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Stochastic Based Optimal Resource Provisioning in Cloud Computing

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Abstract — **In cloud computing, providing an optimal resource to user becomes more and more important. Cloud computing users can access the pool of computing resources through internet. Cloud providers are charge for these computing resources based on cloud resource usage. The provided resource plans are reservation and on demand. The computing resources are provisioned by cloud resource provisioning model. In this model resource cost is high due to the difficulty in optimization of resource cost under uncertainty. The resource optimization cost is dealing with an uncertainty of resource provisioning cost. The uncertainty of resource provisioning cost consists: on demand cost, Reservation cost, Expending cost. This problem leads difficulty to achieve optimal solution of resource provisioning cost in cloud computing. The Stochastic Integer Programming is applied for difficulty to obtain optimal resource provisioning cost. The Two Stage Stochastic Integer Programming with recourse is applied to solve the complexity of optimization problems under uncertainty. The stochastic programming is enhanced as Deterministic Equivalent Formulation for solve the probability distribution of all scenarios to reduce the on demand cost. The Benders Decomposition is applied for break down the resource optimization problem into multiple sub problems to reduce the on demand cost and reservation cost.**

Index Terms—**Benders Decomposition, Cloud Computing, Deterministic Equivalent Formulation (DEF), Optimal Resource Provisioning, Stochastic Integer Programming (SIP), Virtualization**

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I. INTRODUCTION

In cloud computing, resource provisioning is an important issue of how resources are provisioned and allocated. Cloud user can access these resources without worrying about any maintenance or management of actual resources. Cloud resource provisioning model provides computing resources include: processing power, storage, software, and network bandwidth. The resources are optimized in poorly defined decision making environments or in cases where scenarios are well-defined or in effective. Effective resource optimization requires a certain rigor, consistency and agreement on processes. The main goal of resource optimization is to reduce the resource provisioning cost in cloud computing.

In spot market, the cost of the resource is fluctuating all the time depending on the resource supply and demand levels. For example, Amazon implements an auction mechanism to determine instance pricing in its spot market. In particular, the following aspect of the cost optimization problem draws significant of optimizing resource price and how to optimally provision cloud resources to meet service requirements. The obstacle lies in the uncertainty of computational resource price. The stochastic programming is a complete solution of optimal resource cost under uncertainty. This programming should optimize On demand cost, Reservation cost, Expending cost to achieve optimal resource provisioning in cloud computing environments. The Deterministic Equivalent Formulation (DEF) algorithm is used for solving linear mathematical optimization programming script errors. The on demand cost is reduced by using this DEF algorithm. The Benders Decomposition algorithm is used for break down the optimization problems which they are reduced to many sub problems. It is used to reduce the on demand cost and reservation cost during the resource provisioning stage.

II. RELATED WORKS

They proposed an optimal model for the problem and gives a solution by applying stochastic integer programming technique [2]. The proposed work considers a stochastic programming problem with simple integer recourse in which value of the recourse variable is restricted to a multiple of a nonnegative integer. The algorithm of a dynamic slope scaling procedure for solving this problem is developed by using a property of the expected recourse function [4].

The proposed system is to develop a Deterministic Resource Rental Planning (DRRP) model, using a mixed integer linear program, to generate optimal rental decisions given fixed cost parameters. The proposed Stochastic Resource Rental Planning (SRRP) model explicitly considers the price uncertainty in rental decision making [1]. In this system, Quantitative modelling and optimization approaches are proposed for assisting such decisions in cloud computing services. The proposed learning curve models can be helpful to capture the providers' cost reduction with economy of scale [3]. In this system a new approach is proposed to optimization of tasks processing time and cost simultaneously. The proposed gravitational attraction search algorithm has been applied to solve Grid Resource Allocation problem [5].

The system is an automated provisioning for database replicas to application allocation in dynamic content web server cluster. The proposed *K*-Nearest Neighbor algorithm is used for light weight monitoring of essential system and application metrics in order to decide how databases should be allocate to a given workload [13]. The system is to develop an optimization framework in the resource provisioning problem. The proposed technique Limited Look ahead Control schema will make accounts for the switching costs incurred

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during resource provisioning and explicitly encodes risk in the optimization problem [12].

