New Multi-resource Fairshare Prioritization Mechanisms for Heterogeneous Computing Platforms

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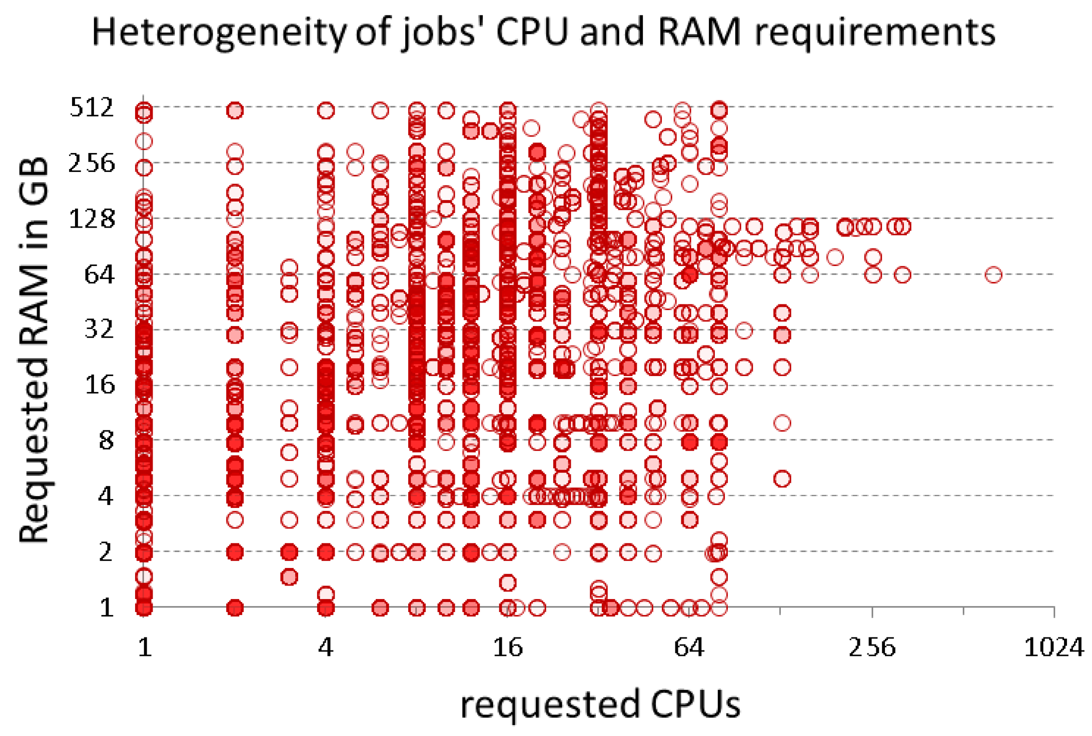
1. Introduction

Existing Grid resource managers usually support only **CPU-aware fairshare** mechanisms to guarantee fairness, disregarding other consumed resources.

We presents newly developed **multi resource-aware prioritization mechanism for guaranteeing fairness in heterogeneous Grid-like systems**. This solution is currently being implemented in the TORQUE resource manager used within the Czech national Grid infrastructure *MetaCentrum* [1].

2. Multi Resource-aware Fairshare



CPU-based fairshare prioritization is not suitable for highly heterogeneous jobs and resources [2].

- $penalty_j = reqCPUs_j \cdot walltime_j$
- users are prioritized wrt. their previously consumed CPU time
- **high RAM, HDD, GPU, etc., requirements are not adequately penalized**

3. Drawbacks of Existing Solutions

Dominant Resource Factor (DRF) and **Bottleneck-based Fairness (BBF)**:

- schedule jobs according to the maximum/bottleneck resource requests
- **unrealistic assumptions that all jobs and resources are infinitely divisible**

Processor Equivalent (PE):

- $PE_j = \max(\frac{reqCPUs_j}{availCPUs}, \frac{reqRAM_j}{availRAM}) \cdot availCPUs$
- **not suitable (unfair) for heterogeneous systems** since PE_j may vary per machine
- user's priority (based on PE_j) may highly depend on scheduler's decisions

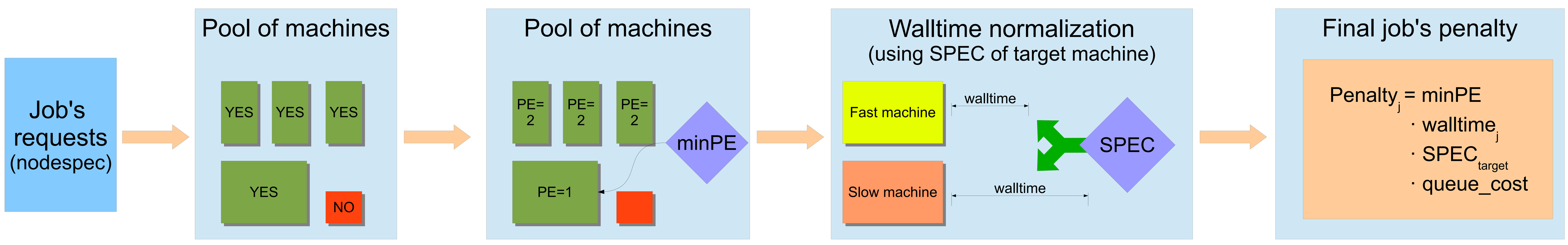
4. Proposed Solution

Main features of the proposed solution:

- **based on an extended PE metric**
- **a multi resource-aware mechanism**
- **fair regardless jobs' and machines' heterogeneity**
- **reflects various machines' speeds**
- **a job's penalty (i.e., user's priority) is not scheduler-dependent**

5. Computation of Fair Job's Penalty over Heterogeneous Resources

The process of penalty calculation



1. Find all suitable machines for a job **2.** Find minimal PE on such machines **3.** Normalize job's walltime **4.** Apply queue cost **5.** Penalty is a product of values

Penalty computation ($penalty_j$) for a given job j and m suitable machines:

- $PE_{j,i} = \max(\frac{reqCPUs_j}{availCPUs_i}, \frac{reqRAM_j}{availRAM_i}) \cdot availCPUs_i \quad (\forall i \text{ such that } 1 \leq i \leq m)$
- $penalty_j = \min(PE_{j,1}, .., PE_{j,m}) \cdot walltime_j \cdot SPEC_{target} \cdot queue\_cost$

Important notes:

- the actual *target* machine(s) where a job is executed may be different from the "cheapest" one
- **a job's "cost" only depends on user's requests and is independent from scheduler's decisions**
- **a job's walltime is normalized** according to the speed of the target machine, eliminating speedup effects of faster machines

6. Conclusion and Future Work

The proposed solution is currently being implemented within *MetaCentrum*'s TORQUE scheduler.

- **it replaces current standard CPU-based fairshare mechanism**
- parameter setup is currently analyzed (SPEC benchmarks for walltime normalization, queue costs, multi-node penalty, etc.)

In the future, **we plan to extend penalty metric to consider other important (but often less restricting) resources like GPUs and HDD.**

- will require modification of $PE_{j,i}$ calculation as, e.g., GPUs are not required by all jobs in the system
- a machine with fully used GPUs may still execute other jobs

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