Condor User Tutorial
Fermilab
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Outline

- Background and principals
- User Tutorial: The Story of Frieda, the scientist
  - Using Condor to manage jobs
  - Using DAGMan to manage dependencies
  - Condor-G
  - Condor-C

The Condor Project (Established '85)

Distributed High Throughput Computing research performed by a team of ~35 faculty, full time staff and students.

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Distributed High Throughput Computing research performed by a team of ~35 faculty, full time staff and students who:

- face software engineering challenges in a distributed UNIX/Linux/NT environment
- are involved in national and international grid collaborations,
- actively interact with academic and commercial users,
- maintain and support large distributed production environments,
- and educate and train students.

Funding – US Govt. (DoD, DoE, NASA, NSF, NIH), AT&T, IBM, INTEL, Microsoft, UW-Madison, …

A Multifaceted Project

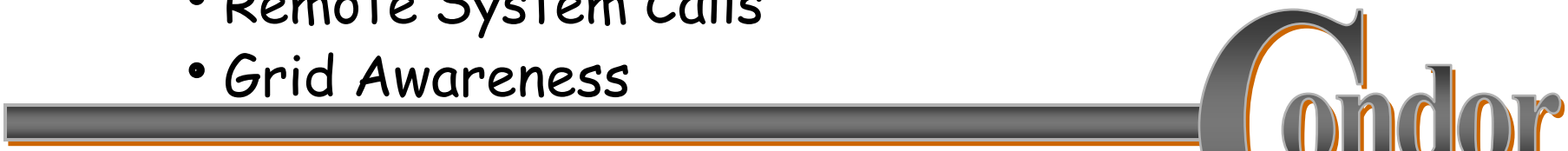
- Harnessing the power of clusters - opportunistic and/or dedicated (Condor)
- Job management services for Grid applications (Condor-G, Stork)
- Fabric management services for Grid resources (Condor, GlideIns, NeST)
- Distributed I/O technology (Parrot, Kangaroo, NeST)
- Job-flow management (DAGMan, Condor, Hawk)
- Distributed monitoring and management (HawkEye)
- Technology for Distributed Systems (ClassAD, MW)
- Packaging and Integration (NMI, VDT)

Some software produced by the Condor Project

- Condor System
- ClassAd Library
- DAGMan
- Fault Tolerant Shell
- Hawkeye
- GCB
- MW
- NeST
- Stork
- Parrot
- Condor-G
- Condor-G
- And others…

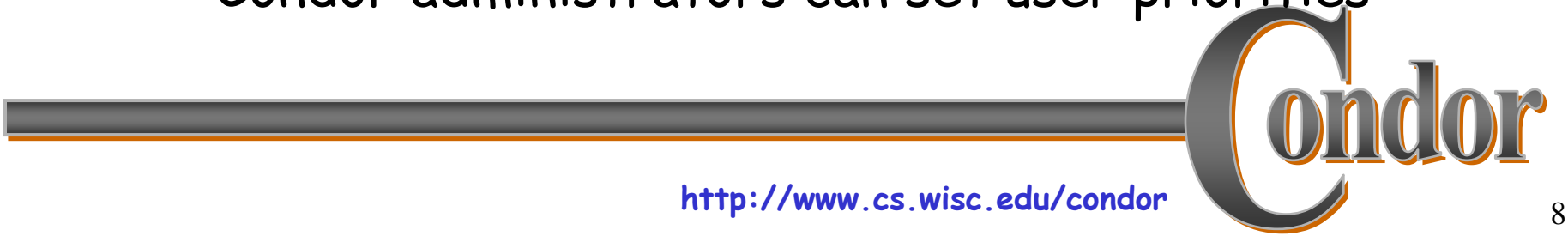
What is Condor?

- Condor converts collections of distributively owned workstations and dedicated clusters into a distributed high-throughput computing (HTC) facility.
- Condor manages both resources (machines) and resource requests (jobs)
- Condor has several unique mechanisms such as :
  - ClassAd Matchmaking
  - Process checkpoint/ restart / migration
  - Remote System Calls
  - Grid Awareness



Condor can manage a large number of jobs

- Managing a large number of jobs
  - You specify the jobs in a file and submit them to Condor, which runs them all and keeps you notified on their progress
  - Mechanisms to help you manage huge numbers of jobs (1000's), all the data, etc.
  - Condor can handle inter-job dependencies (DAGMan)
  - Condor users can set job priorities
  - Condor administrators can set user priorities



Condor can manage Dedicated Resources…

- Dedicated Resources
  - Compute Clusters
- Grid Resources
- Manage
  - Node monitoring, scheduling
  - Job launch, monitor & cleanup

…and Condor can manage non-dedicated resources

- Non-dedicated resources examples:
  - Desktop workstations in offices
  - Workstations in student labs
- Non-dedicated resources are often idle --- ~70% of the time!
- Condor can effectively harness the otherwise wasted compute cycles from non-dedicated resources

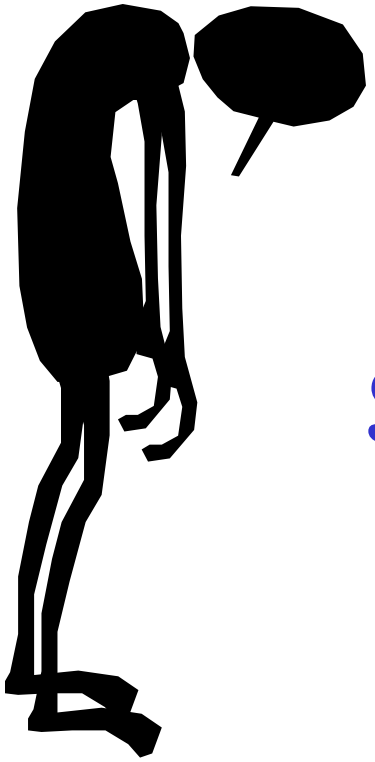
Meet Frieda.

She is a scientist. But she has a big problem.

Frieda's Application …

Simulate the behavior of **F**(*x,y,z*) for 20 values of *x*, 10 values of *y* and 3 values of *z* (20*10*3 = 600 combinations)

- **F** takes on the average 3 hours to compute on a "typical" workstation (total = 1800 hours)
- **F** requires a "moderate" (128MB) amount of memory
- **F** performs "moderate" I/O - (*x,y,z*) is 5 MB and **F**(*x,y,z*) is 50 MB



I have 600 simulations to run.

Where can I get help?

Install a Personal Condor!

Installing Condor

- Download Condor for your operating system
- Available as a free download from

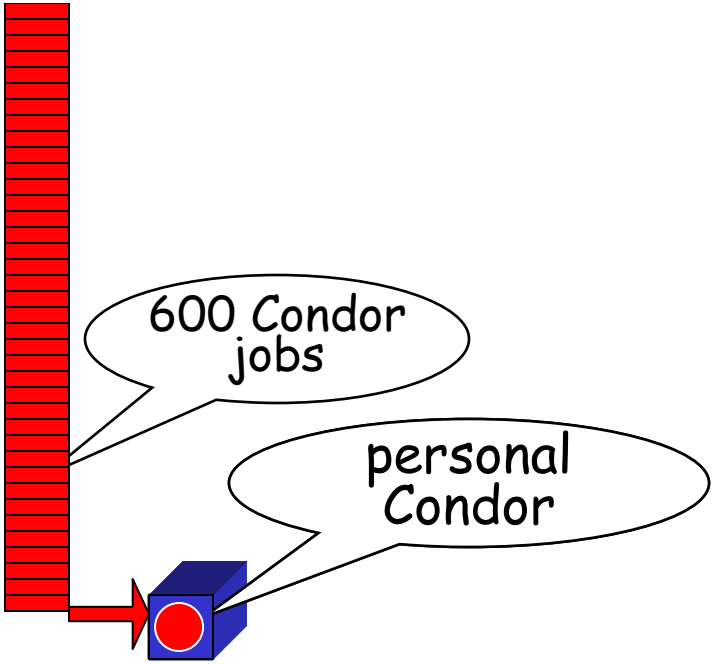
  http://www.cs.wisc.edu/condor
- Stable –vs- Developer Releases
  - Naming scheme similar to the Linux Kernel…
- Available for most Unix platforms and Windows (2000 & XP)

Or install from distributions

- Install from NMI:
  - http://www.nsf-middleware.org
  - Condor-G only
- Install from VDT:
  - http://www.cs.wisc.edu/vdt
- Install from ROCKS:
  - http://www.rocksclusters.org/Rocks/
- Condor can be installed on your own workstation, no root access required, no system administrator intervention needed

So Frieda Installs Personal Condor on her machine…

- What do we mean by a "Personal" Condor?
  - Condor on your own workstation, no root access required, no system administrator intervention needed
- After installation, Frieda submits her jobs to her Personal Condor…


600 Condor jobs
personal Condor

Personal Condor?!

What's the benefit of a Condor "Pool" with just one user and one machine?

Your Personal Condor will ...

- ... keep an eye on your jobs and will keep you posted on their progress
- ... implement your policy on the execution order of the jobs
- ... keep a log of your job activities
- ... add fault tolerance to your jobs
- ... implement your policy on when the jobs can run on your workstation
- ... make a nice demo Condor installation for a hands-on tutorial

Getting Started: Submitting Jobs to Condor

- Choosing a "Universe" for your job
  - Just use VANILLA for now
- Make your job "batch-ready"
- Creating a *submit description* file
- Run *condor_submit* on your submit description file

Making your job ready

- Must be able to run in the background: no interactive input, windows, GUI, etc.
- Can still use `STDIN`, `STDOUT`, and `STDERR` (the keyboard and the screen), but files are used for these instead of the actual devices
- Organize data files

Creating a Submit Description File

- A plain ASCII text file
- Tells Condor about your job:
  - Which executable, universe, input, output and error files to use, command-line arguments, environment variables, any special requirements or preferences (more on this later)
- Can describe many jobs at once (a "cluster") each with different input, arguments, output, etc.

Simple Submit Description File

```
# Simple condor_submit input file
# (Lines beginning with # are comments)
# NOTE: the words on the left side are not
#       case sensitive, but filenames are!
Universe   = vanilla
Executable = my_job
Queue
```

Running condor_submit

- You give *condor_submit* the name of the submit file you have created
- *condor_submit* parses the file, checks for errors, and creates a "ClassAd" that describes your job(s)
- Sends your job's ClassAd(s) and executable to the condor_schedd, which stores the job in its queue
  - Atomic operation, two-phase commit
- View the queue with *condor_q*

Running condor_submit

```
% condor_submit my_job.submit-file
Submitting job(s).
1 job(s) submitted to cluster 1.

% condor_q

-- Submitter: perdita.cs.wisc.edu : <128.105.165.34:1027> :
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD
  1.0    frieda           6/16 06:52    0+00:00:00 I  0    0.0  my_job

1 jobs; 1 idle, 0 running, 0 held

%
```

Another Submit Description File

```
# Example condor_submit input file
# (Lines beginning with # are comments)
# NOTE: the words on the left side are not
#       case sensitive, but filenames are!
Universe   = vanilla
Executable = /home/wright/condor/my_job.condor
Input      = my_job.stdin
Output     = my_job.stdout
Error      = my_job.stderr
Arguments  = -arg1 -arg2
InitialDir = /home/wright/condor/run_1
Queue
```

"Clusters" and "Processes"

- If your submit file describes multiple jobs, we call this a "cluster"
- Each job within a cluster is called a "process" or "proc"
- If you only specify one job, you still get a cluster, but it has only one process
- A Condor "Job ID" is the cluster number, a period, and the process number ("23.5")
- Process numbers always start at 0

Example Submit Description File for a Cluster

```
# Example condor_submit input file that defines
# a cluster of two jobs with different iwd
Universe   = vanilla
Executable = my_job
Arguments  = -arg1 -arg2

InitialDir = run_0
Queue      ← Becomes job 2.0

InitialDir = run_1
Queue      ← Becomes job 2.1
```

```
% condor_submit my_job.submit-file
Submitting job(s).
2 job(s) submitted to cluster 2.

% condor_q

-- Submitter: perdita.cs.wisc.edu : <128.105.165.34:1027> :
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD
  1.0    frieda           6/16 06:52  0+00:02:11 R  0   0.0  my_job
  2.0    frieda           6/16 06:56  0+00:00:00 I  0   0.0  my_job
  2.1    frieda           6/16 06:56  0+00:00:00 I  0   0.0  my_job

3 jobs; 2 idle, 1 running, 0 held

%
```

Submit Description File for a *BIG* Cluster of Jobs

- The initial directory for each job is specified with the $(Process) macro, and instead of submitting a single job, we use "Queue 600" to submit 600 jobs at once
- $(Process) will be expanded to the process number for each job in the cluster (from 0 up to 599 in this case), so we'll have "run_0", "run_1", … "run_599" directories
- All the input/output files will be in different directories!

Submit Description File for a *BIG* Cluster of Jobs

```
# Example condor_submit input file that defines
# a cluster of 600 jobs with different iwd
Universe   = vanilla
Executable = my_job
Arguments  = -arg1 -arg2
InitialDir = run_$(Process)
Queue 600
```

Using condor_rm

- If you want to remove a job from the Condor queue, you use *condor_rm*
- You can only remove jobs that you own (you can't run *condor_rm* on someone else's jobs unless you are root)
- You can give specific job ID's (cluster or cluster.proc), or you can remove all of your jobs with the "*-a*" option.

Temporarily halt a Job

- Use *condor_hold* to place a job on hold
  - Kills job if currently running
  - Will not attempt to restart job until released
- Use *condor_release* to remove a hold and permit job to be scheduled again

Using condor_history

- Once your job completes, it will no longer show up in *condor_q*
- You can use *condor_history* to view information about a completed job
- The status field ("ST") will have either a "C" for "completed", or an "X" if the job was removed with *condor_rm*

Getting Email from Condor

- By default, Condor will send you email when your jobs completes
  - With lots of information about the run
- If you don't want this email, put this in your submit file:

```
notification = never
```

- If you want email every time something happens to your job (preempt, exit, etc), use this:

```
notification = always
```

Getting Email from Condor (cont'd)

- If you only want email in case of errors, use this:

```
notification = error
```

- By default, the email is sent to your account on the host you submitted from. If you want the email to go to a different address, use this:

```
notify_user = email@address.here
```

A Job's life story: The "User Log" file

- A UserLog should be specified in your submit file:

  Log = filename

- You get a log entry for everything that happens to your job:
  - When it was submitted, when it starts executing, preempted, restarted, completes, if there are any problems, etc.
- Very useful! Highly recommended!