The system is to develop a large scale workflows containing millions of tasks and requiring thousands of hours of aggregate computation time. The traditional approach to accessing these resources suffers from many overheads that lead to poor performance. The proposed techniques are advance reservations, multi-level scheduling, and infrastructure as a service (IaaS) [11]. The proposed Optimal Virtual Machine Placement (OVMP) algorithm makes decisions based on the optimal solution of stochastic integer programming (SIP) to rent resources from cloud providers. The performance of the OVMP algorithm is evaluated by numerical studies and simulation [14].

The proposed multi-stage decomposition, which is a recursive application of standard Logic based Benders' Decomposition (LBD) [15]. The proposed brokering strategy is based on the stochastic analysis of routing in distributed parallel queues and takes into account the response time of the Cloud provider and the local cluster while considering computing cost of both sides [7]. This system addresses the problem of maximizing the providers revenue through Service Level Agreement (SLA) based dynamic resource allocation as SLA plays a vital role in cloud computing to bridge service providers and customers. The system is to formalize the resource allocation problem using Queuing Theory and propose optimal solutions for the problem considering various Quality of Service (QoS) parameters such as pricing mechanisms, arrival rates, service rates and available resources [8].

In this system Time and Cost Optimization for Hybrid Clouds (TCHC) algorithm is proposed to reduce the execution time and cost of multiple workflows scheduling [6]. In this system, a Cost based Resource Provisioning Policy (CRPP) has been proposed. Cost is the major factor in Grid services and is considered as a QoS parameter in Grid resource provisioning. This system provides the formal representation of cost based resource provisioning policy for Grid environments [10]. This system suggests architecture for the automatic execution of large-scale workflow-based applications on dynamically and elastically provisioned computing resources. Especially, system focus on its core algorithm named PBTS (Partitioned Balanced Time Scheduling), which estimates the minimum number of computing hosts required to execute a workflow within a user-specified finish time. The PBTS algorithm is designed to fit both elastic resource provisioning models such as Amazon EC2 and malleable parallel application models such as MapReduce. The experimental results with a number of synthetic workflows and several real science workflows demonstrate that PBTS estimates the resource capacity close to the theoretical low bound [9].

III. Proposed Scheme

The overall process of the proposed system is depicted in Fig.1which contains resource provisioning model, stochastic integer programming, Deterministic Equivalent Formulation, Benders Decomposition.

