Replication and Redundancy in BOINC

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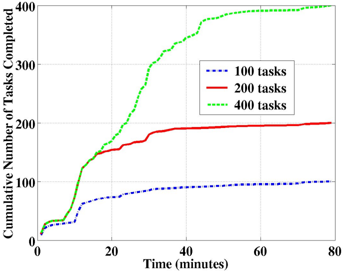
Outline

1. Improving BOINC Turnaround Time (Job Replication)
2. BOINC As a Storage Facility (Data Redundancy)

The Straggler Issue

- FCFS scheduling on a desktop Grid[KTB+04]



A.k.a the last finishing task issue

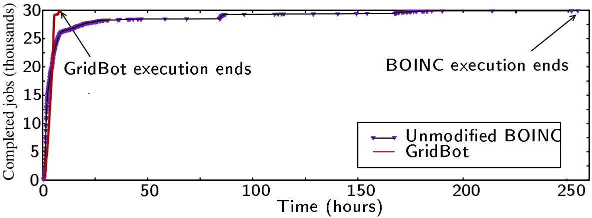
In BOINC, large deadlines and connection interval can make it worse.

- Can be quite problematic
  - Batch information and the corresponding files need to stay on the server (WCG) $\rightsquigarrow$ server overload
  - The system may starve when there is a limit on the number of active batches (CAS@home).
- Many solutions in the literature... but few implemented in practice
  - Exclude resources
  - Prioritize resources
  - Replicate jobs

The GridBot project

GridBot[SSGS09] (Technion - Israel Institute of Technology)

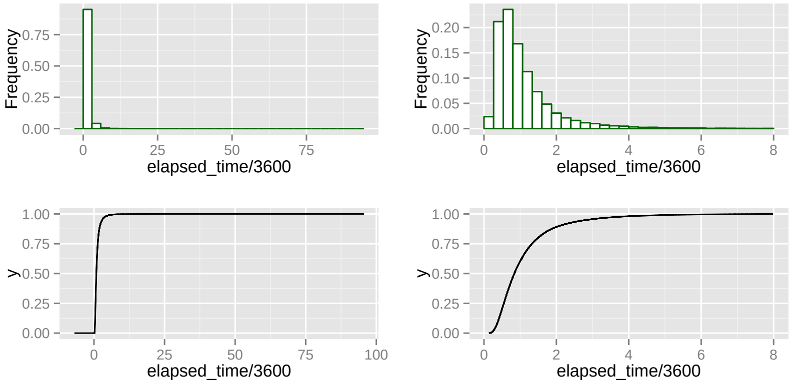
- Focus on response time of BoTs
- Use both community resources (BOINC) and grid resources (Condor)
- Better than BOINC and than Condor for this kind of workload
  - Replicate on reliable resources *toward the end*
  - Tighter deadlines for reliable resources (although you have to be careful with this. . .)



- Two other articles where BOINC is helped with reliable cloud resources
- Focus on the response time optimization of a single large batch

A Glance At The CAS@home Workload

- Batches comprise 32 jobs with roughly the same computation workload.
- The running time of a job is .5 to 4 hours.
  - Jobs are short $\rightsquigarrow$ `elapsed_time` is not so different from `cpu_time`.
- Deadline is set to 36 hours



90% of the jobs take less than two hours to run

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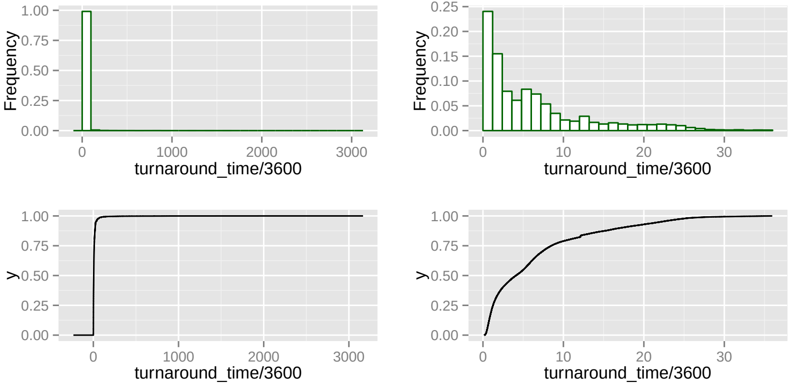

The job turnaround can be huge! (up to 5 months!)

