Science United: Implementation

David P. Anderson

Spaces Sciences Laboratory

University of California, Berkeley

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# 2 Coordinator development and administration

## 2.1 Design, development, and deployment

The coordinator is being designed and developed by my group, with funding from the NSF.

The coordinator’s software is hosted on Github and is released under the LGPLv3 license.

The coordinator will initially run on existing servers at UC Berkeley.

# 3 Keywords

As a basis for volunteer preferences, we have defined a system of “keywords” for describing jobs. The system has the following structure:

* Category: currently “science area” or “location”. We could also consider categories for openness of results, but this may be hard to define.
* Hierarchy: each level N+1 keyword is a child of a single level N keyword. The hierarchy can change over time.
* Each keyword has a permanent integer ID, and short and long textual descriptions that can change over time.

## 3.1 Project and job attributes

Each job has an associated set of keywords. These are specified in the job submission process. For example, if a TACC job is submitted by a cancer researcher at UCB, the attributes would include “cancer research” and “UCB”.

Each project publishes a set of keywords, and for each keyword the estimated fraction of current jobs having that keyword. If the fraction is one, the keyword is implicitly associated with all the project’s jobs. The set of project keywords can change over time, reflecting changes in the project’s workload. The coordinator polls projects for their keywords.

## 3.2 Keyword preferences

A volunteer can specify, on the coordinator web site, a set of “preferences”, represented as a map from keywords to (yes, no, maybe). “No” means don’t send jobs with that keyword. “Yes” means preferentially send jobs with that keyword. A “no” for a keyword trumps “yes” for descendant keywords.

If a project has a keyword with job fraction 1, and a volunteer has “no” for that keyword, the volunteer’s devices should not be attached to that project.

When a new keyword is added, the default setting is “maybe” for all volunteers. Volunteers are notified of the new keyword in case they want to change this.

## 3.3 Keyword-based scheduling

The BOINC job dispatcher uses “score-based” scheduling: in deciding which jobs to send to a device, the scheduler computes a score for each job that includes a number of different factors; it then sends the highest-scoring jobs. We have extended this to include keywords. For each of the job’s keywords, if the volunteer has “yes” the score is incremented, and if “no” the score is zero (meaning don’t send the job).

# 4 Resource usage accounting

The coordinator does accounting of resource usage. This serves two main purposes:

* It provides basis for volunteer incentives: for example, graphs showing work done recently, work “milestones”, and so on.
* It provides a basis for resource allocation to projects, and gives an estimate of the system-wide throughput.

BOINC has a sophisticated credit system for estimating the FLOPs performed by a completed job. It is fairly “cheat-proof”: it is difficult to get credit for computation not actually performed. However, this is based in part on job replication, meaning that credit for a job may not be granted until the companion job is completed, which could take weeks. This makes it undesirable for volunteer incentives.

Instead, we use a quantity called “estimated credit” (EC), which is maintained by the BOINC client on a per-job and per-project basis, based on the runtime of jobs and the peak FLOPS of the processors they use. EC is a cruder estimate than credit, and it is not cheat-proof. But it accumulates continuously, without waiting for job replicas.

# 5. Resource allocation

The central function of the coordinator is to allocate resources among projects. It does this by assigning projects to computers.

Resource allocation is constrained by volunteer preferences: if 100% of volunteers said “no” to cancer research, the coordinator can’t assign computers to that project. However, we anticipate that volunteer preferences will be primarily positive (“yes”). This gives the coordinator some freedom, since “yes” is non-binding: the coordinator is free to assign “maybe” work even if “yes” work is available.

## 5.1 Linear bounded model

Resource allocation will be based on a “linear bounded model” which works as follows:

* Each project P has a “balance” BP which continuously increases at a rate RP, up to a limit LP. Balance is in units of floating-point operation (FLOPs). RP can be thought of as the project’s “share” of the total resource pool. If project A has twice the share of project B, and they both have a continuous supply of jobs, A should get about twice the computing B (all other things, such as keywords, being equal).
* When computation is done for a project P, BP is decremented by the amount of computation.
* At any point, computing resources are assigned to the project P for which BP is greatest.

This model handles both continuous and sporadic workloads well. For a project P with continuous workload, BP will remain around zero. For a project P with sporadic workload, BP will usually be at the limit LP. Then P generates a burst of work, it will have priority over the continuous-workload projects, and will get done quickly.

## 5.2 Allocation

Initially, all projects will have equal shares (RP values). However, at some point we’ll want the capability of giving projects greater shares, on either a temporary or permanent basis. These “allocations” will be consist of elevating RP to a given, starting and ending at given times.

Allocation decisions will be made by the coordinator committee, according to a published policy. Allocations could be based on merit, on special circumstances, or on payment.