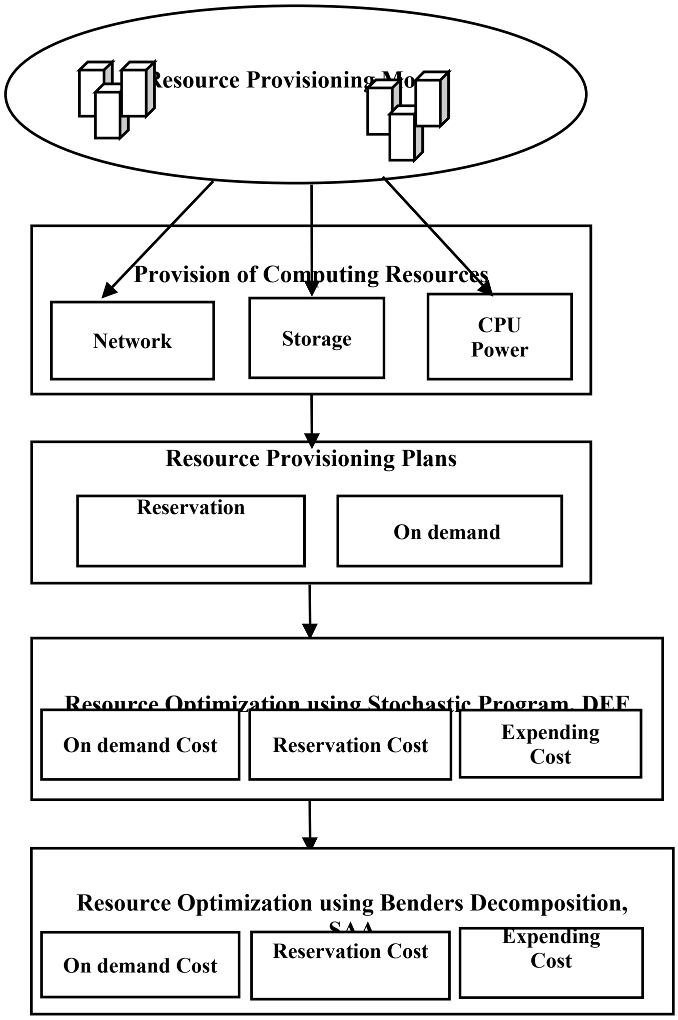

Fig. 1 Overall Process of the Proposed System model

A. Resource Provisioning Model in Cloud

In this proposed system the oracle VM virtual box is used to mount ubuntu operating system in order to access the open stack private cloud. The computing resources are provisioned by using the resource provisioning model and the provision resources are network, storage, CPU processing power**.** The amount of resource types can be computing power in unit of CPU-hours, storage in unit of GBs/month, and network bandwidth for Internet data transfer in unit of GBs/month. In Virtual Machine repository each Virtual Machine class specifies the amount of resources in each resource type. The provisioned amount of resources is directly accessed by cloud consumer using this model.

Key Notations of Resource Provisioning Model

I=Set of Virtual Machine (VM) classes while $i \in I$ denotes the VM class index

J=Set of Cloud providers while $j \in J$ denotes the cloud provider index

K=Set of Reservation Contracts while $k \in K$ denotes the reservation contract index

T=Set of provisioning stages while t ∈ T denotes the provisioning stage index

R=Set of Resource types while r ∈ R denotes the resource type index

Ω =Set of Scenarios while ω ∈ Ωdenotes the scenario index

$c_{ijk}^{(R)}$= Reservation Cost subscribed to reservation contract k charged by cloud provider j to cloud consumers VM class i in the first provisioning stage

$c_{ijkt}^{(r)}(\omega)$= Reservation Cost subscribed to reservation contract k charged by cloud provider j to cloud consumers VM class i in provisioning stage t and scenario ω

$c_{ijkt}^{(e)}(\omega)$ = Expending Cost subscribed to reservation contract k charged by cloud provider j to cloud consumers VM class i in the provisioning stage t and scenario ω

b_{ir}= Amount of resource type r required by VM class i

d_{it} (ω) = Number of Virtual Machines (VM) required to execute class i in provisioning stage t and scenario ω

a_{jrt} (ω) = Maximum capacity of resource type r that cloud provider j can offer to cloud consumer in provisioning stage t and scenario ω

$x_{ijk}^{(R)}$= Decision variable representing the number of VMs in class i provisioned in Reservation Phase subscribed to reservation contract k offered by cloud provider j in the first provisioning stage

$x_{ijkt}^{(r)}(\omega)$== Decision variable representing the number of VMs in class i provisioned in reservation phase subscribed to reservation contract k offered by cloud provider j in provisioning stage t and scenario ω

$x_{ijkt}^{(o)}(\omega)$= Decision variable representing the number of VMs in class i provisioned in on-demand phase offered by cloud provider j in provisioning stage t and scenario ω

$x_{ijkt}^{(e)}(\omega)$= Decision variable representing the number of VMs in class i run expending phase subscribed to reservation contract k offered by cloud provider j in provisioning stage t and scenario ω

B. Stochastic Integer Programming with Recourse

Stochastic Programming is a Mathematical Programming about decision making under uncertainty. The objective of the stochastic programming model function is to minimize the cloud consumer's total resource provisioning cost.

