A Simulation Study of Auction Based Pricing Strategies in Grid Computing

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Abstract

The optimal utilization of assets for cloud/grid resources is a strategy that may be employed to increase the profit of service providers. In this paper, we empirically investigate the Continuous Double Auction (CDA), the Stable Continuous Double Auction (SCDA), and the Threshold Price Double Auction (TPDA) strategies, as well as the Preston McAfee Double Auction (PMDA) strategies to demonstrate how the use of grid/cloud computing might have a highly positive impact on the allocation of computing resources. The CDA, SCDA, PMDA, and TPDA strategies are analyzed in terms of their suitability for their end-users while taking into account; prospective resources, deadline consumption, budget spending, resource-derived profits, and immediate resource allocation. According to the measured results, SCDA performs efficient budget spending, CDA is good in resource allocation, with TPDA and PMDA demonstrating the highest performance with respect to deadline consumption.

Keywords: Cloud/grid computing; market-based computing resource economic management; CDA; SCDA; PMDA; TPDA.

1 Introduction

Better resource utilization is equally important for fog, cloud, and grid computing applications [8]. The terms 'cloud' and 'grid' are used interchangeably in this paper. Over the past several years, the consumption of information technology resources by the general public and businesses has increased exponentially. The advancement of service-oriented computing, defined as cloud and grid computing systems, has been led by utility computing, SaaS (Software as a Service), as well as the convergence of the cloud. The central instigator behind this progress is the external deployment of computing power, storage, or applications as services on a self-appeal basis [5]. The long-term ambition of utility computing has been realized [4, 7] as a consequence of the grid/cloud paradigm. The contributions of several companies, namely, Amazon, Microsoft, and IBM, allow consumers to utilize resources and amenities in a pay-as-you-go manner. The prospect of a positive net revenue via leveraging their available data center resources to serve conceivably thousands of consumers is one of the fundamental motivators for Infrastructure as a Service (IaaS).Cloud computing providers aim to maximize the number of accepted new requests to increase profit; however, the Quality of Service (QoS) per the agreed-upon Service Level Agreement (SLA) must not be compromised. The establishment of some efficient resource management is vital to achieving this goal [9]. Resource management is a fundamental challenge in grid/cloud computing systems. It has inspired researchers to identify features that facilitate economizing the grid/cloud environment, with one domain exemplar of such attempts being the ones applied in finance, trading, and pricing. Defining a computational market, in which grid providers and users interrelate, is compulsory in the economics-based models of grid resource allocation. Establishing price levels is an integral factor of the interaction and it must be concurrent with the client's assessment of the commodities traded [14]. This category of mechanisms is based on brokerage policies and trading between the resource owners (resource providers) and users (service consumers).

Several articles of research conducted on economic-based resource management systems have identified distributed resource management challenges as well as the requirements of economy-based grid systems. Moreover, they have deliberated on many diversified representative economy-based systems, emergent or otherwise, for both sympathetic and antagonistic trading of assets, including CPU cycles, storage, and bandwidth. The following emphasizes the reasons why market-based allotment mechanisms are preferable for grid resource allocation [2]:

- Market-based allocation systems eradicate the necessity of a central control point and accommodate the decentralized constitution of a computational grid. All users and providers are involved in the decision-making process. Self-interested participants may enact effective decisions once associated trading rules and an exchange protocol have been established.
- The market's introduction promotes the informed use of resources and attempts to encourage general users' decisions that would maximize overall value. Markets form a competitive environment that stabilizes any conflicts of interest between the parties.
- High prices incentivize providers to offer resources; however, users may withdraw from using them.
- Low prices may bankrupt the providers but attracts users.
- Complex combinatorial resource requests may be conducted in a market environment. Users can designedly

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obtain assets in a market whenever they require, provided that these resources have been sufficiently paid.

