Scheduling Bag-of-Tasks Applications

Theoretical Results, Practical Environments, and Perspectives

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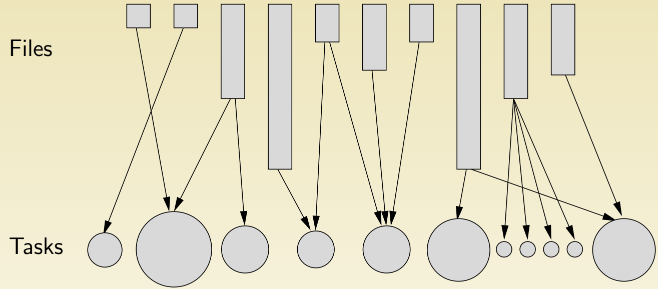
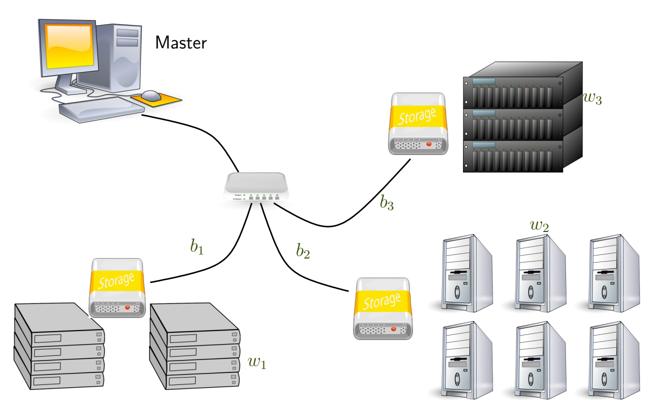


Difficulties:

- File sharing;
- Task size heterogeneity;
- Task/cluster affinity;
- Large number of Tasks (small tasks issue + scheduling complexity).

Platform Description



Outline

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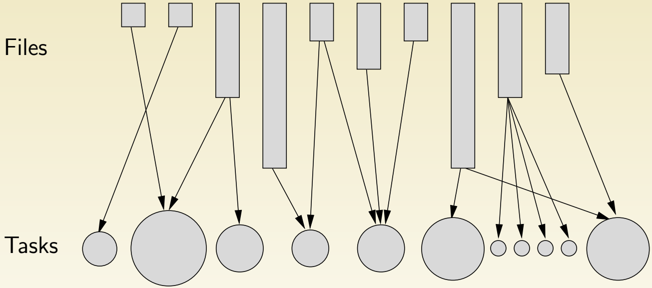
No Input Files

Sometimes, input files are very small or are transfered before hand.



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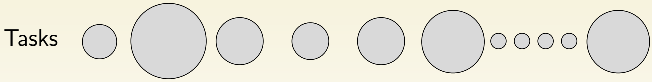

In this case, we end up with some packing problem.

Theoretical Results

The homogeneous case $\langle P||C_{\max}\rangle$

- Any List schedule is a $(2 - 1/m)$ approximation [Cof76].
- The $(2 - 1/m)$ bound is tight for SPT.
- LPT is a $(\frac{4}{3} - \frac{1}{3m})$ approximation [Gra69].

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The uniform case $\langle Q||C_{\max}\rangle$ [CK98]

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The unrelated case $\langle R||C_{\max}\rangle$

- A "complex" (LP+rounding) 2-approximation [LST90].
- Not approximable within $3/2 - \varepsilon$ for any $\varepsilon > 0$ [LST90].
- Admits a FPTAS for the case where m is constant.

And in "Practice"?

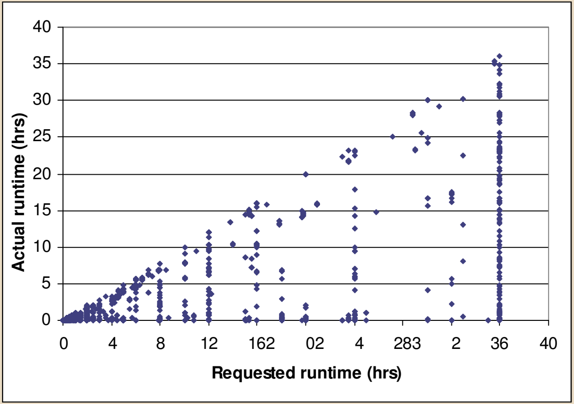
The greedy approach Min-min (SPT), Max-Min (LPT), Sufferage (takes affinity into account) [MAS+99]. $O(mn^2)$.