Minimize: (1)

Subject to: $x_{ijk}^{(R)} \in \mathbb{N}_0, \quad \forall i \in I, \forall j \in J, \forall k \in K$ (2)

The objective of Equation (1) is to minimize the resource provisioning costs include: on demand cost, reservation cost, expected cost. In this equation the stochastic two stage integer recourse is formulated for solving complexity of resource cost optimization problems under uncertainty. In this formulation, notation $\mathbb{E}_\Omega$ represents the reduced expected cost of resource provisioning. In Equation (2) the reservation cost belongs to number of cloud provider, number of virtual machines, and set of provisioning stages. In two-stage stochastic programming, the decision variables of an optimization problem under uncertainty are partitioned into two sets. The first stage variables are those that have to be decided before the actual realization of the uncertain parameters. Subsequently, once the random events have presented themselves, further design or operational policy improvements can be made by selecting, at a certain cost, the values of the second-stage, or recourse, variables. The second-stage variables are interpreted as corrective measures or recourse against any infeasibilities arising due to a particular realization of uncertainty. The second-stage problem may also be an operational-level decision problem following a first-stage plan and the uncertainty realization. Due to uncertainty, the second-stage cost is a random variable. The objective is to choose the first-stage variables in a way that the sum of the first-stage costs and the expected value of the random second-stage costs is minimized.

Algorithm for Stochastic Integer Programming

N denotes the number of cloud providers
Step1: first get the sample reservation cost from cloud provider
Step2: initialize the cost for basic variables like $C_{ijk}^{(r)}$ (ω)
for i = 1,2,... ,N do
for j = 1,2,... ,N do
for k = 1,2,... ,N do
z= scenario of reservation phase* decision variable of reservation phase I
(or) z=$C_{ijk}^{(r)}(\omega)$* $X_{ijk}^{(r)}(\omega)$
I = min (decision variable of reservation phase, on demand phase, Expending phase) *c(y)
(or) I=min ($X_{ijk}^{(r)}(\omega)$ * $X_{ijk}^{(o)}(\omega)$* $X_{ijk}^{(e)}(\omega)$
End for;
End for;
End for;
for i = 1,2,... ,N do
for j = 1,2,... ,N do
for k = 1,2,... ,N do
for t = 1,2,... ,N do
c(y)= scenario of reservation phase* decision variable of reservation phase + scenario of on demand phase* decision variable of on demand phase + scenario of expanding phase* decision variable of expanding phase (or)
c(y)= $C_{ijkt}^{(r)}(\omega)$* $X_{ijkt}^{(r)}(\omega)$ + $C_{ijkt}^{(o)}(\omega)$* $X_{ijkt}^{(o)}(\omega)$ + $C_{ijkt}^{(e)}(\omega)$* $X_{ijkt}^{(e)}(\omega)$
Here, some constraints to be followed
$X_{ijk}^{(e)}(\omega)$<=$X_{ijk}^{(r)}(\omega)$;
$X_{ijk}^{(R)}$= $X_{ijkt}^{(r)}(\omega)$;
$X_{ijk}^{(e)}(\omega)$+$X_{ijk}^{(o)}(\omega)$ => $d_{it}(\omega)$
bir($X_{ijk}^{(e)}(\omega)$+$X_{ijk}^{(o)}(\omega)$) <= $a_{jrt}(\omega)$
)
End for;
End for;
End for;

C. Deterministic Equivalent Formulation (DEF)

The two stage stochastic programs are formulated as large stochastic linear programs. This formulation is called as Deterministic Equivalent Formulation. A deterministic equivalent formulation is a mathematical program that can be used to compute the optimal first-stage decision. This formulation exists for continuous probability distributions as well, when one can represent the second-stage cost. The probability distributions of both price and demand must be available in deterministic equivalent formulation. In this optimization problem on demand cost is considered to be obtaining optimal solution of resource provisioning. The stochastic programming model uncertainty problems are solved here using deterministic formulation. In this formulation number of cloud provider are considered to optimize the on demand cost of resource provisioning. The linear mathematical optimization programming script errors are reduced by using this formulation.