Market-based allocation mechanisms are attractive for grid resource allocation. Markets constitute a competitive environment that naturally balances the conflicts of interest between parties. We studied the auction models for resource management using the GridSim simulator. We compared CDA, SCDA, PMDA, and TPDA strategies using deadline consumption, budget spend resource profit, and immediate resource allocation.

This paper is organized as follows: In Section 2 we discuss pertinent studies: The Auction Allocation Model and the model participant's roles are explained in Section 3; Section 4 describes the CDA, SCDA, PMDA, and TPDA strategies. In Section 5 we demonstrate the experimental setup and measured results. We reach a conclusion for this paper in Section 6.

2 Related Work

"A taxonomy is proposed to characterize and categorize various market-based distributed systems (RMSs) that can support utility-driven cluster computing in practice. The taxonomy emphasizes five different perspectives: (i) the Market Model, (ii) the Resource Model, (iii) the Job Model, (iv) the Resource Allocation Model, and (v) the Evaluation Model. A survey was also conducted wherein the taxonomy is mapped to selected market-based RMSs designed for both cluster and other computing platforms" [13]. "Economic models for cloud service markets framework have been developed based on inter-organizational economic models for pricing cloud network services when several cloud providers co-exist in a market, servicing a single application type" [12]. "The proposed work in [10] investigates three types of auction allocation protocols: (i) *First-Price Auction*, (ii) *Vickrey Auction,* and (iii) *Double Auction*. The goal was to find which one is best suitable for the grid environment from the users' perspective as well as from the resources' perspective. They studied these protocols in terms of economic efficiency and system performance. The results showed that the First-Price Auction is better from the resource's perspective while the Vickrey Auction is more suitable from the user's perspective" [1]. "This implements a dynamic pricing model by using advanced reservations as a substrate resource allocation model. Unfortunately, there is one aspect that these works did not consider: as the price is set at the beginning of the execution, applications coming into the system in a low-demand period will be charged a low price. While urgent applications arriving later, may not get all the resources they require for their execution" [6].

In this paper, we empirically evaluate the performance of four double auction-based pricing strategies in a grid/cloud environment. We evaluate which strategy is suitable in terms of user perspective and which one is suitable from a resource perspective. For this purpose, different parameters are used, such as the consumed budget by a certain user, the deadline for each user to complete a job, how much profit is gained by a certain resource provider, and how fast a resource is allocated to a user.

3 Auction Allocation Model

Three parties constitute our market model: resource providers, users, and the market itself. Providers sell resources according to a selling strategy, whilst consumers buy resources following a buying strategy, alongside which, the market determines an appropriate price. Below, we explain each role in terms of the model. The players' interaction in the auction-based model in terms of resource allocation is shown in Figure 1.

3.1 Users

Users express their willingness to buy a resource from a resource provider to do their jobs. Each user has a limited budget, which is assigned to tasks, and each user has a limited time or deadline [5]. The user is also accountable for: bid submission to the auctioneer present at the local market, collecting results, sending user jobs to resources, and providing a uniform view of grid resources to the user. We infer that there are 'Ui' users in our model, all of whom have an executable task ready for submission. The two types of users are defined by their affinity to risk. The first category, risk-averse users, are expected to be in a winner's curse situation, in which the winner pays a surplus for an item more than its actual value. On the other hand, risk-neutral users are less expected to be in this situation.

3.2 Resource Provider

Providers host a configurable number of resources with different processing rates; they contribute to the grid with their resources, charging users for the services from which they benefit [10]. An internal auctioneer prepares every resource placed in the auction process. The service providers publish their resource requests (ask) in the central market. In our model, we assume that we have 'RPi' resource providers that have an 'N' number of resources. A resource (Ri) is characterized by:

- Reserved price: price reserved for auction participation
- Processing rate: in MIPS
- Cost: the cost incurred by a resource provider to execute a job

3.3 Central Market for Auction

The central market contains complete information about every consumer and resource provider's current auction offer. It also provides a set of external auctioneers (EA), which will be responsible for running two-sided auctions (e.g., continuous double auctions). The central market takes offers (bids and asks) from consumers and providers, decides on the winning bid and ask, and then informs both the consumer and provider about the price.

