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Enhanced Automated Dynamic Pricing Marketplace for Cloud Users

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ABSTRACT

Dynamic forms of resource pricing have recently been introduced by cloud providers that offer Infrastructure as a Service (IaaS) capabilities, in order to maximize profit and balance resource supply and demand. The design of a mechanism that efficiently prices perishable cloud resources in line with a provider's profit maximization goal remains an open research challenge however. In this paper, we propose enhanced dynamic pricing in the marketplace for cloud users using prioritization. The prioritization based on the customer categorization and urgency level. Excellent, Good and Poor are the categorization of the customer. Our simulation-based evaluation of the mechanism demonstrates its effectiveness under a broad variety of market conditions. In particular, we show how it improves on the dynamic pricing auction, revenue maximization and urgency of the customers.

Keywords

Keywords are your own designated keywords separated by semicolons (";").

1. INTRODUCTION

Cloud computing is a promising technology enabling high performance services for all categories of IT facilities presented to the clients as a service [1] [2] [3]. The term cloud refers to the service provider that organizes all categories of resources like storage, computing, etc. In the cloud computing environment, three types of services in the form of infrastructure, platform and software are provided for the customers on the cloud market. IaaS provides the infrastructure for different functions such as storage and computing. Secondly, PaaS gives platform to the client so that the users can effortlessly make the applications. At last, SaaS provides software to the clients and it does not require installing the software[4]. Efficient allocation of resources is naturally associated with a Service Level Agreement (SLA) in service computing. SLA provides a wide range of services and the cost is decided between users accessing cloud service request model with their constraints. Cloud Market Maker (CMM) a system which has been developed to create a dynamic pricing marketplace for providers and to provide users with decision support when choosing a cloud resource. Such a market will work for both cloud customers and providers. The automatic selection and comparison feature of this system will help attract customers which will also provide an opportunity to emerging providers to get recognition. In order to attract customers, the market will also assist providers to revise their resource prices. Furthermore, the market also provides suggestions regarding quality of service provision to cloud providers; it communicates the current market situation to all listed providers. This will increase competition among providers which will lead to better service provision and will also create more options for cloud customers. Cloud customers will not only be able to select the most suitable provider but would also be able to acquire an economical resource. Presently, there exist some systems which help in selection of IAAS cloud provider but these systems are different from CMM. These systems are discussed in detail in Section 2.

The contribution of the paper is twofold. Firstly, the CMM dynamically adjusts the prices of cloud resources in real-time using a supply demand auction based model. It assists providers in determining the market price for their resources. Secondly, the CMM also works on the behalf of the cloud customer. It supports customers in making the decision regarding the most effective provider for their requirements. Both of these main features have novelty in themselves but together they produce an approach which has not been tried before according to the understanding of the authors. In this paper, we propose enhanced dynamic pricing in the marketplace for cloud users using prioritization for customer's satisfaction.

The rest of this paper is organized in the following manner: The previous research dynamic pricing strategies for cloud providers and existing comparison portals for IaaS cloud customers is discussed in Section 2. The existing the Cloud Market Maker system is discussed in section 3. An evaluation of the approach is covered in Section 4. Finally, the conclusion and future work are presented in Section 5.

2. Literature Review

2.1. Cloud pricing models

In a rapidly changing environment such as the cloud, dynamic pricing is required in order to adapt to the constantly changing market conditions. It is an effective strategy to cope with unpredictable demand, unutilized resources, and to generate more

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revenue. At present however most cloud providers offer resources at a fixed price (with the exception of Amazon's Spot Instances). The resources offered by providers are mostly categorized as On-Demand and Reserved Instances. Amazon is the only major provider at present who is providing spot instances , on-demand, and reserved instances. However, spot pricing has its risks as resources can be lost at any point in time when the spot price increases. This makes it of limited value in the majority of usage scenarios. The usage of a Dynamic pricing strategy to maximize revenue for an individual provider, Amazon, was proposed by Xu and Li . Further, an auction mechanism has been employed by Wei et al. for dynamic price adjustment in a cloud environment [5]. The proposed approach addresses the shortcoming of Amazon's spot instances. A mechanism has been suggested in the paper that guarantees the service; the instances once auctioned off are not made available to other users until the user terminates it