Algorithm for DEF

P (ω) - Probability distributions of both price and demand,
N denotes the number of cloud providers
Step 1: first get the sample reservation cost from cloud provider
Step 2: initialize the cost for basic variables like $C_{ijk}^{(r)}(\omega)$
for i = 1,2,... ,N do
for j = 1,2,... ,N do
for k = 1,2,... ,N do
for t = 1,2,... ,N do
$z=C_{ijk}^{(R)}(\omega)* X_{ijk}^{(R)}(\omega) +(p(\omega) * C_{ijkt}^{(r)}(\omega)* X_{ijkt}^{(r)}(\omega)) +p(\omega) *(C_{ijkt}^{(o)}(\omega)* X_{ijkt}^{(o)}(\omega) + C_{ijkt}^{(e)}(\omega)* X_{ijkt}^{(e)}(\omega))$;
where,
$X_{ijk}^{(e)}(\omega)<=X_{ijk}^{(r)}(\omega)$;
$X_{ijk}^{(R)}= X_{ijkt}^{(r)}(\omega)$;
$X_{ijk}^{(e)}(\omega)+X_{ijk}^{(o)}(\omega)$;=> $d_{it}(\omega)$
End for;
End for;
End for;
End for;

D. Benders Decomposition

The Benders decomposition algorithm is applied to solve the stochastic programming problem which is formulated in stochastic programming model. This algorithm can be used for any kind of optimization problem, but it should require a certain substructure within the problem to obtain efficient optimization of resource provisioning cost. The goal of this algorithm is to break down the optimization problem into multiple smaller problems which can be solved independently and parallelly. The Benders decomposition algorithm can decompose integer programming problems with complicating variables into two major problems: master problem and sub problem. The master problems are constituted by the complicating variables and the sub problems are constituted by the other decision variables are solved, and then lower and upper bounds are calculated by this approach. This estimation is used to find the higher and lower provisioning cost

Algorithm for Bender Decomposition

Step 1: split the problem to master and sub problem up to possibility
Step 2: Initialization of master problem,
Step 3: Solve the sub problem
for i = 1,2,... ,N do
for j = 1,2,... ,N do
for k = 1,2,... ,N do
S1= $Z_v^{(r)} =\sum\sum\sum C_{ijk}^{(r)} + \sum p(\omega) * C_{ijkt}^{(r)}(\omega)* X_{ijkt}^{(r)}(\omega)$
Here, $X_{ijkt}^{(r)}(\omega) = X_{ijkt}^{(fix)}(\omega)$ // it is for minimize the reservation cost
S2: $Z_v^{(o)}=\sum\sum\sum p(\omega) *C_{ijk}^{(o)} * X_{ijk}^{(o)}(\omega)$
Here, $X_{ijkt}^{(o)}(\omega) = X_{ijkt}^{(fix)}(\omega)$ // it is for minimize the on demand cost
Where,
$X_{ijk}^{(e)}(w)$ => $d_{it}(\omega)$
bir $(X_{ijk}^{(e)}(w))$ <= $a_{jrt}(\omega)$
End for;
End for;
End for;
Setp 4: Check the convergence condition
$z_{v'}^{(ub)}= z_v^{*(e)} - \alpha v + z_v^{*(r)} +\sum z_v^{*(o)}(\omega)$
Step 5: If $z_{v'}^{(ub)}$ then
Stop the process (got optimal solution)
Else if;
Master problem
$Av =\sum\sum\sum\sum\sum((Y_{ijktv}^{(r)}(\omega)+ Y_{ijktv}^{(o)}(\omega)) * (X_{ijktv}^{(e)}(\omega) - X_{ijktv'}^{(e)}(\omega))$
Here v'=1…v-1 and iteration counter be increased by v=v+ 1 for solve the sub problem and combine the master problem. After solving this master problem, Step-3 is repeated and the same iterative process continues.

IV. Implementation Details

The performance of the proposed resource optimization framework is implemented using eclipse based java platform. The optimal resource provisioning cost is obtained by solving different optimization problems under uncertainty. In this platform mathematical programming scripts are implemented in user friendly manner.