Sample Condor User Log

```
000 (8135.000.000) 05/25 19:10:03 Job submitted from host: <128.105.146.14:1816>
...
001 (8135.000.000) 05/25 19:12:17 Job executing on host: <128.105.165.131:1026>
...
005 (8135.000.000) 05/25 19:13:06 Job terminated.
        (1) Normal termination (return value 0)
                Usr 0 00:00:37, Sys 0 00:00:00  -  Run Remote Usage
                Usr 0 00:00:00, Sys 0 00:00:05  -  Run Local Usage
                Usr 0 00:00:37, Sys 0 00:00:00  -  Total Remote Usage
                Usr 0 00:00:00, Sys 0 00:00:05  -  Total Local Usage
        9624  -  Run Bytes Sent By Job
        7146159  -  Run Bytes Received By Job
        9624  -  Total Bytes Sent By Job
        7146159  -  Total Bytes Received By Job
...
```

Job Priorities w/ condor_prio

- *condor_prio* allows you to specify the order in which your jobs are started
- Higher the prio #, the earlier the job will start

```
% condor_q
-- Submitter: perdita.cs.wisc.edu : <128.105.165.34:1027> :
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD
  1.0    frieda           6/16 06:52  0+00:02:11 R  0   0.0  my_job
% condor_prio +5 1.0
% condor_q
-- Submitter: perdita.cs.wisc.edu : <128.105.165.34:1027> :
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD
  1.0    frieda           6/16 06:52  0+00:02:13 R  5   0.0  my_job
```

The Scheduler Universe

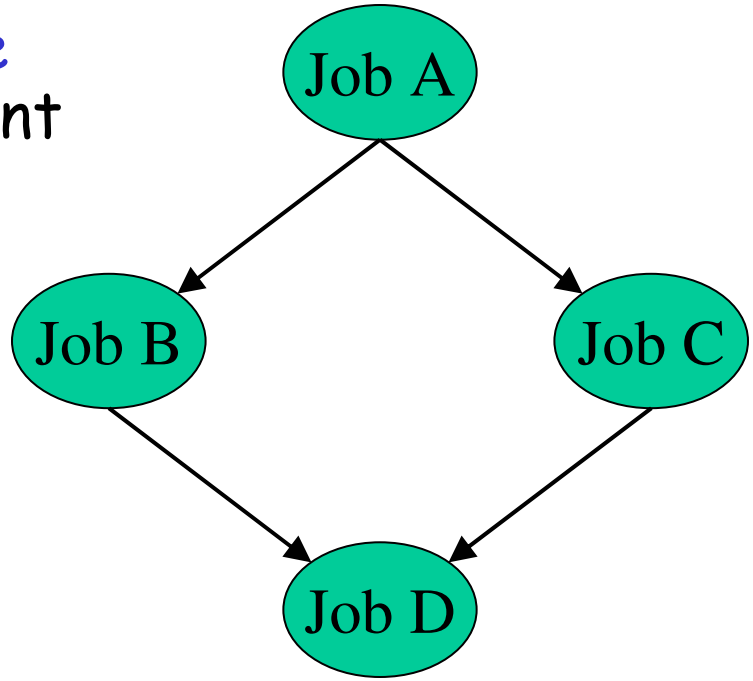
- In addition to VANILLA, another job universe is the *Scheduler Universe*.
- Scheduler Universe jobs run on the submitting machine and can serve as a meta-scheduler.
- DAGMan meta-scheduler included

DAGMan

- **Directed Acyclic Graph Manager**
- DAGMan allows you to specify the *dependencies* between your Condor jobs, so it can *manage* them automatically for you.
- (e.g., "Don't run job "B" until job "A" has completed successfully.")

What is a DAG?

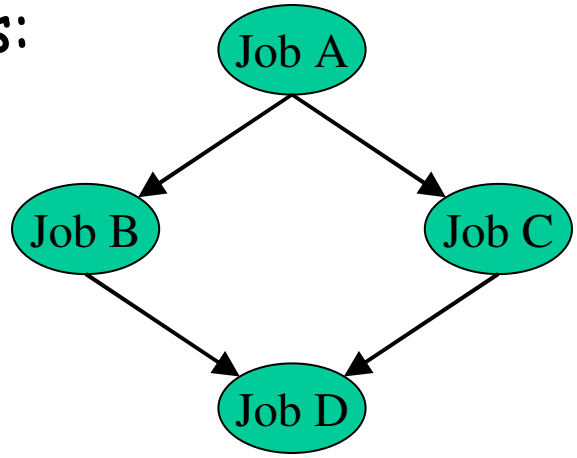
- A DAG is the data structure used by DAGMan to represent these dependencies.
- Each job is a "node" in the DAG.
- Each node can have any number of "parent" or "children" nodes – as long as there are no loops!



Defining a DAG

- A DAG is defined by a *.dag file*, listing each of its nodes and their dependencies:

```
# diamond.dag
Job A a.sub
Job B b.sub
Job C c.sub
Job D d.sub
Parent A Child B C
Parent B C Child D
```



- each node will run the Condor job specified by its accompanying Condor submit file

Submitting a DAG

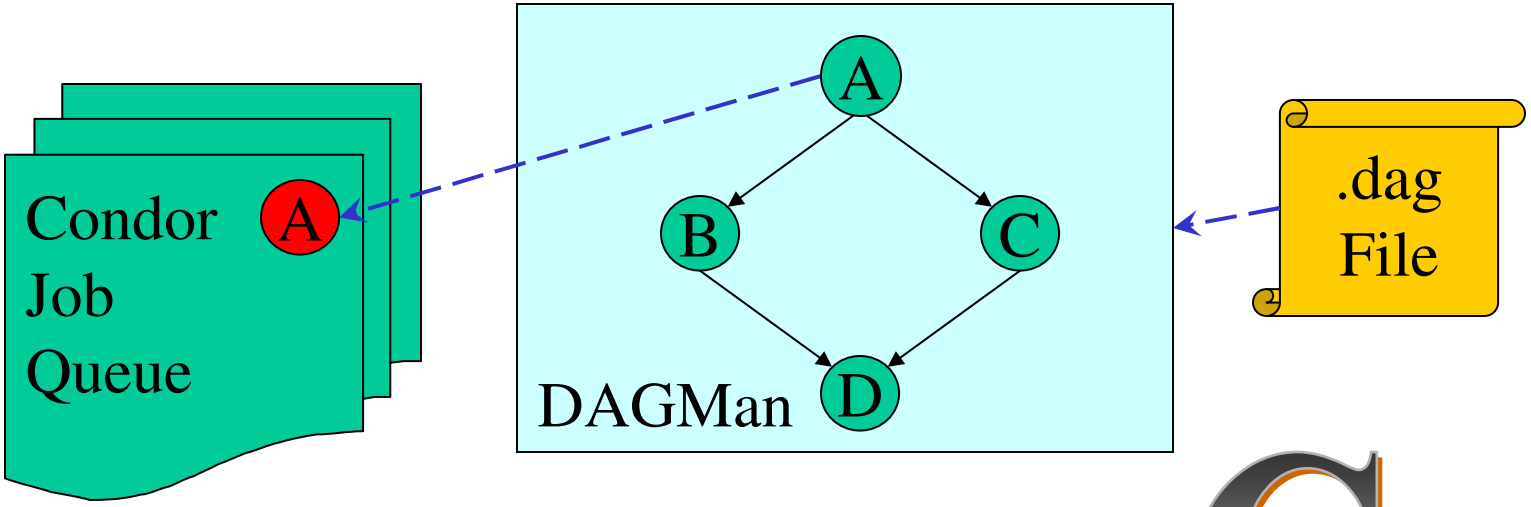
- To start your DAG, just run ***condor_submit_dag*** with your .dag file, and Condor will start a personal DAGMan daemon which to begin running your jobs:

```
% condor_submit_dag diamond.dag
```

- condor_submit_dag submits a Scheduler Universe Job with DAGMan as the executable.
- Thus the DAGMan daemon itself runs as a Condor job, so you don't have to baby-sit it.

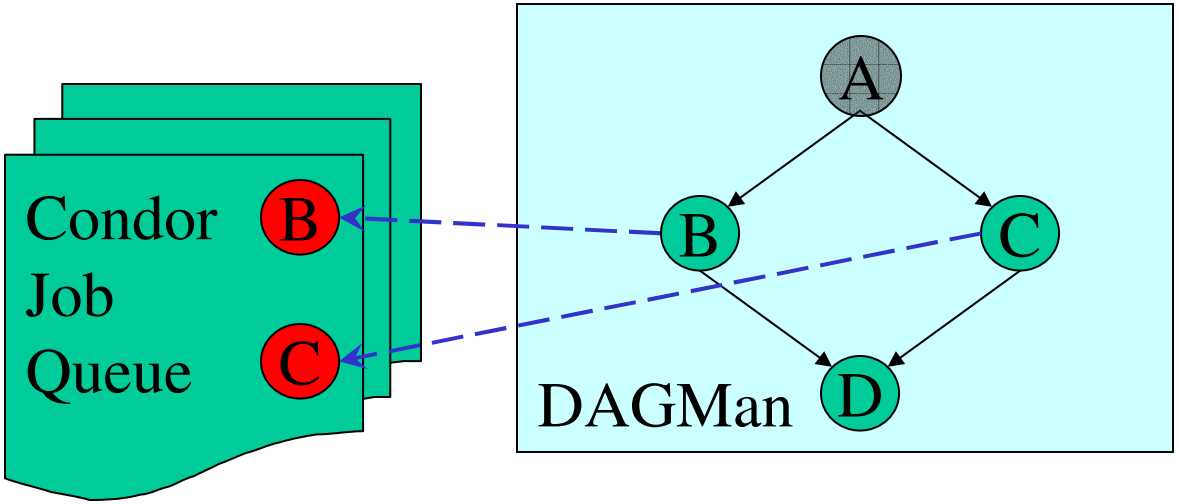
Running a DAG

- DAGMan acts as a "meta-scheduler", managing the submission of your jobs to Condor based on the DAG dependencies.



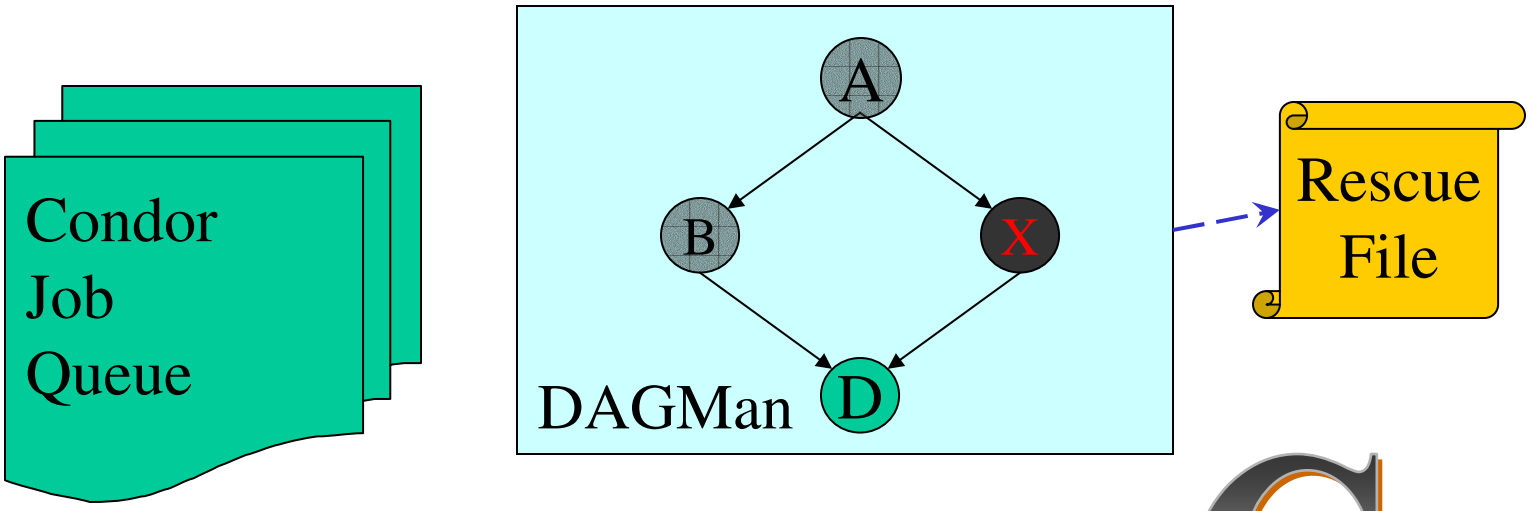
Running a DAG (cont'd)

- DAGMan holds & submits jobs to the Condor queue at the appropriate times.



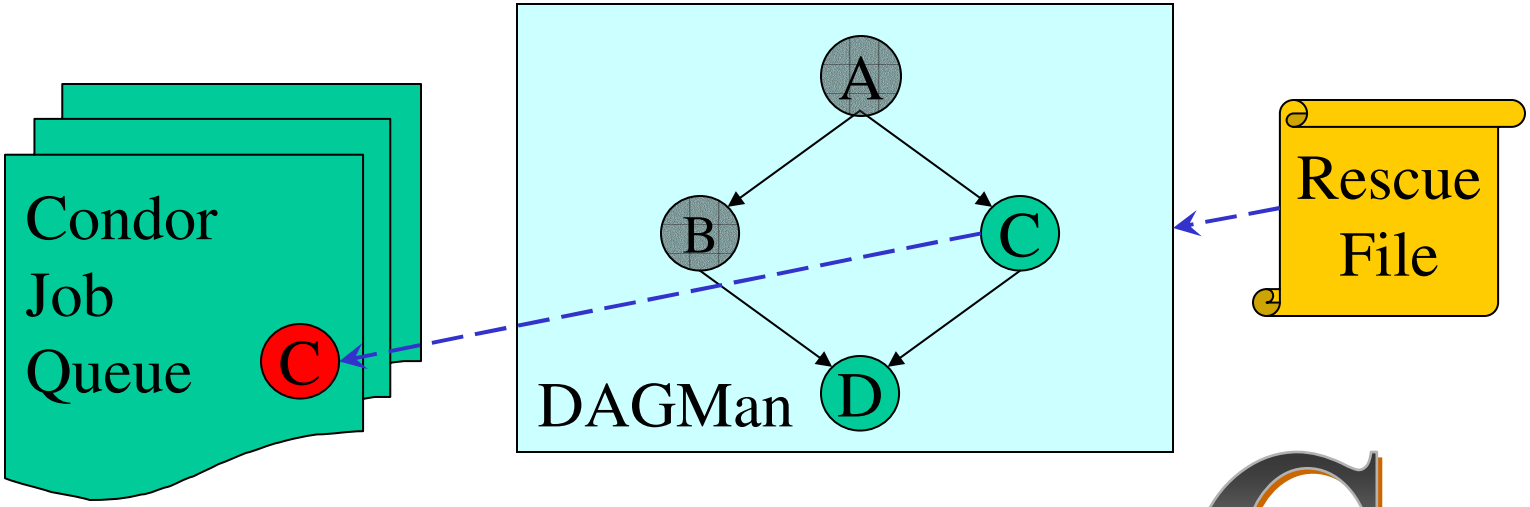
Running a DAG (cont'd)

- In case of a job failure, DAGMan continues until it can no longer make progress, and then creates a *"rescue" file* with the current state of the DAG.



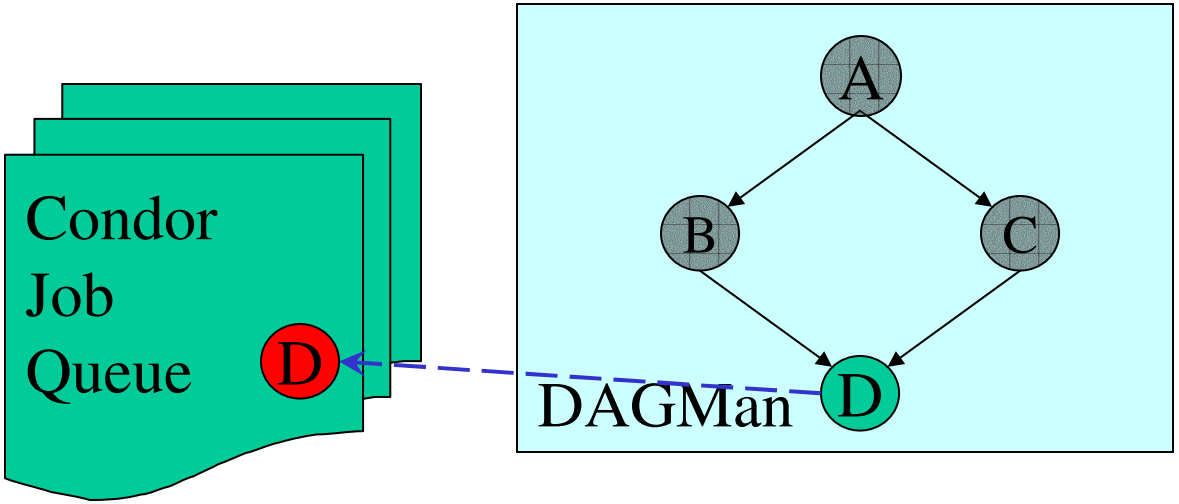
Recovering a DAG

- Once the failed job is ready to be re-run, the rescue file can be used to restore the prior state of the DAG.



