Towards a New Approach to Rationalize the Operators' Choice in Telecommunication Networks

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Abstract

Optimization is an essential tool in the field of decision support. In this paper, we interested to study an inverse problem applied in the telecommunication networks. Indeed, in the telecommunication networks, service providers have subscription offers to customers. Since competition is strong in this sector, most of these advertising offerings, totally or partially ambiguous, are prepared to attract the attention of consumers. For this reason, customers face problems in making decisions about the choice of the operators that gives them a better report price/QoS. Mathematical modeling of this decision support problem led to the resolution of an inverse problem. More precisely, the inverse problem is to find the function of the QoS real knowing the QoS theoretical or advertising. This model will help customers who seek to know the degree of sincerity of their operators, as well as it is an opportunity for operators who want to maintain their resources so that they gain the trust of customers. We have used the Genetic Algorithm to resolve the optimization problem proposed in our work. We were able to learn that when the SP bandwidth increase their weight in the system increase, because they able to offers a better quality of services. However, when their demand increase without changing the bandwidth, the quality of services decreases with their weight.

Keywords: Telecommunication Networks, QoS, Pricing, Inverse problem, Optimization, Genetic Algorithm

1. Introduction

In the recent years, the privatization and liberation of services in telecommunication networks sectors lead to a diversification of services providers. This diversity leads to strong competition between them, each of which tries to attract and / or retain customers. Since do not give true information about their systems (client confusion), customers do not have complete information to make a good decision. This confusion present an obstacle to customers to have all the information on the operator's offer. For it, consumer confusion has been studied as an important in many markets due to dynamics, such as over choice, excessive marketing communications, and similar tariffs and promotions. Hence, in the presence of confusion, the customer's choice is often uncertain (bounded rationality).

Telecommunication networks also have been considered in the economic literature as one of the sectors that causes confusion among consumers [13]. Complex fee structures introduced by service providers, number portability, loyalty

programs and complicated service variations make it difficult for consumers to understand the type of transaction and get the best report price /QoS.

The problems related to the choice of an operator is on several parameters including real quality of service, theoretica service quality, bandwidth, price... Operators decide a price and QoS for services offered to its customers. QoS proposed remains a parameter that depends on other variables namely bandwidth, the share of this market operator. In these circumstances, an operator can never guarantee the quality of service it promises to customers. We call it then theoretical QoS, while the QoS perceived by customers is the real QoS. In the telecommunications networks, the credibility of each operator is measured by the difference between its theoretical QoS and the real QoS. A customer is interested in the recognition of with good credibility (which has a real QoS close to the theoretical QoS). In addition, as there is no real QoS to operators cannot solve this problem in a direct way. Hence, this kind of problem can be modeled within the meaning of the inverse problem. The inverse problem is generally ill-posed problem, on the contrary live with the problem said that the solution exists, is unique and depends on data. For example, if it is to reconstruct the past state of a system knowing its current state, we are dealing with an inverse problem; but the fact of predicting the future state given the current state is a direct problem. Similarly, in the case of a determination of parameters of a system knowing a part of the stage (a part of the set of parameters); we speak of parameter identification problems.

In related work, many studies have contributed to the study of the problem of consumer confusion and their bounded rationality. However, to my knowledge there is no work that is interested in finding the form of real QoS to know the confidence level of service providers in telecommunication networks. The authors of the paper [13] they proposed a model that is based on the economic weighing of and the Luce probabilistic choice model. They concluded that the client is confused or not by the SPs, if its degree of irrationality increases, the earns more; this model of Luce's choice is often more complicated than the discrete choice model implied by the authors of the paper [14]-[16]. In addition, the authors of the book [15] debate the confusion concept, display that irrational decision-making can be explained if one takes into account that human capacities to process information are limited. Thus, they used and improved heuristic techniques to predict the quality of the decision by formulating and solving optimization problems. The use of heuristic methods for the optimization of the proposed models is due to their efficiency in the search for the global optimum.

The instead of this paper is organized as follows: in Section 2, we present modeling problematic using the inverse problem theory. We present in Section 3 the genetic algorithm as optimization method used to solve the models proposed in our work. In Section 4, we present the different numerical results obtained. We conclude this study with perspectives in Section 5.