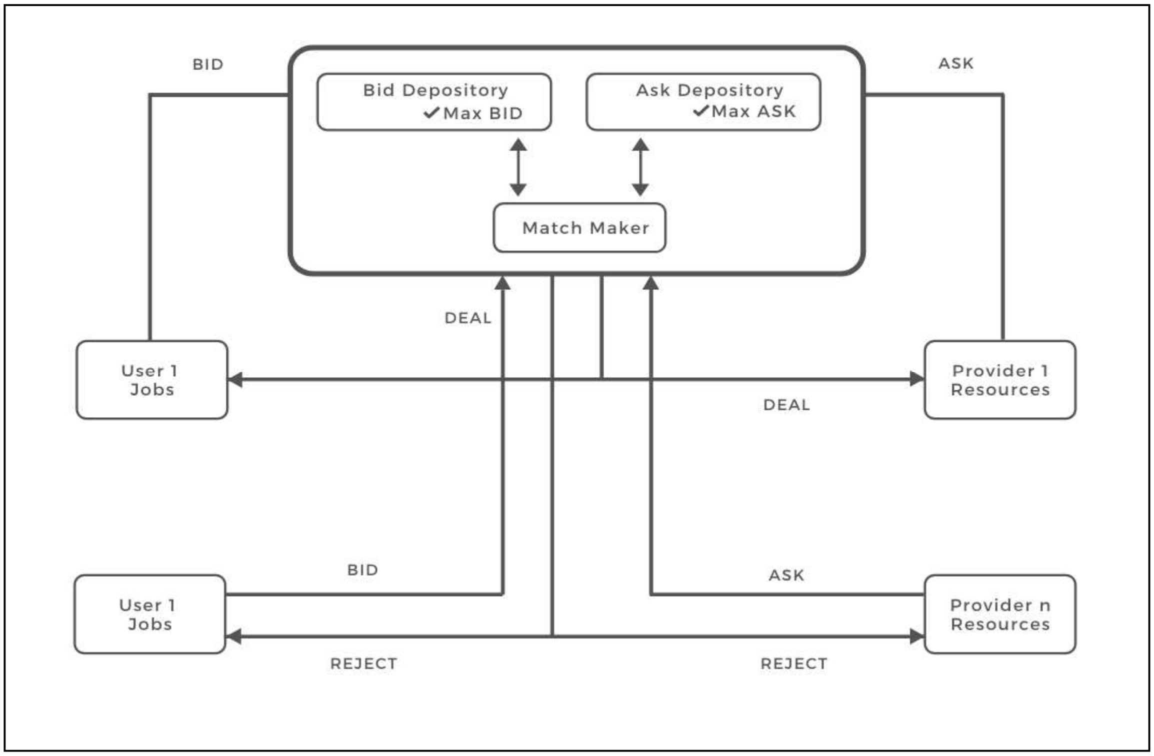


Figure 1: Player's interaction in auction-based model for resource allocation

4 Auction-based Resource Allocation Strategies

In this section, we will describe the CDA, SCDA, PMDA, and TPDA strategies.

4.1 Continuous Double Auction (CDA) Strategy [1]

The most popular form of the CDA strategy is open-cry with an order queue. In this strategy the bids and asks prices that are unsuccessful stay open until they are accepted in a transaction or are changed by their owner(s). There are no trading phases in the CDA, and Grid Services Providers (GSPs), as well as users, may yield asks prices and bids to the EA. The EA organizes lists of the current ask price and bids and matches the two offers when the ask price is lower or equal to the highest bid. At the average of the matching bid and asks prices, the trade occurs. The EA executes this strategy, which is part of local markets for auctions (LMA). The EA posts the auction description on LMA [1] once a set of GSPs decides to engage in a CDA. The pseudo-code of the CDA strategy is shown in Figure 2.