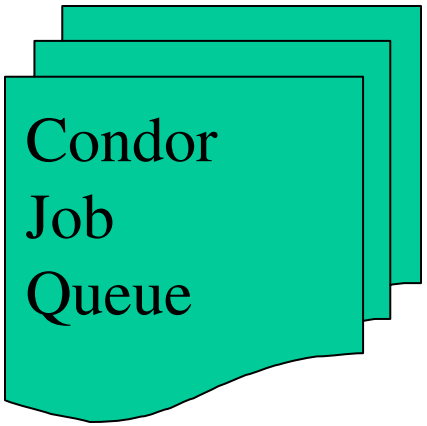
Recovering a DAG (cont'd)

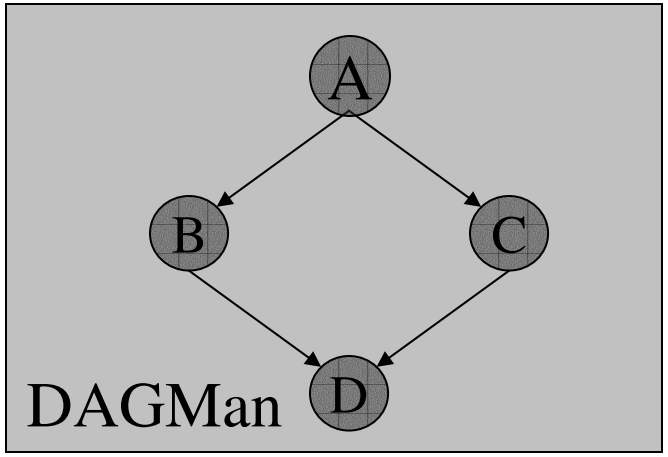
- Once that job completes, DAGMan will continue the DAG as if the failure never happened.



Finishing a DAG

- Once the DAG is complete, the DAGMan job itself is finished, and exits.

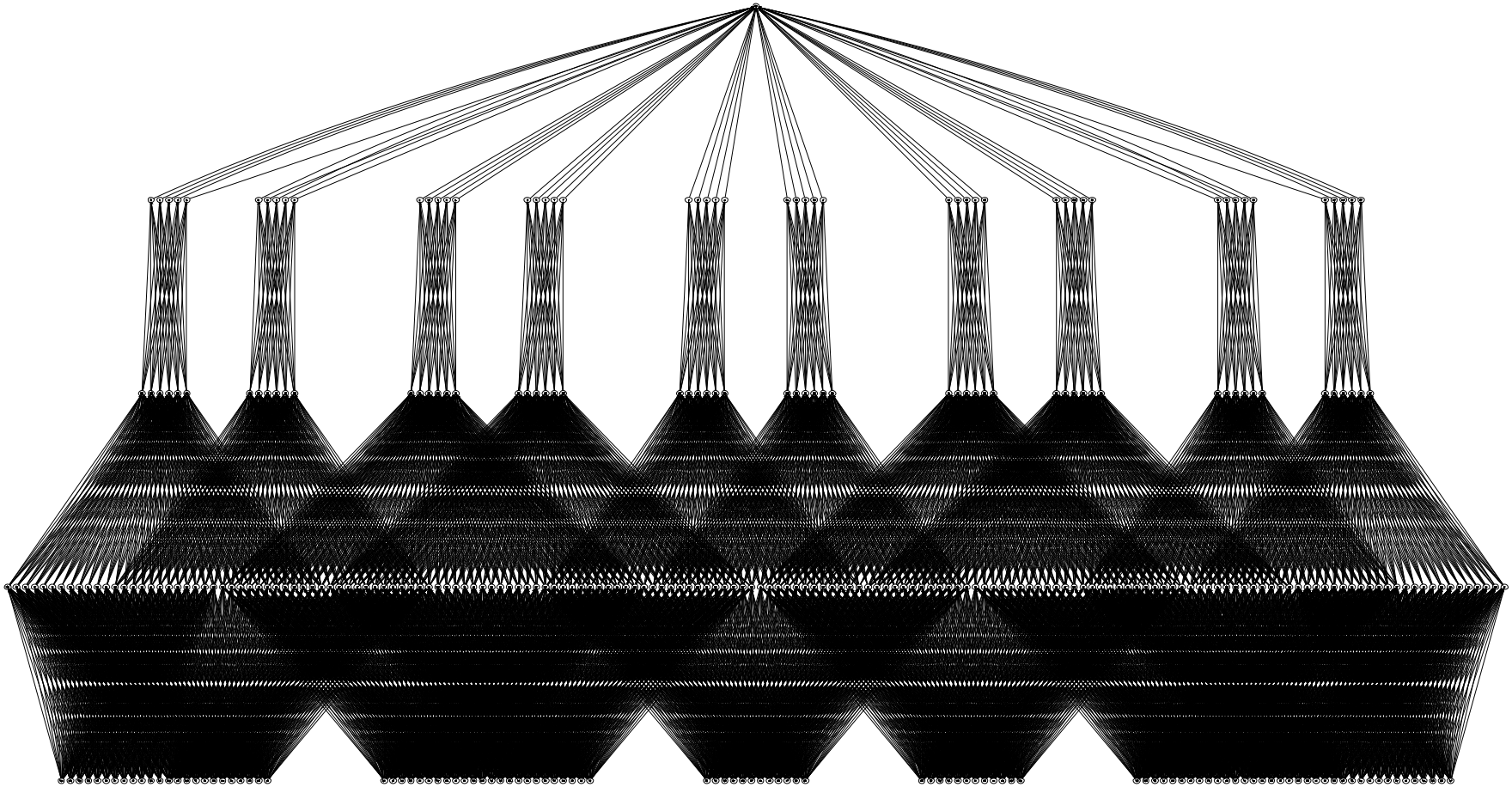




Additional DAGMan Features

- Provides other handy features for job management…
  - nodes can have PRE & POST scripts
  - failed nodes can be automatically re-tried a configurable number of times
  - job submission can be "throttled"

And Even Bigger: 744 Files, 387 Nodes



We've seen how Condor will

… keep an eye on your jobs and will keep you posted on their progress

… implement your policy on the execution order of the jobs

… keep a log of your job activities

… add fault tolerance to your jobs ?

What if each job needed to run for 20 days?

What if I wanted to interrupt a job with a higher priority job?

Condor's Standard Universe to the rescue!

- Condor can support various combinations of features/environments in different "Universes"
- Different Universes provide different functionality for your job:
  - Vanilla – Run any Serial Job
  - Scheduler – Plug in a meta-scheduler
  - Standard – Support for transparent process checkpoint and restart

Process Checkpointing

- Condor's Process Checkpointing mechanism saves all the state of a process into a checkpoint file
  - Memory, CPU, I/O, etc.
- The process can then be restarted *from right where it left off*
- Typically no changes to your job's source code needed – however, your job must be *relinked* with Condor's Standard Universe support library

Relinking Your Job for submission to the Standard Universe

To do this, just place "*condor_compile*" in front of the command you normally use to link your job:

```
condor_compile gcc -o myjob myjob.c
```

OR

```
condor_compile f77 -o myjob filea.f fileb.f
```

OR

```
condor_compile make -f MyMakefile
```

Limitations in the Standard Universe

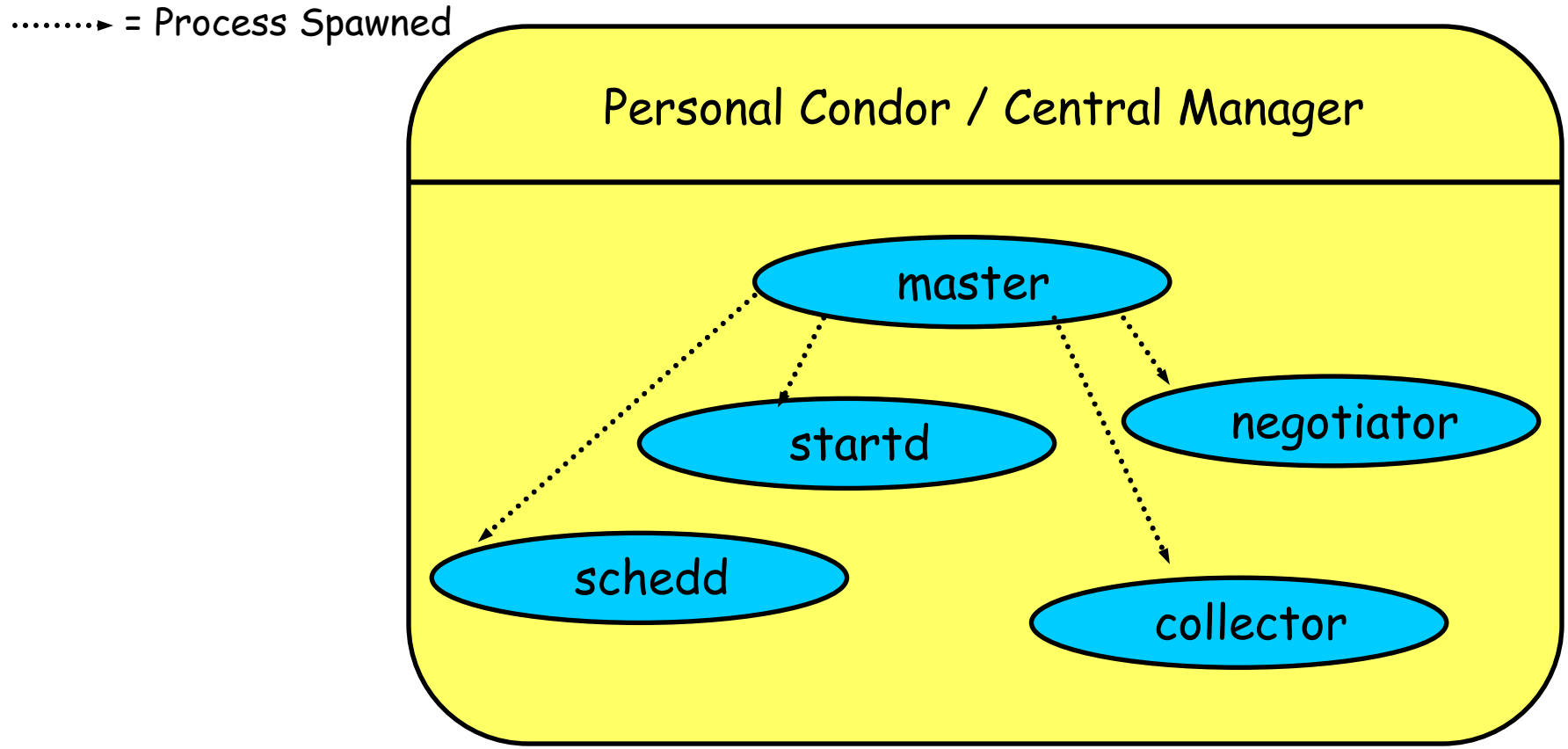
- Condor's checkpointing is not at the kernel level. Thus in the Standard Universe the job may not
  - fork()
  - Use kernel threads
  - Use some forms of IPC, such as pipes and shared memory
- Many typical scientific jobs are OK

When will Condor checkpoint your job?

- Periodically, if desired
  - For fault tolerance
- To free the machine to do a higher priority task (higher priority job, or a job from a user with higher priority)
  - Preemptive-resume scheduling
- When you explicitly run *condor_checkpoint*, *condor_vacate*, *condor_off* or *condor_restart* command

What Condor Daemons are running on my machine, and what do they do?

Condor Daemon Layout

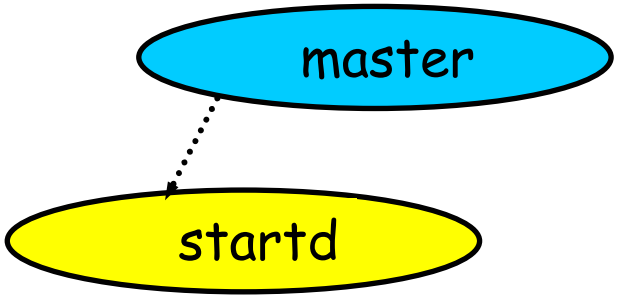


condor_master

- Starts up all other Condor daemons
- If there are any problems and a daemon exits, it restarts the daemon and sends email to the administrator
- Checks the time stamps on the binaries of the other Condor daemons, and if new binaries appear, the master will gracefully shutdown the currently running version and start the new version

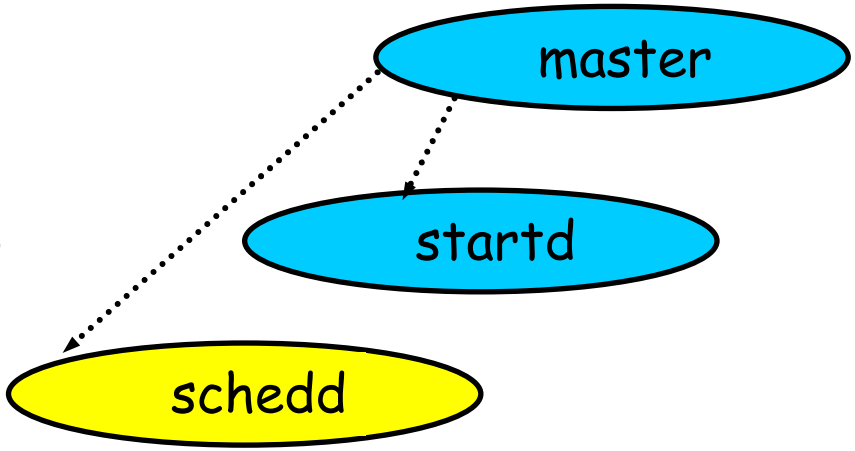
condor_startd

- Represents a machine to the Condor system
- Responsible for starting, suspending, and stopping jobs
- Enforces the wishes of the machine owner (the owner's "policy"... more on this soon)

