Pricing Reserved and On-Demand Schemes of Cloud Computing Based on Option Pricing Model

Deyuan Wang*, Ying Wang†, Jichun Liu‡, Ke Xiao§, Wenjing Li¶and Xuesong Qiu‖
*State Key Laboratory of Networking and Switching Technology, Beijing University of Posts and Telecommunications, Beijing, 100876, P. R. China
Email: peterwdy@gmail.com

***Abstract*—In this paper, we treat the pricing of the cloud resources as an option pricing problem. The pricing of the Reserved scheme can be solved as a European option problem and the pricing of the On-Demand Scheme can be solved as an American option problem. We adopt the method of Trinomial tree to resolve the European option problem and the American option problem. The model we proposed can calculate the pricing of those two schemes according to the investment and contract time and the prices can satisfy the interests of both resource providers and users.**

***Keywords*-cloud; pricing; Reserved Scheme; On-Demand Scheme.**

I. INTRODUCTION

Nowadays as cloud computing gains great popularity, the pricing of cloud resources becomes a hot issue. The pricing issue is crucial for both cloud resource providers and users for the reason that the ultimate goal of cloud resource providers is to maximize their profit and at the same time it is vital for users to purchase the resources at a reasonable price.[1] Many recent literatures focus on the pricing issue, nevertheless, there are few researches jump out of the box to see the process in an economic way. In this paper, we treat cloud resources as assets to deal with the pricing problem.

The pricing model of the three schemes of cloud computing varies due to the diverse features and applicable scene of each scheme. Many existing works focus on the pricing of Spot Scheme. To the best of our knowledge however, there is no research considering the pricing of Reserved and On-Demand Scheme. In this paper, we use the option pricing model to deal with the problem. Cloud resources are the underlying asset of resource providers and the value of the asset could not be determinately predicted. Therefore, an option can be written on the resources. Users have to fix the amount of time they are willing to use the resources in the Reserved Scheme and the contract continues to be effective until the time is due. The pricing scheme resembles the pricing of European Option. So we present the European Option model to price the Reserved Scheme. There is no time limit in On-Demand scheme, resource provider can take back their resources when the user finishes. It is similar to the American Option pricing. Therefore, in this paper, we price the On-Demand scheme using the pricing model of American Option.

In practice, numerical methods are more commonly used in solving both the European option and American option than the classic Black-Scholes economic model[2]. In this paper, we use Trinomial tree method which is fast and effective for European option and American option.

II. THE PROPOSED APPROACH: AN EFFECTIVE WAY OF SOLVING THE PRICING PROBLEM

In this section, we present our adapted Trinomial tree method to solve the pricing of Reserved scheme and On-Demand Scheme.

A. Parameters

There are several parameters to be figured out before we use the Trinomial tree method. They are Initial Investment S_0, Strike Price K, Contract Time T, Risk-free interest rate r and volatility δ. S_0, T, r, δ can be get from the specific examples and K is calculated from S_0. According to the Moore's Law the value of the resources of the same processing capacity $ProcessingCapacity$ will reduce along with the Contract Time T. It can be given by the expression:

$$ProcessingCapacity_{t=T} = ProcessingCapacity_{t=0} \times 2^{\frac{T}{2}} \tag{1}$$

Considering the rate of inflation and other problems, the future value of the resources can't be fully used this formula to calculate. Assuming the Contract Time is T, Risk-free interest rate is r, the future value of the cloud resource can be calculated as:

$$FutureValue = PresentValue \times (1+r)^T \tag{2}$$

Combining 1 2 we can get the value of resources at time T:

$$ResourceValue_{t=T} = \frac{PresentValue}{(1+r)^T \times 2^{T/2}} \tag{3}$$

Knowing $ResourceValue_{t=T}$ is K then we get:

$$K = \frac{S_0}{(1+r)^T \times 2^{T/2}} \tag{4}$$

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B. Trinomial tree approach

In the Trinomial tree model, during time Δt, the asset price S raises to S_u with the probability of p_u, or falls to S_d with the probability of p_d or stay the same as S with the probability of $1 - p_u - p_d$. Let the rise size be u and fall size be d, we can define the Trinomial tree as:

$$S(t+\Delta t) = \begin{cases} S(t)\,u; probablity : p_u \\ S(t)\,; probablity : 1 - p_u - p_d \\ S(t)\,d; probablity : p_d \end{cases} \tag{5}$$