Existing work demonstrates the suitability of dynamic pricing for use in the cloud. It has been shown to increase the profit and utilization of resources. Dynamic pricing is presently employed by only one IaaS cloud provider (Amazon) whereas most of the other IaaS cloud providers employ static pricing for their resources. Furthermore, it has been observed from the literature that much of the work has been done to improve the existing dynamic pricing schemes work with an individual provider such as Amazon. At present, no system is available that works for a number of cloud providers. Our system however has the ability to create a market in which several IaaS cloud providers can list their resources and the market maker adjusts their resource price based on the current market situation.

2.2. Decision portals, brokers, and marketplaces for cloud customers

Our work not only acts on the behalf of IaaS cloud providers but it also assists cloud customers. Each supplier tends to have their own pricing models for their resources. A provider commonly packages their network, storage, and compute services differently which makes it difficult for customers to understand which factors make up their charges. A platform is therefore required that provides decision support and a unified view of IaaS cloud providers for cloud customers.

2.2.1. Decision portals

In order to assist customers in decision-making, the Cloud Harmony portal provides benchmarks for public cloud providers. Benchmarking parameters include network, performance, and up-time monitoring. Based on the benchmark results, the selection of cloud provider is often left to the customer. This is a time consuming task because customers need to compare each and every provider's benchmarks. Similarly, Smart Cloud Broker assist cloud customers in the selection of a suitable cloud provider (it presently considers three providers: Amazon, Rackspace, and Go Grid). With this system, users can benchmark software systems that are running on servers. This assists cloud customers in com-paring results and in selecting the suitable provider for their given application. The Cloud orado portal also provides the pricing de-tails of IaaS cloud providers to cloud customers. In order to make a comparison the customer is required to visit each and every cloud provider which is a time consuming task. This makes it difficult for the consumer to decide which provider is more appropriate for their requirements.

2.2.2. Cloud brokers

A financial brokerage model for cloud computing has been proposed by Rogers and Cliff (R&C). It aims to forecast future demand. It buy resources from cloud providers and provide those to cloud customers. It tends to select the most economical resource and it works only for reserved instances. The broker proposed in acts as an intermediary for cloud providers and customers. The cloud broker provides on-demand and reserved resources at a price lower than respective providers. The broker employs dynamic programming to estimate the duration and quantity of resources that are likely to be required.

2.2.3. A marketplace for cloud users

In order to allow Amazon cloud customers to sell their unused EC2 reserve instances to other Amazon customers, Amazon recently opened the Reserved Instance Marketplace . The goal is to provide a new facility for existing Amazon customers through which they can sell their unused resources. John and Philip argue that the opportunities which exist for cloud brokerage are reducing and that new secondary markets, such as Amazon's Re-served Instance Marketplace are replacing them. Recently, the IaaS cloud provider Enomaly opened a clearing house and marketplace called Spot Cloud . Using Spot Cloud, cloud service providers can sell their unused resources to buyers and resellers who require resources at the best possible price. Spot Cloud provides the opportunity to providers to sell their unused resources which may otherwise go unsold. Cloud computing has a dynamic nature i.e. resource that is available at one moment may disappear at the next. This means that an intelligent entity needs to be able to work 24/7 without human intervention. A Multi-agent System (MAS) seems suitable for this task because agents have potential to intelligently take decisions and can manage rapidly changing conditions.

2.3. Multi-agent systems for managing complex environments

MAS has shown to reduce the human effort and has proved to be useful in open and constantly changing environment such as internet where MAS is being employed for information gathering, retrieval, and provision. A multi-agent approach can be utilized for resource discovery, brokering, trading, and managing of cloud resources .