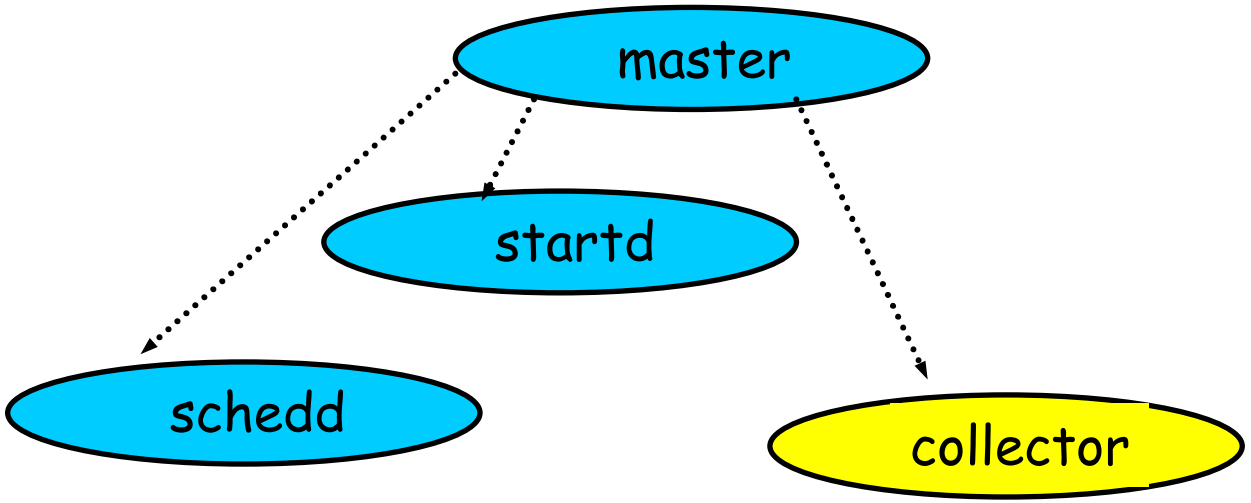


condor_schedd

- Represents users to the Condor system
- Maintains the persistent queue of jobs
- Responsible for contacting available machines and sending them jobs
- Services user commands which manipulate the job queue:
  - *condor_submit, condor_rm, condor_q, condor_hold, condor_release, condor_prio, …*

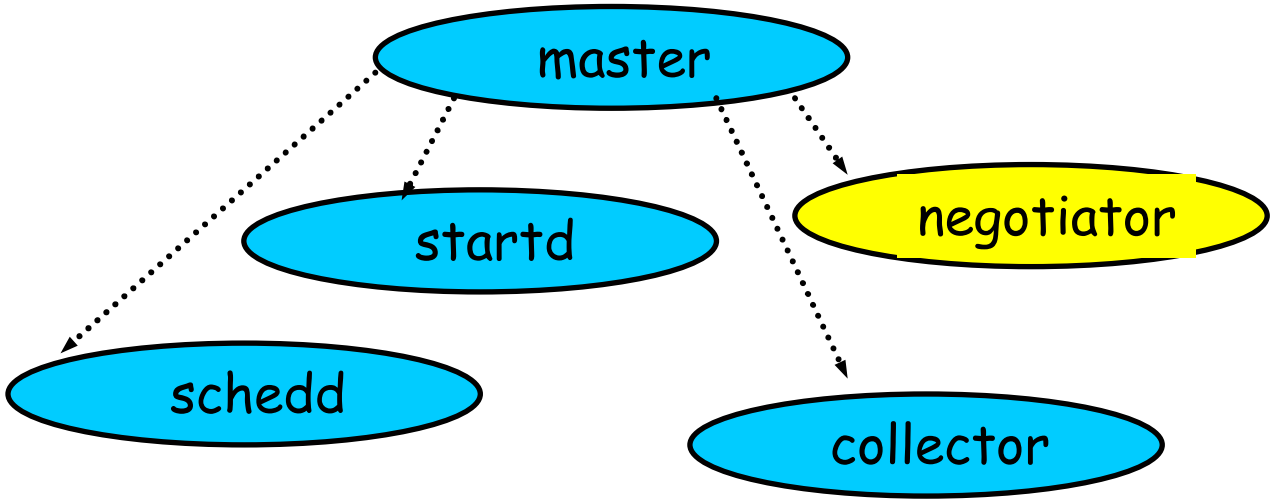


condor_collector



- Collects information from all other Condor daemons in the pool
  - "Directory Service" / Database for a Condor pool
- Each daemon sends a periodic update called a "ClassAd" to the collector
- Services queries for information:
  - Queries from other Condor daemons
  - Queries from users (*condor_status*)

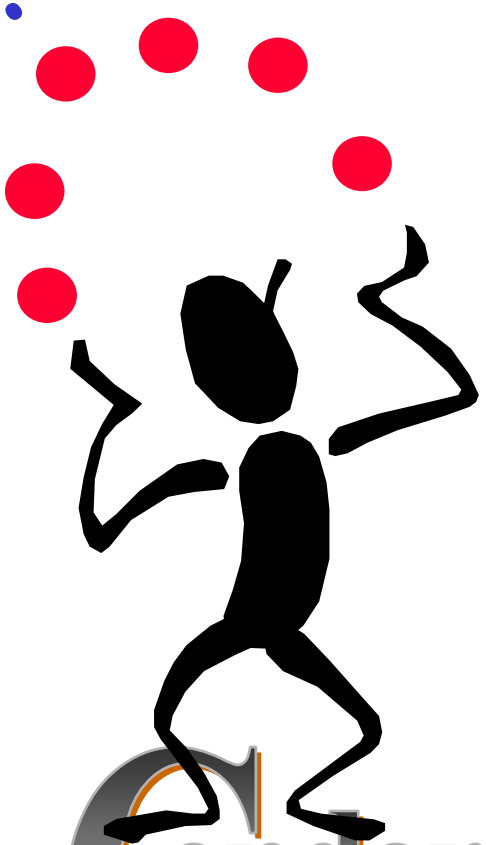
condor_negotiator

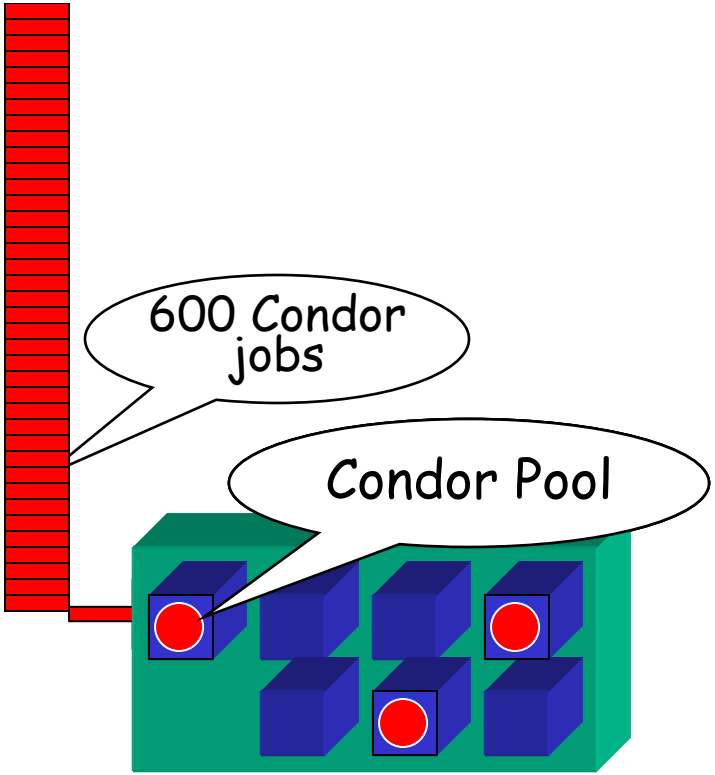


- Performs "matchmaking" in Condor
- Gets information from the collector about all available machines and all idle jobs
- Tries to match jobs with machines that will serve them
- Both the job and the machine must satisfy each other's requirements

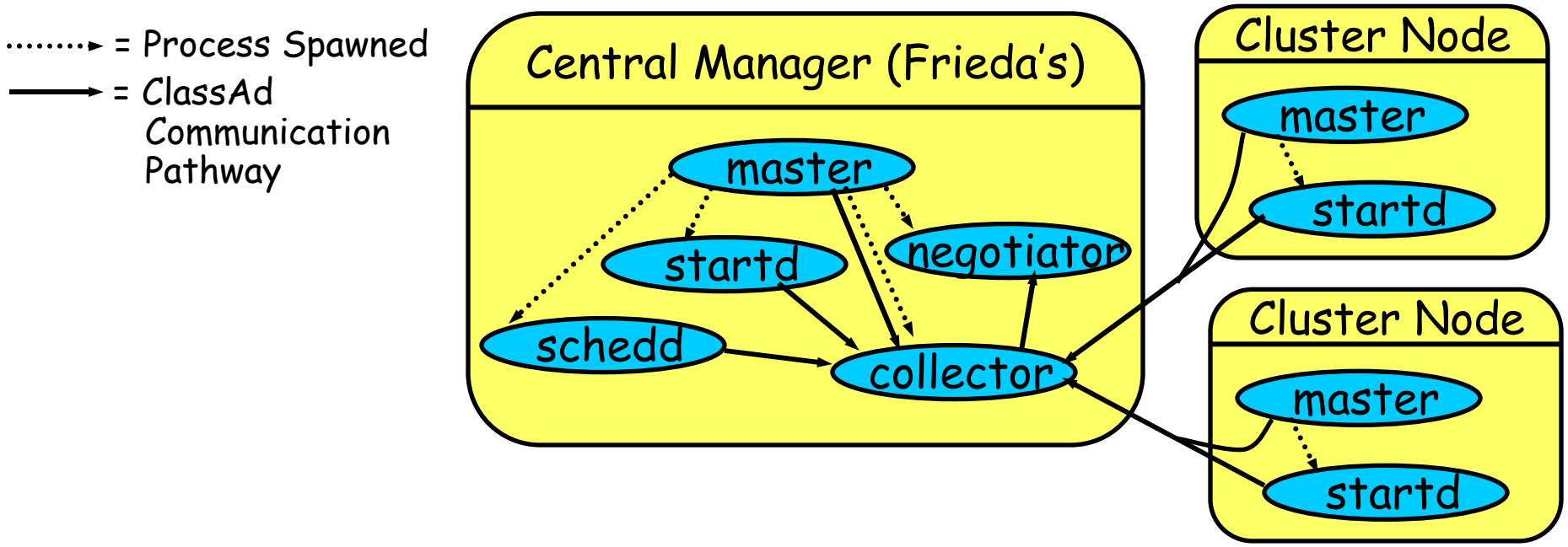
Happy Day! Frieda's organization purchased a Beowulf Cluster!

- Frieda installs Condor on all the dedicated Cluster nodes, and configures them with her machine as the central manager…
- Now her Condor Pool can run multiple jobs at once




600 Condor jobs
Condor Pool

Layout of the Condor Pool



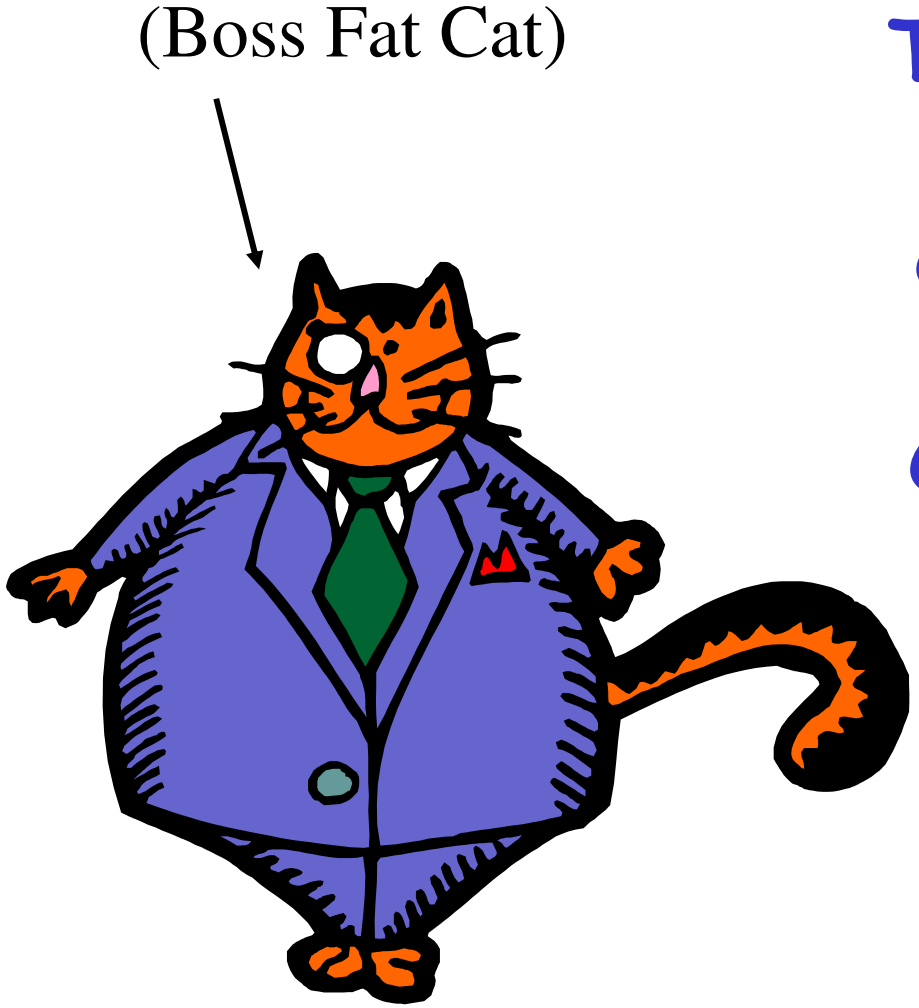
condor_status

```
% condor_status

Name          OpSys       Arch   State      Activity   LoadAv Mem   ActvtyTime

haha.cs.wisc. IRIX65      SGI    Unclaimed  Idle       0.198   192  0+00:00:04
antipholus.cs LINUX       INTEL  Unclaimed  Idle       0.020   511  0+02:28:42
coral.cs.wisc LINUX       INTEL  Claimed    Busy       0.990   511  0+01:27:21
doc.cs.wisc.e LINUX       INTEL  Unclaimed  Idle       0.260   511  0+00:20:04
dsonokwa.cs.w LINUX       INTEL  Claimed    Busy       0.810   511  0+00:01:45
ferdinand.cs. LINUX       INTEL  Claimed    Suspended  1.130   511  0+00:00:55
vm1@pinguino. LINUX       INTEL  Unclaimed  Idle       0.000   255  0+01:03:28
vm2@pinguino. LINUX       INTEL  Unclaimed  Idle       0.190   255  0+01:03:29
```