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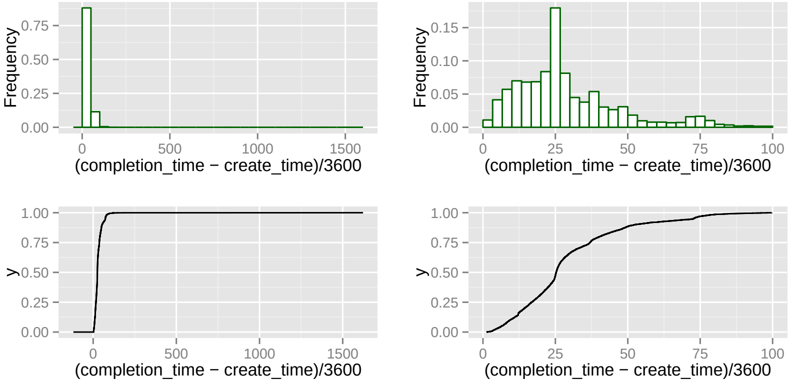

and so is the batch turnaround...

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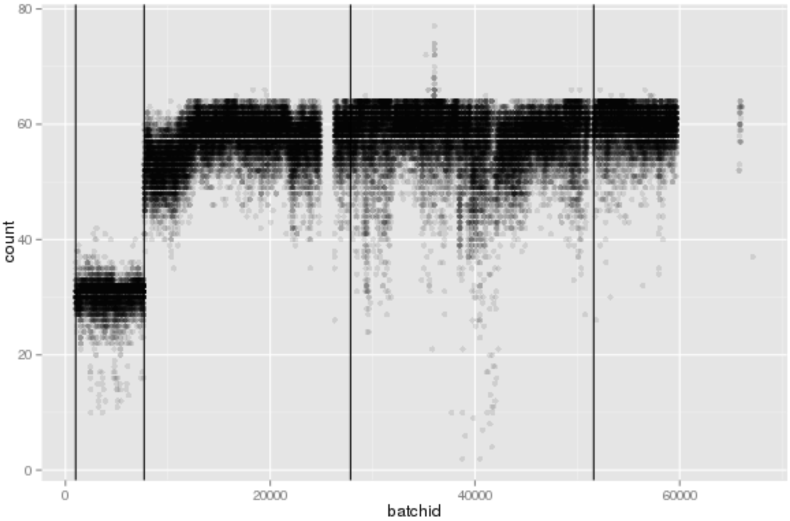
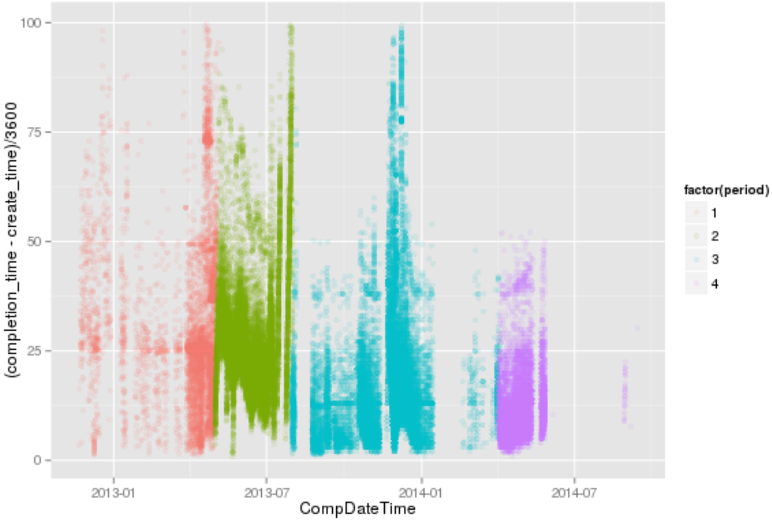
- Deadline is set to 36 hours
- CAS@home now has no more than 300 active batches at a time (a new batch comes in only when another one is completed) so the system can starve.
- At the moment: one additional replica for each job to improve the batch response time, which improves the system throughput despite the waste.