while there remains a task to schedule **do**
    for each unscheduled task T_i **do**
        for each processor P_j **do**
            Evaluate completion time $CT(T_i, P_j)$
        Evaluate schedule cost $C(T_i) = f(CT(T_i, P_1), \ldots, CT(T_i, P_m))$
    Choose task T_b with the best schedule cost.
    Find out the best processor $P_{b'}$ of T_b.
    Schedule T_b on $P_{b'}$

Practical Issues

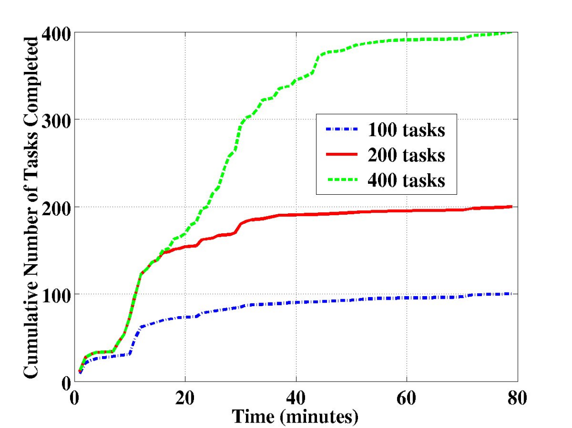
How do you get an estimate of the p_i?

You cannot trust user estimates [MF01]



The last finishing task issue

FCFS scheduling on a desktop Grid [KTB+04]



Practical Issues

How do you handle millions of tasks?

Small tasks induce large overheads.

- They "pollute" the queues.
- Most batch scheduler submission mechanism are ineffective in this setting.
- You have to pay the latency for small file transmission...
- ...or setup mechanisms like advance submission, buffering, pipelining, ...
- $n^2, n \log n$ may be impractical. Need for low-complexity algorithms.

Looking for the "optimal" does not make sense anymore.

$\leadsto$ Small jobs are a pain!

Practical Issues

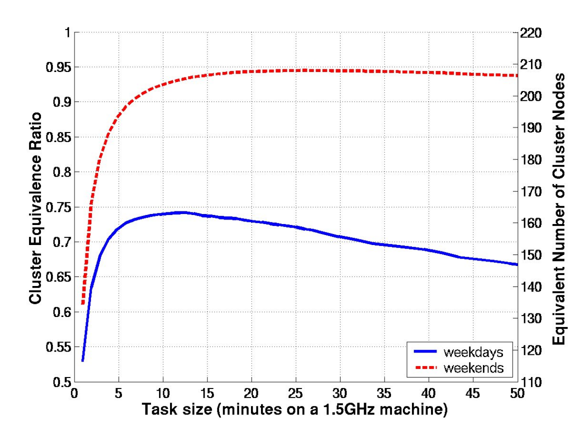
How do you handle failures?

- Jobs are migrated on another machine whenever the resource is reclaimed (Condor).
- Jobs get suspended whenever the resource is reclaimed and resumed later whenever it is available.
- Jobs get suspended whenever the resource is reclaimed. It the resource is not available again shortly, the jobs is considered as lost and resubmitted elsewhere (Entropia).
- Jobs get killed whenever the resource is reclaimed (OAR).
- Jobs are submitted with a deadline, no more communication next; if the deadline is missed the job is lost and resubmitted (BOINC).

$\rightsquigarrow$ Large jobs are a pain too!

Practical Issues

There is an "optimal" job size [KTB+04]



Many Grid Projects Handle This Kind of Applications

- Example:

  Condor Univ. of Wisconsin, started in 1988 [TTL02]
  APST Univ. of California, San Diego, started in 1998 [HC02]
  CiGRI Univ. of Grenoble, started in 2001 [YGR07]
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  Another option is to use alternative submission mode.

- Very small tasks are a real issue though and aggregating is tedious.
- Very large tasks are a real issue too because of potential failure.

Outline

Natural Extension

- The min-min/max-min/sufferage heuristics naturally extend to this problem [CLZB00]. Xsufferage was a natural extension to take the cluster aspect into account. $\rightsquigarrow O(mn^2 + mnf)$.