Frieda tries out 'static' parallel jobs: MPI Universe

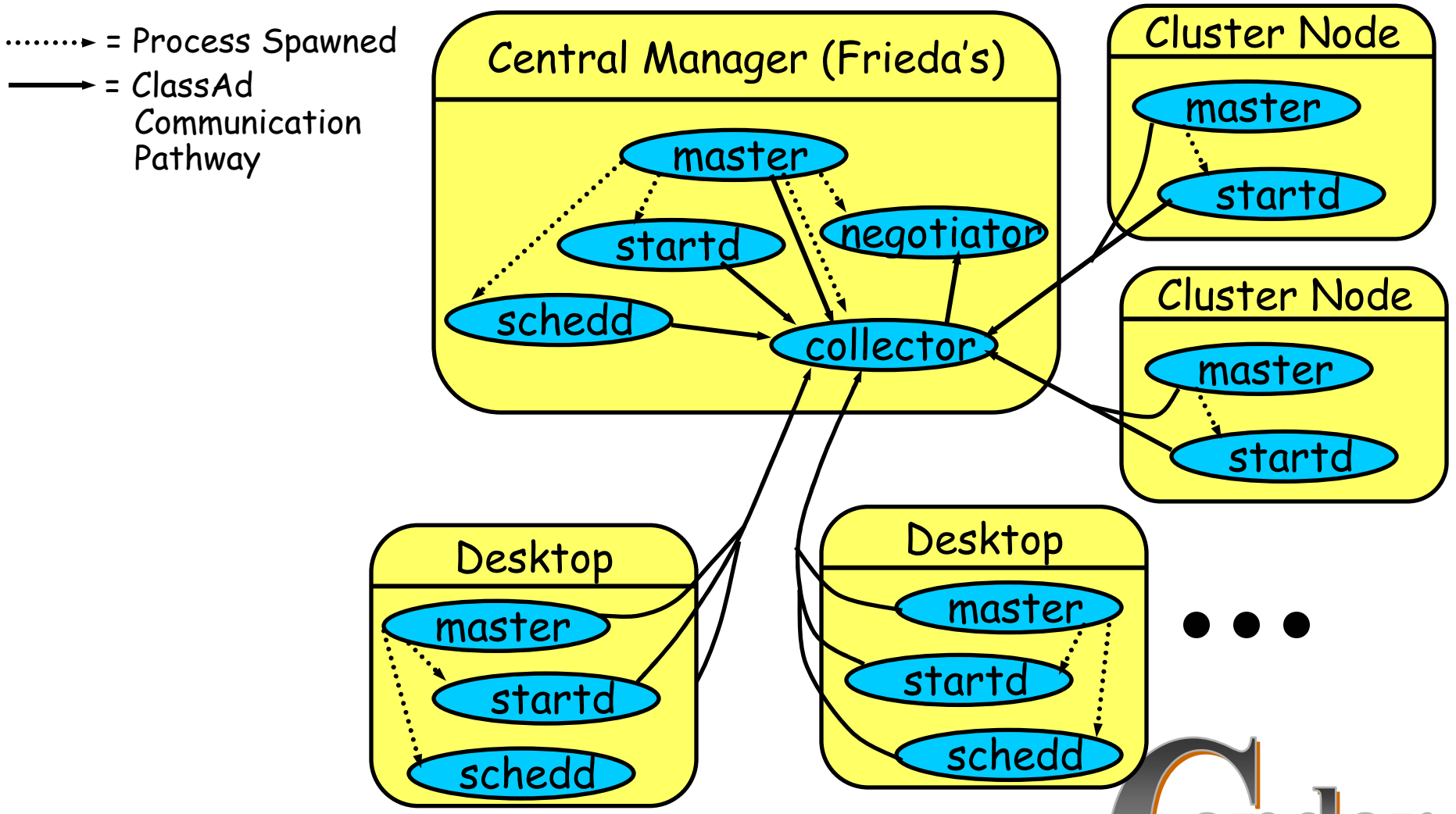
- Schedule and start an MPICH job on *dedicated resources*

```
## MPI example submit description file
universe = MPI
executable = simplempi
log = logfile
input = infile.$(NODE)
output = outfile.$(NODE)
error = errfile.$(NODE)
machine_count = 4
queue
```



The Boss says Frieda can add her co-workers' desktop machines into her Condor pool as well… but only if they can also submit jobs.

Layout of the Condor Pool



Some of the machines in the Pool do not have enough memory or scratch disk space to run my job!

Specify Requirements!

- An expression (syntax similar to C or Java)
- Must evaluate to True for a match to be made

```
Universe   = vanilla
Executable = my_job
InitialDir = run_$(Process)
Requirements = Memory >= 256 && Disk > 10000
Queue 600
```

Specify Rank!

- All matches which meet the requirements can be sorted by preference with a Rank expression.
- Higher the Rank, the better the match

```
Universe   = vanilla
Executable = my_job
Arguments  = -arg1 -arg2
InitialDir = run_$(Process)
Requirements = Memory >= 256 && Disk > 10000
Rank = (KFLOPS*10000) + Memory
Queue 600
```

What attributes can I reference in Requirements/Rank ?

- Answer: Any attributes that appear in the machine or job classad
- Out of the box, Condor has ~70 attributes per machine classad and ~70 attributes per job classad
- Sites can add their own custom attributes to machine or job classads
- To see all ad attributes:
  - condor_status -long (for machine classads)
  - condor_q -long (for job classads)

Condor ClassAds

- ClassAds are at the heart of Condor
- ClassAds
  - are a set of uniquely named expressions; each expression is called an *attribute*
  - combine query and data
  - semi-structured : no fixed schema
  - extensible

Sample ClassAd

```
MyType = "Machine"
TargetType = "Job"
Machine = "froth.cs.wisc.edu"
Arch = "INTEL"
OpSys = "SOLARIS251"
Disk = 35882
Memory = 128
KeyboardIdle = 173
LoadAvg = 0.1000
Requirements = TARGET.Owner=="smith" ||
  LoadAvg<=0.3 && KeyboardIdle>15*60
```

ClassAd Matching

- Two ClassAds are said to "match" if the Requirements expression from both ads evaluates to True when evaluated within the context of each other.
- The Rank expression is the "goodness" of the match (higher is better).

How can my jobs access their data files?

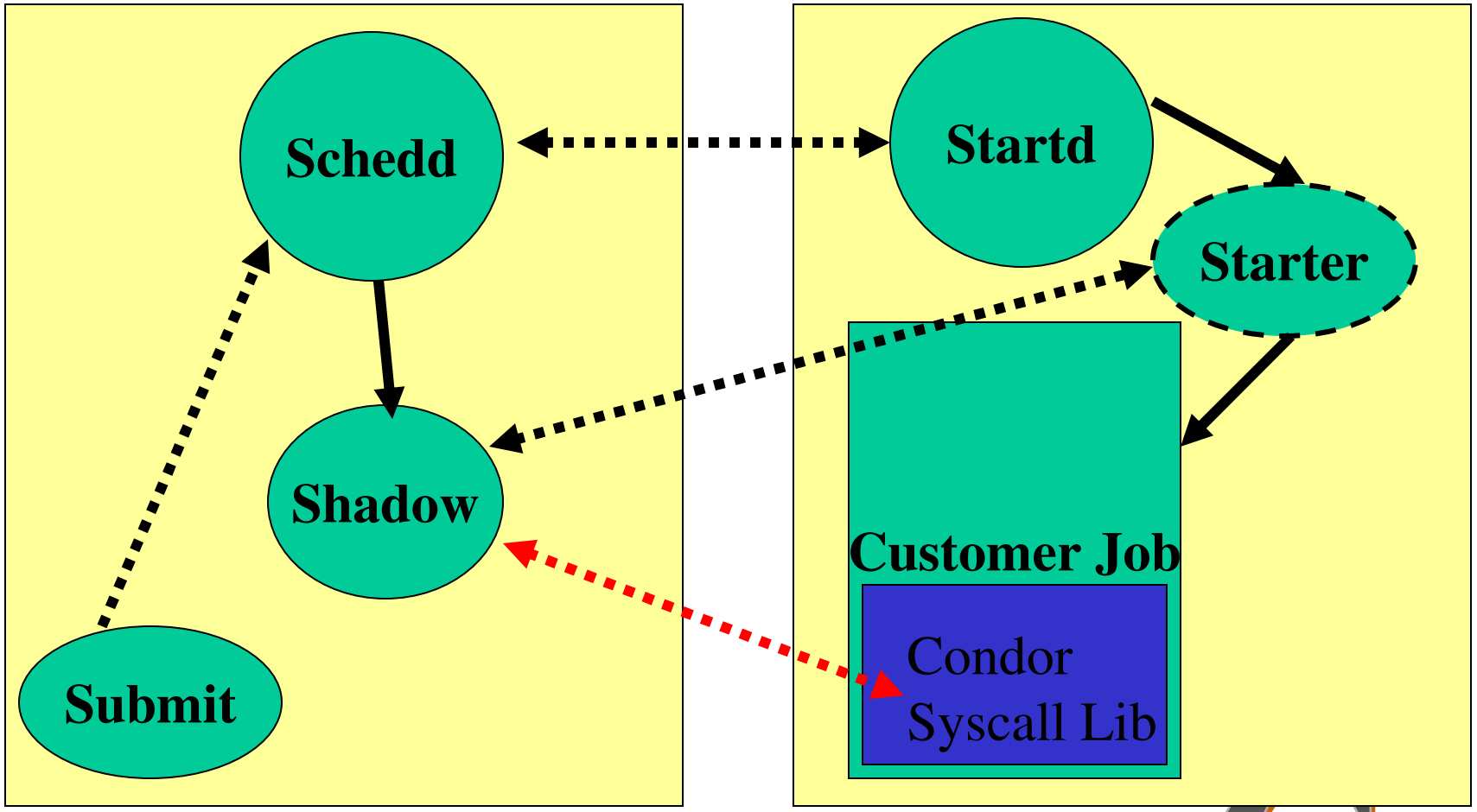
Access to Data in Condor

- Can use shared filesystem if available
- No shared filesystem?
  - *Remote System Calls (in the Standard Universe)*
  - Condor File Transfer Service
    - Can automatically send back changed files
    - Atomic transfer of multiple files

Standard Universe Remote System Calls

- I/O System calls trapped and sent back to submit machine
- Allows Transparent Migration Across Administrative Domains
  - Checkpoint on machine A, restart on B
- No Source Code changes required
- Language Independent
- Opportunities
  - For Application Steering
    - Example: Condor tells customer process "how" to open files
  - For compression on the fly
  - More…

Job Startup

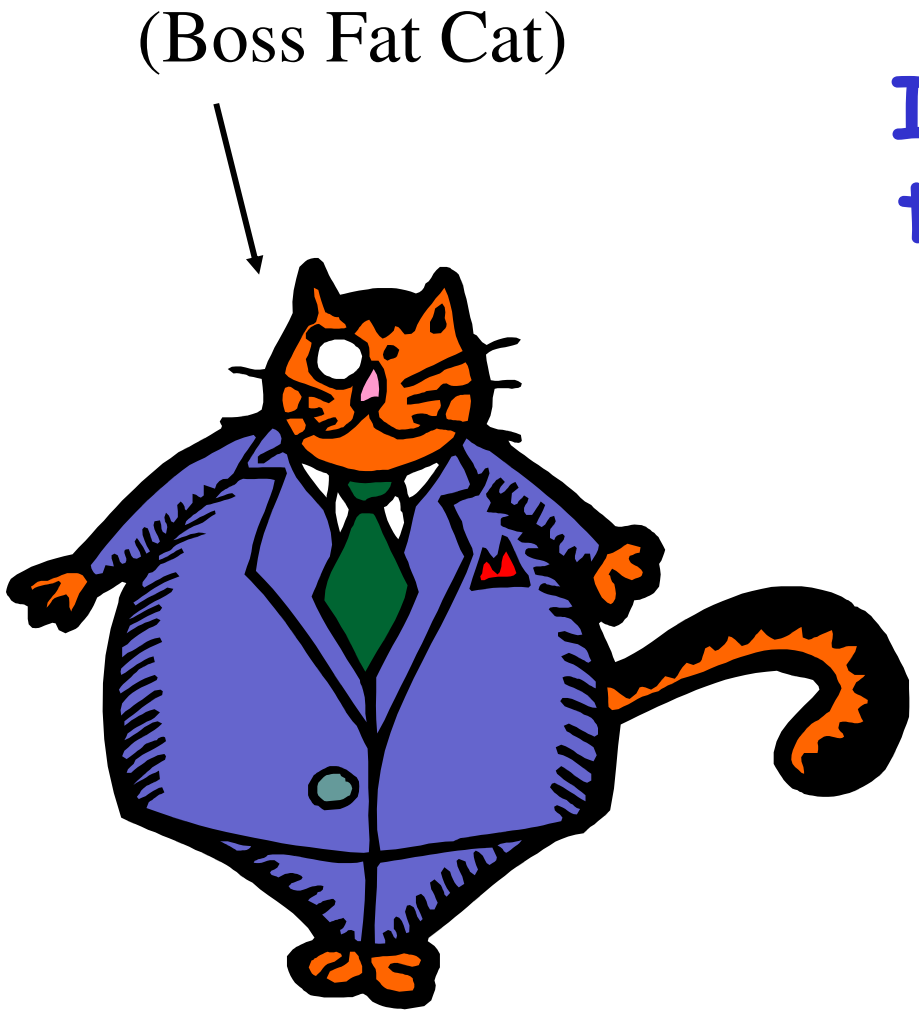

Schedd
Startd
Starter
Shadow
Customer Job
Condor
Syscall Lib
Submit

Condor File Transfer

- Set Should_Transfer_Files
  - YES : Always transfer files to execution site
  - NO : Rely on a shared filesystem
  - IF_NEEDED : will automatically transfer the files if the submit and execute machine are not in the same FileSystemDomain
- Set When_To_Transfer_Output
  - ON_EXIT or ON_EXIT_OR_VACATE

```
Universe   = vanilla
Executable = my_job
Requirements = Memory >= 256 && Disk > 10000
Should_Transfer_Files = IF_NEEDED
When_To_Transfer_Output = IF_NEEDED
Transfer_input_files = dataset$(Process), common.data
Queue 600
```

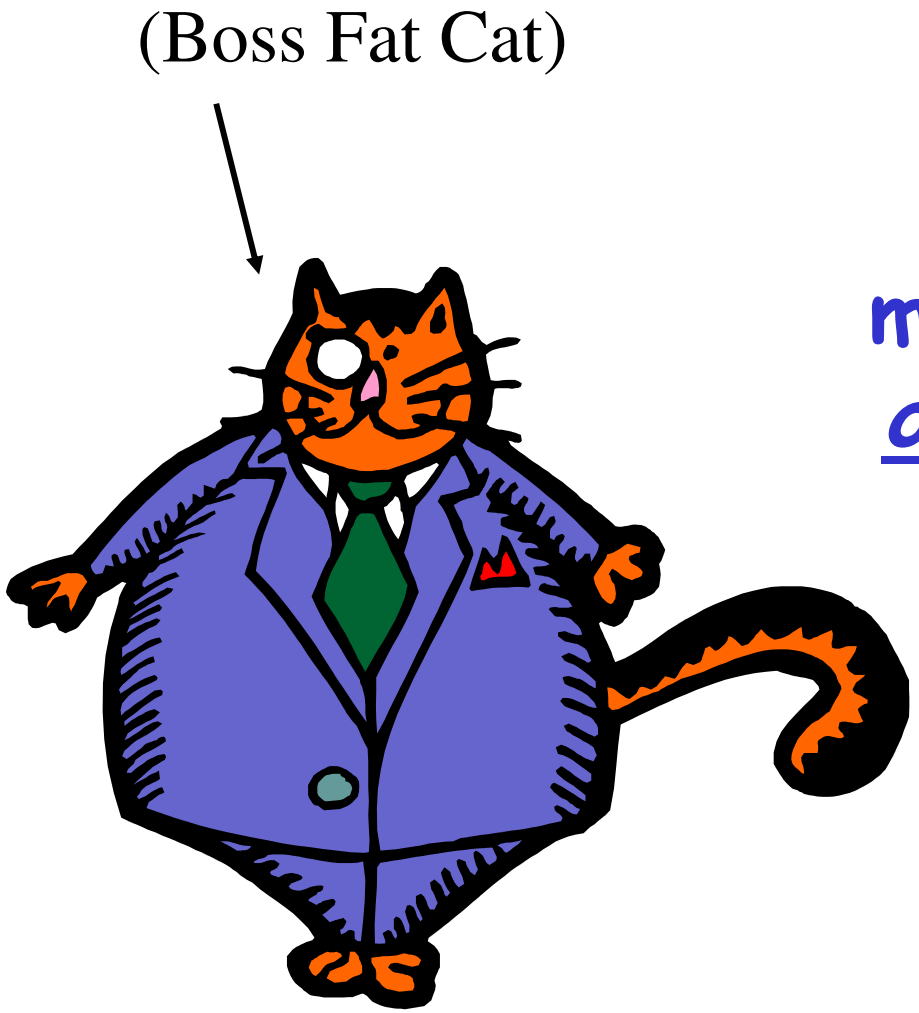
Policy Configuration



I am adding nodes to the Cluster… *but the Engineering Department has priority on these nodes.*

Machine Policy coming this afternoon… Ooohhhh… the suspense!