A. Optimal Solution of Stochastic Programming model

Fig. 2 depicts the optimal solution of total provisioning cost by using stochastic Integer Programming Model (SIP). In this optimization reservation demand phase and expending phase is to be considered for obtaining optimal cost of resource provisioning. In this optimization program resource reservation cost is subscribed to the reservation contract which is charged by cloud provider. The cloud consumers Virtual Machine (VM) class is assigned in resource provisioning stage. The Decision variable representing the number of VMs in class provisioned in reservation phase subscribed to reservation contract offered by cloud provider in resource provisioning stage. The reservation demand cost, expending cost (or) total cost is optimized by stochastic program.

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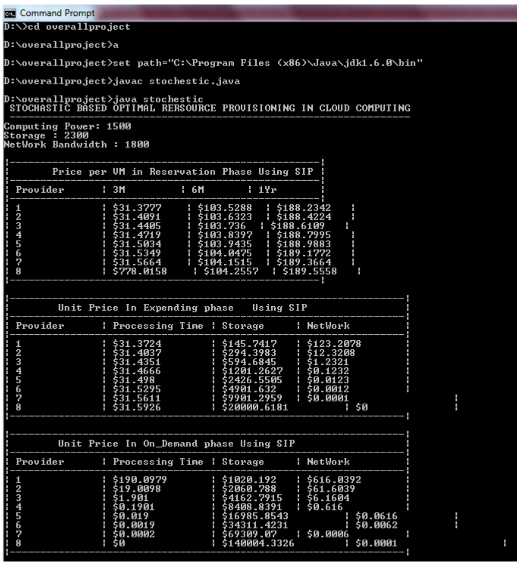

Fig. 2 Stochastic Integer programming

B. Optimal Solution of Deterministic Equivalent Formulation

Fig. 3 depicts the optimal solution of on demand cost by using Deterministic Equivalent Formulation algorithm. In this formulation on demand phase is to be considered for obtaining optimal cost of resource provisioning. The on demand cost is reduced based on number scenarios, regarding to cloud consumers demand during the resource provisioning stage.

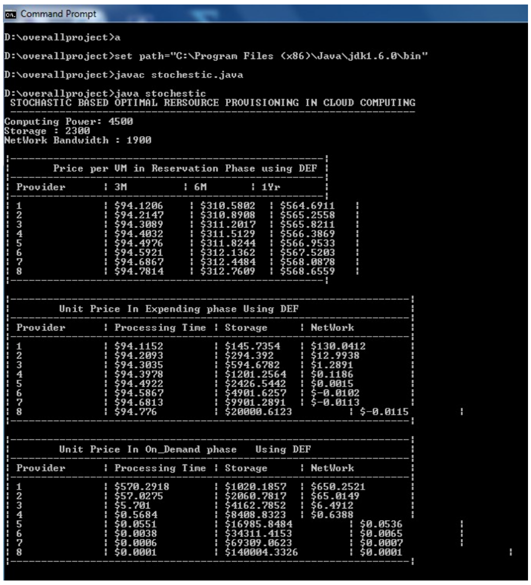

Fig. 3 Deterministic Equivalent Formulation

C. Optimal Solution of Benders Decomposition

Fig. 4 depicts the optimal solution of on demand cost and reservation cost by using Benders Decomposition algorithm. In this optimization on demand phase and reservation phase are to be considered for obtaining optimal cost of resource provisioning. In this decomposition the major problem scenario is formulated and sub divided in to multiple sub problems, which is based on scenario size. The divided problem scenario should contain optimized resource provisioning cost. In this optimization program resource on demand cost is subscribed to the reservation contract which is charged by cloud provider. The cloud consumers Virtual Machine (VM) class is assigned in resource provisioning stage. The Decision variable representing the number of VMs in class provisioned in expending phase subscribed to reservation contract offered by cloud provider in resource provisioning stage. The on demand cost and reservation cost are optimized based on number scenarios. The on demand Cost is subscribed to the reservation contract is charged by cloud provider. The on demand cost and reservation cost are reduced based on number scenarios regarding to cloud consumers demand and reservation during resource provisioning stage. The performance of benders decomposition algorithm is good compare with stochastic algorithm and deterministic equivalent formulation. The complexity of resource provisioning problems solved. The resource provisioning cost of different phase should be minimized while using this algorithm. Resource reservation cost is considered to be very important in the resource problems of reservation stage. The decomposition process starts when the resource reservation request is not completed due to uncertainty problems of resource provisioning. The resource provisioning cost is efficiently optimized by using benders decomposition method.