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- Another greedy approach with comparable performance [GRV04] but better complexity: $O(mn \log n + mnf)$.

```
for each processor P_j do
    for each unscheduled task T_i do
        Evaluate OBJ(T_i, P_j)
    Build the list L(p_j) of the tasks sorted by OBJ
while there remains a task to schedule do
    for each processor P_j do
        Let T_i be the first element of L(p_j)
        Evaluate completion time CT(T_i, P_j)
    Pick a (T_i, P_j) with minimum completion time.
    Schedule T_i on P_j
```

Hypergraph Partitioning

- A hypergraph $H = (V, N)$ ($n_k \subseteq V$ for each $n_k \in N$).
- Let $\Pi = (V_1, \ldots, V_K)$ be a K-way partition of V.

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Definition.

[The K-way hypergraph partitioning problem] Find a K-way partition minimizing

$$CutSize(\Pi) = \sum_{n_k \in N} w(n_k)(|\Lambda_k| - 1)$$

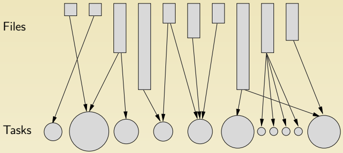
while maintaining the balance

$$\frac{W_{max} - W_{avg}}{W_{avg}} \leq \varepsilon$$

Hypergraph Partitioning (cont'd)

- There is a natural correspondence between our bags of tasks and a hypergraph.

  Tasks ≈ pins and Files ≈ nets.



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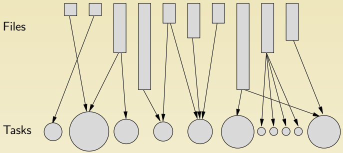

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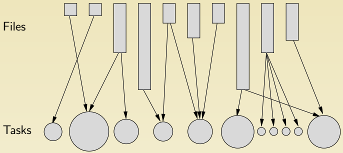

- In a homogeneous setting, finding a K-way partition amounts to minimize file transfers while ensuring a good load balance of computations.
- Adapting the idea to an heterogeneous is slightly more tricky [Kay06] but worth the effort since there are efficient heuristics for the K-way partition problem.
  - Such heuristics have complexity $O(mn \log n + cnf)$.
  - They have up to 32% of improvements compared to Min-min, Sufferage and such (for high communication to computation ratio).
  - They run more than 10 times faster.

Model Flaws

Of course there are many practical aspects that are not taken into account in the previous model:

- Storage are not infinite.
- The one-port model for distributing the files is simplistic.
- NFS saturation occurs inside the cluster.
- Getting the file size and dependencies is OK but getting the processing time is even more difficult in a heterogeneous setting.

And in Practice ?

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- Local file managements are LRU anyway but the EGEE project has been investigating a lot about this with simulations.
- Most of the time, file staging is a pain for users because the middleware support is lame. . .
- . . . but none of the previous problems is that hard in practice.

Outline

State of the Art

Campaign completion is important, not task completion!

- Few projects have a notion of campaign and of users.

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Interesting question (for us) How do you handle?

- fairness between users, institutions;
- campaign size heterogeneity;
- campaign heterogeneity (e.g. compilation test campaigns);
- interference with other jobs (support for best-effort).

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Important question (for developers)

- Hardware heterogeneity (portability issues);
- Security (user and resource point of view);
- Failures.

Fairness Management in Various Projects

CONDOR Work-queue FCFS.

APST Yuck! If several APST daemons use the same set of resources, the sharing is determined by the resource local sharing policy.

CIGRI Work-queue FCFS.
Could use the OAR "fair-sharing" mechanism: keep track of user's time consumption in a sliding window and use a simple ORDER BY at the task scheduling level.

BOINC Volunteers do not want to work for *any* project. Some sharing emerge from volunteer's priorities.

OURGRID Network of favors, designed to deter free-riders.

- $v_A(A, B) =$ how much A gave to B (according to A).
- A give priority to users with the higher rank $R_A(B) = \max\{0, v_A(B, A) - v_A(A, B)\}$.

Handles lab friendship gracefully.

Outline

Conclusion

- At a coarse-grain level, campaigns are divisible and preemptible.
- Average task size and task campaign could be estimated from observations.

- I am not sure there is much work to do in scheduling for tasks (simple workqueues with replication work fine).
- I think there is a lot of work to do in campaign scheduling. We know of many online efficient algorithms for "fair" divisible tasks.

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