Approximation algorithm for scaling out large-scale bag-of-tasks applications across multiple clouds

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1. BoT Task

characterization of large-scale bag-of-tasks (BoT) applications:

1. Massive compute-intensive job
2. Independent operations

Many applications in science, engineering and business analytics are classified as BoT.
Some example: Parameter sweeps, fractal calculations and simulations, study of microbial genomes, even Map-Reduce. Now, 70% of workloads in current parallel machine are BoT-type.

2. Private and Public Cloud

- Many organizations already operate their own computing facilities, called private clouds or data centres.
- use of a public cloud (e.g., Amazon EC2) is cost-effective alternative as well.

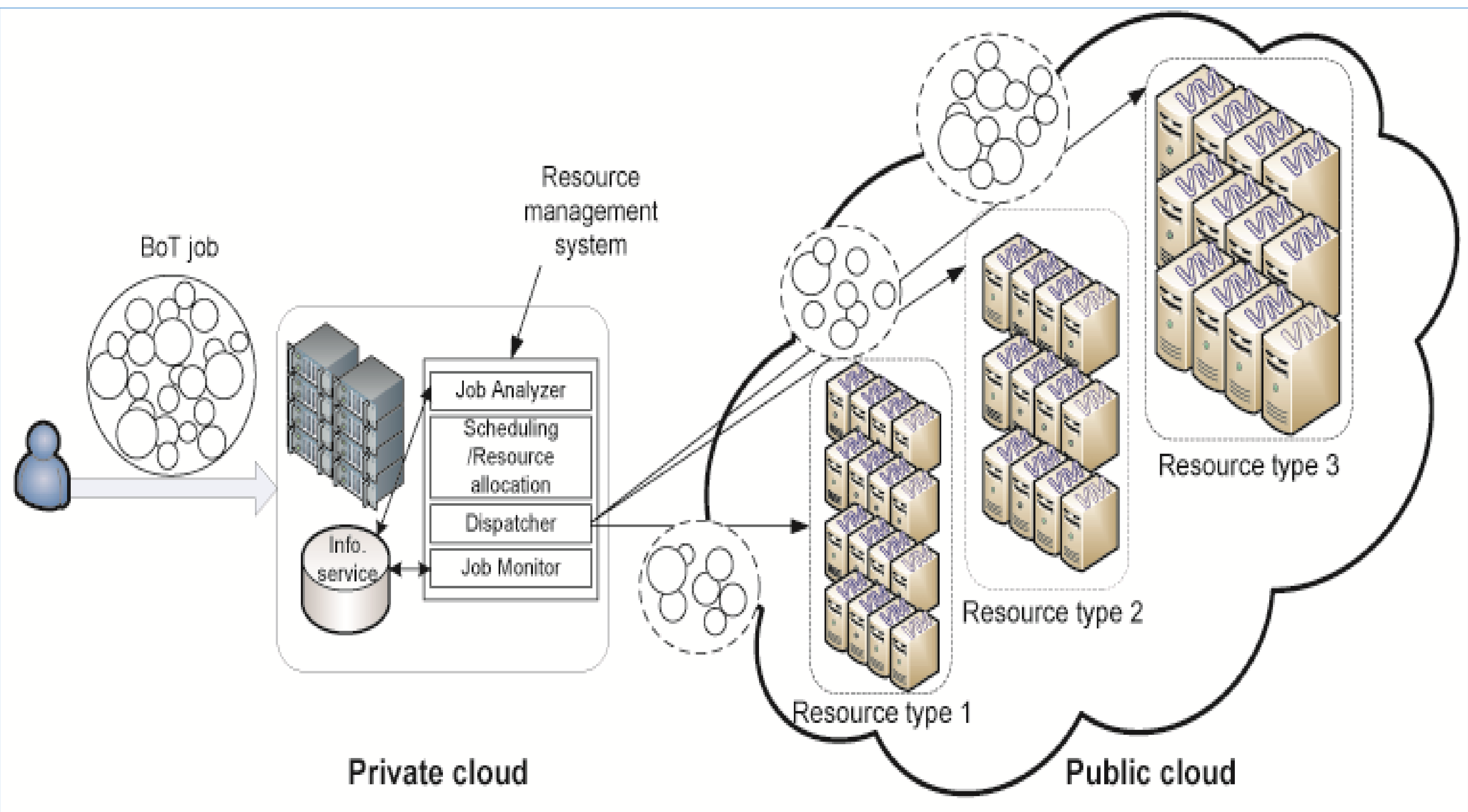
However, in public cloud

- partial hour is charged at the whole hour rate.
- non-proportionality of cost to performance ratios in different resource types

For example: Amazon EC2 offers six instance types (Standard, High-Memory, and High-CPU) their hourly rates not directly comparable. Cost per compute unit for the High-CPU medium instance type is \$0.034, whereas for the Standard small instance type is \$0.08.

3. Aim of the project

We address the problem of assigning a large number of tasks in a given BoT application to resources in both private and public clouds with the main objective of optimizing the cost to performance



4. What's the big picture of our approach

- Consider heterogeneity of resources and tasks
- Model Cost and performance of running jobs across multiple clouds
- Proposed algorithms guarantee that the quality of task assignments optimal or near-optimal
- The time complexity of these algorithms is low,