In this work we employed MAS to construct the Cloud Market Maker. Agents work on behalf of customers and providers. It selects a suitable provider for customer and dynamically adjusts the price for providers. Further, dynamic approach has been adopted for pricing of the cloud resources. Besides the many advantages of a dynamic pricing approach, it does however have some drawbacks which need to be addressed.

2.4. Auctions

A dynamic pricing scheme introduces additional complexities that are associated with market pricing and budget planning . An auction mechanism appears to be well suited to these challenges because of its abilities in terms of price determination and

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adjustment. Given the supply and demand at any given point of time the price of the resource is automatically set. Furthermore, it also provides the room for price negotiation between parties.

A multi-auction approach has a great deal of promise, especially as it closely follows the ways in which humans create supply demand based marketplaces. This strongly suggests that it is also suitable for use in our Cloud Market Maker. Unlike Amazon spot instances, CMM employs an auction mechanism to determine the dynamic price of cloud resources by creating a market within which a number of different cloud providers participate. Furthermore, our system employs a multi-auction approach to increase the probability that customers will be able to acquire resources within their time constraints.

3. The Cloud Market Maker system

System architecture

The Cloud Market Maker is required to perform complex tasks (price regulation and decision regarding best provider), work on behalf of users, work autonomously, and dynamic nature of the cloud requires it to work 24/7. Therefore an intelligent entity has been identified for this purpose. The literature review, which was briefly summarized in Section 2, demonstrated the suitability of a multi-agent system for our purpose and it has therefore been employed in CMM. Furthermore, the literature showed the benefits of a multi-auction approach for dynamic price adjustment and it has therefore been applied to create a marketplace. The use of agents in auctions has been shown to outperform humans in several studies. The auction process involves bidding which is time consuming; the use of agents in the bidding process saves time and also provides the flexibility of participating in multiple simultaneous auctions. Based on the analysis made in the previous section, the Cloud Market Maker has been designed and developed accordingly.

The architecture of the Cloud Market Maker has been designed by taking into consideration the multi-auction approach and agents that are required for complex decision making. Therefore, the system follows a multi-agent architecture. The agents work autonomously and create automated marketplace for cloud users. The system is required to incorporate agents that can work for providers and customers, manage and run auctions (for dynamic price adjustment), handle the information regarding the auctions running in the system, and control the overall platform. The architecture of the Cloud Market Maker system has been designed by taking this in consideration and is shown in Fig. 1. It shows how the six classes of agents in the system work together.

The Agents in the Cloud Market Maker
Agents: Platform Agent (PA), Customer Agent (CA), Provider Agent (PrA), Blackboard Agent (BA), Leader Auctioneer Agent (LAA), and Auctioneer Agent (AA)
1. The PA is responsible for launching and managing the agents and scaling the system up and down in relation to system load. 2. The customer makes requests and the provider issues offers via the respective CA and PrA. 3. The BA displays the auctions running in the system. 4. The AA are managed, launched, and deleted from the system by LAA.

3.3. The working of the Cloud Market Maker

The architecture, as shown Fig. 1, shows that customer and provider agents work on behalf of the cloud customers and providers. The customer agent is responsible for placing bids in an auction and selection of most suitable resource for the customer. The cloud users (providers and customers) provide the requirements details to the system through the interface of the Cloud Market Maker (as shown in Fig. 1). The requirements details include system specification and user details. In IAAS cloud services, resources are commonly delivered in the form of virtual machines (VMs). In order to attract customers, cloud providers offer different types of VMs which are created after a careful market analysis. Different types offer customers a number of possible features (e.g. each type containing a number of pre-built software libraries/repositories and OS types). However, it is common for customers not to have exact knowledge regarding their requirements. Our system selects the resource that most closely matches user requirements and is the most economical for them. Furthermore, customers often have limited knowledge regarding

number of resources that are needed for their application. It is common given the on-demand nature of the cloud that new resources are added as and when they are required. This not only saves customers from acquiring extraneous resources but also enables providers to address the over-provisioning challenge (which may result in zero return on investment (ROI)) . Considering this, our system focuses on single VM selection (similar to spot instances). However, our system has the ability to add more resources when required whilst respecting the dynamic pricing model.