Policy Configuration, cont



The Cluster is fine. But not the desktop machines. *Condor can only use the desktops when they would otherwise be idle.*

Machine Policy coming this afternoon… Ooohhhh… the suspense!

I want to use Java. Is there any easy way to run Java programs via Condor?

Java Universe Job

condor_submit →

```
universe = java
executable = Main.class
jar_files = MyLibrary.jar
input = infile
output = outfile
arguments = Main 1 2 3
queue
```

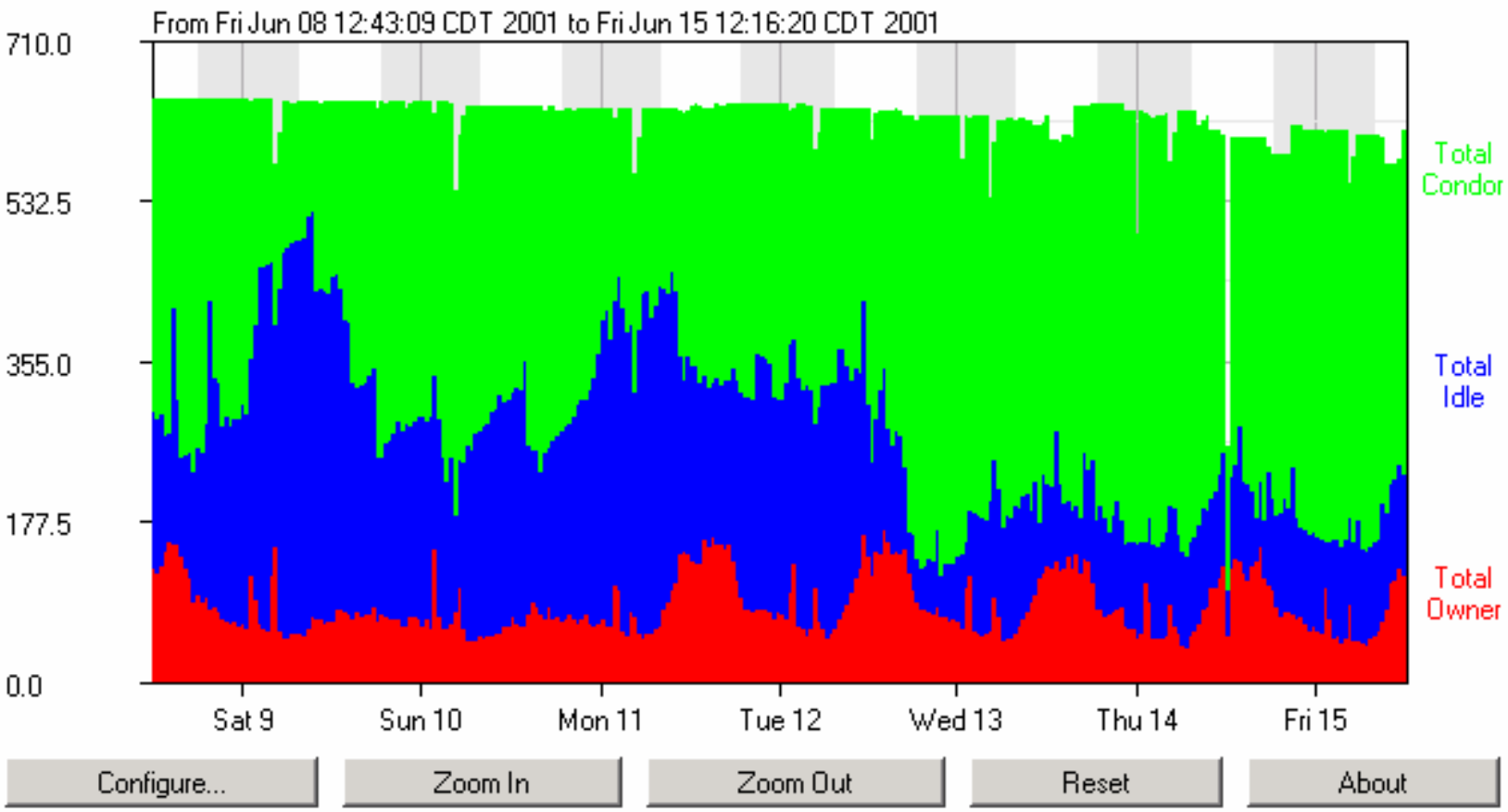
Why not use Vanilla Universe for Java jobs?

- Java Universe provides more than just inserting "java" at the start of the execute line
  - Knows which machines have a JVM installed
  - Knows the location, version, and performance of JVM on each machine
  - Provides more information about Java job completion than just JVM exit code
    - Program runs in a Java wrapper, allowing Condor to report Java exceptions, etc.

General User Commands

condor_status	View Pool Status
condor_q	View Job Queue
condor_submit	Submit new Jobs
condor_rm	Remove Jobs
condor_history	Completed Job Info
condor_submit_dag	Specify Dependencies
condor_checkpoint	Force a checkpoint
condor_compile	Link Condor library

CondorView Usage Graph



Job Submit files: Built-in and Defined Macros

- Macros are resolved by condor_submit before creating the Job ClassAd.
- We've seen the $(Process) built-in macro. There are others:
  - $(Cluster)
  - $ENV(foo)
  - $RANDOM_CHOICE(x,y,z,…)
  - $(Dollar)
- User Defined macros can be defined anytime in the submit file with the syntax

  <macro_name> = <string>

  and then used with the form $(macro_name).

Job Submit File Example

```
# Run foo –mem 512 –seed [0|1|2] –dir <directory>
#
Universe = vanilla
Executable = foo
Memory = 512
Requirements = Memory > $(Memory)
Arguments = -mem $(Memory)  \
    -seed $RANDOM_CHOICE(0,1,2)
    -dir $ENV(HOME)
output = log.$(cluster).$(process)
Queue 100
```

Job submit files: Match Ad Substitution macros

- A substitution macro takes the value of the expression from the resource (machine ClassAd) after a match has been made. These macros look like:

  $$(attribute)

- An alternate form looks like:

$$(attribute:string_if_attribute_undefined)

Example Submit File

```
# Run on Solaris or Linux
Universe = vanilla
Requirements = Opsys=="Linux" ||  Opsys ==
   "Solaris"
Executable = foo.$$(opsys)
Arguments = -textures
   $$(texturedir:/usr/local/alias/textures)
queue
```

Submit File: Job Failure Policy Expressions

- You can supply job failure policy expressions in the submit file.
- Can be used to describe a successful run, or what to do in the face of failure.

```
on_exit_remove = <expression>
on_exit_hold = <expression>
periodic_remove = <expression>
periodic_hold = <expression>
periodic_release = <expression>
```

Job Failure Policy Examples

- Do not remove from queue (i.e. reschedule) if exits with a signal:

```
on_exit_remove = ExitBySignal == False
```

- Place on hold if exits with nonzero status or ran for less than an hour:

```
on_exit_hold = ((ExitBySignal==False) &&
(ExitSignal != 0)) || ((CurrentTime -
JobStartDate) < 3600)
```

- Place on hold if job has spent more than 50% of its time suspended:

```
periodic_hold = CumulativeSuspensionTime
>  (RemoteWallClockTime / 2.0)
```

Submit file: Job Environment

- Environment = var=val; var1=val1; …
- Getenv = [True | False] Defaults to be false.
  - Often GetEnv=TRUE fixes problems due to an empty environment, BUT
  - Be wary – the submit machine's environment may not make sense on the execute machine!
  - Note: job will always be started with a CONDOR_SCRATCH_DIR environment variable to a subdir that is removed when the job leaves.

What is a "negotiation cycle" ?

What happens if the workstation running the Central Manager crashes?

What happens if the workstation running my job (execute machine) crashes?

What happens if the workstation running my schedd (submit machine) crashes?

Disconnected Shadow/Starter

- Once upon a time, only one answer: job restarts.
- Now for Vanilla and Java universe jobs, Condor now supports reestablishing the connection between the submitting and executing machines.
- To take advantage of this feature, the user must put the following line into their job's submit description file:

    +JobLeaseDuration = <N seconds>

For example:

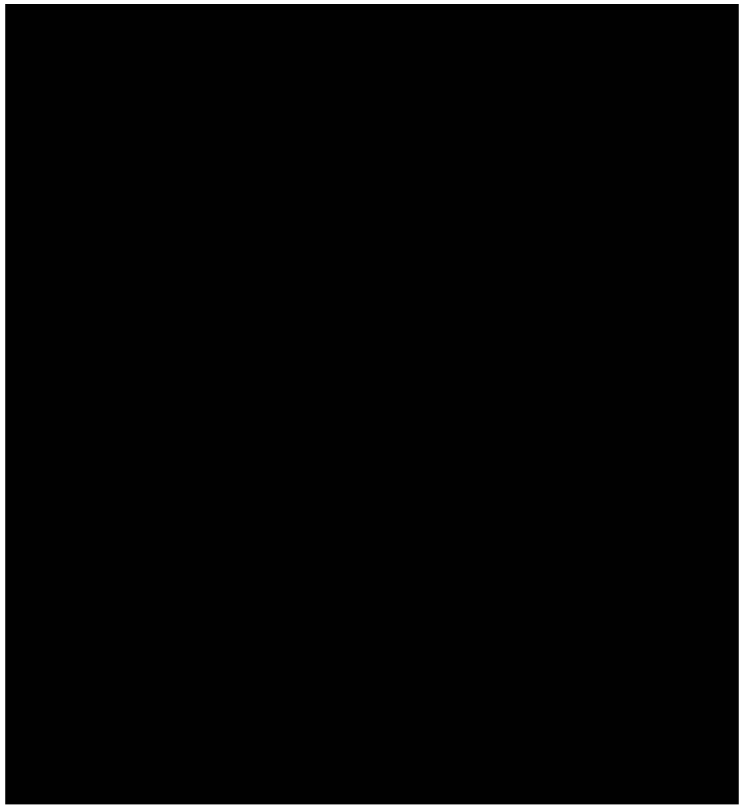
    +JobLeaseDuration = 1200

Why is my job not running?

Troubleshooting "stuck" jobs

- Try
  - condor_q –analyze
    - Check ClassAd requirements
  - Maybe user priority?
  - Check job log or ShadowLog – maybe job is starting and failing right away.

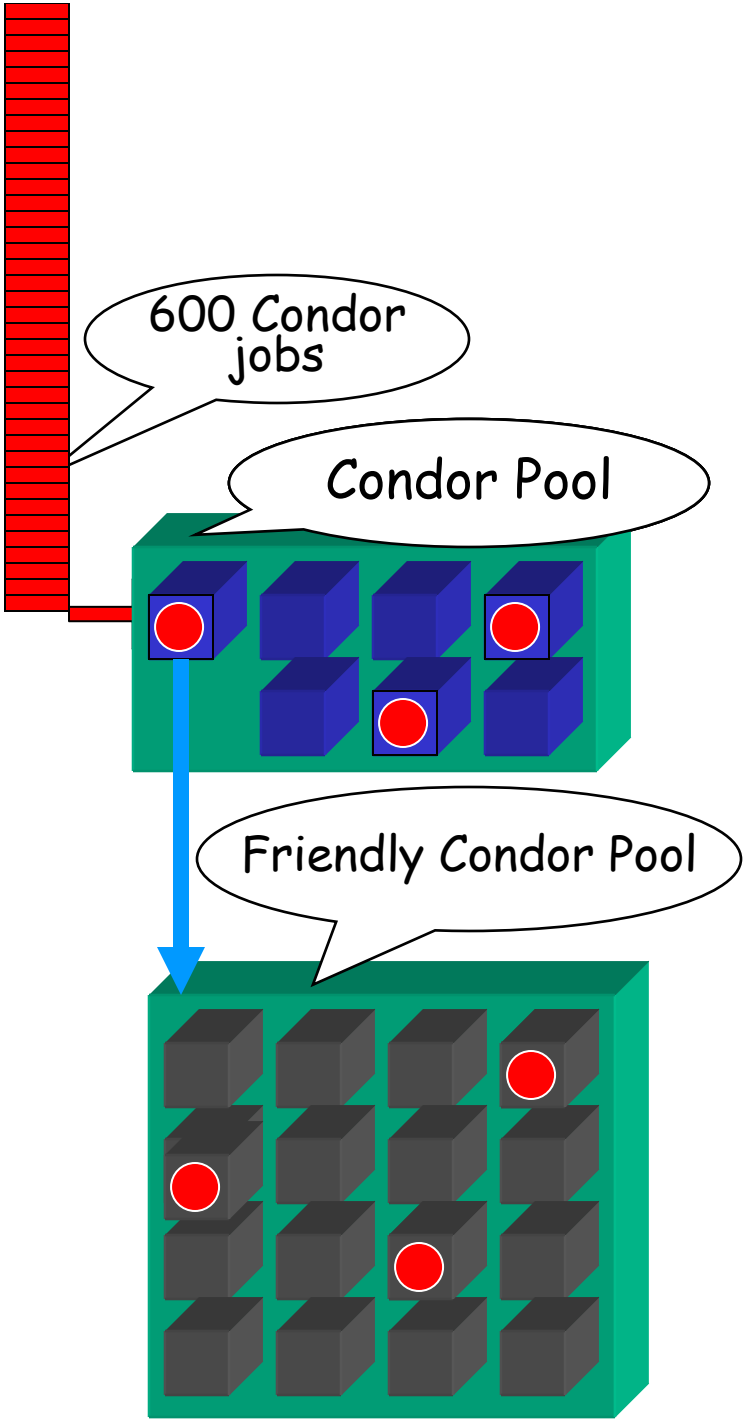
Back to the Story…



Frieda Needs Remote Resources…

Frieda Builds a Grid!

