Optimal implementation of critical peak pricing in cloud computing

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Abstract

Cloud computing offers a variety of services and hence the opportunity to make profit by using a suitable pricing strategy by selling these services. Yet, the instability of the dynamic price, create a risk for cloud tenants so as to effectively implement a pricing strategy which is beneficial for both tenants and end user. To overcome the dynamic price risk for tenant, method of dynamic pricing scheme between tenants and end user is employed. This paper proposes a model of dynamic pricing scheme, i.e. Critical Peak Pricing based on demand response program for profit of cloud tenants as well as end user satisfaction. The proposed model used the price responsiveness model of end user and the parameters of Critical Peak Pricing that simultaneously affects the benefit of cloud tenants and end user.

Keywords:

Cloud computing,
critical peak pricing (CPP),
demand response,
critical days,
cloud tenant,
end user

1 Introduction

Cloud computing offers a variety of computing services to the end user. There are several companies such as IBM, Google, Amazon are making huge investment in cloud computing. Therefore, the emergence of cloud computing in the market will change the IT sectors into IT industry. In a simple way, cloud resources like CPU, storage, network domain, memory etc are quoted as the utility in cloud computing which is rented by the cloud service provider to user as per demand [1]. Cloud Service provider (CSP) like Amazon EC2, Google, and Microsoft Azure etc. offers resources in the form of virtual machine (VMs) using various pricing scheme such as pay per use, on demand etc. As per the end user perspective, honesty is a major concern in resource pricing and allocation [2]. As far as economics is concerned, fairness is major concern in cloud computing. If pricing is unfair, users get disappointed and as a result CSP fail to gain the loyalty of users. Additionally, the loyalty of users also affects the utilization of the services of the datacenters.

Mostly, the user would pay on the basis of amount of resources they used. This pricing scheme termed as pay as you go model or pay per use [3]. User's demand of computing resources are either scaled up or scaled down based on their needs. But they used to pay according to price fixed by cloud service provider. Consider the example, Billing period of Amazon EC2 on demand instance is 1hour.if user want to use virtual machine for 10 minutes or 1hour they have to pay the same price. Therefore, it leads to serious problem for users whose demands are not consistent in nature. Moreover, as increase in demand of users cloud computing become worldwide that creates more heterogeneous infrastructure. Result in user's challenges for selecting the appropriate CSP for their increasing as well as time varying demand. To reduce this problem at some extent, cloud tenant are introduced in cloud environment. Cloud tenants are worked as agent between the cloud service provider and end user. Users are requested their demand to the cloud tenants. And the cloud tenant's rents virtual machines from CSP to service the users demand. They charge the end user based on the utilization of VMs is used to service their request. Since these tenants are not only developing the new technologies related to migration, virtualization etc. but they are also addressing the new provisioning and pricing scheme to provide the resources to the end users efficiently [4]. Therefore, the tenants invested in cloud market to maximize their profit and end user satisfaction. In existing scenario, the tenants can have made a profit by matching the end users demand with provider's s. They used the various methods to get optimal prices between these providers and end users.

The spot pricing is started by Amazon web services in 2009 for selling unused capacity of resources. The spot pricing is known as real time price or market price or dynamic price which is change over based on demand and supply [5]. The real-time price is far below than on demand and reserve price of services [6].

So, real time price is more efficient for tenants to purchase the resources than on demand pricing but the issues are that how to effectively implement the pricing scheme that tenants also increased their profit and provides benefit to the end user.

In cloud, DR is the action to change the cloud services demand with response to changes in prices. So, Demand response can be considered as the instantaneously demand controlling. It is often more expensive to build new datacenters. Therefore, it is better and efficient solution for balancing the demand and supply is to cut or shift the demand.

The proposed model deal with the Virtual machine pricing design of Cloud tenants whose end users engaged in price sensitive demand response. Our approach modeling the optimal Critical Peak Pricing implementation strategy for incrementing in profit of cloud tenants via reducing their purchasing cost of Virtual Machine (VMs) and taken in to account for end user satisfaction in term of reducing their Virtual Machine cost. Most of the research work has been done earlier for profit maximization of cloud provider or datacenters using DR which is implemented between cloud service provider and tenants. Therefore, cloud service provider profit depends on tenant's demand, and tenants demand depends on the end user satisfaction. If the end user is not participating conveniently during peak load of service then, tenant's demands directly effects on data center profit during peak load of service. So, the proposed model aims to balance the satisfaction between tenants and end user especially in term of benefit. This approach is used for multi-party win.

2 Motivation

In electricity market, Load Serving Entities (LSEs) are suppliers who supplies electricity to the retail customers [7]. In the Deregulation of electricity market, DR program is implemented that make capable market participants to take responsibilities as well as action [9]. Accordingly, the demand response programs make customer enable to adjust their consumption pattern of power which enhances the efficiency of power system by reducing the peak demand [8]. As mentioned in [10], Demand response programs can be classified into two classes: Time based program and Incentive based program. Time based Program includes Time of Use (TOU) Program, Real time Pricing (RTP) Program, Critical peak Pricing (CPP) which are used to determine the price for different periods as per supply e.g. high price for peak load period, low prices for low load period. While Incentive based program includes Direct Load Control (DLC), Capacity Market program (CAP), Interruptible Curtailable Service, Demand Bidding Buy Back, Emergency Demand Response program (EDRP), Ancillary Service Market. These programs provide incentive if the consumption of power is reduced by the customer, and if they do not reduce load then penalty is applicable in various forms.

In cloud computing in order to attract the users, tenants should offer the service that reduces the service charge of users. That is why the cloud tenant's aim is to reduce their service purchasing cost and provides benefits to end user by reducing their selling cost of service.

Cloud tenants can earn profit by purchasing the service from cloud provider at dynamic price and reselling to users its own retail price. If demand response program would be used in cloud, user will also be able to participate to increase the efficiency of cloud by adjusting their demand pattern at peak demand of cloud services i.e. DR program implementation will make users able to take appropriate action or responsibility.