2. Formulation and Modeling of the Problem

In this section, we model the profit of a customer if he chooses to subscribe in the SP_i and we use the Luce model to mathematise the discrete choice of clients by exploiting the softmax function or the normalized exponential function [11], as in the article [10].

2.1. Model of Utility Customers

The benefit of a consumer is often calculated based on the strategies of its operator, which are the QoS and the price it offers. The profit u_i of a consumer registers with the operator's services SP_i is as follows:

$$u_i(q_i, p_i) = \alpha q_i - p_i \tag{1}$$

with αq_i is a client's revenue if he chooses the SP_i and $\alpha > 0$.

2.2. The Luce Model

The Luce model is a first probabilistic choice model that incorporates boundedly rational choice of customers[1]-[2]-[13]. With this model, customers can choose the operator that will maximize profits by choosing one that has the maximum probability; but forcing this choice is inadequate in this area given the existence of hidden information that has not been represented in this model. The following equation represents the probability that the customer chooses SP_i:

$$\rho_i(p,q) = \frac{e^{\frac{u_i}{\lambda}}}{\sum_{j=1}^{N} e^{\frac{u_j}{\lambda}}} \tag{2}$$

with $\lambda \in [0,1]$ is the degree of customer irrationality, N is the number of SPs and p and q are respectively the vector of price and QoS.

When λ tends to 0, means that customer behavior is rational, *i.e.*, they have all the information and rules that allow them to maximize their profit, while customers are irrational when λ approaches 1.

2.3. Demand Model D_i

We consider a market size n (the total number of customers), the function of the application to the operator's services i, D_i is the probability that a customer selects the operator multiplied by the size, n, of the market. It is expressed by:

$$D_i(p,q) = n.\rho_i(p,q) \tag{3}$$

2.4. Theoretical Quality of Service

We consider $Delay_i^u$ the time required for data transmission to a SP_i user u. This time is expressed in telecommunications [3] as a function of bandwidth available at SP_i and the demand D_i:

$$Delay_i^u = \frac{1}{\Phi_i - D_i} \tag{4}$$

That means more demand is greater than the time increases, and vice versa, over the bandwidth increases the time becomes less important. This proportionality is logical since:

• More as demand increases, the number of customers connected to the SP_i becomes large and thus the time becomes more important.

• More than the bandwidth increases, the *SP* largely has capacity to cover all customers and therefore the time became smaller.

In the model of L. Kleinrock [8] with queues, Quality of service QoS is the inverse of the total response time when the user wants to access the service. Let c_i the deadlines for transmission of data between the service provider and the provider services l' SP_i, the total time of the answer is accumulates between c_i and $Delay_i^u$. Thus the quality of service is expressed by the following equation (as [4]):

$$q_i = \frac{1}{Delay_i^u + c_i} \qquad (5)$$

From the two equations (4) et (5), we show the existence of the relationship between the quality of service, demand $D_i(p,q) = n\rho_i(p,q)$ and bandwidth Φ_i by the following equation [3]:

$$q_i = \frac{\Phi_i - D_i}{1 + c_i(\Phi_i - D_i)} \qquad (6)$$

or by the following equation:

$$\Phi_i = D_i + \frac{q_i}{1 - q_i c_i} \qquad (7)$$

From the equations (6), we can deduce that when demand of SP_i approach covering all the bandwidth; QoS becomes less.

2.5. Problem Formulation

From equation (1), we find that the theoretical benefit of a user is:

$$u_i(q_i, p_i) = \alpha.q_i - p_i, \qquad (8)$$

then the real benifit is:

$$u_i^R(q_i^R, p_i^R) = \alpha.q_i^R - p_i^R, \qquad (9)$$

with q_i^R is a real QoS and p_i^R is a real price.

Assumption 1 *In telecommunications, there is no general difference between promotional price (theoretical) and the real price that the user paid when the invoice settlement. However, in our study we assume that $p_i = p_i^R$.*

Taking into consideration this assumption 1, the difference between the real and theoretical benefit becomes:

$$u_i - u_i^R = \alpha.q_i - p_i - (\alpha.q_i^R - p_i^R) = \alpha(q_i - q_i^R)$$

2.5.1. Resource Management Model

Used to help operators in the telecommunications field to maintain their resources so that the difference between their offers and advertising that benefit the customer actually is optimal. It is a tool to customers who want to register with the operator that meets their needs.

$$\min \quad F_i(p,q) = \frac{1}{2}.\alpha.\rho_i \cdot [(q_i - q_i^R)^2]$$

under the constraints:

$$\begin{cases} p_i < P_{max} \\\\ q_{min} \leq q_i^R \leq q_i \end{cases}$$

The first constraint is related to customer purchasing power. the second constraint is a formulation in terms of customer needs in real QoS. it must meet a minimum threshold and it should not exceed the theoretical QoS.