4.2 Stable Continuous Double Auction (SCDA) Strategy [13]

This strategy is designed to reduce unnecessary price volatility contributed by the insensitive or impatient behavior of the bidders [14]. To construct an SCDA, a Compulsory Bidding Adjustment Layer (CBAL) is added around a CDA. All orders first have to go through the CBAL before reaching the CDA. A heuristic mechanism is used to identify unreasonable orders for the current market conditions in the CBAL and are then adjusted appropriately before submission to the core CDA. There are two intuitions that the CBAL is based on (1) the Kaplan strategy that it is a very good time to trade when the ask-bid spread is small, and (2) the reference price r (the median value of the history prices Hl) which is an important indicator of the market condition notably so after taking r, a min, and b max into account [xx]. Intuition (1) reflects changes in market conditions more efficiently, while (2) and stabilizes the market [2]. The pseudo-code of the SCDA Strategy is shown in Figure 3.

4.3 Preston McAfee Double Auction (PMDA) Strategy [9]

In this type of auction, the users submit bids and GSPs submit asks to an EA. The equilibrium price is determined by matching asks (starting from the lowest price to the highest) with demand bids (starting from the highest price to the lowest). Once a set of GSPs decided to participate in a double auction, EA posts the auction description on LMA. We assume that only GSPs having resources of the same type participate in one double auction strategy. The pseudo-code of the CDA strategy is shown in Figure 4.

4.4 Threshold Price Double Auction Strategy [11]

The possibility of cheating by false-name bids is accounted

Three players of CDA interact with each other

1. User Side:

Ui, i=1,2,3.. M send the bid bi and mi to Central Auctioneer (CA)

2. Resource provider side:

RPn, n= 1,2, 3 ..k send asks price ak to CA

3. Central Auctioneers (CA):

After receiving bids and asks price

Sorts bids in ascending order

Sorts asks price in descending order

Compares incoming bid with minimum ask price

Compares incoming ask with maximum bid

Satisfies conditions

Sends winner bid and ask price with final price to broker

Figure 2: Pseudocode of CDA strategy

Three players of SCDA interact with each other

1. User Side:

Ui, $i = 1,2,3....,M$ *sends bid* $\rightarrow$ *CBAL*

2. Resource provider side:

RP^n, $n = 1,2,3....k$ *sends ask* $a_k \rightarrow$ *CBAL*

3. CBAL Side:

Receives Bid and asks

Sorts bids ascending order

Sorts asks descending order

Uses mundane fuzzy rules to stabilize the price

Sends modify bid and ask $\rightarrow$ *CA*

Compares incoming ask with maximum bid

Satisfies conditions

Sends winner bid and ask with final price to broker

Figure 3: Pseudocode of SCDA strategy

1. ***User Side:***

U_i , i = 1,2,3….,M sends bid → CBAL

2. ***Resource provider side:***

RP^n , n= 1, 2, ..k sends ask a_k → CBAL

3. ***Central Auctioneers (CA):***

After receiving bids and asks

Stores bids in ascending order

Stores asks in descending order

Receives the asks and bids for specific time interval once the interval clear

Finds trade price

Satisfies condition on the basis of trade price

Sends winner bid and ask with final price to broker

Figure 4: Pseudocode of PMDA strategy

Three players of CDA interact with each other

1. User Side:

U_i , i = 1,2,3….,M sends bid → CBAL

2. Resource provider side:

RP^n , $n = 1,2,3 \ldots k$ sends ask a_k → CBAL

3. Central Auctioneers (CA):

After receiving bids and asks

Stores bids in ascending order

Stores asks in descending order

Finds the Threshold price

Satisfies condition on the basis of Threshold price

Sends winner bid and ask with final price to broker

Figure 5: Pseudocode of TPDA Strategy *1 User Side*

for in this strategy. A GSP may try to cheat by pretending to be a user (a potential buyer) and submitting a false-named bid. To counteract. this, the TPDA Strategy uses a threshold price that is determined by the EA without knowing the evaluations of GSPs and users. The number of trades and the trading price will be controlled by this threshold price. As in PMDA, the GSPs submit asks to an EA and the users submit bids. Thus, the trading price is determined by matching asks (in ascending order) with demand bids (in descending order) considering the threshold price. This strategy is performed by the EA (part of LMA). The pseudo-code of this strategy is shown in Figure 5.