3 Related works

Demand response (DR) is one of the program which recently identified a method for profitable operation of data centers [11]. DR is motivated by the power system that has used to balance the electricity demand and supply at all level of power grid [12]. In electricity market environment, different types of DR program are used for decision making of pricing of electricity [13].This section listed the research work related to our proposed model.

[14] Provide a framework for DR program in cloud. The DR based on dynamic pricing scheme used for geo distributed data center (DCs) to maximize its profit. In this work [14] decision making of DCs is difficult because of dependency on each utility. Utilities set their price when they know the total demand also DCs demand. It is possible only when the price is available. [15], [16] the two works presented pricing strategies for maximizing the profit of cloud brokers. To serve the demand at each time slots based on the reserve instance or on demand instance pricing scheme. If the demand is remaining continuously for a long time then it has used the Reserve instance scheme. If users demand falls instantly it used on demand instance. [17] Proposed a pricing framework based on leader-follower game with the aim of maximize the cloud's profit. These frameworks recoup the energy cost with its tenants for profitability. Energy cost is big contributor in overall cost of cloud provider. In [17], DR program is carrying out between tenants and service provider. Tenants are price sensitive so the VMs procure by the tenants in response of prices set via provider. They perform empirical and analytical evaluation using myopic control with short term prediction of price and workloads.

Most of the research work mentioned above, does not considered the tenants profit with respective of end user satisfaction with demand response program.

4 Proposed model

In presented work, we proposed the DR program based Critical Peak pricing that improve the relationship between cloud tenants and end user. Critical Peak Pricing is a dynamic pricing model that is designed to reward the participating user that shift or reduce their demand during on peak hour to off peak hours. Basically, critical peak pricing is a tariff plan which is applied to the end user in electricity market. When the end users have massive demand of services refers to on peak hour and less demand refers to the off-peak hours. CPP includes four schemes [18]: Variable-Period CPP (CPP-V), Variable Peak Pricing (VPP), critical peak rebates and Fixed-Period CPP (CPP-F). This work analysis on CPP-F scheme to offers the services to user and then optimally implements the CPP scheme between them. The proposed pricing scheme categorizes the days in critical days and non-critical days. Therefore, during critical day cloud tenants charge high price from end users. Typically, this scheme has predefined the number of critical days, starting and ending time of critical periods. Critical Peak Period is limited in a month (16-18hr in month) that is invoked by tenants. So, users are informed by the cloud tenants about the critical days of services in day-ahead, and thus end user can change their strategy for utilization of services.

Critical days and non-critical days are recognized by the days with and without critical periods. In CPP-F scheme, there are only limited critical days are present; it is significant for tenants to implement the optimal CPP scheme strategies to increase its profit [19]. So, tenants must choose the proper critical days to increase their profit and return benefit to end user in non-critical days. Thisproposed pricing scheme aim to realize multiparty win.

4.1 NEED OF CPP

There is very hard for cloud tenants to exist in competitive market of cloud as they are bound to offer the services to the user at low price as possible. However, if the tenants could not fulfill the expectation of end user they can never exists in this competitive market. So, the tenant's requirement is to fulfill user's expectations also their own expectations. How it is possible for tenants to fulfill their requirements as well as user's expectation simultaneously. Since, service provider also always wants to maximize their profit. So, it provides the services in such a way that it always gets profit. If tenants purchase the services in real time price and reselling the service to end users at fixed prices, it does not allow the tenant to adjust their price of service with regardsto time and demand. End user also gets affected if the services are underutilized mainly when the service prices are high. So, it is better opportunity to provide the services by tenant to user in dynamic way.

As the tenants work in the cloud computing market as a retailer, so it procures the services in time varying prices and to attract the end user, they use own pricing model to provide the benefit to end users. CPP scheme is one of the dynamic mechanisms used for developing a pricing model which is efficiently works between tenants and enduser.

4.2 SYSTEM MODEL

In cloud computing, the cloud tenants receive the resources from different kind of cloud provider and construct virtualized resources for the end user. The cloud tenants buy the various kinds of resources from the cloud e.g., Virtual Machine (VM), Software Services and Storage, etc. with a range of pricing scheme e.g. on-demand pricing, spot pricing and reserve based pricing etc. Generally, tenants try to buy the resources at minimum prices from the service providers.

We consider a simple system in which single type of instances i.e. VM is procured by tenants from the Cloud Service provider and resell to end user. Since, cloud tenants cannot be considered as cloud service provider because tenants only purchase the services and resell them. Instead, the tenant's deal with cloud service provide for services. However, the service provider provides the resources and the capabilities in the form of services. Hence, tenants procure the services from the provider at real time price and resells to user based on the demands using its own pricing scheme. Numerous enterprise and business are moving towards the cloud computing to grow their business using cloud service and this tendency also maintained in future [20]. The cloud tenants are increases their investment into cloud computing, because the price responsive of users will help to increase their profit e.g. the video steaming giant Netflix acquires its computational resource from the Amazon's EC2 cloud [21]. Figure.1 illustrates the model of general cloud ecosystem and highlights the elements which are used in the model [22].

- Cloud-Tenants

The Cloud service provider (CSP) sold the services at real time price to the tenants. The service demand of tenants depends on the service demands of end users. So, Tenants need to predict the future demand of end users. Therefore, tenant's purchase the services from the CSP equal to selling of services to the users. In order to decide the critical day, Tenants used the price forecasting model to predict the price of services in day ahead before the delivery of services. Accordingly, tenants set their own price of services based on the decision of critical day. The realizations of purposed model will base on CPP-F pricing scheme policy.

