Handling Collusion in Dynamic Desktop Grids

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Outline

1. Collusion in Desktop Grids
2. Scheduling
3. Reputation system
4. Simulation
5. Conclusion
Distributed Computing

The server assigns job \( j \in J \) to each active worker \( w \in W \). Each worker returns a result \( r \in R \) for the corresponding job. The client wants to have the correct result for each submitted job. Example: SETI@Home, BOINC-based projects.
Cheating

Byzantine fault

Unreliability or malicious isolated peer (worker).
35% of workers gives at least one wrong result (Derrick Kondo et al. 2007).
Allow to increase credit for example.
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$k$-majority
Assign a job to $k$ distinct peers (redundancy) and select the result that has the majority. BOINC use a quorum-based system.
Collusion

A subset of the workers produces the same wrong result for some given job.
Against Sybil attack or library with platform specific bugs.
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Generality

Generic and non-intrusive mechanism: no information available on the structure of the jobs and their results.
No trustworthy computation resources.
Blacklisting is not necessary (risk of churn and whitewashers).
Mechanisms

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Main components

Resource grouping assures duplications of jobs by creating a set of workers for each job.

Result certification selects one of the results as the best one.
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Objectives (Zhao and Lo, 2005)

- **Overhead**: minimum redundancy.
- **Accuracy**: maximum of correct certified results.
Detection orientation

Large groups with workers with unknown interactions (exploration).
Grouping strategies

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Avoidance orientation
Group with workers belonging to distinct colluding sets (exploitation).
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Group with workers belonging to distinct colluding sets (exploitation).

Need for informations
In either cases, the probability to collude of a set of workers is needed. More generally, the colluding characteristics of the system.
Problem description

Based only on the generated results, what can we say?
Build a reputation system that will then be used at higher level.
Goal

Determine the probability of collusion of any subset of workers.
Objectives of the reputation system

**Goal**

Determine the probability of collusion of any subset of workers.

**Criteria (Jøsang, Ismail, and Boyd, 2007)**

- **Accuracy** Root Mean Square Deviation (RMSD) of all generated informations
- **Adaptativeness or dynamicity** 
  - #iterations to acknowledge changes
  - Robust resistant to attacks
  - Smooth aggregated difference between 2 iterations
- **Introversion** RMSD of error estimations
Reputation system

Observations

Input

\(< t, w, j, r >\) (timestamp, worker, job, result)
\(< t, j >\) whenever a job is finished
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### Observations = pairwise interactions

Considering that we observe interactions between individual workers lead to quadratic complexity for most involved algorithms and low precision for workers with low activity.
Observations

Input

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\[ < t, j > \) whenever a job is finished

Observations = pairwise interactions

Considering that we observe interactions between individual workers lead to quadratic complexity for most involved algorithms and low precision for workers with low activity.

Observations = group interactions

Consider that an observation informs us on the interaction between group(s) of workers. This involves to characterize the group to which each worker belongs.
Data structure

Graph: each node corresponds to a set of worker; each edge, to some collusion characteristics.
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**Algorithm**

Initially, each worker is in a singleton. We proceed by succession of merges and splits operations.
Reputation representation

- collusion likelihood between workers from set $i$ and set $j$: $c_{ij}$
- agreement likelihood: $a_{ij}$
Reputation representation

**Representation**
- collusion likelihood between workers from set $i$ and set $j$: $c_{ij}$
- agreement likelihood: $a_{ij}$

**Relation**

\[

a_{ij} = 1 + 2 \times c_{ij} - c_{ii} - c_{jj}
\]

\[

\frac{1+a_{ij}-a_{1i}-a_{1j}}{2}
\]

where the index of the biggest set is 1
Reputation system

Reputation representation

Representation

- collusion likelihood between workers from set $i$ and set $j$: $c_{ij}$
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Relation

$$a_{ij} = 1 + 2 \times c_{ij} - c_{ii} - c_{jj}$$
$$c_{ij} \leq \frac{1 + a_{ij} - a_{1i} - a_{1j}}{2}$$
where the index of the biggest set is 1

Comparison

$\{c_{ij}\} \rightarrow \{a_{ij}\}$ but $\{c_{ij}\} \leftrightarrow \{a_{ij}\}$, then collusion likelihood has more informations.
Agreement likelihood is easier to manage, faster and more stable.
Example of a merging criterion

Merging sets $i$ and $j$ with collusion representation.
Input: $c_{ii}$, $c_{ij}$ and $c_{jj}$

\[
c_{ii} \approx c_{ij} \approx c_{jj} \land \min(N(c_{ii}), N(c_{ij}), N(c_{jj})) > \max(\Sigma, \frac{n}{m}) \times \frac{\alpha}{(1 - d_1)(1 - d_2)(1 - d_3)}
\]

- $N(c)$ number of observations with which $c$ is estimated
- $\Sigma$ sum of size of sets $i$ and $j$
- $n$ number of workers
- $m$ number of characterized groups
- $d_k$ difference between $c_{ii}$ and $c_{ij}$

\[\alpha = \begin{cases} 
2.5 & \Sigma > B \\
1 & \text{otherwise}
\end{cases}
\]

$B$ is the size of the biggest characterized set
How to deal with uncertainty (sparse observations)?

Values are modeled by random variables, e.g. Beta function (Jøsang, Ismail, 2002).

Arithmetic operation propagates errors (variance).
Reputation system

Estimator

How to deal with uncertainty (sparse observations)?

Values are modeled by random variables, e.g. Beta function (Jøsang, Ismail, 2002).

Arithmetic operation propagates errors (variance).

How to deal with dynamicity?

Bayesian inference is used to reinitialize each estimator when estimation is too far from recent observations.
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No ready traces

We want \( < t, w, j, r > \).

We have availability traces (FTA, \ldots), workload archive (GWA, \ldots) and one performance file (FTA/SETI@home).
Simulation

Trace preparation (1)

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Mixing distinct traces

We mix FTA and GWA trace together.
Number of needed cores for each job in GWA is eluded.
GWA is for HPC platform not Desktop grid (still better than arbitrary model).
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Other adjustment

The same performance file is used for distinct availability trace because availability and power are uncorrelated on SETI@home.
Scheduling

Redundancy-based scheduler: achieve a quorum of $q$ with initial and maximal duplication $l$ and $l_{max}$.

Jobs scheduled on workers when available (durations determined with the performance file and the normal duration of the job).

Result computations are based on reliability and colluding probabilities.
Trace preparation (2)

Scheduling

Redundancy-based scheduler: achieve a quorum of $q$ with initial and maximal duplication $l$ and $l_{\text{max}}$. Jobs scheduled on workers when available (durations determined with the performance file and the normal duration of the job). Result computations are based on reliability and colluding probabilities.

Trace that could have been useful

Job-centric traces on Desktop Grid: start and end times of the computation of a job; hash of the result.
Results with synthetic input

Evolution of collusion error

- agreement
- collusion

Collusion RMSE

Step
Results with traces

Evolution of collusion error

- agreement
- collusion

Time (days)

Collusion RMSD
Main contributions

- Propose a reputation system that observes interaction between groups of workers with 2 representations (agreement, collusion)
- Use a realistic input based on existing traces

Perspective

- Correct the dependance reliability/collusion (the system does not converge)
- Apply clustering techniques based on agreement distance