- Good result of experiments done in both simulation and Amazon EC2 using several real-world BoT applications.

5. PROBLEM DESCRIPTION

1. Let assume there are exactly k different resource types in the public cloud with corresponding speed and cost
2. Accountable time unit (ATU): cost of renting a resource, normally hour
3. The private cloud has its own speed and cost
4. the number of resources to be leased by a particular user is limited by cloud provider
5. BoT application consists of a set of n tasks and each of them has processing time Pj
6. All of them are ready to start at time $t = 0$
7. the cost of executing task j in a resource i is equal to $\frac{Pj}{Si}$

Objective function

1. User wants "cost" to be low
2. User wants "time" for completing all of the tasks to be low
3. User prefers a "stable" task assignment. Stability refer to the "variance" of time or cost of a particular assignment
4. We we devise the following objective function $\min z = \sum_{i\in\Gamma\cup\{v\}} cost_i \times time_i$

6. Equal length task

problem can be stated as an integer programming:

$$\min z = \sum_{i\in\Gamma} L_i c_i \left\lceil \frac{x_i P}{s_i} \right\rceil \frac{x_i P}{s_i} + L_v c_v \left(\frac{x_v P}{s_v}\right)^2$$

$$s.t. \quad \sum_{i\in\Gamma} L_i x_i + L_v x_v = n$$

$$x_v, x_i \in \mathbb{Z}^{\geq 0}$$

As it satisfies KKT conditions, solution for the relaxed problem:

$$\alpha_i = L_i c_i P^2 / s_i^2$$

$$x_i = \frac{nL_i}{\alpha_i \sum_{j\in\Gamma\cup\{v\}} \frac{L_j^2}{\alpha_j}}$$

Refinement phase:
We use task rearrangement technique to achieve an optimal point: a task in a slow resource is moved to a faster resource such that the time in the faster resource to run all of the tasks does not incur any extra cost.
Running time is bounded by $O((\frac{s_j}{P})^{k-2})$