## 5.3 Performance guarantees

Some existing HTC systems can offer “performance guarantees”: a client can be guaranteed a given throughput over a given period of time with very high probability. It’s desirable to offer analogous guarantees with VC resources.

The performance of a pool of volunteer computers can vary, in terms of both throughput and job latency. However, with a large pool, these quantities change slowly over time, and we can measure these changes and establish the statistics of their change. For example, given the total throughput T at a given time, we could find a T0 < T such that total throughput will remain above T0 for a week.

In this way, it’s likely that the “allocations” described above can be mapped to specific performance guarantees; the details remain to be figured out.

Such guarantees would be project-level. Can we provide performance guarantees to a particular job submitter within a project that serves lots of job submitters? This is more complex but it may be possible. The BOINC server software uses the linear-bounded model, exactly as described above, to allocate resources among computing job submitters within the project. It’s possible that the combination of a project-level allocation and a submitter-level allocation provide some form of performance guarantee to the submitter.

# 7. Project account creation

Each BOINC project has its own set of accounts, identified by unique email address. When the BOINC client attaches to a project, it specifies an account and provides credentials.

Volunteers who use the coordinator create an account on the coordinator, which includes an email address. The coordinator then (transparently to the volunteer) creates accounts on various projects with the same credentials. To minimize overhead, these accounts are created on demand.

The coordinator creates project accounts using Web RPCs. These RPCs may take several seconds to complete, and they may temporarily fail (e.g. because the project is down). So we don’t want to do them synchronously with user interactions. So we use the following approach:

* The coordinator maintains a database table of project accounts, both established and pending. A periodic daemon process retries account creations that previously had transient failures.
* When a volunteer creates a coordinator account, the coordinator identifies an initial set of projects, creates database records, and triggers the daemon. Typically the project accounts will be created within 10-20 seconds. Thus, by the time the volunteer installs and runs the BOINC client, the project accounts will exist and the client will be able to begin fetching jobs and computing immediately.
* When a client does an AM RPC to the coordinator, the RPC handler identifies a set of projects the client should run (see below). For some of these, a project account may not already exist. The RPC handler creates database records, triggers the daemon, and tells the client to repeat the request in 60 seconds.

Project account creation can fail because the project already has an account with the given email address but different password. In this case the coordinator shows these “problem accounts” on the main page and the user page. The volunteer is taken to a page that lets them enter the other password.

# 8. Project assignment algorithm

Clients using the coordinator periodically (perhaps once per day) issue an AM RPC. The request message includes a list of currently-attached projects and their work totals; these are used to update account records. The reply message includes a list of projects to attach to. The client detaches from any projects not on this list. For each project, the reply specifies a “resource share”: a value of zero means that the client should do work for this project only if none of the other projects have work available.

Being attached to a project has a disk overhead; the client caches applications files for the project, which may include large VM image files. Hence we want to limit the number of projects each client is attached to. On the other hand, if a project has a large disk footprint on a client, we may want the client to remain attached (with a zero resource share) even if we don’t want it to compute at this point.

With these factors in mind, here is a sketch of the project assignment algorithm currently used by the coordinator:

* For each project (of all the projects managed by the coordinator) compute a score for this client. This score includes several components:
  + A keyword factor. Increment the score if the project has keywords in the volunteer’s “yes” list. Don’t use the project if it has a “no” keyword with job fraction one.
  + Increment the score if the host has a GPU of the type the project can use.
  + Increment the score if the host has Virtualbox and the project can use it.
  + Add the project’s allocation balance.
  + Increment the score if the host is already attached to the project.
* Choose the top 3 highest-scoring projects. If the user doesn’t have an account on any of these, initiate an account creation and tell the client to retry in 1 minute.
* If the client is currently attached to a project not in the top 3 but whose disk footprint exceeds 10 MB and whose score is nonzero, tell the client to remain attached with zero resource share.

The algorithm has lots of undetermined parameters. We’ll guess appropriate values. An interesting research project would be to create a simulator for studying system behavior with different alforithms and parameters.

# 9. Implementation notes

The BOINC web code (used for project web sites) has lots of features needed by the coordinator:

* Account creation and login.
* Computing preferences.
* List of hosts.
* Message boards, private messages, “friends”, and other community-oriented features.

The code is configurable so that features related to job processing (which are not relevant to the coordinator) can be disabled. So we are using existing BOINC web code (PHP, database schema) as a basis for implementing the coordinator.

We have added a number of web pages and tables that are specific to the coordinator: projects, allocations, project and volunteer keywords, project accounts, accounting records, and so on.

We have implemented a separate web interface for coordinator admins. This interface supports adding and editing projects, viewing accounting graphs, and so on.