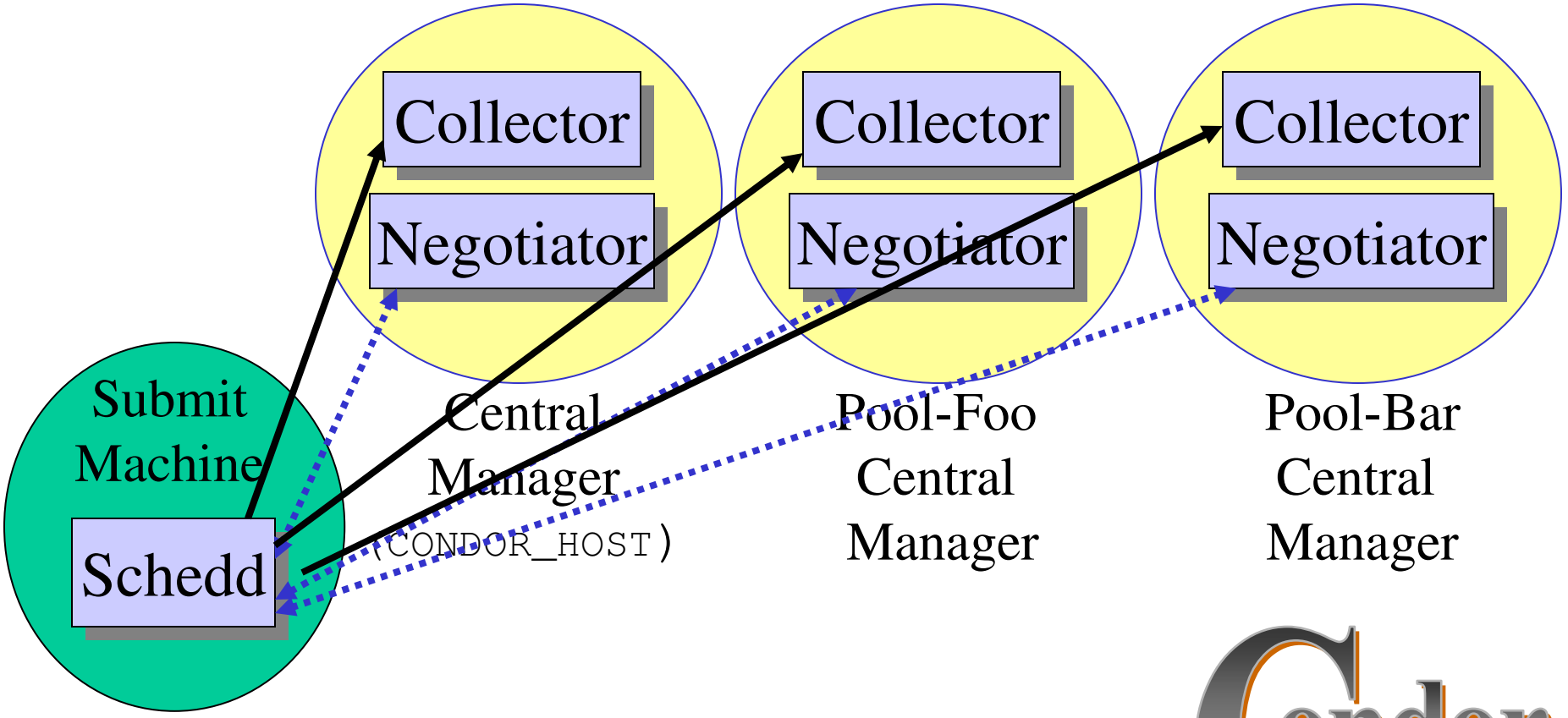
- First Frieda takes advantage of her Condor friends!
- She knows people with their own Condor pools, and gets permission to access their resources
- She then configures her Condor pool to "flock" to these pools


600 Condor jobs
Condor Pool
Friendly Condor Pool

How Flocking Works

- Add a line to your condor_config :

```
FLOCK_HOSTS = Pool-Foo, Pool-Bar
```



Condor Flocking

- Remote pools are contacted *in the order specified* until jobs are satisfied
- The list of remote pools is a property of the Schedd, not the Central Manager
  - So different users can Flock to different pools
  - And remote pools can allow specific users
- User-priority system is "flocking-aware"
  - A pool's local users can have priority over remote users "flocking" in.

Condor Flocking, cont.

- Flocking is "Condor" specific technology…
- Frieda also has access to Globus resources she wants to use
  - She has certificates and access to Globus gatekeepers at remote institutions
- But Frieda wants Condor's queue management features for her Globus jobs!
- She installs Condor-G so she can submit "Globus Universe" jobs to Condor

Condor-G: Access non-Condor Grid resources

Globus

- middleware deployed across entire Grid
- remote access to computational resources
- dependable, robust data transfer

Condor

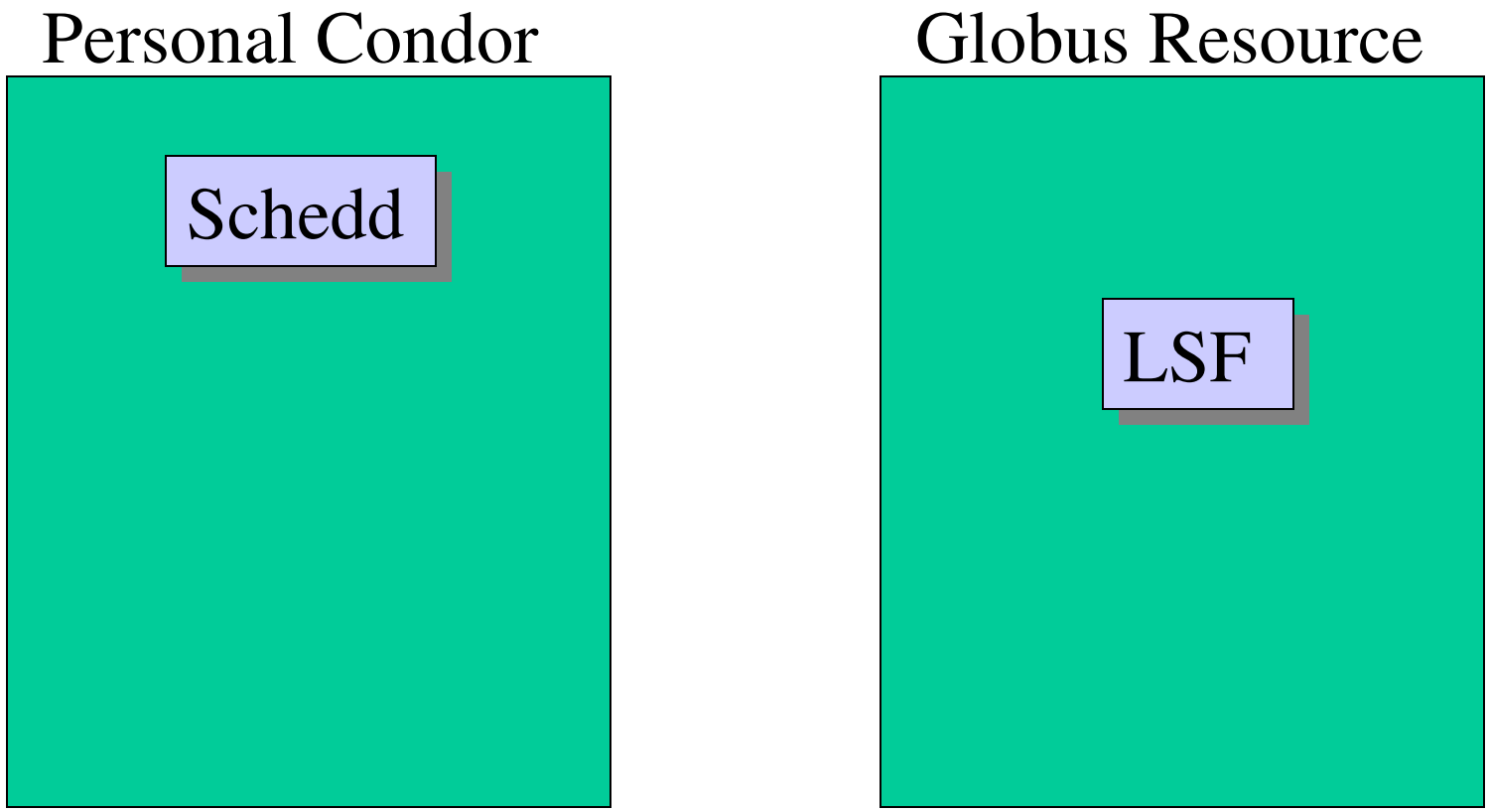
- job scheduling across multiple resources
- strong fault tolerance with checkpointing and migration
- layered over Globus as "personal batch system" for the Grid

Frieda Submits a Globus Universe Job

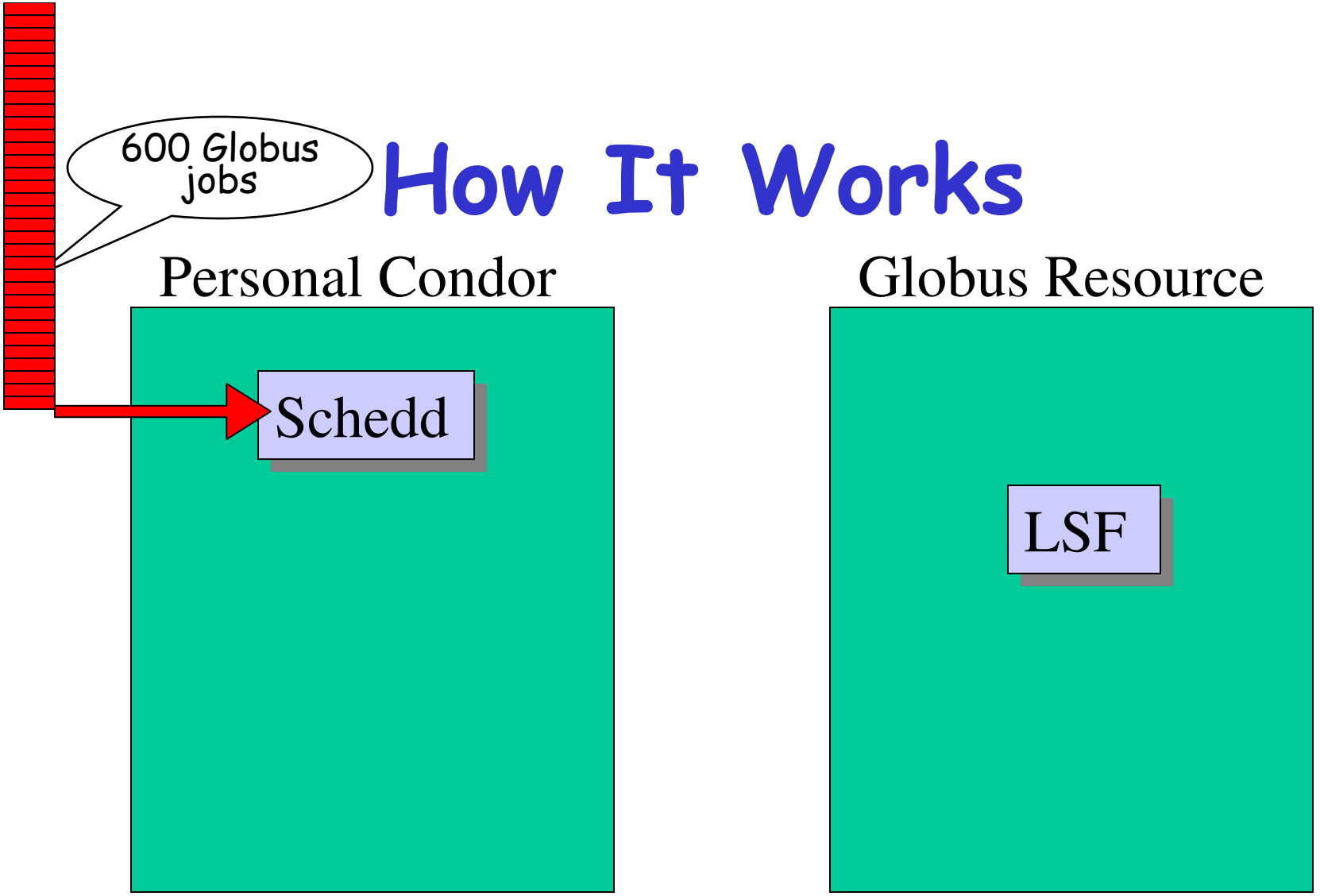
- In her submit description file, she specifies:
  - Universe = Globus
  - Which Globus Gatekeeper to use
  - Optional: Location of file containing your Globus certificate

```
universe      = globus
globusscheduler = beak.cs.wisc.edu/jobmanager
executable    = progname
queue
```

