# CLASSIFICATION OF RESOURCE MANAGEMENT AND PRICING MODELS IN CLOUD COMPUTING

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**Abstract**- The wide acceptance of Cloud Computing by small and medium enterprises to large enterprises for achieving computing service has been the latest trend. With such a move enormous demand for the resources arises in different dimensions. Due to the nature of cloud, dynamic allocation of resources to provide desired services among different users in a cost effective way becomes very challenging and essential among the cloud providers. They incorporate different resource management techniques to meet the QoS specified by the users. To have a clear insight on the resource allocation methods used in cloud environment and to come up with better strategies, in this paper we provide some of the previous resource management techniques and analyze them. These approaches are classified rigorously from different perspectives and analyzed along with their merits and demerits. Further, we present different pricing models used during resource allocation. This paper could bring an intuition among researchers in developing new optimal resource management and pricing methods such that cloud computing potential can be reaped to the fullest extent.

**Keywords**- Cloud Computing, Resource management, Pricing model.

## I. INTRODUCTION

Cloud computing the popularly used model is a distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned based on SLA. It provides a pool of computing resources which the users can access based on pay-as-you use concept. The basic principles of cloud computing is to shift the computing done from the local computer into the network. Small medium and large enterprises procure resources which include server, network, storage and application services without huge investment on its purchase and maintenance, but use it for getting their work done easily. Managing resources in such large dynamic cloud environments is a very complex and challenging task due to the dynamic nature of the cloud. In view of this, efficient resource management techniques are the prerequisite in order to gain the real benefit of cloud model. Resource management includes scheduling the applications, allocation, control and coordination of the resources among the virtual machines (VMs). Resources can be requested on-demand or can be reserved which guarantees the availability of resources which are instances of metered services. Economic models for such resource management (RM) techniques should provide cost effective services to consumers along with good profit margin for the service providers. This has motivated the survey on literature and to discuss several resource management and pricing techniques used at various levels during the service of the request. Different perspectives towards the classification of resource management and pricing techniques are presented based on their relevance to several factors.

## II. CLASSIFICATION OF RESOURCE MANAGEMENT TECHNIQUES AND PRICING MODELS

In this section, we present the classification of the existing RM and pricing techniques based on different criteria and are explored in tabular form. A. Classification based on resource management techniques used during resource negotiation Managing resources in large dynamic cloud environments is a very complex and challenging task as requests for the type and amount of resources is not known in advance most of the time [4]-[6]. Table I presents the classification of RM techniques used during resource negotiation. Resource negotiation

TABLE I CLASSIFICATION BASED ON RESOURCE MANAGEMENT TECHNIQUES USED FOR RESOURCE NEGOTIATION.

| Literature Work | Resource Allocation Method/Technique | Efficiency | Platform Used | Scalability/QoS | Application Supported | Merits/Demerits |
|---|---|---|---|---|---|---|
| An e2e Framework for Provisioning-Based Resource and Application Management [22] | Advertisement and query based interfaces or resource provisioning with backfilling | Providing deterministic QoS, performance optimization and fairness | Trace based simulations of clusters using Synthetic workflow | Provides deterministic quality of service | Large-scale scientific applications | Superior performance for the application at a realistic price |
| High Performance Resource Allocation Strategies for Computational Economies [30] | Just-in-Time bidding, Flexible Advanced Reservations, 2-phase contracts, II Chance Substitute Providers | To reduce the failure and reallocation rate | Distributed metascheduler | Provides the support for scalability | Diverse synthetic workloads | It increase occu-pancy and thereby increase the obtain-able utilization of the system |
| Efficient Bidding in Dynamic Grid Markets [31] | Repeated auction-based with myopic equilibrium strategies | Prevents congestion & collapse of grid with improved long-term profits | Software framework written in Matlab | QoS is enchanced by causing more jobs to finish be-fore the deadline | Scientific and high-performance applications | Hedging using op-tions improves re-source allocation |

TABLE II
CLASSIFICATION BASED ON RESOURCE SCHEDULING TECHNIQUES USED FOR RESOURCE MANAGEMENT.

