H. and W. Liao (2005). Utility-based optimal resource allocation in wireless networks. In *GLOBECOM'05. IEEE Global Telecommunications Conference, 2005.*, volume 6. IEEE, pages 5–pp

La, R. J. and V. Anantharam (2002). Utility-based rate control in the Internet for elastic traffic. *IEEE/ACM Transactions On Networking*, **10**(2); 272–286

Liotou, E., D. Tsolkas, and N. Passas (2016). A roadmap on QoE metrics and models. In *2016 23rd International Conference on Telecommunications (ICT)*. IEEE, pages 1–5

Petrova, K. (2003). ISPs - pricing internet success. *GBATA International Conference, New York, 1042-1051*

Puspita, F. M. and M. Oktaryna (2017). Improved bundle pricing model on wireless internet pricing scheme in serving multiple qos network based on quasi-linear utility function. In *2017 International Conference on Electrical Engineering and Computer Science (ICECOS)*. IEEE

Puspita, F. M., K. Seman, and B. M. Taib (2014). The Improved Models of Internet Pricing Scheme of Multi Service Multi Link Networks with Various Capacity Links. In *Lecture Notes* *in Electrical Engineering*. Springer International Publishing, pages 851–862

Qiu, L., Y. R. Yang, Y. Zhang, and S. Shenker (2006). On selfish routing in internet-like environments. *IEEE/ACM Transactions on Networking*, **14**(4); 725–738

Reichl, P., S. Egger, S. Möller, K. Kilkki, M. Fiedler, T. Hoßfeld, C. Tsiaras, and A. Asrese (2015). Towards a comprehensive framework for QoE and user behavior modelling. In *2015 Seventh International Workshop on Quality of Multimedia Experience (QoMEX)*. IEEE, pages 1–6

Roughgarden, T. (2001). Designing networks for selfish users is hard. In *Proceedings 42nd IEEE Symposium on Foundations of Computer Science*. IEEE, pages 472–481

Sandeep, S. and P. Nuggehalli (2006). QoS with selfish nodes in wireless networks. In *2006 1st International Conference on Communication Systems Software & Middleware*. IEEE, pages 1–1

Sitepu, R., F. M. Puspita, and S. Apriliyani (2017). Utility function based-mixed integer nonlinear programming (MINLP) problem model of information service pricing schemes. In *2017 International Conference on Data and Software Engineering (ICoDSE)*. IEEE, pages 1–6

Tsiaflakis, P., Y. Yi, M. Chiang, and M. Moonen (2012). Throughput and delay performance of DSL broadband access with cross-layer dynamic spectrum management. *IEEE Transactions on Communications*, **60**(9); 2700–2711

Varade, P., A. Wabale, R. Yerram, and R. Jaiswal (2018). Throughput Maximization of Cognitive Radio Multi Relay Network with Interference Management. *International Journal of Electrical & Computer Engineering (2088-8708)*, **8**(4)

Wang, X. and H. Schulzrinne (2001). Pricing network resources for adaptive applications in a differentiated services network. In *Proceedings IEEE INFOCOM 2001. Conference on Computer Communications. Twentieth Annual Joint Conference of the IEEE Computer and Communications Society (Cat. No. 01CH37213)*, volume 2. IEEE, pages 943–952

Wu, Y., P. H. Hande, H. Kim, M. Chiang, and D. H. Tsang (2010). QoS-revenue tradeoff with time-constrained ISP pricing. In *2010 IEEE 18th International Workshop on Quality of Service (IWQoS)*. IEEE, pages 1–9