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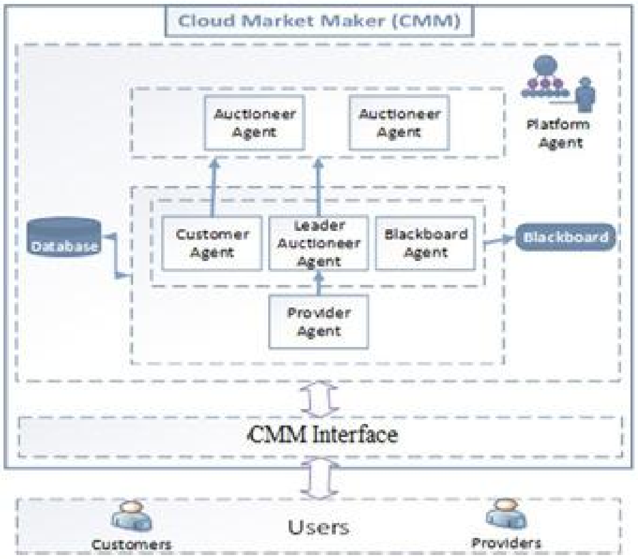

Figure 1. Architecture of the cloud Market Maker

In addition to information regarding their requirements cloud customers also provide their urgency values to the system; this will be discussed in detail in Section 3.4. The platform agent controls the overall system. The leader auctioneer agent handles the auctioneer agents. The auctioneer agent in the system is responsible for managing the auctions that include starting, restarting, and closing of auctions. The auctioneer agent is also responsible for dynamic price adjustment. When cloud provider provides the details of unused/available resources to the system, the system will make the resource available to customers by auctioning it. . If an auction is unable to sell the resource then auctions are rescheduled every 30 min (in our system each auction lasts 30 min).

The auction selection process is just as important as bidding in an auction. If the auction selection is poor then chance of acquiring the resource is also likely to be very low. The selection algorithm has therefore been carefully designed and is covered later in this section. The selection source is equally important i.e. the mechanism by which the customer agent gets to know about the auctions that are currently running in the system. The architecture of the system shows that a blackboard has been employed to display the auctions. In a blackboard architecture agents do not directly communicate with each other instead the information is made available to all agents in a system through a common information space. This reduces the complexity and overhead of message exchange between the agents. Furthermore, this is well suited for dynamic environments. The customer agent interacts with the respective blackboard to get the required information. It saves the time of customer agent and reduces the message overheads. The working of the system is explained below.

Providers send details regarding their available resources to the PrA. The PrA sends information to the LAA regarding the new entry. On receiving the resource details from the provider, the LAA starts an auction. The customers enter the system via the PA. The PA registers the customers and the customer request is then given to CA. Based on the customer's request; the CA is redirected to the blackboard agent. The BA is responsible for managing the blackboard. The blackboard displays the available resources of providers for auction. The offers are given to the BA by the provider agent who takes the requirements details from providers. The blackboard has seven entries (i) Auction (ii) Provider ID (iii) Item ID (iv) Current highest bid in an auction (v) Number of bidders in an auction (vi) End-Time (each auction will run for 30 min) and (vii) requirements details. The reason for including the ItemID is that it might be possible that one provider lists multiple resources; the ItemID helps in distinction. The CA reads the blackboard and based on the selection function, given in the subsequent section, the CA selects the auction to participate in. In case if agent finds that winning is not possible in the auction then the CA can switch to some other auction. This increases the probability of getting the resource. Finally, the result of the auction is given to the customer and the provider agents. The customer and provider agents return the result to the customer and the provider. Furthermore, the database as shown in Fig. 1 holds the information of customers, providers, feedback, and rating of providers.