| Literature Work | Resource Allocation Method/Technique | Efficiency | Platform Used | Scalability/QoS | Application Supported | Merits/Demerits |
|---|---|---|---|---|---|---|
| Cloud Computing Resource Scheduling Policy Based on Genetic Algorithm with Multiple Fitness [33] | Hybrid genetic algorithm combined with knapsack problem. Pre- migration strategy | Improved resource utilization and saves energy cost | Experiment done in a simulated environment | Algorithm supports scalability to any extent | Any application that can be specified in three dimensions | Improved genetic Algorithm calculates more precisely with reasonable scheduling policy |
| A Cooperative Game Framework for QoS Guided Job Allocation Schemes in Grids [34] | Nash Bargaining Solution based game theoretic solution | Provides a Pareto optimal solution to the QoS objective, relatively low overhead and good performance | It is a centralized strategy | Optimal solution to the QoS | High-performance computing applications | Accounts for fairness to users, but is less fault-tolerant |
| A Hierarchical Approach for the Resource Management of Very Large Cloud Platforms [35] | Control theoretic feedback loop techniques with adaptive machine learning approaches | Satisfies performance, availability guarantees and minimize energy costs. | Trace driven simulation | Provides scalable distributed resource management | Transactional service applications | Unifying framework supports capacity allocation and load balancing |
| Dynamic Resource Allocation using Virtual Ma- chines for Cloud Com- puting Environment [36] | Live VM migration with exponentially weighted moving average | Improves overall utilization of server, pre- vent overload in the system effectively | Trace driven simulation | With higher VM to PM ratio, the load is distributed more evenly among PMs | Combines different types of workloads to improve the overall utilization of server resources | Achieves overload avoidance and green computing |
| A Budget Constrained Scheduling of Workflow Applications on Utility Grids using Genetic Algorithms [43] | The genetic algorithm Markov decision processes to make the genetic algorithm con- verge | Meet users budget constraint and execution time minimization. | Grid testbed | Workflow execution cost is based on users QoS constraint | Applications in areas such as bioinformatics and astronomy | Automatic handling of overload & under utilization during job execution is not addressed |

are done using strategies such as Just-in-Time Bidding, Flexible Advanced Reservations, Two Phase Contracts, Second Chance Substitute Providers, Advertisement and query based interfaces. Platforms such as Distributed meta-scheduler, Matlab and Discrete time simulators are considered for conducting the experiments. These method provides improved resource utilization and ensures availability of resources followed by achieving the desired QoS for the consumers.

B. Classification based on resource scheduling techniques used for resource management

Resources are scheduled based on cost constraints, time constraints and QoS for which different scheduling algorithms are considered. Table II presents the classification based on resource scheduling techniques used for RM. Max-Min and Min-Min, Gang scheduling, Priority based scheduling, genetic algorithm combined with knapsack problem, aggressive and conservative backfill algorithms are used for scheduling the resources. They meet the QoS within the budget constraints and in the given time from the consumer's perspective.

C. Classification based on techniques used in federated clouds

In view of accommodating all the requests in the cloud with minimal rejections, federated clouds are used where in cloud providers give their unused capacities during low demand periods and take spare capacity during their peak time in order to maximize their profits. Table III provides the details for techniques used in federated clouds. Game theory, Semi-Markov Decision Process, push-pull, live virtual machine migration are the techniques used in federated cloud.

VM sharing decision provides good resource utilization followed by optimal execution efficiency and maximized profit for the providers.

D. Classification based on resource management techniques used for different types of workload.

Ad hoc parallel data processing are one of the killer applications for IaaS clouds.

Table IV provides the details of techniques used for different types of workload. Static and dynamic allocation of resources for data processing are supported, wherein dynamic allocation provides better utilization of heterogeneous resources.

Consolidation of workloads, parametric estimation, feedback control model, non-cooperative game theory and adaptive mechanism are used to schedule VM which improves minimizes migration overheads and maximize mixed workload performance with guaranteed optimal benefits within time constraints.

E. Classification based on load balancing and fault management techniques used in resource management

Unpredicted bursty request in cloud could arise at any time for which the cloud should be able to handle. It is addressed by extending the capacity of a local cloud, finding least loaded system or a general mobile cloud computing system which consists of multiple cloud domains each with its own set of resources. Table V provides the details for load balancing and fault management related work to RM. Semi-Markov Decision, Gossiping protocols, push-pull, checkpointing-recovery and trace-replay methods are used for load balancing and fault management. Fair resource allocation among sites/applications is obtained by dynamic adaptation in response to the load changes and any faulty situation in the cloud.