2.5.2. Discrete Choice Model Customers

Lets customers know the weight (sincerity) of all operators in the telecommunications market. This problem is formulated as a this multi-objective model:

$$min \ \ G(p,q) = \begin{pmatrix} F_1(p,q) \\\\ F_2(p,q) \\\\ \vdots \\\\ F_N(p,q) \end{pmatrix}$$

under the constraints:

$$\begin{cases} \forall \, i \in \{1,...,N\} \ p_i < P_{max} \\\\ \forall \, i \in \{1,...,N\} \ q_{min} \leq q_i^R \leq q_i \end{cases}$$

To solve the multi-objective problem (MOP), we must transform it into a single-objective problem weighted. For this, we applied the aggregation method and the result of the transformation is:

$$minG(p,q) = \sum_{i=1}^{N} \gamma_i . F_i(p,q)$$

under the constraints:

$$\begin{cases} \forall \, i \in \{1,...,N\} \ 0 \leq \gamma_i < 1 \ et \ \sum_{i=1}^{N}\gamma_i = 1 \\\\ \forall \, i \in \{1,...,N\} \ p_i < P_{max} \\\\ \forall \, i \in \{1,...,N\} \ q_{min} \leq q_i^R < q_i \end{cases}$$

and

$$F_i(p,q) = \frac{1}{2}.\alpha.\rho_i \cdot [(q_i - q_i^R)^2], i = 1,2,...,N$$

With γ is considered vector weight of the operators in the telecommunications market.

3. Genetic Algorithm

Genetic Algorithms (GAs) developed by Holland [9] and his student Goldberg [6], are based on the mechanics of natural evolution and natural genetics[5]-[7]. GAs differ from usual inversion algorithms because they do not require a starting value. The GAs use a survival-of-the-fittest scheme with a random organized search to find the best solution to a problem. Solve an optimization problem is find the optimum of a function from a finite number of choices, often very large. The practical applications are numerous, whether in

the field of industrial production, transport or economics - wherever there is need to minimize or maximize digital functions in systems simultaneously operate a large number of parameters. Algorithm (1) represents the genetic algorithm used to optimize the models proposed in this work.

Algorithm 1: Genetic Algorithm

1. Initialize the initial population **P**.
2. Evaluate $P(t)$.
3. **While** No convergence **do**
4.   a. $P(t+1)$ = Selection of Parents in $P(t)$.
     b. $P(t+1)$ = Apply Crossing Operator on $P(t+1)$
     c. $P(t+1)$ = Apply on Mutation Operator $P(t+1)$
     d. $P(t)$ = Replace elders of $P(t)$ Descendants of their $P(t+1)$
     e. Evaluate $P(t)$
5. **End while**

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4. Numerical Results

In this section, we present the numerical results obtained by assuming that we have SP s in this telecommunications market. We use the genetic algorithm with the parameters that will allow us to obtain the optimal solution for our proposed models.

4.1. The Real Quality of the Function Study

4.1.1. Study of a Limited Case

In the telecommunications market, the real quality of service is a function that depends on the bandwidth Φ_i and the demand D_i of SP_i. In reality, we know that when the bandwidth increases, the real quality of service (QoS) increases and vice versa; also when demand increases, real service quality decreases and increases when demand decreases. In this context, we observed that the real quality can be expressed as a polynomial of degree 2, the variable x_i is the ratio between Φ_i and D_i, as following:

$$q_i^R(\Phi_i, D_i) = \alpha_i^1 * (\frac{\Phi_i}{D_i})^2 + \alpha_i^2 * (\frac{\Phi_i}{D_i}) + \alpha_i^3$$

We used the genetic algorithm (with the table settings 1) to find these coefficients for different values of bandwidth Φ_i and of demand D_i. The Figures 1 et 2 show the influence of respectively Φ_i and D_i on QoS (theorical and real).