3.4. Selection of resource and dynamic price adjustment

This section covers the resource selection and dynamic price adjustment techniques in detail. In the first step the blackboard is read by the CA, which selects an auction using a Selection Function (Algorithm 1) presented in the next section (Section 3.4.2). The CA considers seven parameters for selection: current highest bid of an auction (a1), remaining time of auction (a2), current number of bidders in an auction (a3), budget of the customer (a4), urgency of the customer (a5), remaining time to get the resource (a6), Quality of Service (QoS) (a7),and Customer categorization(a8). Urgency is an option which gives the customer the ability to indicate how urgently the resource is required. The urgency is categorized into six groups (i) Immediate (i.e. within 1 h) (ii) within 2 h (iii) within 3 h (iv) within 6 h .v) within 12 h (vi) and within 16 h. Urgency plays an important role in price acclimation. The immediate urgency level reflects the customer's willingness to pay the maximum of their budget. The lower urgency levels (such as 12 h, 16 h) indicate that a customer prefers to get the most economical resource and it gives agents the chance to search for the most affordable ones. The urgency values can be fined tuned during the experimentation phase. The selected values reflect the capability of system to adjust the price in relation to different urgency levels; The customer is categorized into three groups (i)Excellent(ii) Good (iii) Poor. This is further explained in bidding algorithm which is given in Section 3.4.3.

3.4.1. Quality Of Service (QoS)

Before going into the detail of how the selection function and bidding algorithm are used in practice, it is important to consider the Quality of Service (QoS) that is provided. In a dynamic environment such as the cloud, it is quite difficult and challenging to analyze QoS levels because users' preferences regarding it may vary. Therefore in order to capture this aspect, our system

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Table 3
Feedback by cloud customers

No.	Parameters	Rating
1.	Availability	
2.	Performance	
3.	Response time	Excellent, Very Good, Good, Average, and Poor
4.	Fulfillment of SLA	
5.	Elasticity	

considers only the rating of cloud providers. Customers' feedback includes availability of instances, performance, response time, fulfillment of Service Level Agreement (SLA) of a provider, and elasticity. The metrics through which customers rate a service is shown in Table 3.

Customers provide feedback regarding the cloud services they access via the CMM system. They rate the services using a range from Excellent to Poor. Based on the customers' feedback, the system implicitly assigns weights (points) to the providers' services; this helps in quantifying the QoS. For Excellent, Very Good, Good, Average, and Poor rating 10, 9, 8, 5 and 0 points have been set. Using the customers' feedback the system calculates the individual provider ratings; it implicitly assigns an overall score of between 0–10 to each provider. The system calculates a provider's QoS by taking the average of its feedback.

3.4.2. Selection function

A selection function has been created in order for agents to be able to choose between resources. A multi-attribute utility function (U) is used for this purpose because in order to select an auction, a number of attributes need to be considered. The urgency value guides the selection of auction in the first place and is also useful in determining how bids should be placed during it. The budget is used during selection to check if the highest bid is less than customer budget or not. Moreover, the comparison of budget and current highest bid in an auction also helps in selecting those auctions that CA can bid in. After pruning the number of auctions (L), the utility function is applied on the selected auctions to see which auction is the most suitable for the agent to participate in.

In order to understand how the selection function is used in practice let us consider the following scenario. Suppose a new customer enters the system and provides the requirements to the CA. Based on the given requirements, the CA reads the relevant black-board. In order to increase the probability of an agent successfully getting a resource, the CA will tend to select an auction that ends within a short period of time. This means that an agent will likely have the chance to participate in multiple auctions (if for example it fails to get the resource from current auction.) The CA needs to select the most appropriate auction to participate in. It firstly considers the customer's urgency and budget. The comparison of highest bid in an auction with the customer's budget is based on the urgency.