C. Pricing of Reserved Scheme

Due to depreciation the value of resources falls to K at time T and the cloud resources option is a put option. Therefore the payoffs of cloud resources option at maturity time T can be calculated:

$$C(S,T) = \max(K - S, 0) \tag{6}$$

And the algorithm for Reserved Scheme is:

Algorithm 1 Reserved Scheme Pricing Algorithm

1: Declare and Initialize S_0, T, r, and δ;
2: Calculate K;
3: Calculate u, d;
4: Calculate p_u, p_d, p_m;
5: Build the Trinomial Tree;
6: Calculate the payoffs of cloud resources option at maturity: $C(S,T) = \max(K - S, 0)$ at node N
7: **for** $i = 1$ to $N - 1$ **do**
8: Calculate the Reserved Price at node j:
9: $C_{n,j} = e^{-r\Delta t}[p_u C_{n+1,j+1} + p_m C_{n+1,j} + p_d C_{n+1,j-1}]$
10: **end for**
11: Output the Reserved Price

D. Pricing of On-Demand Scheme

Users can stop using their resources leased from resource provider whenever they want in the On-Demand scheme. Therefore the payoffs of cloud resources option at maturity time T can be calculated as:

$$Payoff = \max(K - S_{i,j}, 0) \tag{7}$$

The backward induction equation is modified to:

$$C_{n,j} = \max\left(optionpayoff\ , \\ e^{-r\Delta t}\left[p_u C_{n+1,j+1} + p_m C_{n+1,j} + p_d C_{n+1,j-1}\right]\right) \tag{8}$$

Therefore, the Algorithm 2 above can calculate the price of On-Demand Scheme.

Algorithm 2 On-Demand Scheme Pricing Algorithm

1: Declare and Initialize S_0, T, r, and δ;
2: Calculate K;
3: Calculate u, d;
4: Calculate p_u, p_d, p_m;
5: Build the Trinomial Tree;
6: Calculate the payoffs of cloud resources option at maturity: $C(S,T) = \max(K - S, 0)$ at node N;
7: **for** $i = 1$ to $N - 1$ **do**
8: Calculate the payoffs of cloud resources option at node j;
9: Calculate the On-Demand Price at node j;
10: Calculate $C_{n,j}$ as equation 8.
11: **end for**
12: Output the On-Demand Price.

III. Experiments and Results

In our work, server resources are regarded as assets for option pricing, and the operation cost of resource providers has not been taken into consideration during the pricing process. The resources is reusable, therefore the operation cost can be covered due to the multiple usage of the resources and profits are generated as well. We will take all the costs into account to realize a more reasonable pricing in the future.

The authors in [3] do analysis on the real cost of service providers, and the price of standard 250W server turned out to be 4500 dollars, thus we can get S_0. According to the formula 4 we can get value of K, so the price of Reserved scheme and On-Demand scheme can be calculated separately from the algorithm above as shown in table I

Table I
PARAMETERS AND RESULTS

Initial Investment	S_0	1500 dollors/year
Interest Rate	r	5%
Volatility	δ	25%
Contract Time	T	3 years
Reserved Pricing	Price	1.44 cent/h
On-Demand Pricing	Price	2.48 cent/h

A. Influence of Initial Investment on pricing

On the basis of the experimental results, the prices increase with the increase of investment, this causes a problem: the service providers who have more resources would charge more than those who have fewer resources. But in fact, large resource providers spend less than small resource provider in purchasing the resources [1], so the prices can be the same for both large and small resource providers.