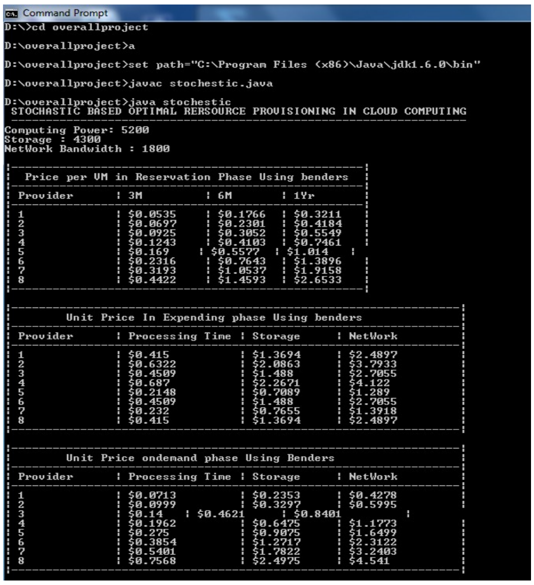

Fig. 4 Benders Decomposition

V. PERFORMANCE EVALUATION

Fig. 5 depicts the resource optimization before and after applying stochastic Programming Model. The results are showing that the resource provisioning costs of computing resources are optimized by after applying stochastic programming model. Fig 5 depicts the computing resources (1-CPU Power, 2-storage, 3-network bandwidth) in x axis and the computing resource costs in y axis.

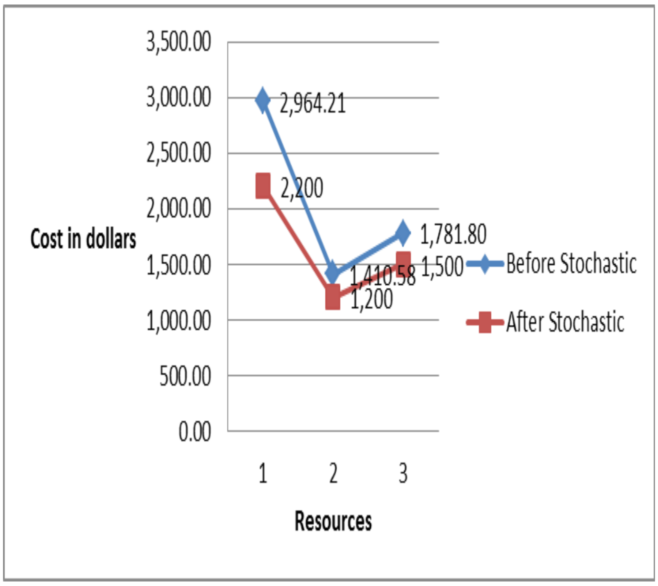

Fig. 5 Resource Optimization Before & after Stochastic Programming

VI. Conclusion

The openstack private cloud environment is configured by using oracle VM virtual box. The cloud resources are provisioned by using openstack resource provisioning model. The Stochastic Integer Programming is applied for difficulty of obtaining the optimal resource provisioning cost. The Two Stage Stochastic Integer Programming with recourse is applied to solve the complexity of optimization problems under uncertainty. The on demand cost and reservation cost are optimized to obtain total cost of resource provisioning. The stochastic programming is enhanced as Deterministic Equivalent Formulation (DEF) for solve the probability distribution of all scenarios to reduce the on demand cost. The Deterministic Equivalent Formulation (DEF) algorithm is applied for solving mathematical optimization of linear programming script errors. The Benders Decomposition is applied for break down the resource optimization problem into multiple sub problems. It is used to reduce the on demand cost and reservation cost during the resource provisioning stage. The performance is compared and evaluated for resource optimization before and after applying stochastic programming model. In this performance comparison, computing resource costs are optimized by after applying stochastic programming model.

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