5 Results and Discussion

Many experiments were conducted to evaluate the performances of CDA, SCDA, TPDA, and PMDA strategies, which consisted of the interactivity of three agents: providers, consumers, as well as the market itself. At this stage, an auctioneer from the local market becomes the central agent who carries out all experiments, while consumers and providers liaise with the auctioneer agent through their asks and bids respectively.

5.1 Experiment Environment and Setup

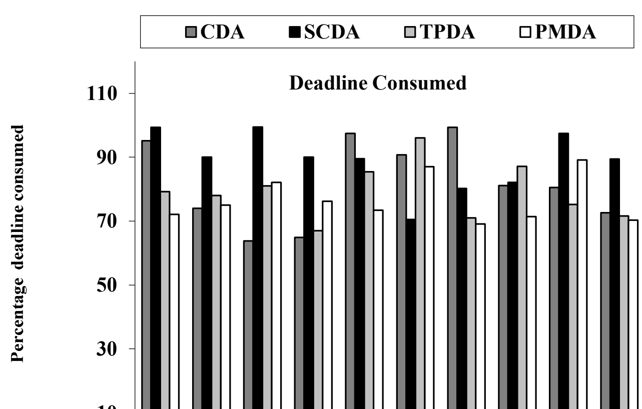
The simulated grid environments consider 16 resources {R0, R1, …, R15} divided into two categories: slow resources (Intel core i3 3.4 GHz – 4.2 GHz) and fast resources (Intel core i52.4 GHz -3.8GHz). Slow resources have lower reservation prices than fast resources. We will use the GridSim toolkit [9] also, regarding its resource allocation. The simulation also consists of 10 users {User 0, User 1, …, User 9}, whom have a number of computational jobs that are achieved to get the resource. Each user wants to execute its jobs in terms of its preferences. There are 30 jobs simulated in the grid system. Each user has a maximum of 3 jobs. Each user has a budget and deadline which are distributed in these jobs according to their preferences.

5.1.1 Deadline Consumed. We are referring here to the deadline consumed by each user who has a job; each job has its deadline for allocating a resource. In Figure 6, we can see that stable continuous double auctions have a much longer deadline than other strategies due to the higher number of extra components within the bidder, asker, and central auctioneer. This strategy establishes the market price but is more time-consuming in terms of completing a job. It has shown that a continuous double auction had a lower time consumption than a stable continuous double auction.

5.1.2 Budget Spent. In terms of budget, every user has a certain budget that is attached to their own job depending on their priority. The aim of this study, for each of the four auction strategies, is to determine which auction strategy is more suitable for the user in terms of budget. The auction strategy defines the budget spent by a winner user for a resource. Figure *7* shows the budget spent by the users in each of the four auction strategies. In Preston McAfee, the spent budget by a certain user is variable but higher than the budget spent in other strategies as users are sending random sealed bids for resources while in Stable Continuous Double Auction (SCDA) budget spent by users is more stable than in other strategies.

In CDA, the budget spent by users is lower than in PMDA because of its open double auction and the price paid by the user is the median value of the winning bid and ask. The budget spent by users in threshold price double auction is higher than the stable continuous double auction and continuous double auction due to sealed random bid but its budget is lower than Preston McAfee Double Auction strategy due to threshold price.