B. The influence of Contract Time on pricing

The contract time T in On-Demand Scheme can be equal to that of the Reserved Scheme. The above result shows that

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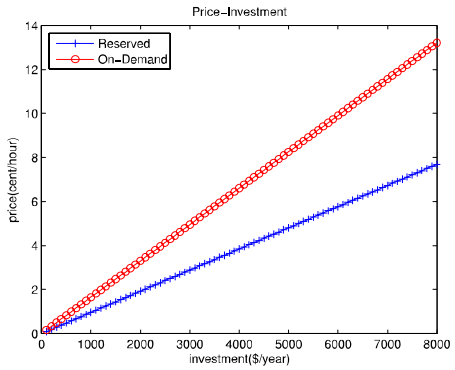

Figure 1. Influence of Initial Investment on pricing

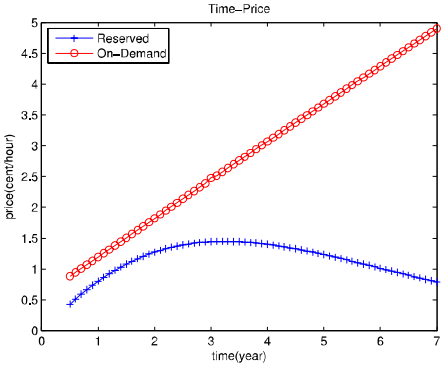

Figure 2. Influence of Contract Time on pricing

for On-Demand Scheme, the longer the estimated contract time is, the higher the price will be. But the estimated contract time can't be too long due to the pay as you go feature of On-Demand scheme. For the Reserved scheme, the price came to an maximum around three years contract time. Therefore it is beneficial for cloud provider to price the resource at the maximum and discount due to different time contracts.

C. The influence of Interest Rate on pricing

The figure 3 above shows that On-Demand scheme is affected more by the interest rate while the interest rate has less influence on Reserved scheme. So in actual pricing process, resource provider does not need to take the factor of interest rate into consideration for Reserved scheme, yet they must consider the interest rate in the pricing of On-Demand scheme.

The price above is for providers to recover the cost, but providers can use virtualization technology to assign the same resources to multiple users. At the same time, for the purchasing of multiple servers, the average cost of one server is less than a single purchase, so the actual prices

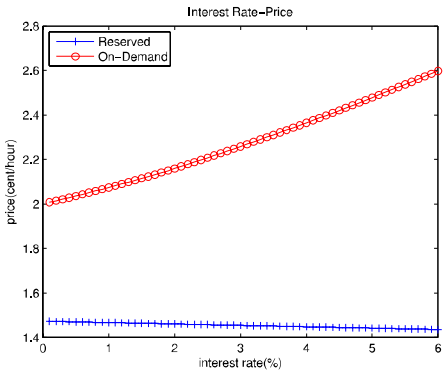

Figure 3. Influence of Interest Rate on pricing

can be lower than the prices above, which can also make the resource providers cover the operation cost and other costs and gain profit.

IV. Conclusion

In this paper, we solve the problem of pricing Reserved and On-Demand schemes in cloud computing. We treat the cloud resources as assets and use the option theory to solve the pricing problem. We use European option to price the Reserved Scheme and American option to price the On-Demand Scheme. We use the Trinomial tree method to solve both problems. Then we discussed how the different parameters such as investment, contract time, Interest rate influence the Reserved and On-Demand Schemes. The deficiency of this article is that we just price for the cloud resources as a whole and did not consider the different combination of resources and we did not take the operation cost and other costs into consideration. We will complete it in our future studies.

Acknowledgment

This research is supported by the Funds for National High Technology Research and Development Program of China(863 Program)(2013AA010602) and the Fundamental Research Funds for the Central Universities BUPT 2013R-C1103.

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