Open Science Grid

An Introduction to High-Throughput Computing

Monday morning, 9:15am

Alain Roy <roy@cs.wisc.edu>

OSG Software Coordinator

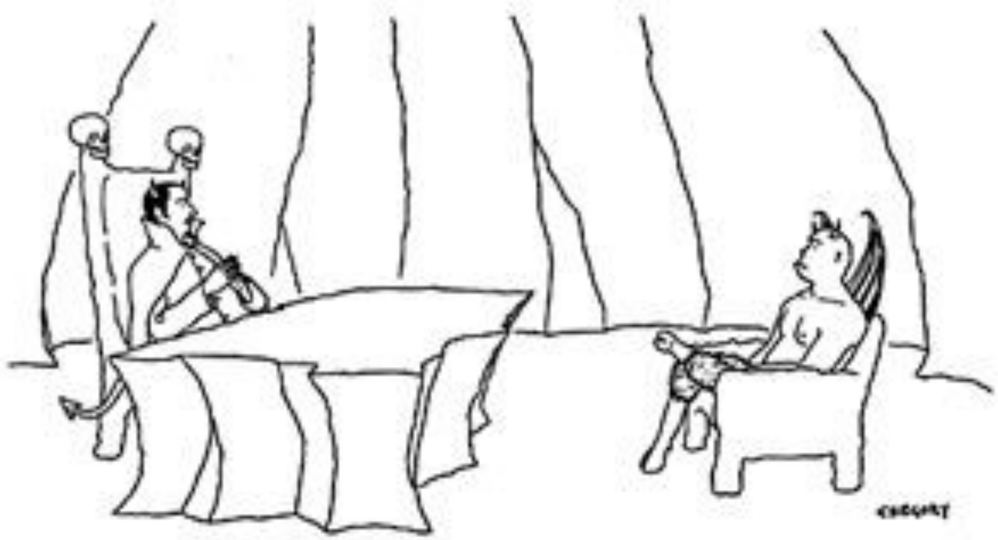
University of Wisconsin-Madison

Who Am I?

- With Condor since 2001
- Open Science Grid Software Coordinator
- Taught at five previous summer schools
- I have the two cutest kids in the whole world:

Overview of day

- Lectures alternating with exercises
  - Emphasis on lots of exercises
  - Hopefully overcome PowerPoint fatigue



"I need someone well versed in the art of torture—do you know PowerPoint?"

Overview of day

- I’ve done most of these exercises in a grid school before, but not with this format:
  - It’s okay to move ahead on exercises if you have time
  - It’s okay to take longer on them if you need to
  - If you move along quickly, try the “On Your Own” sections and “Challenges”

Most important!

- Please ask me questions!
  - During the lectures
  - During the exercises
  - During the breaks
  - During the meals
  - Over dinner
  - The rest of the week

Before we start

- Sometime today, do the exercise on getting a certificate.
  - It is **required** for all exercises Tuesday-Thursday.
  - It will be easiest if you do it today.

Goals for this session

- Understand basics of high-throughput computing
- Understand the basics of Condor
- Run a basic Condor job

Open Science Grid

What is high-throughput computing? (HTC)

- An approach to distributed computing that focuses on long-term throughput, not instantaneous computing power.
  - We don't care about operations per second
  - We care about operations per year
- Implications:
  - Focus on reliability
  - Use all available resources (not just high-end supercomputers)

Open Science Grid

Good uses of HTC

- “I need as many simulation results as possible before my deadline…”
- “I have lots of small-ish independent tasks that can be run indepdently”

What's not HTC?

- The need for "real-time" results:
  - (Ignore fact "real-time" is hard to define.)
  - HTC is less worried about latency (delay to answer) than total throughput
- The need to maximize FLOPS
  - "I must use the latest supercomputer, because I need the fastest computer/ network/storage/…"

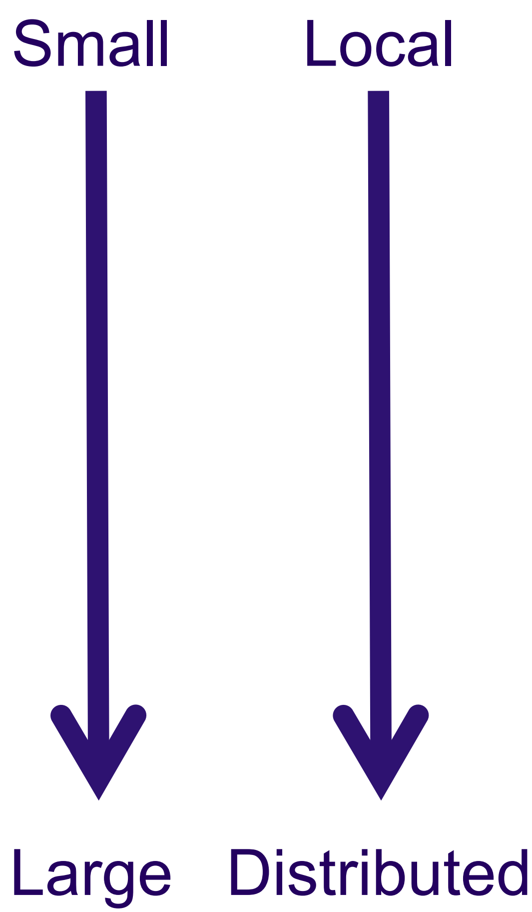
An example problem: BLAST

- A scientist has:
  - Question: Does a protein sequence occur in other organisms?
  - Data: lots of protein sequences from various organisms
  - Parameters: how to search the database.
- More throughput means
  - More protein sequences queried
  - Larger/more protein data bases examined
  - More parameter variation
- We'll try out BLAST later today