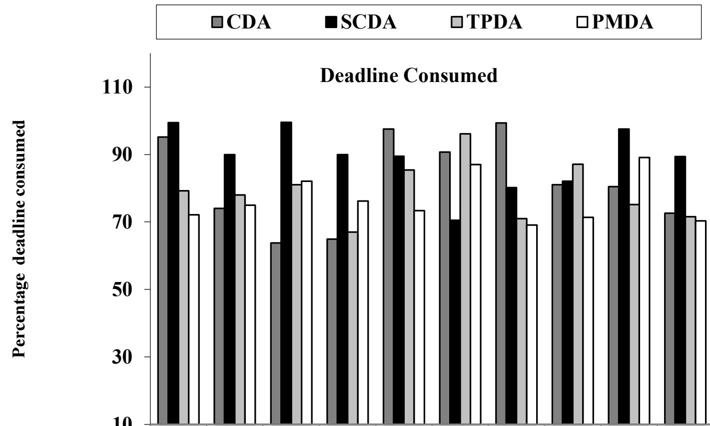
5.1.3 Resource Profit. It is the difference between the payment received from the winning users and the cost of the resource assigned to it. Figure 8, demonstrates that resource profit in Preston McAfee double auction varied from resource to resource, some resources have higher resource profit and some of them have a lower profit. In a Stable Continuous Double Auction, the resource profit for every resource from R0 – R11 is consistent. In Preston Continuous Double Auction, the resource profit is lower than Preston McAfee Double Auction because of using median value trade price of bids and asks are sent. Threshold Price Double Auction has variability in the budget as compared with other strategies due to threshold price



	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
CDA	95.2	74	63.8	64.9	97.5	90.75	99.3333	81.0833	80.5	72.5917
SCDA	99.4	90	99.5	90	89.5	70.5	80.2	82.1	97.5	89.4
TPDA	79.2	78	81	67	85.4	96.1	71	87.1	75.2	71.6
PMDA	72.1	75	82.1	76.2	73.4	87	69.1	71.4	89.1	70.3

No. of Users

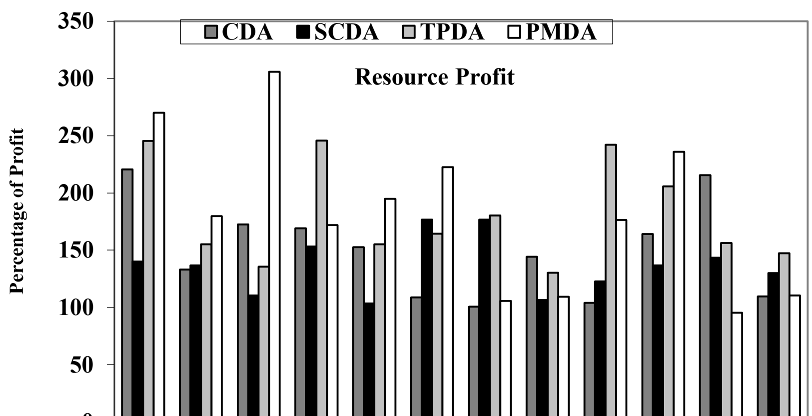
Figure 6: Percentage of deadline consumed by users



	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
CDA	95.2	74	63.8	64.9	97.5	90.75	99.3333	81.0833	80.5	72.5917
SCDA	99.4	90	99.5	90	89.5	70.5	80.2	82.1	97.5	89.4
TPDA	79.2	78	81	67	85.4	96.1	71	87.1	75.2	71.6
PMDA	72.1	75	82.1	76.2	73.4	87	69.1	71.4	89.1	70.3

No. of Users

Figure7: Budget spends by each user



	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
CDA	220.48	133.122	172.414	169.082	152.554	108.764	100.796	144.374	104.06	164.15	215.445	109.689
SCDA	140	136.666	110.333	153.333	103.333	176.666	176.666	106.666	122.667	136.666	143.333	130
TPDA	245.3	155.2	135.7	245.7	155.2	164.3	180.2	130.2	242.1	205.7	156.3	147.2
PMDA	270.017	179.791	305.82	172.028	194.779	222.614	105.656	109.272	176.371	235.996	95.33	110.4

No. of Resources

Figure 8: Percentage of resource profit

because trading is done based on threshold price.