CAS@home: An Evolving System



Evolution of the number of jobs sent per batch

CAS@home: An Evolving System



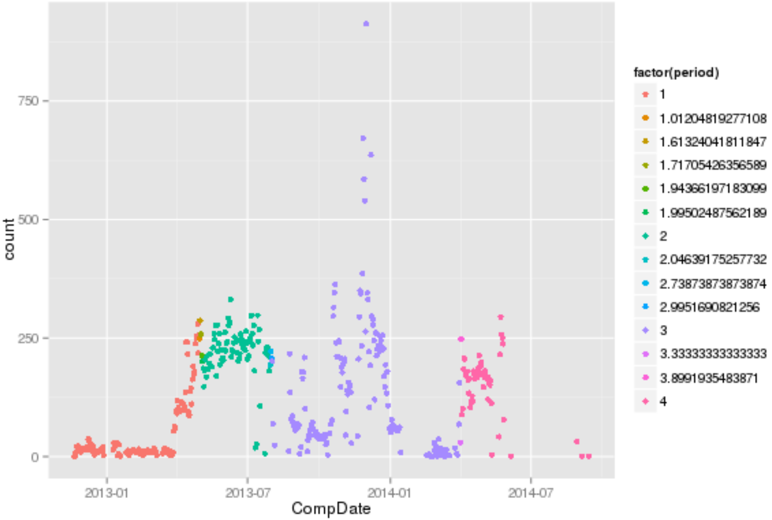
Evolution of the batch response time (hours)

CAS@home: An Evolving System

period	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
1	1.25	16.61	25.24	29.46	37.65	99.75
2	0.98	19.15	24.96	28.04	32.90	99.45
3	1.00	9.00	14.01	18.98	23.01	99.49
4	1.00	7.00	11.01	13.05	16.01	52.01

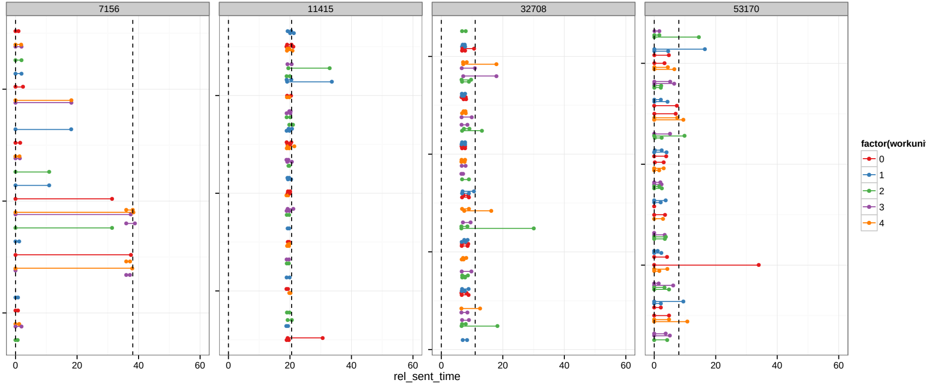
Evolution of the batch response time (hours)

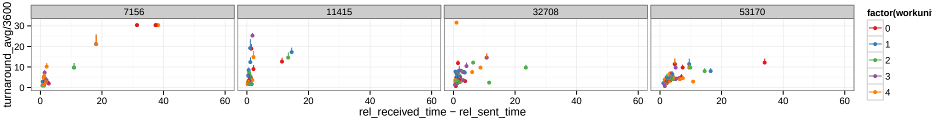
CAS@home: An Evolving System



Evolution of the batch throughput (batch per day)

CAS@home: An Evolving System





Evolution of the scheduling

What Can We Do About It?