Algorithm 1: Selection Function

```
Input: a1, a2, a3, a4, a5, a6, a7
Output: Selected Auction
IF a5 NOT EQUAL 0
  Then
    IF a4 Greater Than a1
      Then
          x1 = (1-(a1/a4))
          x2 = 10-a3
          x3= (1- (a2) /(a6))
          x4= a7
      IF u=u1then
      U=∑(x1, x2, x3, x4)
      Else
          U=∑(x1, x3, x4)
        END IF-ELSE
      END IF
END IF
```

3.4.3. Bidding algorithm

After the selection of the relevant auction, the customer agent bids in the auction using the bidding algorithm (Algorithm 2) presented below (only first and last cases are shown here). The auction determines the market price of a given resource. In some cases a large number of bidders may act to increase a resource price but the system always ensures that selected resources remain within the customer's budget. In a similar way to that of the selection function, urgency also plays an important role in bid placement during an auction. The reason for using different urgency levels during bidding is to give the customer agent a chance to acquire most economical resource for the customer. In cases with a low urgency level (16 h, 12 h, 6 h) the customer agent attempts to get a resource at the lowest possible cost to the user even if this means participating in several auctions.

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Algorithm 2: Bidding Algorithm

Input: Bids in Auction

Output: Result (Win or Lose)

Auction A selected

After selection CA switches to the following cases;

```
Case1: a6 LESS than Equal 1hour
IF a1 LESS than 95% of customer's Budget then
    Continue bidding until 100% of
    customer's budget is reached.

  IF outbid then
   Use selection function to select another
   auction

Case6: a6 EQUALS 16 hours
IF a1 LESS than 20% of customer's budget then
   Continue bidding until 20% of customer's
   budget is reached.

  IF outbid OR a1 GREATER than 20% of
  customer's budget then
   Use selection function to select another
   auction
```

The selection of suitable resource is considered during auction selection whereas the bidding algorithm dynamically adjust the price.

Challenges in dynamic pricing market price

Dynamic pricing market price deals only with these parameters like current highest bid of the customer, remaining time of the auction and so on. But it fails to provide priority to the repeated customer for their auction. so selection function has been modified to provide priority to them using an additional parameter like customer categorization.

4. Evaluation

Customer categorization will be included in a selection function algorithm as a parameter (a8). Based on the Customer Categorization bidding will be done for a customer. Customer Categorization will be depend upon 3 parameters namely excellent, good, poor.

Algorithm 1: Selection Function

Input: cur_hb, rt1, bdrs, cb, urg, rt2, Qos, cc
Output: Selected Auction

```
IF urg NOT EQUAL 0
  THEN
        IF cb GREATER THAN cur_hb
          THEN
                x1= (1-(cur_hb/cb))
                x2=10-bdrs
                x3= (1-(rt1) / (rt2))
                x4= Qos

IF u=u1 THEN
        U=∑(x1, x2, x3, x4)
ELSE
        U=∑(x1, x3, x4)
END IF-ELSE
END IF
END IF
```

Resource allocation takes place based on the priority of resources and auction bids between cloud user and datacenters. Proposed model is implemented in simulation environment and several experimental tests are performed to analyze its performance. After fetching the required parameters and statistics, resource allocation algorithm would analyze the client requirements. Then, it will try to compute a resource assignment which will not only fulfill all the requirements but also allocate resources in an efficient manner by using priority of the resources. Auctioneer will perform auction between selected Hosts and resources will be allocated to respective clients through Resource Manager. Consequently, Resource Manager would update its statistical data, to reflect the changes, which would be used for succeeding client requests.

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Algorithm 2: Bidding Algorithm

Input: Bids in Auction
Output: Result (Win or Lose)

Auction A selected
After selection CA switches to the following cases;

Case1: rt2 LESS THAN EQUAL 1hour
IF cur_hb LESS THAN 95% of Customer's budget THEN
Use **cus_cat( )** function for priority and
Continue bidding until 100% of customer's
budget is reached.
IF outbid THEN
Use Selection function to select another auction

Case6: rt2 EQUALS 16hours
IF cur_hb LESS THAN 20% of Customer's budget THEN
Use **cus_cat ( )** function for priority and
Continue bidding until 20% of customer's
budget is reached.
IF outbid OR a1 GREATER THAN 20% of customer's budget THEN
Use Selection function to select another auction