Why is HTC hard?

- The HTC system has to keep track of:
  - Individual tasks (a.k.a. jobs) & their inputs
  - Computers that are available
- The system has to recover from failures
  - There will be failures! Distributed computers means more chances for failures.
- You have to share computers
    - Sharing can be within an organization, or between orgs
    - So you have to worry about security.
    - And you have to worry about policies on how you share.
- If you use a lot of computers, you have to deal variety:
  - Different kinds of computers (arch, OS, speed, etc..)
  - Different kinds of storage (access methodology, size, speed, etc…)
  - Different networks interacting (network problems are hard to debug!)

Let's take one step at a time



- Can you run one job on one computer?
- Can you run one job on another local computer?
- Can you run 10 jobs on a set of local computers?
- Can you run 1 job on a remote computer?
- Can you run 10 jobs at a remote site?
- Can you run a mix of jobs here and remotely?
- This is the (rough) progress we'll take in the school.

Open Science Grid

Discussion

- For 5 minutes, talk to a neighbor: If you want to run one job in a local cluster of computers:
  - What do you (the user) need to provide so a single job can be run
  - What does the system need to provide so your single job can be run?
    - Think of this as a set of processes: what needs happen when the job is given? A “process” could be a computer process, or just an abstract task.

Alain's answer: What does the user provide?

- A "headless job".
  - Not interactive (no GUI): how do you interact with 1000 simultaneous jobs?
- A set of input files
- A set of output files.
- A set of parameters (command-line arguments).
- Requirements:
  - Ex: My job requires at least 2GB of RAM.
  - Ex: My job requires Linux.
- Control:
  - Ex: Send me email when the job is done.
  - Ex: Job 2 is more important than Job 1.
  - Ex: Kill my job if it's run for more than 6 hours.

Alain's answer: What does the system provide?

- Methods to:
  - Submit/Cancel job.
  - Check on state of job.
  - Check on state of avail. computers.
- Processes to:
  - Reliably track set of submitted jobs.
  - Reliably track set of available computers.
  - Decide which job runs on where.
  - Advertise a single computer.
  - Start up a single job.

Surprise! Condor does this (and more)

- Methods to:
  - Submit/Cancel job. `condor_submit/condor_rm`
  - Check on state of job. `condor_q`
  - Check on state of avail. computers. `condor_status`
- Processes to:
  - Reliably track set of submitted jobs. `schedd`
  - Reliably track set of avail. computers. `collector`
  - Decide which job runs on where. `negotiator`
  - Advertise a single computer `startd`
  - Start up a single job `starter`