- Tenants-Users

The cloud tenant's charges its users based on CPP pricing scheme. The tenant would choose the optimal price of services that increase their revenue and also return benefit to the end user. Tenants are the entities that must maintain the trust of end-users. So, in trade of exchange services with price is transparent to end users. So, Users would inform of critical day one day ahead so, they are effectively participated in Demand Response program; e.g., a Netflix play the crucial role informs of manages and control in responses, in the different variations of capacity of resources of Amazon EC2 VMs [20]. If end users are not well participated in Demand Response Program they suffered by loss. In developing the model, user's responses to CPP are explained via User price responsive model of demand.

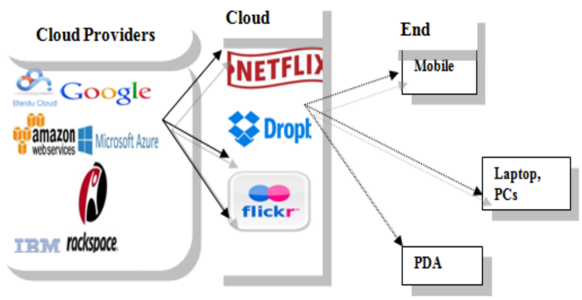

FIGURE 1 Illustrative Model of general cloud ecosystem and its elements [22]

4.3 CPP IMPLEMENTATION SCHEME

End Users plays a key role in implementation of CPP scheme in cloud computing. In order to allow end user, participate conveniently, includes the price structure of Services in CPP scheme during non-critical days and critical days [23]. Table 1 show the hour of the day pattern price structure in CPP scheme. End users shifts or reduce the workloads of services during critical days. In non-critical day, end user obtains a price discount during non-critical days of on peak periods. So, they will encourage to actively participating in CPP.

TABLE 1 Hour of the day's pattern and price structure in CPP

CPP days	Off peak periods	On peak periods	Critical peak periods
Critical day	p_{off}	p_{on}	p_{peak}
Non-critical days	p_{off}	p_{base}	–

The critical days are separated in to critical peak periods, on peak periods, off peak periods. While non-critical days are categorizing in to on-peak periods and off-peak period. In proposed approach tenants also offers the service based on critical day and non-critical days. In off-peak period the tenants sell the services to user in same price they purchased because in this time period service provider offers the services in low price. While in on- peak period service providers offer the services in high cost to tenants because at this period time real time price is high. So, this particular time periods, tenants offer the services to the end users in discount price referred to $\mathrm{p_{base}}$ which is less than the real-time price ($\mathrm{p_{base}} < \mathrm{p_{RTP}}$). The price during critical peak periods is very expensive because of real time price is extremely high. So, tenant charge the users during this period is very high to the users refer to $\mathrm{p_{peak}}$ which is greater than the real-time price ($\mathrm{p_{peak}} >> \mathrm{p_{RTP}}$). At critical time periods, users either shift or cut the demand of services. It is because tenants provide the notification of critical day in day ahead after prediction of next day price. Actually, the users respond to extremely high price not the usage of services. Only those users are willing to pay for services that have great need of services.

4.4 USER PRICE RESPONSIVE MODEL

In proposed model, real time price change in each hour, so tenants expected revenue depend on the end user demands of services as well as cost of services. As assumption, tenants purchased the services from the CSP in RTP that would change in specified time period (1hour). So, the price elasticity of demand can measure the performance of dynamic pricing scheme that represents the customer sensitivity of demand corresponding to price. Therefore, Price elasticity of demand plays a key role for tenants in designing the rational service price scheme. To maximize the expected revenue, tenants use the demand price elasticity intended for receiving the response of users.

Price elasticity of demand can measure the change in demand in response to change in price [25]. This is formulate as-

$$\mathrm{E} = \frac{\Delta d/d}{\Delta p/p}. \quad (1)$$

Since, the Δd and Δp represents the change in demand and price and p and q signify that initial demand and price. Usually, any commodity does not cover linear price – demand curve [18]. So, elasticity E could be linear by balancing the initial demand and price (d_0, p_0). So, one equilibrium point is necessary for each period because prices and demands decrease if the prices are above the equilibrium points (d_0, p_0) [18]. In cloud, users demand response to price could not justify by the price of particular period only, but also depends on the price of services in adjacent periods. Because users can be described into two categories, 1) short range users 2) long range users. Long ranges users can decide their demand by concerning the price in all periods to maximize the long-term benefit. Where short range users set, their demand based on price of current period. To identify the demand response of users in corresponding of price can be determined by using the coefficient of self elasticity and cross elasticity. Self elasticity measure the demand reduction in particular time interval corresponding to price of that interval. Cross elasticity measure the demand of certain interval in respect of price of another interval [26]. So, it would describe the user demand response of price in single period as well as in multi period. These two coefficients are integrated together to express overall demand price elasticity of service of the users.

$$\begin{bmatrix} \Delta d_1/d_1 \\ \Delta d_2/d_2 \\ \Delta d_3/d_3 \\ \vdots \\ \Delta d_l/d_l \end{bmatrix} = E \begin{bmatrix} \Delta p_1/p_1 \\ \Delta p_2/p_2 \\ \Delta p_3/p_3 \\ \vdots \\ \Delta p_l/p_l \end{bmatrix}. \quad (2)$$

So, E can be obtained as;

$$E = \begin{bmatrix} e_{11} & e_{12} & \dots & e_{1l} \\ e_{21} & e_{22} & \dots & e_{2l} \\ \vdots & \vdots & \vdots & \vdots \\ e_{n1} & e_{n2} & \dots & e_{nl} \end{bmatrix}, \quad (3)$$

$$e_{ii} = (\Delta d_i/d_i)/(\Delta p_i/p_i). \quad (4)$$

The above equation signifies that users demand of service in particular period on behalf of price at that period.

$$e_{ij} = (\Delta d_i/d_i)/(\Delta p_j/p_j). \quad (5)$$

The above equation (3) demonstrate that price of services of adjacent period can also affect the demand of users in another period. So, the tenants receive meaningful demand of users in each period. Create the matrix of price elasticity of demand for l=24 hour. The 24-rank matrix of price elasticity E can be obtained via statistical regression analysis of historical data.