5.1.4 Immediate Resource Allocation. Figure 5 shows that CDA has a higher rate of resource access than other strategies due to continuously sending bids for resources. Here, users have more chances to complete their jobs. Users 0, 3, 5, 8, and 9 have 50 % of resources and the other users have a higher rate of resource allocation. The SCDA also has a higher rate of resource allocation due to its continuously sending bids and asks the central auctioneer, but resource allocation is lower than

CDA because of performing the extra activity to stabilize the price. In TPDA and PMDA resources allocated by users are lower because of their discrete time. The users' bids and resources ask will stay there for a specific time interval. Figure 9 shows that both TDPA and PMDA have a lower rate of resource allocation. Users 6, 7, and 8 have a higher rate of resource allocation due to their budget spending and deadline consumption.

6 Conclusion

This paper considered the issues concerning the management of CDA, PMDA, TPDA, and SCDA computing systems in terms of deadline consumption, budget spending, resource profit, and immediate resource allocation. The results of this empirical investigation demonstrate conclusively that whereas the SCDA framework would perform more efficiently in terms of budget spending, the CDA may be seen as highly efficient concerning immediate resource allocation. The efficiency of the CDA may be attributed to such factors as the lack of specific trading phases and the direct transmission of the relevant information to the EA responsible for evaluating the bids in question. On the other hand, the TPDA and PMDA frameworks have demonstrated the highest performance in concordance with deadline consumption.

References

[1] R. Ananthakumar and K. Kartheeban, "Effectual Resource Allocation using Auction Mechanism in Cloud Computing," *International Journal of Innovative Technology and Exploring Engineering*, 9(2S2):2278-3075, December 2019.

[2] Amina Chikhaoui, Kamel Boukhalfa, and Jalil Boukhobza, "A Cost Model for Hybrid Storage Systems in a Cloud Federations," 2018 Federated Conference on Computer Science and Information Systems (FedCSIS), pp. 220-232, 2018.

[3] Se-Hak Chun and Byong-Sam Choi, "Service Models and Pricing Schemes for Cloud Computing," Journal of *Cluster Computing,* 17:529-535, 2014.

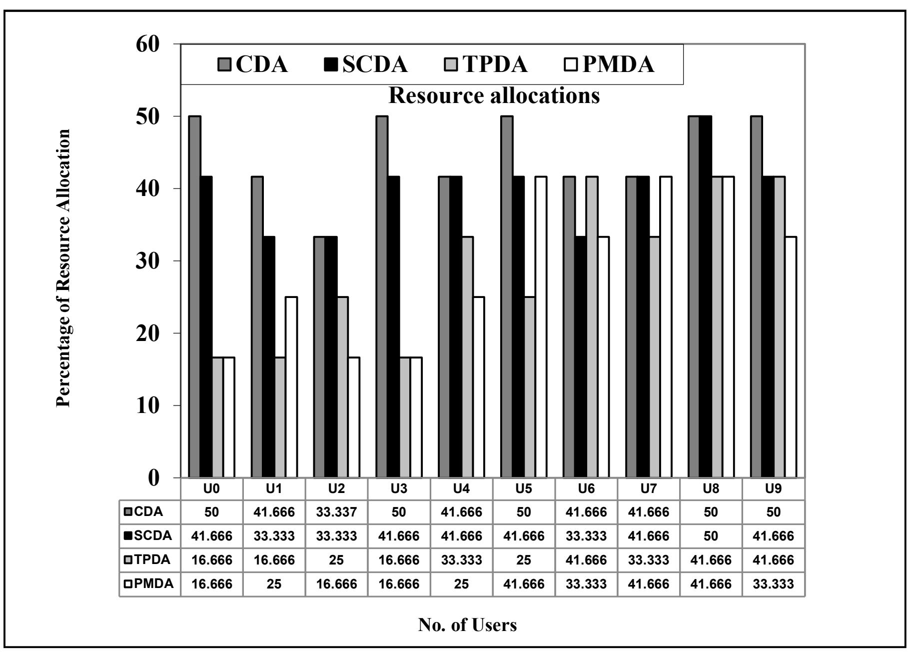
[4] Thibaud Ecarot, Djamal Zeghlache, and Cedric Brandily, "Consumer-and-Provider-Oriented Efficient IaaS Resource Allocation," *Parallel and Distributed Processing Symposium Workshops (IPDPSW) 2017 IEEE International*, pp. 77-85, 2017.