- Improving job response time would help:
  - ~~Decrease the deadlines~~ (volunteers will complain)
  - Implement an "execute as possible" option
  - Implement a "report as possible" option
- The server can make a smarter use of resources. Whenever a host requests work, look for the right batch:
  - There is a continuum of behaviors and setting thresholds is difficult
  - Intuitively: use the fastest hosts to get rid of "almost finished" batches
  - We may want to "sacrifice" a batch to slow unreliable hosts so that they can still contribute without hurting response time
- Last week, we have crafted a simulation of BOINC and fed it with a profile of the CAS@home volunteers
- Short term work: check the modeling, test scheduling alternatives
- Long term work: handle non identical batches (SRPT), fair sharing between umbrella projects

Outline

1. Improving BOINC Turnaround Time (Job Replication)
2. BOINC As a Storage Facility (Data Redundancy)

BOINC As a Storage Facility

Volunteer computing is based on the idea that idle personal computers could as well be used to make distributed computations.

David coined a few years ago that we could do the same with storage space.

Disk space average 50 GB available per client $\leadsto$ 35 Petabytes total

Trends disk sizes increasing exponentially, even faster than processing power.

- 1 TB $\times$ 1M clients = 1 Exabyte

Could we construct a distributed "data center" from empty disk space from volunteers?

Volunteer Data Archival

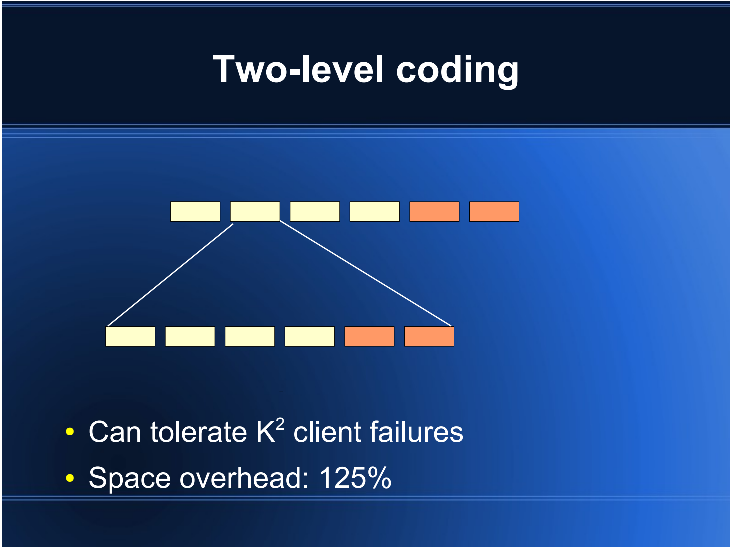
Same difficulty as usual:

- Volunteers are unreliable resources. They may leave (or enter) the system at any time, destroying whatever data and computations thy have been storing.
- Volunteers cannot be easily contacted. In BOINC, we need to volunteers to contact the server.

Our goal is to design a reliable data storage out of unreliable volunteers by coding data and storing redundant chunks in volunteers.

- Files originate on server
- Chunks of files are stored on clients
- Files can be reconstructed on server (with high latency)
- Design Goals
    - arbitrarily high reliability (99.999%)
    - support large files

David's Proposal : Two-Level Coding + Replication



Open questions: Why two levels ? How much redundancy ?

Using a Cost Model...

Assumptions:

- Single file split in N chunks
- Local storage is expensive: holding cost of H per time unit and per chunk.
- Each volunteer stores one chunk of data
- Erasure coding: the whole file is encoded with $M \geq N$ chunks but any N chunks out of M can be used to recreate the file
  - The server can create and upload a chunk to a volunteer iff it has N chunks in its own memory.

How to choose the best redundancy $M - N$?

. . . and Markov Chains

Volunteers are independent from each others so we can model most events as Poisson process.

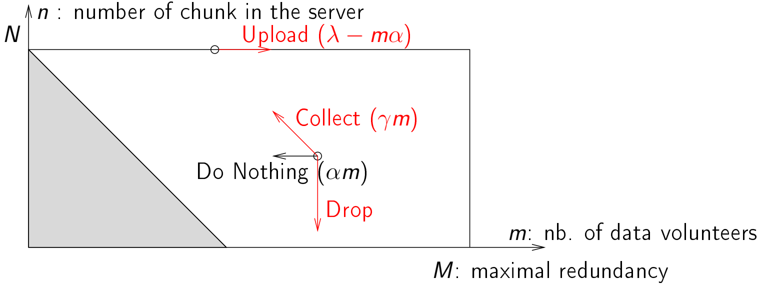
- New volunteers join the system and request data with rate λ.
- Each volunteer that is already storing a chunk is called a data volunteer.
  - Data volunteers contact the server at rate γ (in which case the server can download its chunk)
  - Data volunteers leave the system at rate α (in which case its chunk is lost)