Tenant predicts the price of services by using historical data of day ahead price, real time price of actual day of each hour and informs about the critical days when the predicted prices is extremely high. If the end user participated in CPP scheme they change their demand of services or shift their demands when service price is extremely high. So, their response toward the price of service could reflect by the change in demand pattern of services.

The time interval of critical peak period is 1h. So, the users demand corresponding to critical peak period can be changed, it can formulate as;

$$\mathrm{d_{cpp}} = \mathrm{d_0}\left\{1 + \frac{\mathrm{E_p(p-p_0)}}{\mathrm{p_0}}\right\}. \quad (6)$$

This equation (6) implies that users have demand price elasticity E_p, change their demand since d_0 to d_{cpp}. d_{cpp} represents the demand of users change with respect to price when the critical day informed to user. $\mathrm{p_0}$ represents the initial price or nominal prices of services. d_0 represents the demand of users which is forecasted before critical day information. P is the forecasted price of next 24 hr. This demand price elasticity E_p can be obtained from the demand price elasticity matrix which is created through historical data.

5 Methodology

The assumption of the model is; 1) The cloud tenants receive the cloud services from cloud provider in real time price and provide the services using CPP pricing schemes; 2) Cloud tenant procure the services equal to selling of services; 3) Critical peak period are defined with the time period of 1hr and matrix of demand price elasticity would be formed for l = 24; 4) Billing period is n= 30 days; These certain assumptions simplify the diversity of model.

When the CPP scheme implements between tenants and end users, tenants have responsibility to acknowledge the critical days when the predicted price is extremely high that service provider offered. So, after acknowledgement of critical days, users would reduce their service rent by adjusting their demand of service at critical days which can be realized through user price responsive model. While the users get benefit of price discount of service during non-critical days of on peak periods. The benefit function of end users can be estimated by considering both the critical day and non-critical days as:

$$K(u) = \sum_{i=i_s}^{i_e} u_i \sum_{j=1}^{24} \left(d_o(i,j) * p_o(i,j) - d_{cpp}(i,j) * p_{peak}(i,j)\right) + \sum_{i=i_s}^{i_e} (1-u_i)(d_{0n}(i) * p_{base}(i)), \quad (7)$$

where $u = \{u_i i = i_s, i_s + 1, \ldots\ldots, i_e = 30\}$ and $d_{cpp}(i,j)$ is obtain from the equation (6) it represents the demand during critical peak periods. $d_o(i,j)$ and $p_o(i,j)$ represents the demand of end user and price of service that tenant charged before implementation of CPP scheme in i^{th} days of j^{th} hour. $d_{0n}(i)$ represents the users demands during non-critical days of on peak periods. u_i represents the binary decision variable of critical days and non-critical days ($u_i = 1$ represents critical days and $u_i = 0$ represents non-critical days). $p_{peak}(i,j)$ and $p_{base}(i,j)$ represents the critical peak price and on peak period price that tenants charge the services to the end users. The first part of above mentioned equation (7) represents the service charge reductions in critical days due to reduction in demand of service. The second part represents the service charge reduction due to price discount during non-critical days.

Tenants can reduce their purchasing cost of services from service provider after CPP scheme implementation so, the benefit function of tenants can be formulated as;

$$C(u) = \sum_{i=i_s}^{i_e} u_i \sum_{j=1}^{24} \left(p_{RTP}(i,j) * \left(d_o(i,j) - d_{cpp}(i,j)\right)\right), \quad (8)$$

where $p_{RTP}(i,j)$ represents the purchasing price of services by tenants from service providers in jth hour of ith day. Now, the profit of tenants would be changed after the CPP implementation. It can be determined by the difference between benefit function of tenants and users. To increase the activity of cloud tenants in CPP implementation, cloud tenant must be ensured that increase their profit growth with CPP accomplishment, i.e.

$$C(u) - K(u) \geq 0. \quad (9)$$

The benefit of implementing CPP scheme that provides the benefit in services charge saving for end users and the purchasing cost saving for cloud tenants. CPP implementation strategies can conclude that how to decide and utilize the limited critical days that increased the entire benefits. Thus, the objective function is:

$$\max A(u) = \max\,(K(u) + C(u)). \quad (10)$$

Constraints are:

$$C(u) \geq 0, \quad (11)$$

$$K(u) \geq 0, \quad (12)$$

$$C(u) - K(u) \geq 0, \quad (13)$$

$$\sum_{i=i_s}^{i_e} u_i \leq N_{CPP}. \quad (14)$$

$$t_y - t_{y-1} = \Delta t_{min}\left(2 \leq y \leq N_{cpp}\right). \quad (15)$$

(10) is objective function, (11) it ensure that tenants would reduce the purchasing cost and increase the selling price during critical peak periods of all critical days;(12) ensure that users would save service charges by contribution and the responses to CPP; (13) ensure that cloud tenants would increase their profit after implementation of CPP scheme between the tenants and end users ; (14) implies the constraint of maximum permitted number of critical days that tenants offer the services to the users in higher price; (15) implies the constraint that describe the least time interval between the two adjacent critical days.

The abovementioned model is solved through 0-1 integer programming function in Matlab to implement the optimal critical peak pricing in cloud computing. In CPP, cloud tenants generally decide that the next day would be noted as critical day according the price prediction of next day prices of service in advance (i.e., informed to end user in advance). Therefore, the continuous approach, i.e., everyday re-calculating the decision model composing of residual study period, could be used to advance the rationality of decision conclusion. In such a way, next day predicting price in residual study period would be combined efficiently in model solving process.

5.1 PERFORMANCE EVALUATION

To perform the study of model in cloud computing required a real cloud environment. For the study in real cloud environment is more time consuming and expensive because it required a different configuration and real data of price and demand which is not available of 24hr.To evaluate the proposed model using the simulation tool of a mat lab that a better alternative to perform experiment without much paying.