A brief introduction to Condor

Condor Takes Computers…

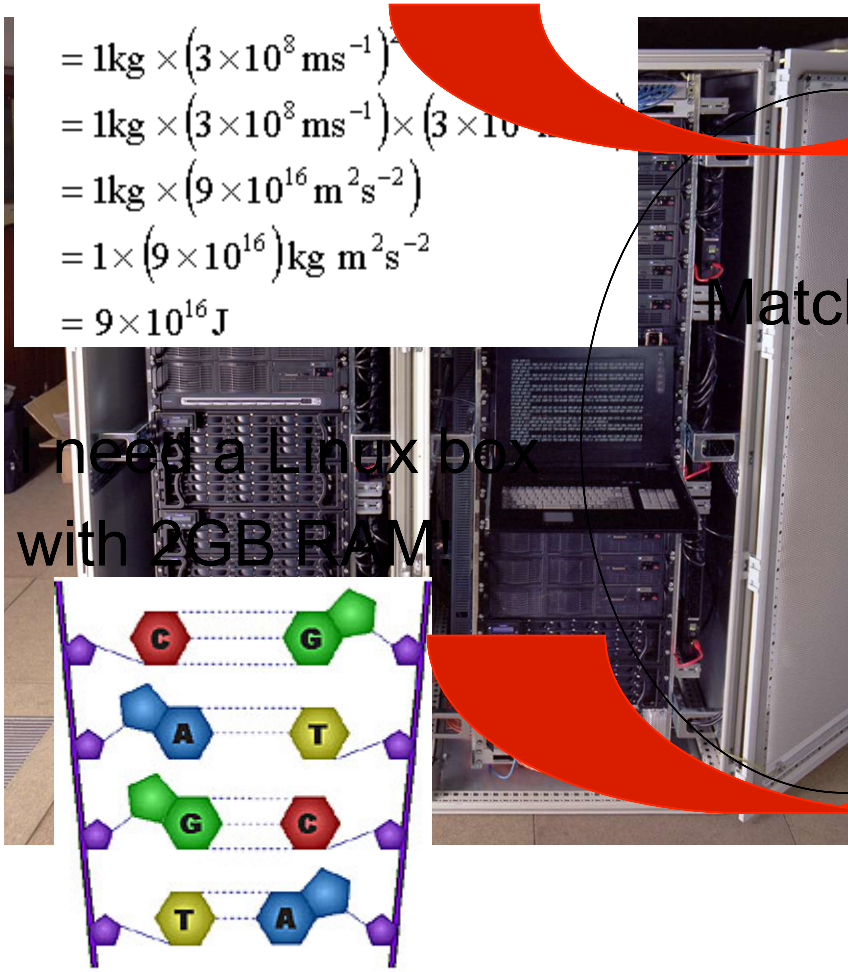
…And matches them

I need a Mac!

Dedicated Clusters

Desktop Computers

$$E = mc^2$$
$$= 1\text{kg} \times (3 \times 10^8\,\text{ms}^{-1})^2$$
$$= 1\text{kg} \times (3 \times 10^8\,\text{ms}^{-1}) \times (3 \times 10^8\,\text{ms}^{-1})$$
$$= 1\text{kg} \times (9 \times 10^{16}\,\text{m}^2\text{s}^{-2})$$
$$= 1 \times (9 \times 10^{16})\,\text{kg m}^2\text{s}^{-2}$$
$$= 9 \times 10^{16}\,\text{J}$$



Matchmaker

I need a Linux box with 2GB RAM!

Quick Terminology

- Cluster: A dedicated set of computers not for interactive use
- Pool: A collection of computers used by Condor
  - May be dedicated
  - May be interactive

Open Science Grid

Matchmaking

- Matchmaking is fundamental to Condor
- Matchmaking is two-way
  - Job describes what it requires:

    I need Linux && 8 GB of RAM
  - Machine describes what it requires:

    I will only run jobs from the Physics department
- Matchmaking allows preferences
  - I need Linux, and I prefer machines with more memory but will run on any machine you provide me

Why Two-way Matching?

- Condor conceptually divides people into three groups:
  - Job submitters
  - Machine owners
  - Pool (cluster) administrator

  May or may not be the same people
- All three of these groups have preferences

ClassAds

- ClassAds state facts
  - My job's executable is analysis.exe
  - My machine's load average is 5.6
- ClassAds state preferences
  - I require a computer with Linux

Open Science Grid

ClassAds

- ClassAds are:
  - semi-structured
  - user-extensible
  - schema-free
  - Attribute = Expression

Example:

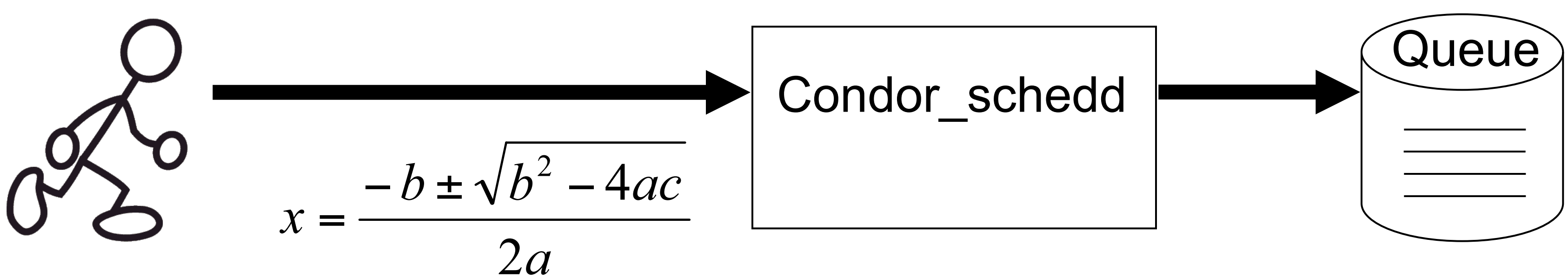
```
MyType       = "Job"        ← String
TargetType   = "Machine"
ClusterId    = 1377         ← Number
Owner        = "roy“
Cmd          = “analysis.exe“
Requirements =
    (Arch == "INTEL")       ← Boolean
&& (OpSys == "LINUX")
&& (Disk >= DiskUsage)
&& ((Memory * 1024)>=ImageSize)
…
```