Table 1. Genetic Algorithm Parameters to the Figures of the Results 1 et 2

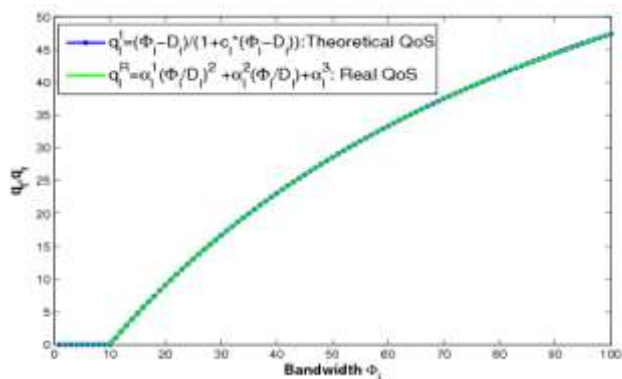|	
Population size N	16
Type selection	at roulette
Type of crossover	Single-points
Probability of crossover P_c	0.7
Type of mutation	uniform
Probability of mutation	0.05
Maximum number of generations	100

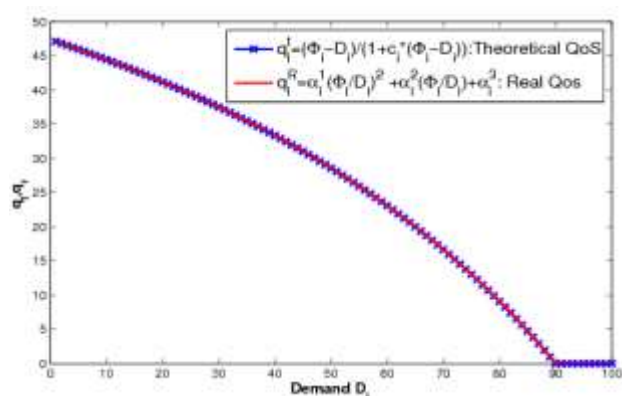**Figure 1. Variation of q_i^t and q_i^R in Terms of Φ_i**

Figure 2. Variation of q_i^t and q_i^R in Terms of D_i

From Figures (1 et 2) we note that with the change of bandwidth Φ_i and the demand D_i, the genetic algorithm was able to find the good coefficients of the polynomial to minimize the gap between what is theoretical and what is real. In the next part, we will not restrict ourselves to the case presented above, but we are expanding the study of the variation of the actual quality using the technique of discretization dominates definition of theoretical quality seeking at each point the value of the actual quality by solving the model for managing resources.

4.1.2. Study of a General Case by Discretization

The quality theoretical of a SP_i may vary within a range delimited by a minimum and maximum value: $q_i^t \in [q_{min}, q_{max}]$. To make a digital resolution, we will discretize the interval 3, that is to say, turn it into an approximate problem (discrete) to find the values of the actual quality q_i^R at each point of the discrete domain.
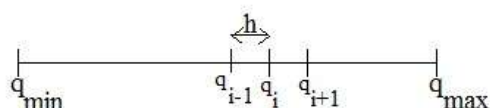

Figure 3. Discretization of an Interval

or h is a positive regular pitch.

A) **Study The Impact of Bandwidth on q_t and q_r**

We launched the genetic algorithm; Matlab programmed with the parameters listed in Table 2; on the model of resource management with variation of bandwidth Φ_i, and we obtain the results shown in Figures 4, 5 and Table 3.

Table 2. Genetic Algorithm Parameters to the Figures of the Results 4 and 5

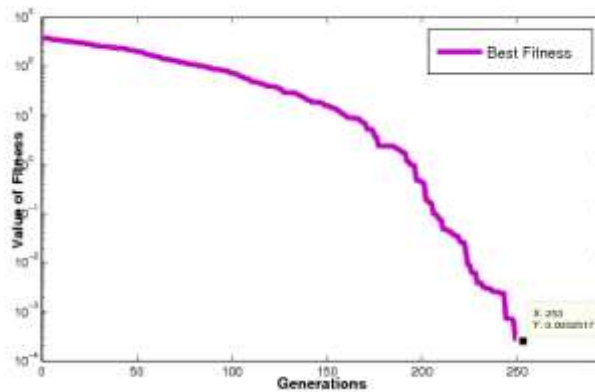|	
Population size N	20
Type selection	at roulette
Type of crossover	Multi-point
Probability of crossover P_c	0.65
Type of mutation	non uniform
Probability of mutation	0.05
Maximal Number of generation	300