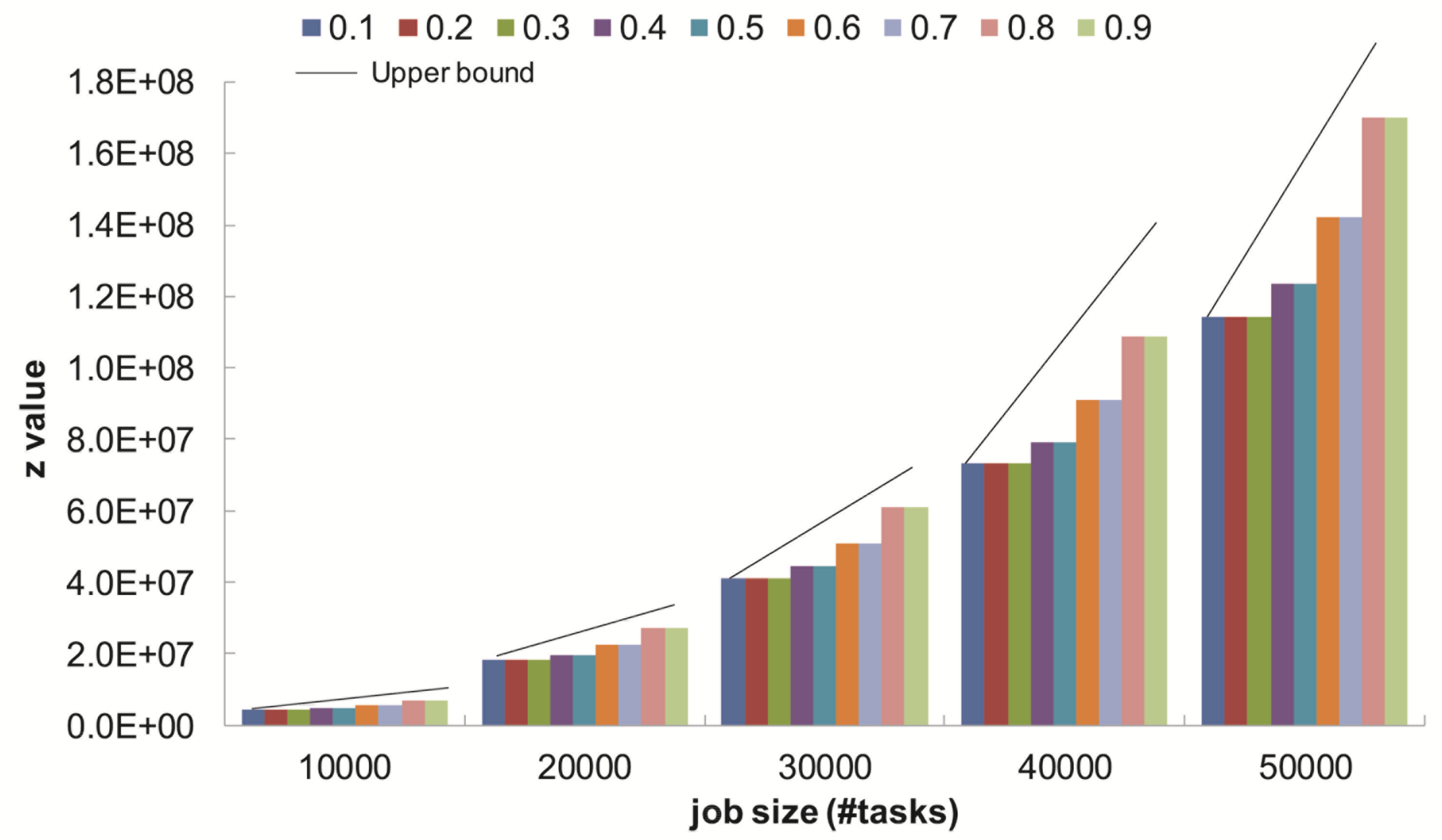
7. Varying-length tasks

We devise a fully polynomial time approximation scheme (FPTAS)
guarantee the quality of solution within a factor of *(1 + e)* of the optimal value for every given *e>0*.
We use a version of approximate subset sum algorithm
the running time of this algorithm is polynomial in terms of both *1/e* and the size of the input.

8. Experimental Evaluation

Experiments of real-world applications have been carried out both in our simulation environment and Amazon EC2

1. Autodock (tools used in (molecular) biology)
2. quantum chromo dynamics in theoretical physics
3. ISOMAP (a nonlinear dimensionality reduction framework)



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