Schema-free ClassAds

- Condor imposes some schema
  - Owner is a string, ClusterID is a number…
- But users can extend it however they like, for jobs or machines
  - `AnalysisJobType = "simulation"`
  - `HasJava_1_4 = TRUE`
  - `ShoeLength = 7`
- Matchmaking can use these attributes
  - ```
    Requirements = OpSys == "LINUX"
              && HasJava_1_4 == TRUE
    ```
    ```

Submitting jobs

- Users submit jobs from a computer
  - Jobs described as ClassAds
  - Each submission computer has a queue
  - Queues are not centralized
  - Submission computer watches over queue
  - Can have multiple submission computers
  - Submission handled by condor_schedd



$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Advertising computers

- Machine owners describe computers
  - Configuration file extends ClassAd
  - ClassAd has dynamic features
    - Load Average
    - Free Memory
    - …
  - ClassAds are sent to Matchmaker

ClassAd

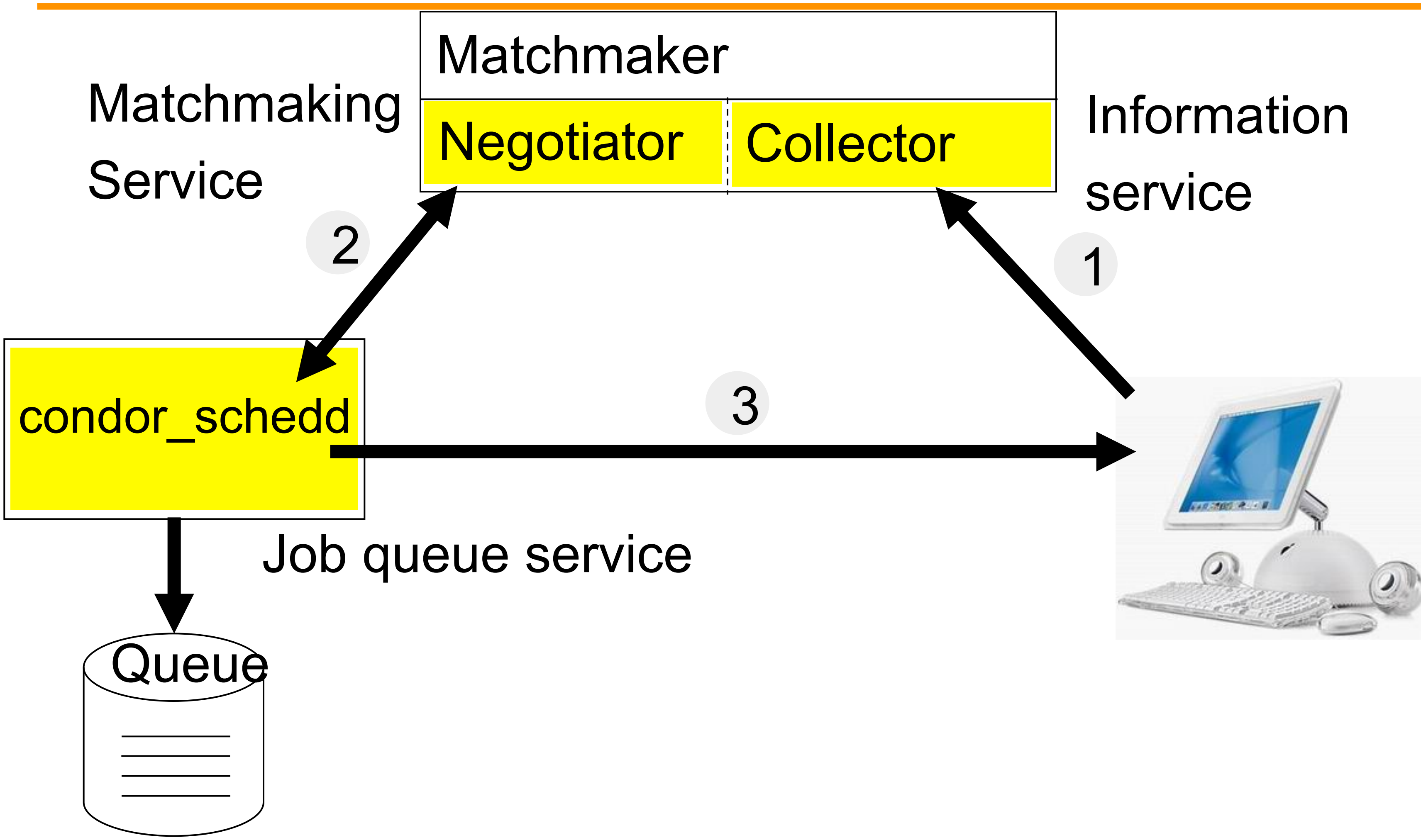
```
Type = "Machine"
Requirements = "…"
```

Matchmaker (Collector)

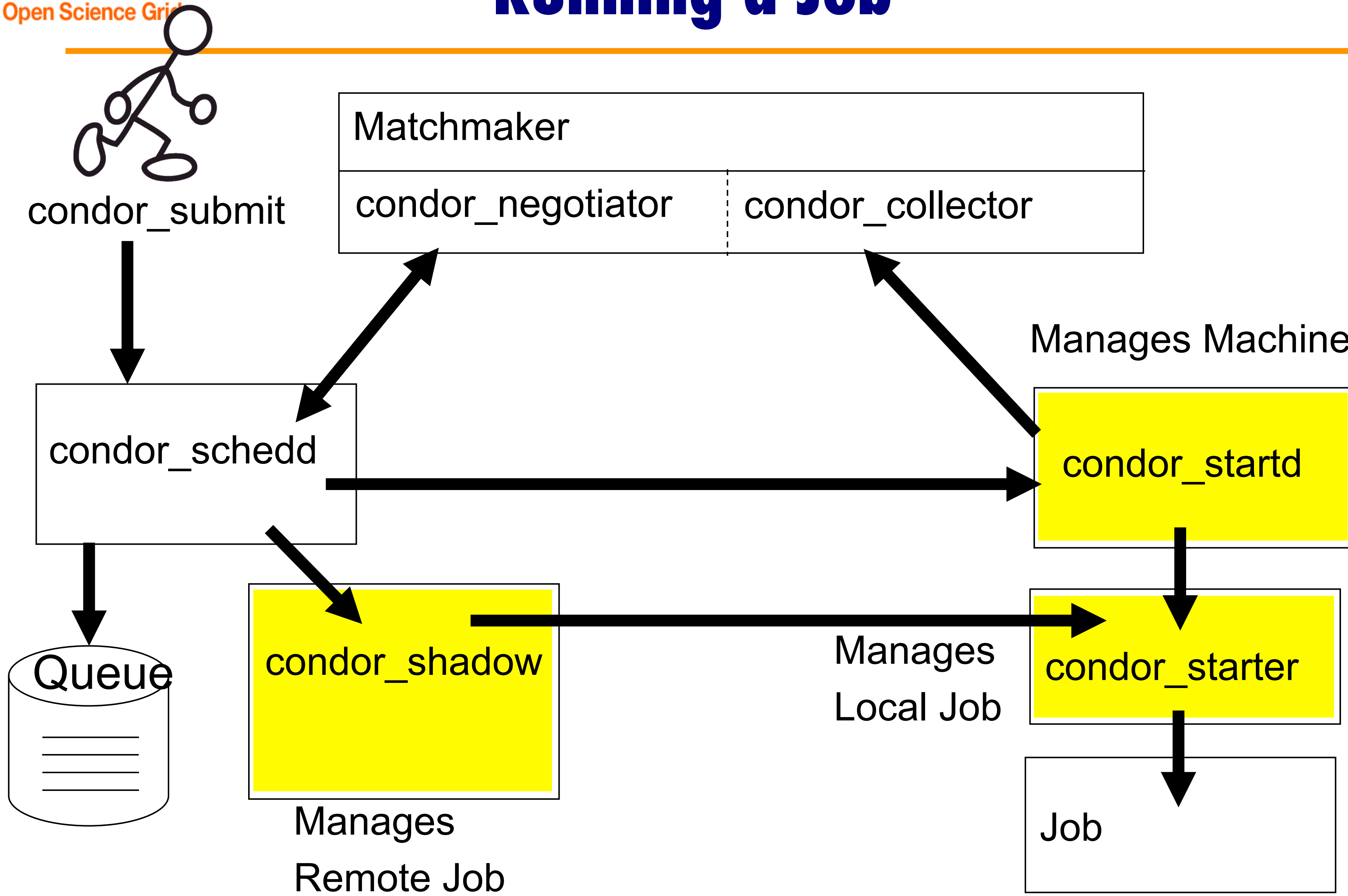
Matchmaking

- Negotiator collects list of computers
- Negotiator contacts each schedd
  - What jobs do you have to run?
- Negotiator compares each job to each computer
  - Evaluate requirements of job & machine
  - Evaluate in context of both ClassAds
  - If both evaluate to true, there is a match
- Upon match, schedd contacts execution computer