Figure 4. Decrease in the Objective Function According Generations
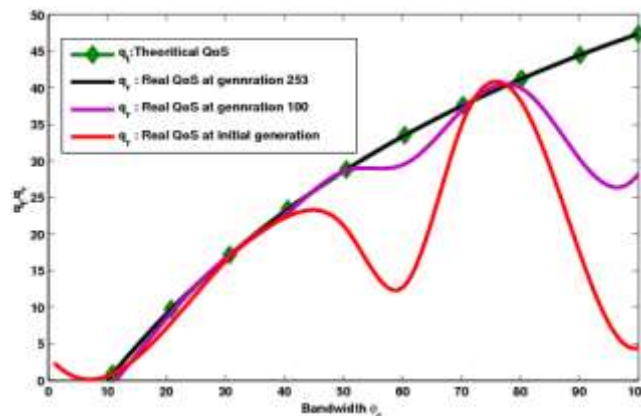

Figure 5. Changes in the Real Quality of Service Over the Generations

Figure 4 shows the decrease of the function *Fitness* relative to iterations (generations) the genetic algorithm. The objective function value begins 10^3, in the first generation, to reach the value 10^{-4}, in the $253^{\text{ème}}$ generation. This result shows that the decrease is Igue (remarkable). From Figure 5, we note that to achieve the same minimum value, the algorithm needs to go to the 253 generation.

Table 3. Convergence Results of the Genetic Algorithm (variation of Φ_i)

Number of generation	253
minimum cost	$2.517*10^{-4}$
step of discretization h	$\dfrac{1}{10}$

B) Impact on Demand Study q_t and q_r

We launched the genetic algorithm; with the parameters listed in Table 4;on the model of resource management with variation of the demand D_i, and we obtain the results shown in the following Figures 6, 7 and Table 5.

Table 4. Genetic Algorithm Parameters to the Figures of the Results 6 and 7

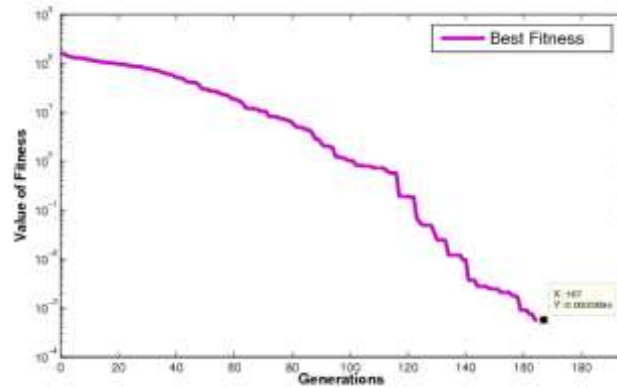|	
Population size N	10
Type of selection	at roulette
Type of crossover	Multi-point
Probability of crossover P_c	0.60
Type of mutation	not uniform
Probability of mutation	0.05
Maximum number of generation	200

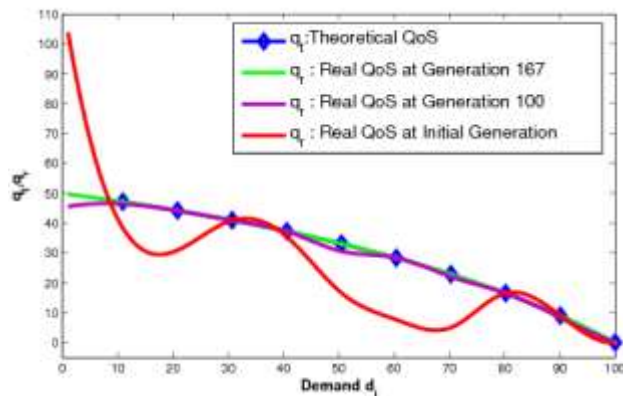## Figure 6. Decrease in the Objective Function According Generations

Figure 7. Changes in the Real Quality of Service Over the Generations

Figure 6 shows the decrease of the function *Fitness* relative to iterations (generations) the genetic algorithm. the objective function value begins with 10^2 in the first generation, reaching the values $5,694*10^{-4}$, in the 167th generation. This result shows that the decrease is Igue (remarkable). From the Figure 7, We note that to achieve the same minimum value, the algorithm needs to go to the 167 generation.