F. Different pricing and penalty models

Based on the resource allocation methods different pricing models are considered in the literature. Table VI gives the details of different pricing and penalty model. These models dynamically adjust the price due to the nature of cloud. Static pricing will either burden the consumer or might lead to revenue loss to the provider, therefore dynamic pricing is an efficient way of pricing. Based on demand, availability of resources, time and QoS constraints pricing models are set. Some pricing models attempts to make use of the discounts available via spot instances but there is no certainty of the resource availability and its price. Static and dynamic penalty functions are also considered in case there are agreement breaches which are obtained based on Win Price, Substitute Price or Bid Difference.

TABLE III
CLASSIFICATION BASED ON RESOURCE MANAGEMENT TECHNIQUES USED IN FEDERATED CLOUDS.

| Literature Work | Resource Allocation Method/Technique Used | Efficiency | Platform Used | Scalability/QoS | Application Supported | Merits/Demerits |
|---|---|---|---|---|---|---|
| A Novel Economic Sharing Model in a Federation of Selfish Cloud Providers [37] | Game theory, dynamic programming approach along with grim trigger strategy is used | Profit obtained from repeated game derives a higher revenue using a simple grim trigger punishment strategy | Matlab | Supports salability | All cloud applications | Long-term revenue maximization based on the future workloads uncertainty |
| An SMDP-based Service Model for Inter-domain Resource Allocation in Mobile Cloud Networks [38] | Service request decision making process is modeled as a Semi-Markov Decision Process | Maximises the rewards for the cloud system and the users | MobiCloud, Matlab | Supports scalability | All cloud applications | Minimal no. of service rejections which degrade user satisfaction level |
| Dynamic Optimization of Multiattribute RA in Self-Organizing Clouds [39] | Virtual machine technology, proportional share model and a range query protocol | Achieves maximized resource utilization and delivers optimal execution efficiency | PeerSim | Supports scalability through self organizing clouds | All cloud applications | Protocol produces one lightweight query message/ task and supports high adaptability in dynamic node- |
| Efficient Resource Mapping Framework over Networked Clouds via Iterated Local Search based Request Partitioning[40] | Hierarchical framework for inter-domain resource mapping in a networked cloud environment with an iterated local search | Costefficiency over a large number of Virtualetwork request instances and networked cloud sizes with minimum computation time | A discrete event java-based simulator | Supports scalability | All cloud applications | Distributed intra-cloud resource mapping approach allows for effi- cient and balanced al- location of cloud re- sources |
| Decentralized Meta-brokers for Inter-Cloud: Modeling brokering coordinators for inter-operable RM [41] | Meta-broker that provides an autonomous orchestrator | Optimize by combining multiple brokers into a single aggregated view identical to distributed resource managers | Cloudsim | Supports scalability as it connects across clouds | Massive amount of services oriented application | Provides effective performance levels with meta-brokering solution |

TABLE IV
CLASIFICATION BASED ON RESOURCE MANAGEMENT TECHNIQUES FOR DIFFERENT TYPES OF WORK LOAD.

| Literature Work | Resource Allocation Method/Technique | Efficiency | Platform Used | Scalability/QoS | Application Supported | Merits/Demerits |
|---|---|---|---|---|---|---|
| Autonomic Placement of Mixed Batch & Transactional Workloads [42] | Consolidation of workloads on the same physical hardware and Leveages visualization control mechanisms | Maximizes mixed workload performance | Discrete event based simulator | Achieves QoS | Heterogeneous set of mixed workloads | Maximizes performance and provides service differentiation based on goals. |
| Exploiting Dynamic RA for Efficient Parallel Data Processing [43] | Task are represented as DAG and uses feedback based monitoring data | Improves utilization and reduce the processing cost | Eucalyptus | Automatically allocate/deallocate VMs in execution | Parallel data processing applications | Automatic handling of overload and underutilization |
| Automatic VM Allocation for scientific application [44] | Epidemic parameter estimation algorithm and multiple loop decomposition algorithm. | Speeding up the execution time for scientific applications | Private cloud and A*STAR | Scalability of parameter estimation module in epidemic forecast | Analytic and scientific applications | Speed up of the execution time with prediction accuracy |
| Resource Provisioning with Budget Constraints for Adaptive Applications in Cloud Environments [45] | Multi-input-multi-output feedback control model with reinforcement learning | Guarante ed optimal application benefit within the time constraint | Linux clusters | Provides required QoS with help of feedback control model | Real world adaptive applicatio ns | Maximizes application QoS, within time constraint and budget limit |