Matchmaking diagram



Running a Job



Condor processes

- Master: Takes care of other processes
- Collector: Stores ClassAds
- Negotiator: Performs matchmaking
- Schedd: Manages job queue
- Shadow: Manages job (submit side)
- Startd: Manages computer
- Starter: Manages job (execution side)

If you forget most of these remember two (for other lectures)

- Master: Takes care of other processes
- Collector: Stores ClassAds
- Negotiator: Performs matchmaking

Schedd: Manages job queue

- Shadow: Manages job (submit side)

Startd: Manages computer

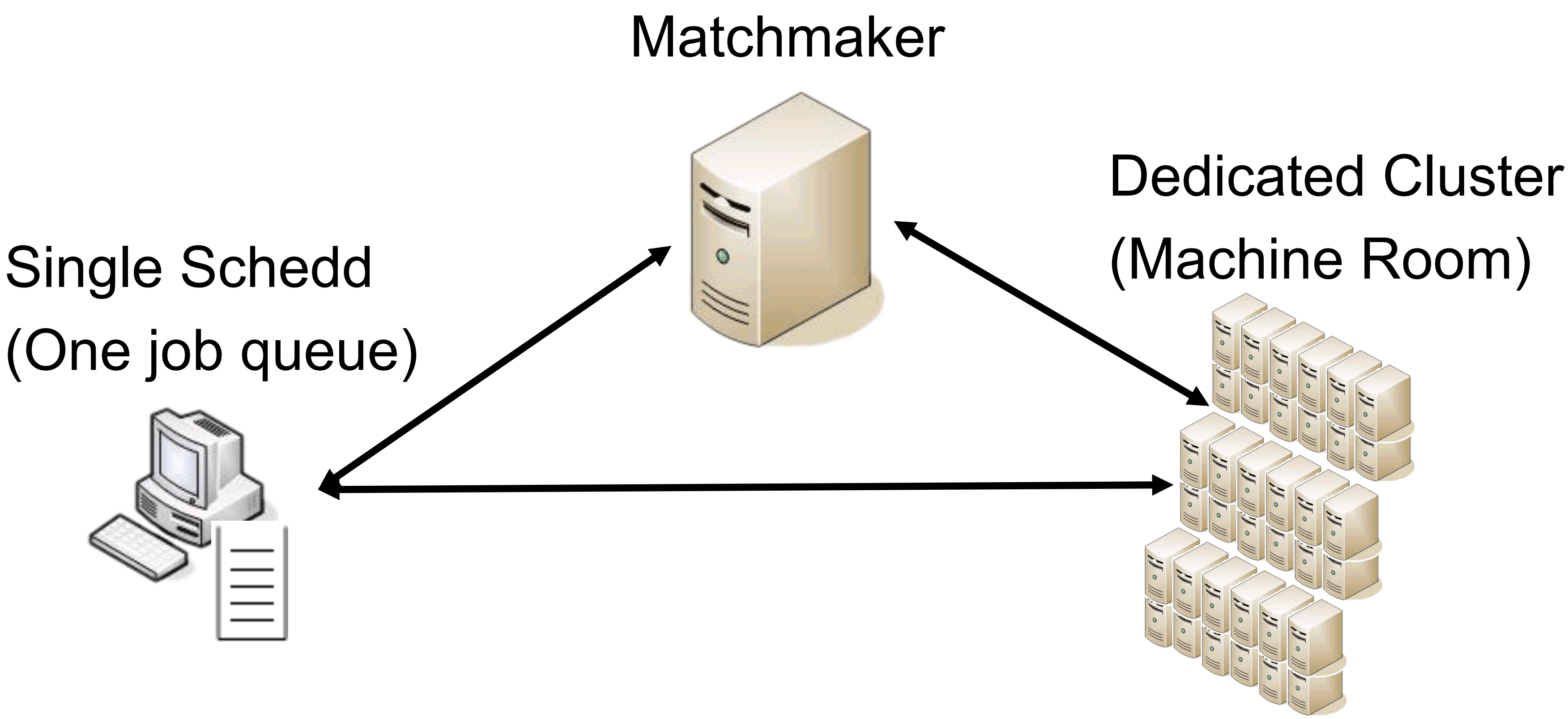
- Starter: Manages job (execution side)

Open Science Grid

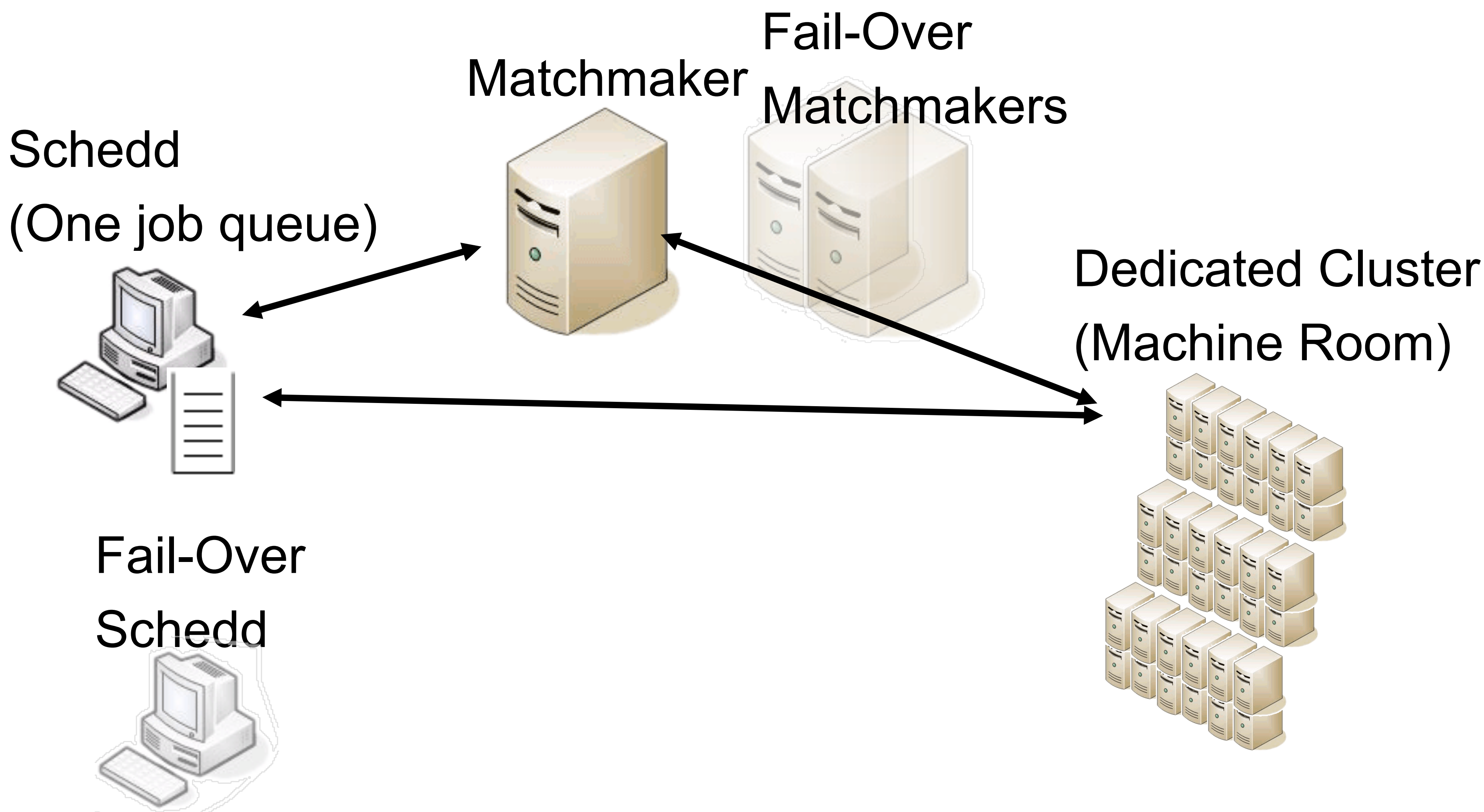
Some notes