[5] Yuan Gao, Yaoxue Zhang, and Yuezhi Zhou, "Performance Analysis and Improvement of Storage Virtualization in an OS-Online System," *Journal of Software Engineering and Applications*, 5(11A):912-922, November 30, 2012.

[6] Sukhpal Singh Gill, Peter Garraghan, Vlado Stankovski, and Guiliano Casale, "Hholistic Resource Management for Sustainable and Reliable Cloud Computing: An Innovative Solution to Global Challenge", *Journal of Systems and Software*, 55:104-129, 2019.

[7] Barka Javad, Peter Bloodsworth, and Raihan Ur Rasool, "CloudMarket Maker: An Automated Dynamic Pricing Marketplace for Cloud Users," *Journal Futire Generation Computer Systems*, Elsevier, 54:52-67 2015.

[8] Kevin Lee, Georg Buss, and Daniel Veit, "A Heuristic Approach for the Allocation of Resources in Large-Scale Computing Infrastructures," *Concurrency and Computation: Practice and Experience*, 28:1527-1540, 2016.



	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
CDA	50	41.666	33.337	50	41.666	50	41.666	41.666	50	50
SCDA	41.666	33.333	33.333	41.666	41.666	41.666	33.333	41.666	50	41.666
TPDA	16.666	16.666	25	16.666	33.333	25	41.666	33.333	41.666	41.666
PMDA	16.666	25	16.666	16.666	25	41.666	33.333	41.666	41.666	33.333

Figure 9: Immediate resource allocations

[9] Sung-Han Lin, Ranjan Pal, Marco Paolieri, and Leana Golubchik, "Performance Driven Resource Sharing Markets for the Small Cloud," *Distributed Computing Systems (ICDCS) 2017 IEEE 37th International Conference,* pp. 241-251, 2017.

[10] Nguyen Cong Luong, Ping Wang, Dusit Niyato, Yonggang Wen, and Zhu Han, "Resource Management in Cloud Networking Using Economic Analysis and Pricing Models: A Survey," IEEE Communications Surveys & Tutorials, 19(2):954-1001, 2017.

[11] Panel ParniaSamimi, Youness Teimouri, and Muriati Mukhtar, "A Combinatorial Double Auction Resource Allocation Model in Cloud Computing," *Journal of Information Sciences*, 357: 201-216, 2016.

[12] Muhammad Bilal Qureshi, Maryam Mehri Dehnavi, Nasro Min-Allah, Muhammad Shuaib Qureshi, Hameed Hussain, Ilias Rentifis, Nikos Tziritas, Thanasis Loukopoulos, Samee U. Khan, Cheng-Zhong Xu, and Albert Y. Zomaya, "Survey on Grid Resource Allocation Mechanisms," Journal of Grid Computing, Springer, pp. 399-441, 2014.

[13] Xingwei Wang, Xueyi Wang, Hao Che, Keqin Li, Min Huang, and Chengxi Gao, "An Intelligent Economic Approach for Dynamic Resource Allocation in Cloud Services," *Cloud Computing IEEE Transactions on*, 3(3): 275-289, 2015.

[14] Muhammad Zakarya and Lee Gillam, "Modeling Resource Heterogeneities in Cloud Simulation and Quantifying Their Accuracy," Journal of Simulation Modeling Practice and Theory, 94:43-65, 2019.

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