Table 5. Convergence Results of the Genetic Algorithm (variation of D_i)

Number of generation	167
Minimum cost	$5.694*10^{-4}$
Step of discretization h	$\dfrac{1}{20}$

4.2. Model Resolution of the Weight Calculation

In this part, we consider a telecommunication network system that we have two services providers. We will use the model of discrete choice of customers to find their weight in this market ranging Φ_i and D_i an operator. The calculation of these weights is a kind of decision support for customers seeking to register with the services of the most sincere operator (who has more confidence in the sense of the difference between q^t and q^R).

4.2.1. Impact of Bandwidth Φ on the Weight of Operators

We vary the bandwidth of the operator 1 and observe the influence on weight and that of the adversary. Figure 8 show that the weight of the operator is an increasing function compared to bandwidth ϕ_1, then the weight of its adversary is a decreasing function with respect to ϕ_1. This result is real, since the increase in bandwidth ϕ_1 causes the improvement of the real QoS q_1^R and therefore the operator 1 must have a good reputation and a good weight for his adversary.

4.2.2. Impact of Demand D on the Weight of Operators

We will vary the request of the operator 1 and observe the influence on weight and that of the adversary. Figure 9 shows that the wight of operator 1 is decreasing function compared to demand D_1, then the wight of its adversary is a increasing function compared to D_1. This result is real, because the increase in demand D_1 causes degradation of the real QoS q_1^R and therefore the operator 1 must not have a good reputation and a good weight for his adversary.
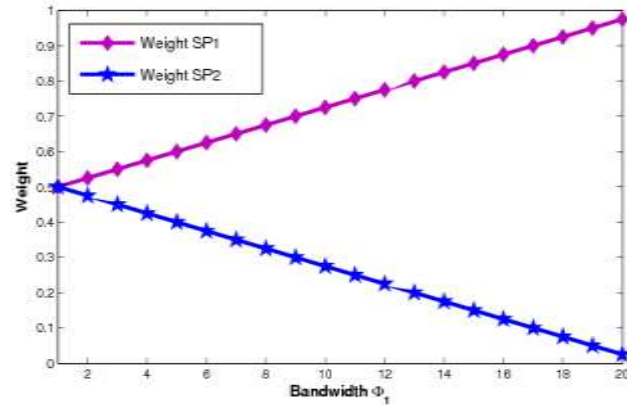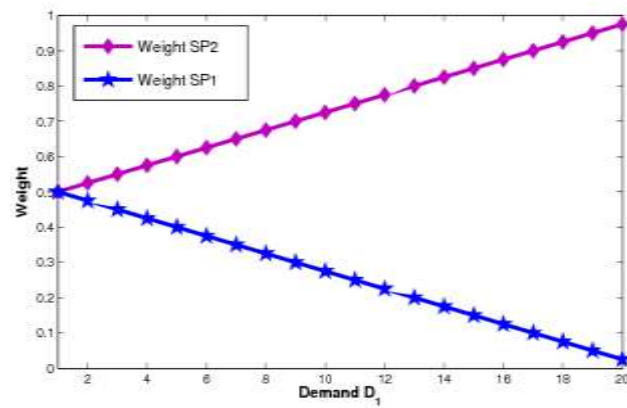
Figure 8. Change in Weight of SPs Increasing Φ_1

Figure 9. Change in Weight SPs Increasing D_1

5. Conclusion

In this work, we have studied the problem of real quality, which is the key to rational customer decision-making in telecommunications networks. We were able to propose an inverse problem reformulated in the form of optimization models. These models will allow customers to know the service provider that best meets their requirements by knowing the demand and the bandwidth they use. Also, it is a modeling that allows service providers to adapt their bandwidth to user demand so that the difference between what is theoretical and what is perceived is optimal. However, we used the genetic algorithm for the numerical solution of optimization models. This choice is due to the efficiency it shows in the field of global optimization.

In future work, we aim to merge our model with the study of cache in information centric networks [12] to understand the impact of caching on the quality of service perceived by customers.

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