- One negotiator/collector per pool
- Can have many schedds (submitters)
- Can have many startds (computers)
- A machine can have any combination of:
  - Just a startd (typical for a dedicated cluster)
  - schedd + startd (perhaps a desktop)
  - Personal Condor: everything

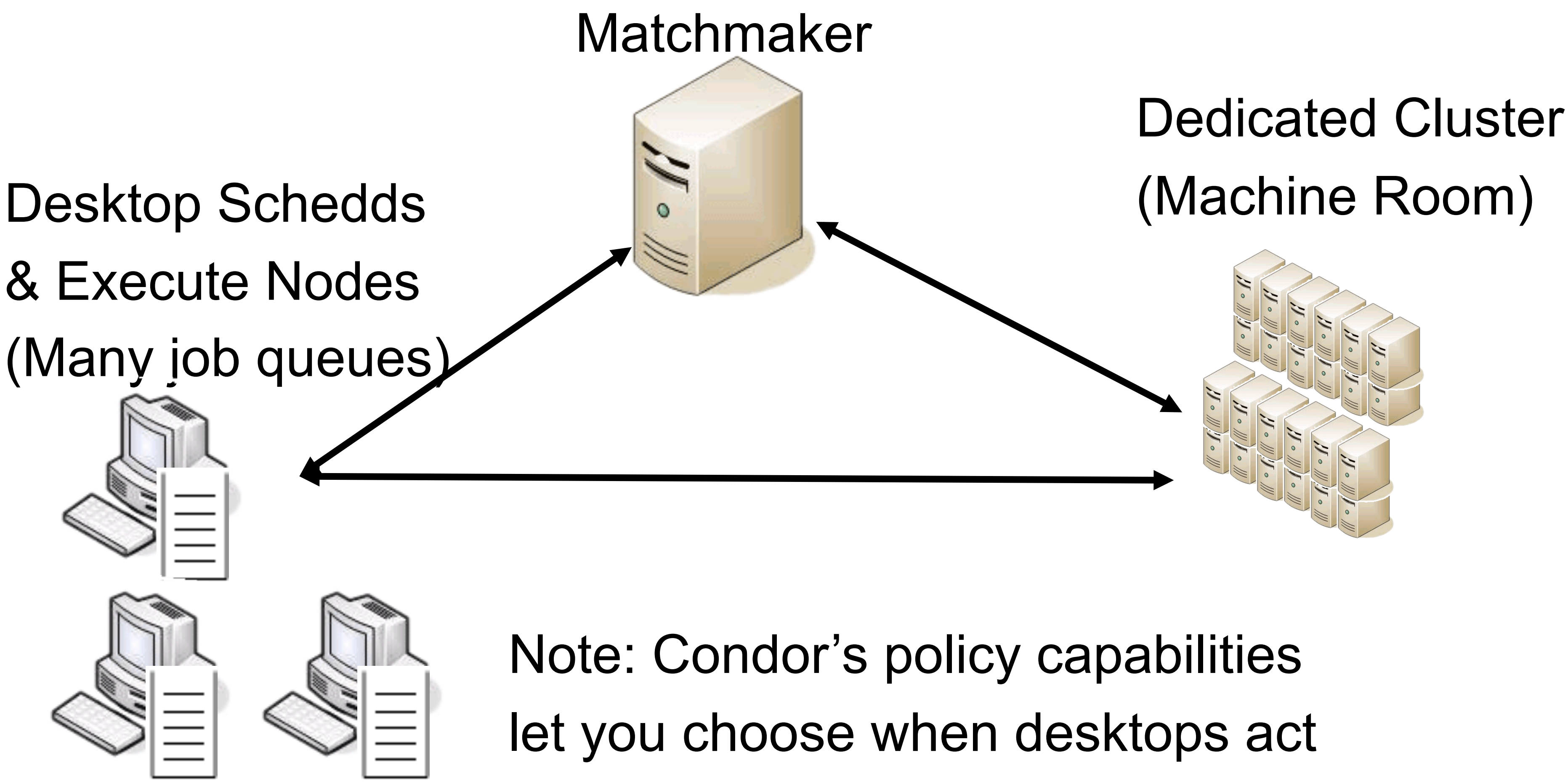
Example Pool 1



Example Pool 1a



Example Pool 2



Note: Condor's policy capabilities let you choose when desktops act as execute nodes.

Our Condor Pools

- One submit computer
  - One schedd/queue for everyone
  - vdt-itb.cs.wisc.edu
- One local set of dedicated Condor execute nodes:
  - About 14 computers, nearly 60 available "batch slots"
- Remote resources at UNL
  - For Tuesday, not today.

Our Condor Pool