5.2 EXPERIMENT EVALUATION OF OPTIMAL IMPLEMENTATION OF CPP IN CLOUD COMPUTING

To illustrate the study performance of proposed model, using the simulation tools of Mat lab. In cloud computing, virtual machines are defined by CPU in MIPs, Storage in Gigabyte or Megabytes and RAM in Gigabytes or Megabytes. Price of a virtual machine considers the CPU as attributes. To consider the base case, demand request per hour is generated through Poisson distribution with parameter (λ). To evaluate the performance that represents the proposed scenario, one month data of price that being offered by the service provider and demand of VMs per hour (one month) by end user is required. Therefore, the parameters required for study the model as shown in Table 1.

Table 1 Parameter Required to study the model

Parameters	Descriptions
Types of Virtual Machine	1 (single)
CPU (processor)	2x
Memory	1 GB
Storage	2.5 GB
Price range	$ [0.027, 0.2625]
VM request per hour range	[6,20]

To illustrate the behaviour of model used the single service provider, single tenant and the aggregate demand of end users request per hour range between [6, 20]. The price of Virtual machine is dynamically changed per hour within range [0.027, 0.2625].

Decision of critical day taken by the tenants based on price of VMs when it is extremely high. According to the model it is decided by the forecasting of price by the tenants that service provider offers the VMs in next day. Instead of focus on forecasting of price and demand, decision of critical day is taken on the price of VMs that being generated through the normal distribution. In CPP scheme, tenant is informed to the end users in advance to change the pattern of demand of VM.To estimate the actual demand of end user by using price responsive model as given in equation (6).Whenever the critical days are triggered. Since, i_s=1 and i_e=31 it represents that the study periods will span for 31 days, $N_{cpp} = 4$ and $\Delta t_{min} = 24h$. The time period of CPP is classify in to critical peak periods, on peak periods and off peak periods. Therefore, the time duration is on peak period is between 12:00-18:00, critical peak period between the 12:00-16:00 and the remaining time period considered as the off-peak periods. For optimal implementation of CPP select the day as 5th, 17th, 19th, and 26th as the critical days in generated data therefore, $\mathrm{u}_5 = \mathrm{u}_{17} = \mathrm{u}_{19} = \mathrm{u}_{26} = 1$.To implement the CPP, end user shift or reduce their demand of VMs from critical peak periods and tenants offer discounted price in non-critical days which ensure that end users obtain the benefit of saving purchasing cost. It is because end users are price sensitive and participated in CPP demand response program. So, the benefit (saving purchasing cost) of end user is calculated as given in equation (7) is 1.107×10^4.The purchasing cost saving for tenant is estimated using the equation (8) is 2.996×10^4. Entire profit increment of tenant estimating from equation (9) is 1.889×10^4. The entire profit of tenants depends on the decision of critical days that how to efficiently utilize the limited critical days. Tenant selling price during critical peak periods is higher than the service provider price of Virtual machine. Due to relatively high price, tenant can effectively stimulate the end users to reduce or shift their demand in critical peak periods by increasing the critical peak price ($\mathrm{p}_{\mathrm{peak}}$). As shown in fig.1 effect of CPP implementation that reduce theVMs demand in a critical peak periods of four hour interval. End user also get benefit during non-critical days because the tenant offer the VMs in discounted price ($\mathrm{p}_{\mathrm{base}}$) which is lower than service provider price.

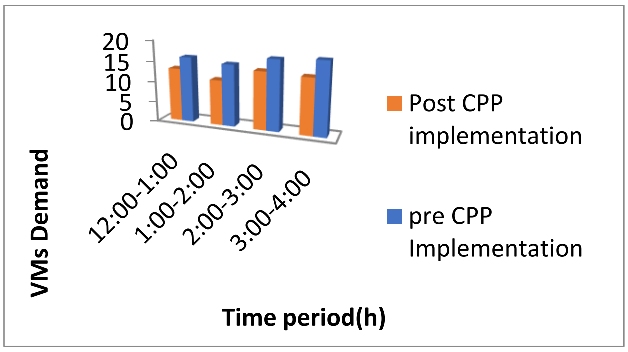

FIGure 1 Illustrate the Role of CPP in reduction of VMs demand

It is clear that reduction in VMs demand during critical periods can also lower the purchasing cost of tenants that ensure the balancing the purchasing cost and selling income, which increased the reliability of tenant to exist in cloud market and relief in shortage of VMs in critical peak hours of the whole system. While combining the tenant selling price during critical peak periods after shifting or reducing the demands of VMs with service provider selling price as shown in fig 2 it illustrates that the selling cost of tenants during critical peak periods is lower than the actual VMs cost of service provider.

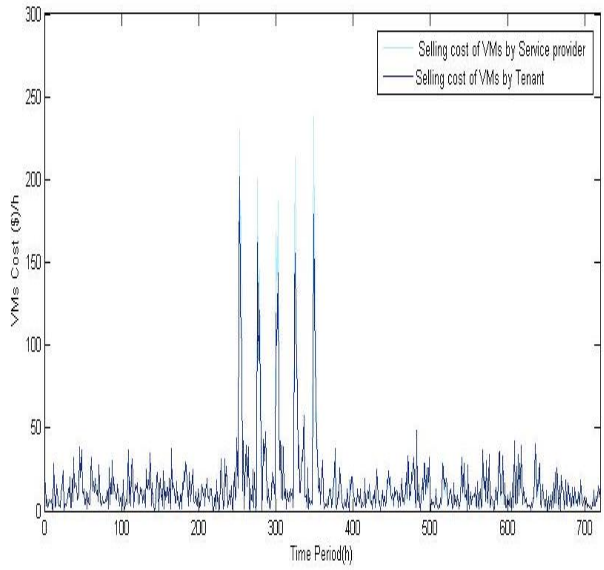

FIGURE 2 Selling cost of tenants during critical peak periods is lower than the actual VMs cost of service provider