At any time, the state of the system is characterized by (n, m):

- n is the number of chunks stored locally
- m is the number of data volunteers

If the file is lost (when the system moves to (n, m) where $N < n + m$) a large cost C is incurred and we go to $(N, 0)$.

Control Actions



The server has four available actions:

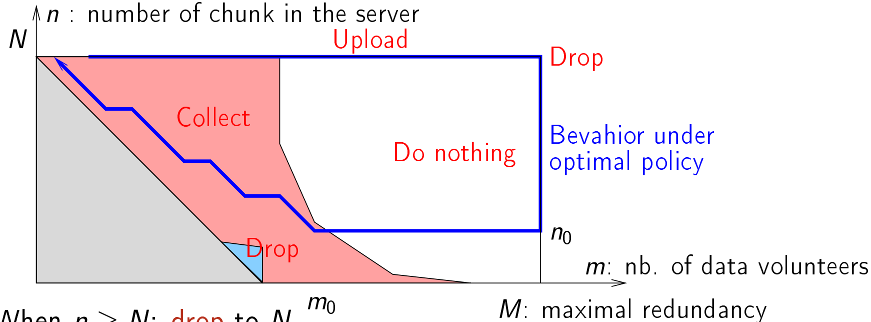
Upload changes new volunteers into data volunteers. As long as $n \geq N$, this is possible $\boxed{\text{whenever a new volunteer arrives}}$. The state changes to $(n, m+1)$.

Collect $\boxed{\text{Whenever a data volunteer arrives}}$, the server can collect its chunk. The state changes to $(n+1, m-1)$.

Drop erases any $k \leq n$ chunks from memory, changing the state from (n, m) to $(n-k, m)$.

Do Nothing in which case some chunks are lost when data volunteers leave

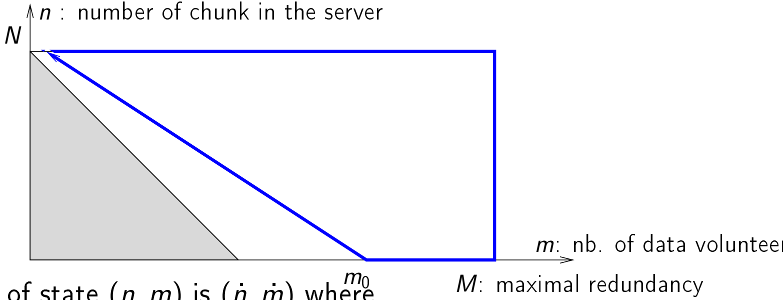
What Does The Optimal Policy Look like ?



- When $n \geq N$: drop to N
- When we have the whole file ($n = N$), as long as $m < M$, there is nothing to loose in uploading the file (except the holding cost).
- When we reach state (N, M), it will be optimal to immediately drop $N - n_0 > 0$ chunks for some n_0.
- There are two switching curves $f_1(m) \geq f_2(m)$, such that:
  - for $n \geq f_1(m)$ it will be optimal to do nothing,
  - for $f_2(m) \leq n < f_1(m)$ it will be optimal to collect chunks,
  - for $n < f_2(m)$ it will be optimal to drop chunks.

Fluid Approximation

Computing f_1 and f_2 for a given N and M is very hard. However, when N and M go to infinity, things average out (fluid approximation).



The rate out of state (n, m) is $(\dot{n}, \dot{m})$ where

- $(\dot{n}, \dot{m}) = (0, -m\alpha)$ if the action is to do nothing,
- $(\dot{n}, \dot{m}) = (0, \lambda - m\alpha)$ if $n = N$ and the action is to upload,
- $(\dot{n}, \dot{m}) = (m\gamma, -m(\gamma + \alpha))$ if the action is to collect,
- and the fluid immediately drops from (n, m) to (n_0, m) if the action is to drop $n - n_0 \geq 0$ of " chunk fluid".