Algorithm 3: cus_cat(cc)

IF (cc==3) THEN
Auction provided
ELSE IF (cc<=2) THEN
Compare with another bidder
with urgency level and auction provided
ELSE
Invalid Input
END IF-ELSE

END IF

5. EXPERIMENTAL RESULTS

The evaluation of the system was quite challenging because at present no comparable system could be found. Therefore, the only system that CMM system can be compared to is that of a manual approach. Such an approach involves humans in the selection process. The manual selection of resource illustrates the humans' capability to make the decision regarding the cloud resource selection. Therefore for this evaluation, the mapping of customers to providers was firstly carried out manually to estimate the possible number of transactions and the transacting price then it was done using our prototype to determine the system's performance. A comparison was then carried out between the number of transactions and the transacting prices that were delivered by the manual and automatic methods. The comparison shows the benefits of using the Cloud Market Maker for complex decision making regarding cloud resource selection and dynamic pricing. The experimental setup is explained in the following section; it also covers the manual and automated methods.

The CMM system requires input from both cloud providers and customers. Cloud customers and providers give their requirements and resource details to the system using a standard web-based interface. Input from cloud customers varies in terms of resource details, requirement details, urgency, and pricing. In order to understand what is necessary in terms of creating a realistic simulation of such an environment let us consider an example. Imagine there are five customers (C1, C2, C3, C4, and C5) and each provides their requirements to the system. Eight virtual machine resources (R1, R2, R3, R4, R5, R6, R7, and R8) are available and the customers want to select a suitable resource (provider) from the available options. Each (Ri) is a type of virtual machine offered by an IaaS cloud provider. C1 has enough budget and its requirements match R3. C1 bids for R3 and acquires the resource as it has sufficient budget. C2 and C3 fail to get a resource because currently the available resources do not match their requirements. Both C4 and C5 bid for R5. C5 wins the auction for the resource due to it having a higher budget and a close mapping between its requirements and R5. C4 has enough time available to get the resource so it waits for a new resource to become available as remaining resources (R1, R2, R4, R6, and R7) do not match its requirements.

6. Conclusion and Future Work

The large upfront cost and changing environment of the cloud requires dynamic pricing to maximize the revenue of cloud providers. Providers also price their resources differently which makes it difficult for consumers to identify or decide which cloud provider is most suitable for their workload. Users may have to rely on what knowledge they have about the cloud providers which may drastically limit their choices. To assist customer's in decision making and providers in dynamic price adjustment, the Cloud Market Maker System (CMM). It employs a multi-agent multi-auction approach for creating an automated marketplace for cloud users which were not possible with other existing systems. In order to assess the implemented approach, it is important to analyze the suitability of dynamic pricing for a cloud environment and the number of customers and providers it satisfies in terms of resource discovery. To do this, several parameters such as the price delivered by the system and numbers of successful transactions were analyzed. The results demonstrate the benefits of dynamic pricing for the cloud environment. The results also demonstrate the system's ability to discover suitable resource for cloud customers. Moreover, in the interviews with customers it was observed that most of them prefer a known and trusted provider. This system will therefore help emerging cloud

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providers to gain recognition.

From the experimental results, it is clear that the dynamic pricing marketplace effectively provides decision support to users in the selection of a suitable provider. After selection and price determination, a Service Level Agreement (SLA) is agreed between the customer and the selected provider using standard methods. Future work will consider how additional parameters and an SLA can be included within the model. In the current implementation of the system cloud providers and customers are not exposed to the internal workings of the system. These design features remove the some risks that are associated with the auction process. However, future work will also consider the issues related to security and privacy of providers and customers. Such work will examine if any improvements can be made to the current reference model as the cloud continues to evolve. Furthermore, CMM can also be employed by organizations who are using Big Data in an increasing range of applications. Growing volumes of information will doubtless be generated by the emerging Internet of Things (IoT). The IoT will require a significant number of computing resources for data storage and processing and as such the selection of the most suitable and economical cloud resources will become increasingly important.

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