Consider the situation in which the N_{cpp} increases while the other parameters are remains same as show in Table 2. Therefore, the actual critical days are increased then profits of tenants increased because users adjust their demand pattern and tenants increased their selling cost in critical days. Because in equation (9) combined the both purchasing cost reduction and selling cost increment. The end user has decreased the saving of purchasing cost because in equation (8) combining the purchasing cost reduction in critical day due to demand adjustment and purchasing charge saving in non-critical day due to reduced selling cost of services by tenants in on peak hours of non-critical days. If N_{cpp} increased to certain degree, for example $N_{cpp} = 5$ then the decision result would not change which is equal to the result of $N_{cpp} = 4$. This is because the actual four critical days are executing, therefore, tenants and users profit would get stable. But in this situation when the N_{cpp} keeps increases, then tenants profit will increase and the end users profit will jeopardize. Hence, the total benefit will be affected. It is also indicated that if $N_{cpp} = 5$ then optimal entire profit will obtain because of same decision result when only actual critical days are executing ($N_{cpp} = 4$).

TABLE 2 Impact of N_{cpp} in Benefit of tenant and end user

N_{CPP}	Benefit of end user ($)	Benefit of tenant ($)	Total Profit increment ($)
5,17	1.637 X 10^4 (4.27%)	2.216 X 10^4 (6.56%)	0.573x10^4 (14.88%)
5,17,19	1.495X10^4 (3.95%)	2.367 X 10^4 (7.06%)	0.872 X 10^4 (17.5%)
5,17,19,26	1.347 X 10^4 (3.58%)	2.496 X 10^4 (7.39%)	1.149 X 10^4 (19.63%)
5,17,19,26	.347 X 10^4 (3.58%)	2.496 X 10^4 (7.39%)	1.149 X 10^4 (19.63%)

6 Comparative study

Real time price increased the efficiency of utilization of services and revenue maximization of service provider because its allow service providers to sell spare or additional capacity in lower price which is less than fixed price (i.e. on demand or reserve price) [5]. Real time price is also claim that it increased the user's satisfaction on overall cloud performance. Real time price is also introduced to encourage the users shift load from peak hour to off peak hour [6]. But the interesting fact is that a user does not shift their work load in real time price they save their purchase cost only by switching to real time price. The additional cost saving is challenging task this can be achieved through the workload shifting. This concludes that the real time pricing does not effectively work to motivate the users to shift their load. Because cloud provider does not provide enough monetary incentive to the users that they shift their workload. To save the additional cost of users only they shift their work load. It is possible only when the users are getting more incentive in monetary. So, to reduce the complexity of heterogeneous environment and save the additional purchasing cost of users, tenants work better between the cloud provider and end users. Since, the tenants efficiently manage the resource and fulfil the expectation of end users. In comparative study, show that if end users rent the virtual machine directly from the service provider how much they pay to them. Secondly, end users rent the virtual machine directly from the tenants, how much they obtain benefit either in renting virtual machines from the service providers or from tenants. Suppose that Single user have 1 month demand of Virtual machine of each hour in each day. Using the Poisson distribution and generate the demand of single users of 1 month. Assume that 4 days are critical days in which 12:00 - 4:00 p.m. are critical peak periods and remaining days are non-critical day and fixed the duration of 12:00 - 6:00 p.m. is on peak periods. Demand of VMs by single users is shown in fig 3. Price of Virtual machine that service provider is being used to offer the services to users are change hourly as per demand of users [5].

Using normal distributions used to generate the cost of single virtual machine cost per hour of one month [6]. Now, there is no early notification of critical day so the user does not shift their demands of Virtual machine they pay the same price of VMs that the service provider charged. This can be shown in Fig 4 that VMs cost pay by users to service provider. While the user purchased the VMs from the tenants they have to pay less cost to tenants then service provider because the early notification of critical day by the tenants make easier to take decision by users to shift their work load as shown in Fig 5. Therefore, the users shift their work load to save their purchasing cost.