TABLE V

CLASSIFICATION BASED ON LOAD BALANCING AND FAULT MANAGEMENT TECHNIQUES USED IN RESOURCE MANAGEMENT.

| Literature Work | Resource Allocation Method/Technique Used | Efficiency | Platform Used | Scalability/QoS | Application Supported | Merits/Demerits |
|---|---|---|---|---|---|---|
| Live VM Migration via Asynchronous Replication & State Synchronization [48] | Checkpointing /recovery and trace/replay technologies are used to provide fast and transparent VM migration | Reduced migration overheads and the migration downtime is less | UMLinux | Supports scalability and required QoS | Kernel-intensive workloads and I/O intensive workloads | Provides reduced migration downtime and network bandwidth |
| Cloud Resource Provisioning to Extending the Capacity of Local Resources in the Presence of Failures [49] | Stochastic based brokering strategy with checkpointing in conservative and aggressive selective backfilling | Improved response time of user's requests | Cloudsim | Supports scalability | High-performance Applicatios requiring large no. of resources over short periods of time | Brokering strategy takes into account the computing cost of both sides |
| A Gossip Protocol for Dynamic RM in Large Cloud Environments [50] | Protocol P* follows push-pull paradigm & uses CYCLON an overlay protocol in a random network | Protocol continuously executes on dynamic, local input and does not require global synchronization | Discrete event simulator | Scales both in the no. of physical machines and sites/applications | Cloud based application | Fair resource allocation, dynamically adapts the allocation to load changes |

TABLE VI

PRICING AND PENALTY MODEL

| Literature Work | Pricing Model | Description | Efficiency | Dynamic Pricing |
|---|---|---|---|---|
| High Performance RA Strategies for Computational Economies [30] | Random Constant Available capacity Win/loss ratio Time based | Pricing based on projected provider capacity, win/loss ratio ,time since the provider last won an auction | The use of overbooking substitute strategies provides revenue | All models support dynamic pricing |
| An End-to-End Framework for Provisioning-Based Resource and Application Management [32] | Price discrimination | Provides efficient allocation of resources minimizing the total expected waiting costs in the system | Provide more service offerings in order to accommodate users with diverse pref- erences | Pricing algorithm is more responsive to the current state of the resource |
| Efficient Resource Mapping Framework over Networked Clouds-Iterated Local Search based Request Partitioning [40] | Multi factor pricing model like availability of resources | A hierarchical framework based on Iterated Local Search | Minimizes the cost of embedding a request by per- forming load balancing and enhancing the cloud scalability | Costs based on scarcity of the resource with average utilization |
| A Mechanism of Specifying and Determining Pricing in Utility Computing Environments [46] | Adaptive pricing model based on Exponential Weighted Moving Average for resource estimation | Adapts price based on supply & demand curves over time intervals making balanced resource utilization | Reservation-based applications are guaranteed with resources | Captures dynamic demand on resources and adapts pricing to dynamic demand |
| Pricing Cloud Compute Commodities: A Novel Financial Economic Model [47] | Financial option theory with Moores law based depreciation of asset values | Initial investment is based on contract time, rate of depreciation, quality of service, age of resources | High QoS and profitability constraints from providers perspectives | Cloud pricing problem has not included providers cost of maintenance and other costs |

## CONCLUSION

Cloud computing is the popularly used utility paradigm for providing services to various end users. Resources are delivered through reservation plan or can be requested on the fly and the pricing model is set accordingly. The benefit of cloud computing can be achieved to maximum extent through efficient resource management. This paper focuses on the various resource management and pricing techniques along with their efficiency and constraints. Many of these focus on managing the resources by considering only a few parameters. A still better approach for resource management will help in diverse usage of cloud computing. The classification made here would lead for developing new resource management techniques and pricing model in future work.

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