```
Name                 OpSys         Arch    State        Activity LoadAv Mem    ActvtyTime

slot1@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+00:00:04
slot2@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+00:00:05
slot3@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+00:29:46
slot4@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+00:29:47
slot5@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.020   2030   0+00:07:45
slot6@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030 13+01:43:11
slot7@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030 13+01:43:12
slot8@miniosg-c01. LINUX       INTEL  Unclaimed Idle   0.000   2030 13+01:43:05
slot1@miniosg-c02. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+05:35:22
slot2@miniosg-c02. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+05:45:29
slot3@miniosg-c02. LINUX       INTEL  Unclaimed Idle   0.000   2030   0+01:35:06
...

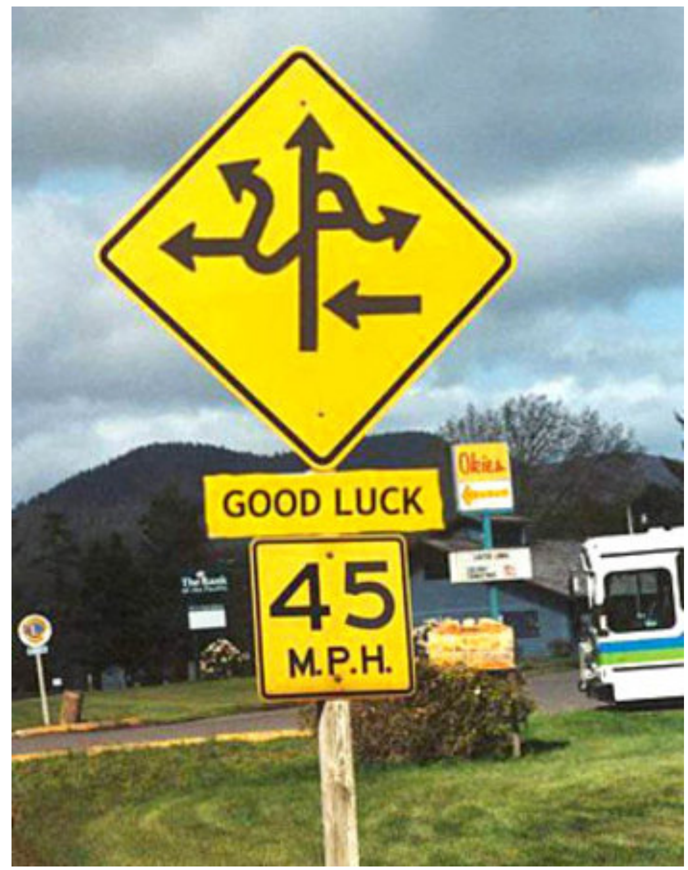
                     Total Owner Claimed Unclaimed Matched Preempting Backfill

   INTEL/LINUX          59       0         59          0        0         0

                Total   59       0         59          0        0         0
```

That was a whirlwind tour!

- Let's get some hands-on experience with Condor, to solidify this knowledge.
- Goal: Check out our installation, run some basic jobs.



Questions?

- Questions? Comments?
  - Feel free to ask me questions later:

    Alain Roy <roy@cs.wisc.edu>
- Upcoming sessions
  - 9:45-10:30
    - Hands-on exercises
  - 10:30 – 10:45
    - Break
  - 10:45 – 12:15
    - More!