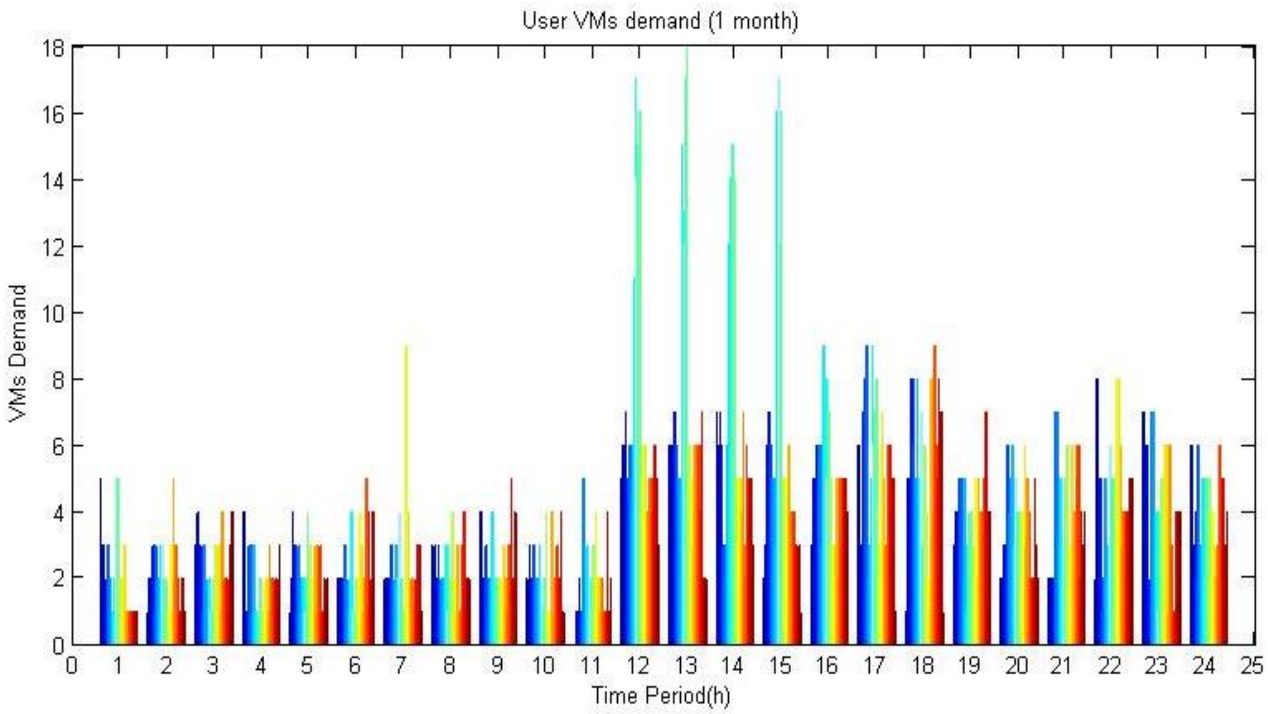

FIGURE 3 User VMs demand to Service Provider

This can be shown in Fig 6 purchasing cost of VMs pay by users to tenants. Critical peak pricing scheme is more efficiently work in cloud computing environment because this enables the user to shift their workload and allow the end users to save their purchasing cost. In addition, demand of same users is shift in CPP scheme that normalized the peak load of critical peak periods and shifted in non-critical days. Therefore, it improves the balance of demand and supply. It is also ensuring the tenants profit because if users shift their demand in critical peak hours then tenants purchasing costs also reduced in critical days. Table 3 shows the comparison of purchasing cost of users from tenants and service provider. Table 4 shows the profit of tenants and users in CPP Scheme.