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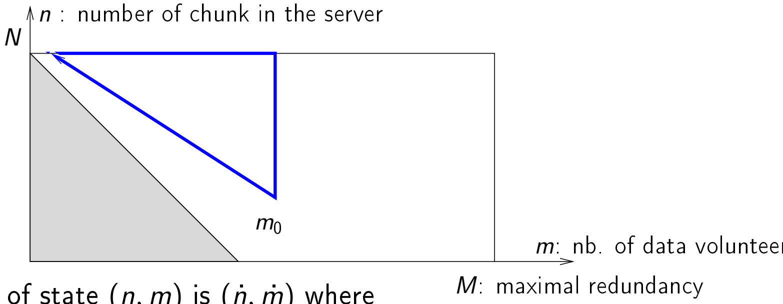

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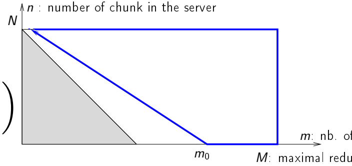
Cost for the Fluid Approximation

1. Starting from $(N, 0)$ we upload and move to (N, M) at rate $(\dot{n}, \dot{m}) = (0, \lambda - m\alpha)$.



$$\begin{cases} t_1 & = -\frac{1}{\alpha}\ln\left(1 - \frac{\alpha}{\lambda}M\right) = \frac{1}{\alpha}\ln\left(\frac{\lambda}{\lambda - \alpha M}\right) \\ C_1 & = HNt_1 = \frac{HN}{\alpha}\ln\left(\frac{\lambda}{\lambda-\alpha M}\right) \end{cases}$$

2. We immediately drop to state $(0, M)$ at t_1 at no cost.
3. From $(0, M)$, do nothing and move to $(0, m_0)$ at rate $(0, -m\alpha)$.

$$t_2 = \left(\ln(M) - \ln(N(\alpha+\gamma)/\gamma + 1)\right)/\alpha \text{ and } C_2 = 0$$

4. From $(0, m_0)$ we collect new chunks and move back towards $(N, 1)$ at rate $(\dot{n}, \dot{m}) = (\gamma m, -(\gamma+\alpha)m)$.

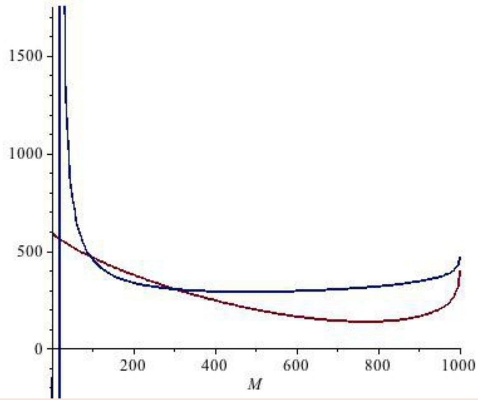
$$\begin{cases} t_3 & = \frac{1}{\gamma+\alpha}\ln(N(\alpha+\gamma)/\gamma+1) \\ C_3 & = \frac{H\gamma}{(\gamma+\alpha)^2}(1 + (N(\alpha+\gamma)/\gamma+1)\ln(N(\alpha+\gamma)/\gamma+1)) \end{cases}$$

In both cases, the total average cost is $\boxed{V = \dfrac{C_1 + C_3}{t_1 + t_2 + t_3}}$

Optimal Redundancy

We get $V = H \dfrac{N \ln\left(\frac{\lambda}{\lambda - \alpha M}\right) + \frac{\gamma\alpha}{(\gamma+\alpha)^2}(1 + m_0 \ln(m_0))}{\left(\ln\left(\frac{\lambda}{\lambda-\alpha M}\right) + \ln M\right) - \frac{\gamma}{\gamma+\alpha}\ln(m_0)}$

With $\alpha = 1$, $\gamma = 1$, $\lambda = 300$, $N = 30$, $H = 20$, we get:



The two level coding is not in the picture yet but it seems feasible to incorporate it.

References

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