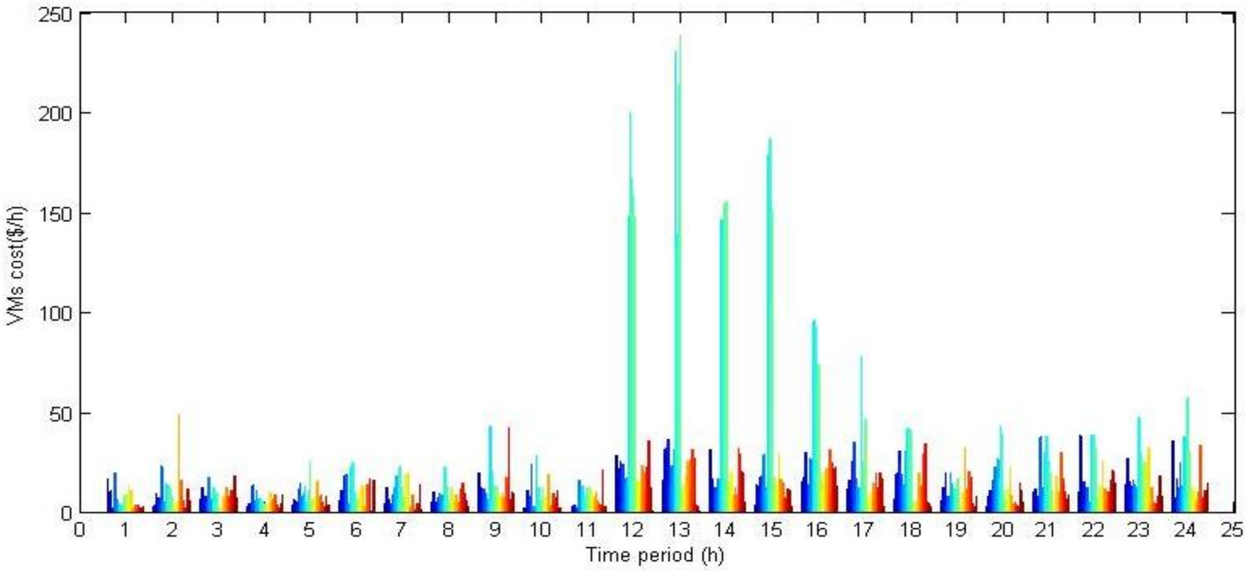

FIGURE 4 User VMs cost pay to Service Provider

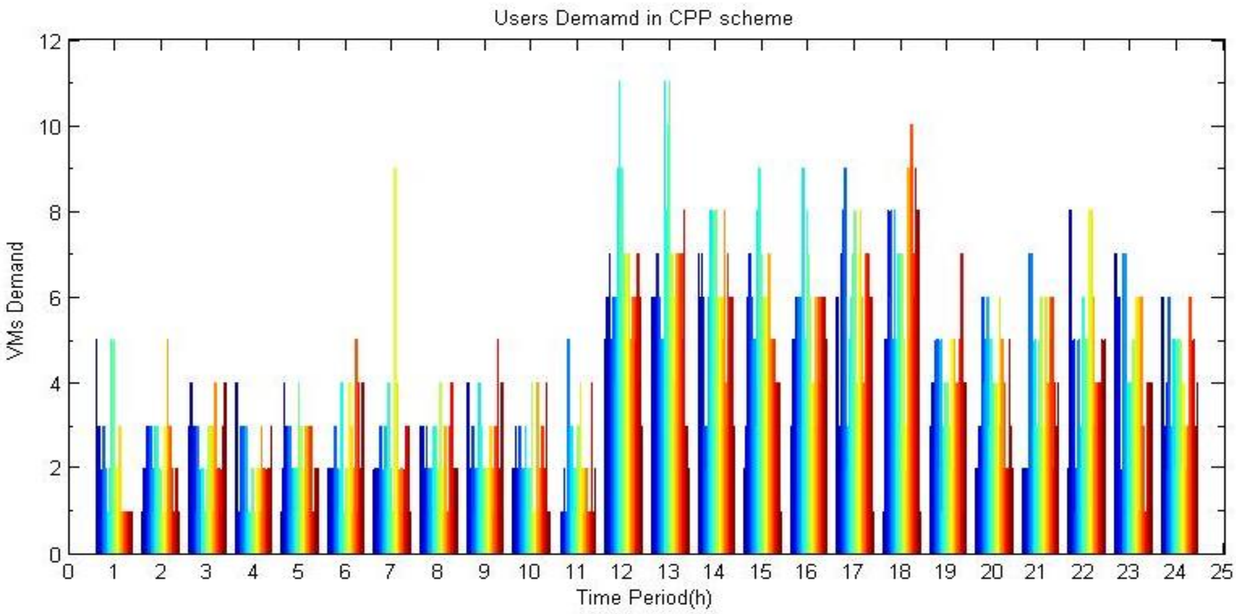

FIGURE 5 User VMs demand to Tenants

Comparison of tenants and service provider cost illustrate that users have less pay to tenants and getting approximate 4.11% profit in purchasing VMs. Additionally, due to incentive monetary users are shifting their demand of VMs in critical day to non-critical. This is profitable for tenants and service provider both because reduced in demand of VMs decreased the purchasing cost and also decreased the peak load of services in critical peak hour.

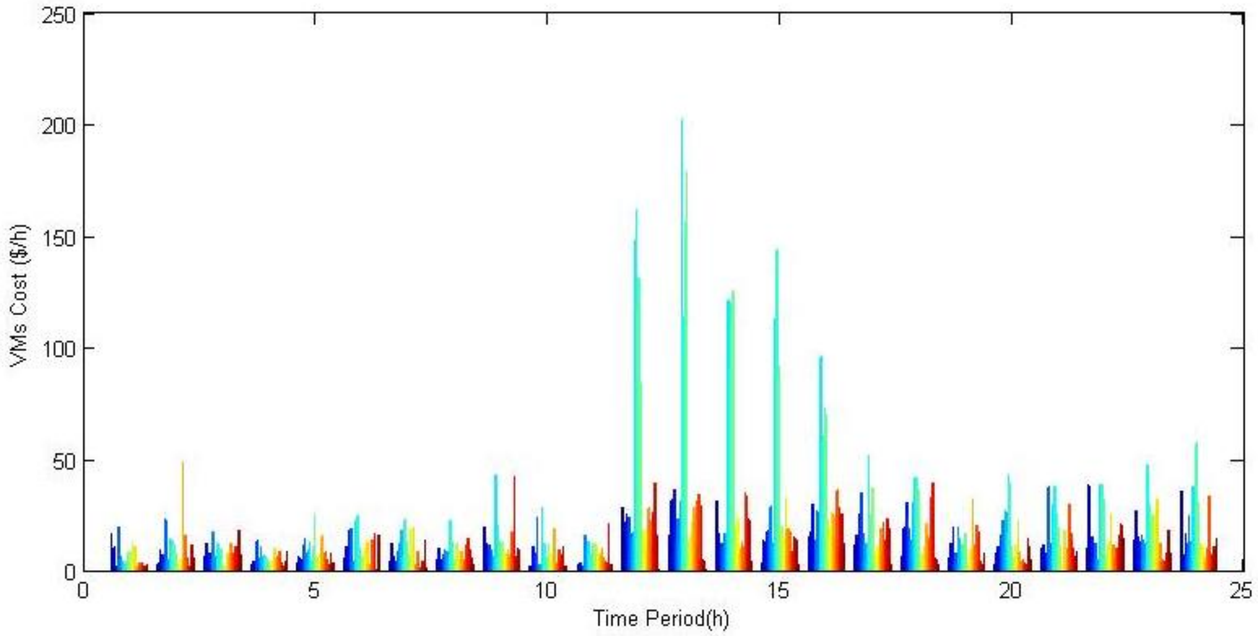

FIGURE 6 Reduced VMs cost pay to tenants

Tenants profit must be higher than the profit of users to exist in cloud market environment. Therefore, the existence of tenants must be possible if users are conveniently participating in cloud computing.

TABLE 3 Profit of an End User (When purchased through tenant)

Purchasing cost from Service Provider (1 month)	**Purchasing Cost from Tenant (1 month)**	**Profit of Users (%)**
1.1492×10^4	1.0994×10^4	$0.0498 \text{ x } 10^4$ 4.11%

TABLE 4 Profit of Tenant

Purchasing Cost Of tenant ($)	**Selling Cost Of tenants($)**	**Total Profit of tenants ($)**
$1.0292 \text{ X } 10^4$	$1.0994 \text{ X } 10^4$	$0.0702 \text{ X}10^4$ (14.14 %)

7 Discussion and conclusion

This work deal with the implementation of critical peak pricing scheme in cloud computing which works between the tenants and end user. This scheme is based on the user's response through price responsive model which incorporate the sensitiveness of user toward the price of services. The problem faced by the tenants in cloud computing is that they purchase the resources from service provider at dynamic price but how to further sell that they get profit with end users satisfaction. To resolve this problem, dynamic pricing scheme is implemented between the tenants and end user. It is designed for satisfactory benefit to both of tenants and users. So, firstly we designed the hour of the day pattern in which the services provided to the user are based on the particular structure. Therefore, by using forecasting method, the demand and price of services were predicted. If the next day price is extremely high then tenants notify the end-user. So, this can be realized through user price responsive model. The DR program, CPP scheme is used by the cloud tenants that work in a cloud environment; it should be appropriately designed to meet the objective such as profit increment of tenant with workload reduction and return benefit to the end users in reducing services cost of user. From table 6.4 and 6.5 it is evident that both tenant and end user are making 14% and 5% using the said scheme as compared to the traditional way of purchasing the services on cloud.

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