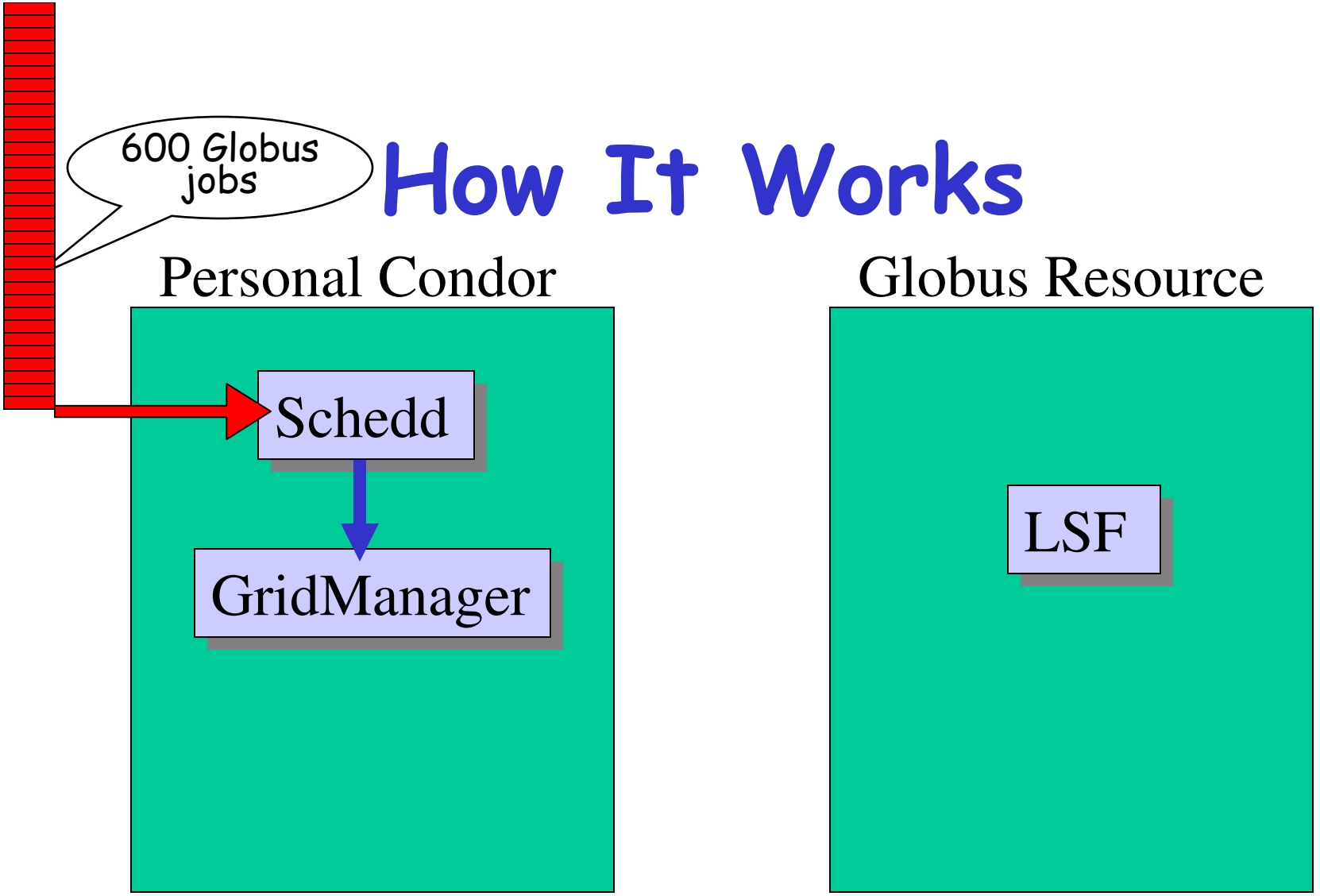
How It Works



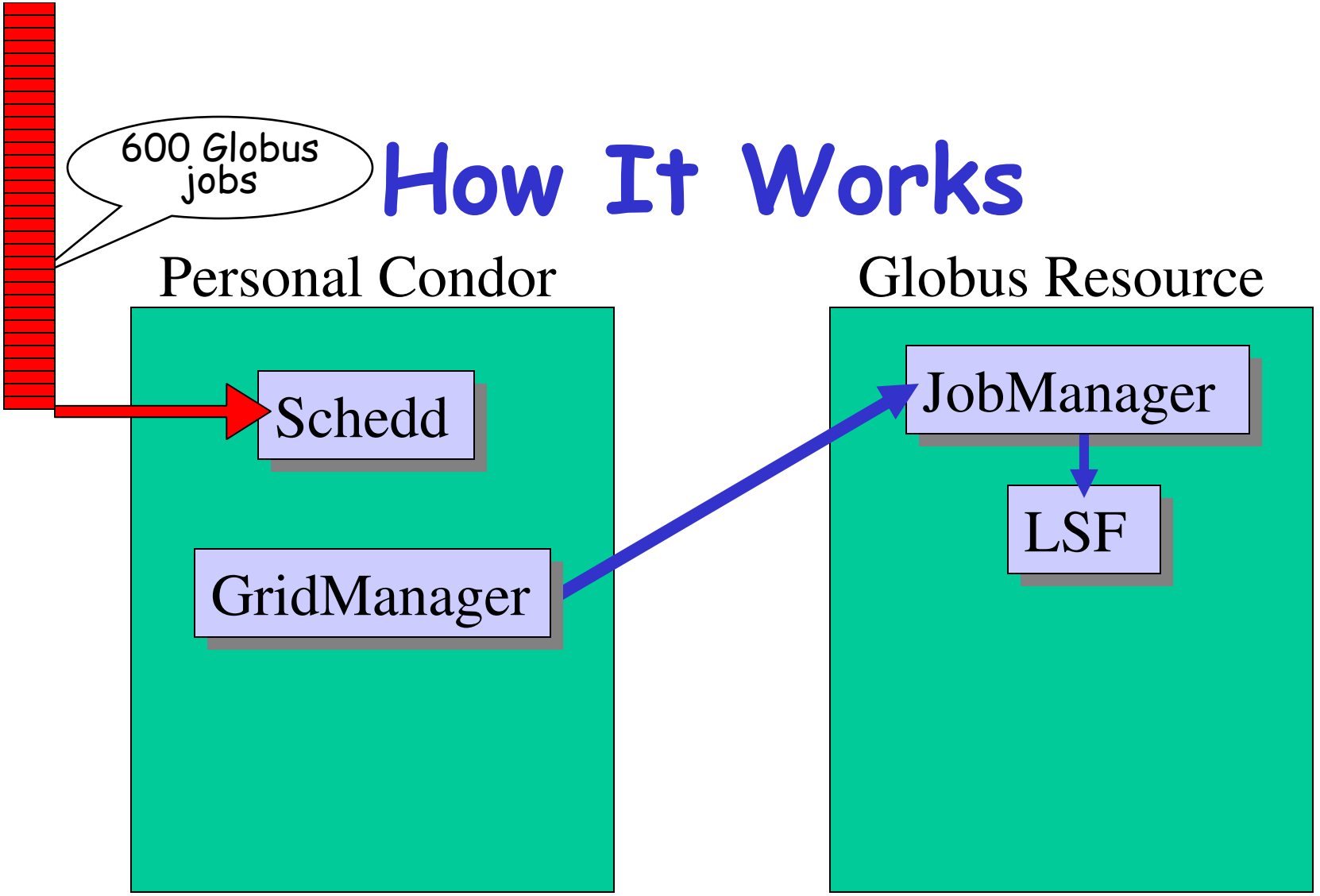
How It Works


600 Globus jobs
Personal Condor
Schedd
Globus Resource
LSF

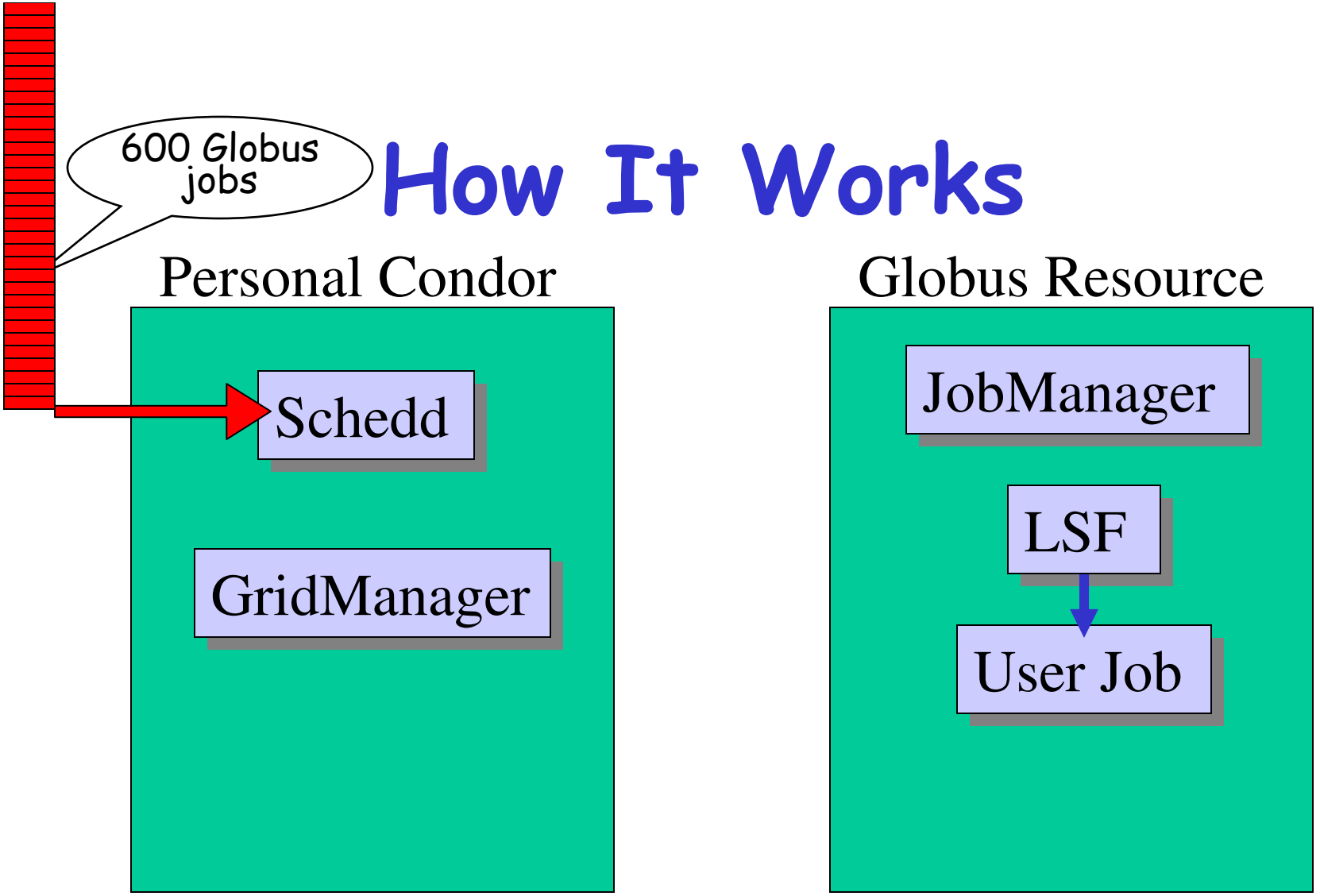
How It Works


600 Globus jobs
Personal Condor
Schedd
GridManager
Globus Resource
LSF

How It Works


600 Globus jobs
Personal Condor
Schedd
GridManager
Globus Resource
JobManager
LSF

How It Works


600 Globus jobs
Personal Condor
Schedd
GridManager
Globus Resource
JobManager
LSF
User Job

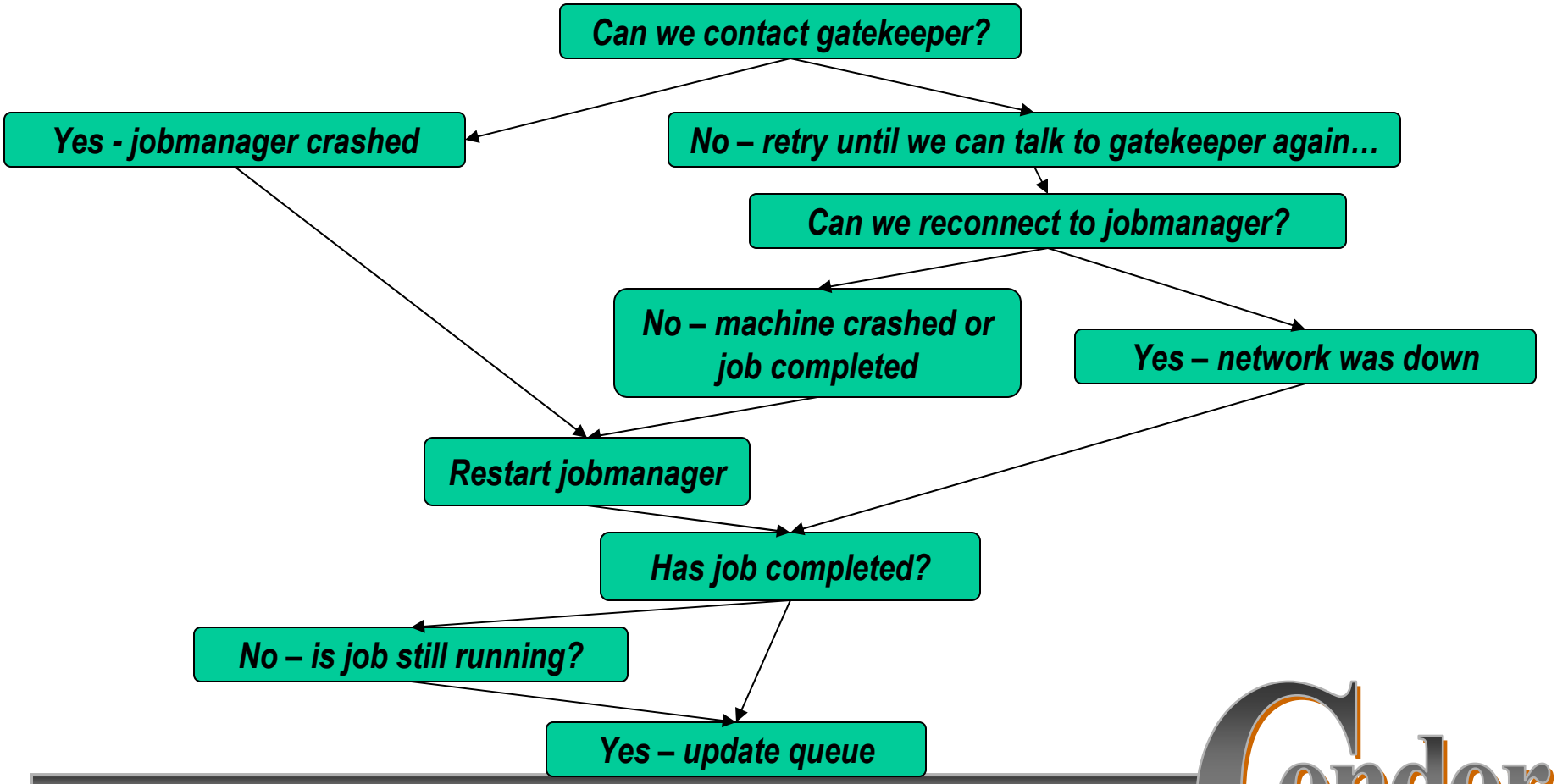
Globus Universe Concerns

- What about Fault Tolerance?
  - Local Crashes
    - What if the submit machine goes down?
  - Network Outages
    - What if the connection to the remote Globus jobmanager is lost?
  - Remote Crashes
    - What if the remote Globus jobmanager crashes?
    - What if the remote machine goes down?

Globus Universe Fault-Tolerance: Submit-side Failures

- All relevant state for each submitted job is stored persistently in the Condor job queue.
- This persistent information allows the Condor GridManager upon restart to read the state information and reconnect to JobManagers that were running at the time of the crash.
- If a JobManager fails to respond…

Globus Universe Fault-Tolerance: Lost Contact with Remote Jobmanager



Globus Universe Fault-Tolerance: Credential Management

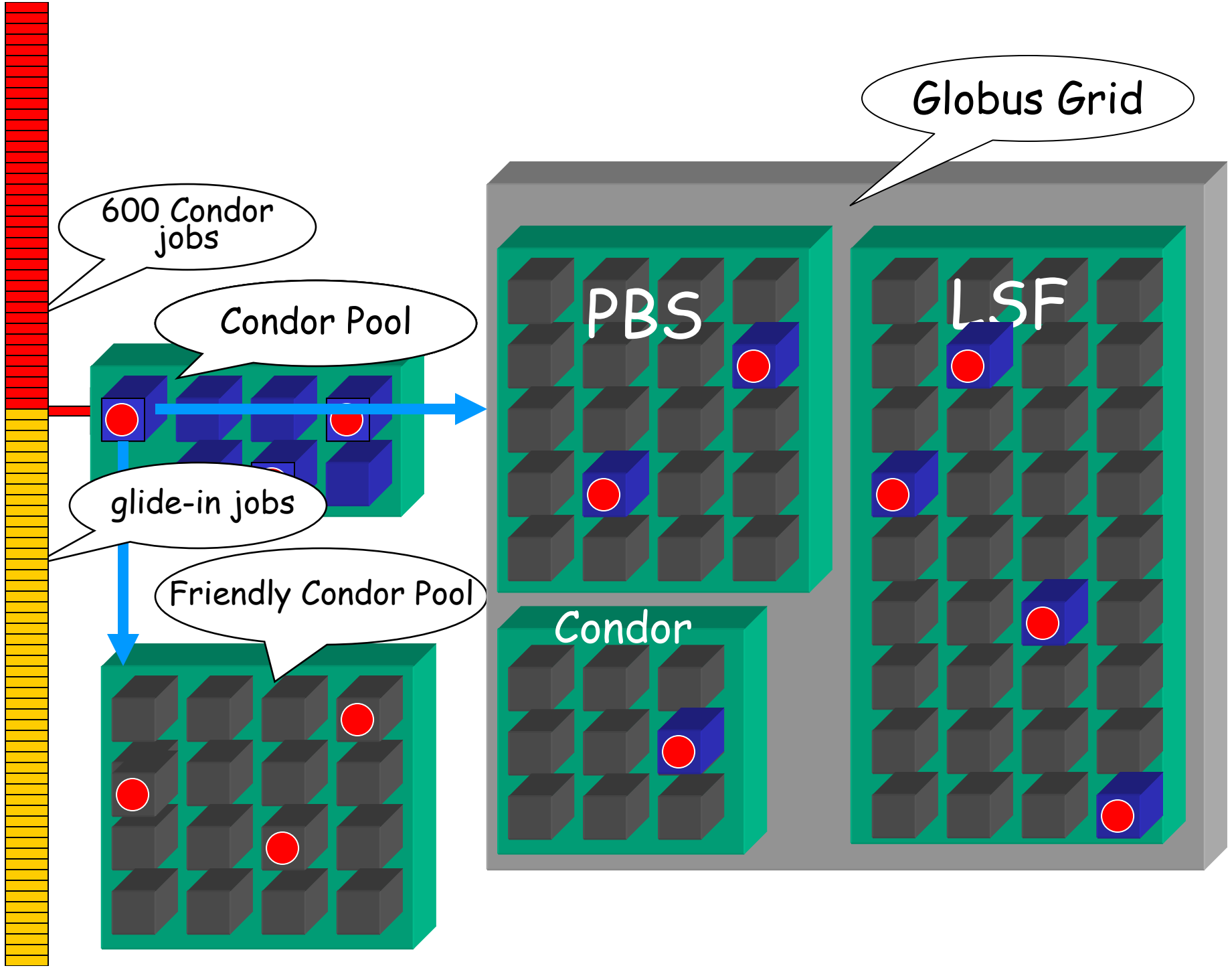
- Authentication in Globus is done with limited-lifetime X509 proxies
- Proxy may expire before jobs finish executing
- Condor can put jobs on hold and email user to refresh proxy
- Can interface with MyProxy…

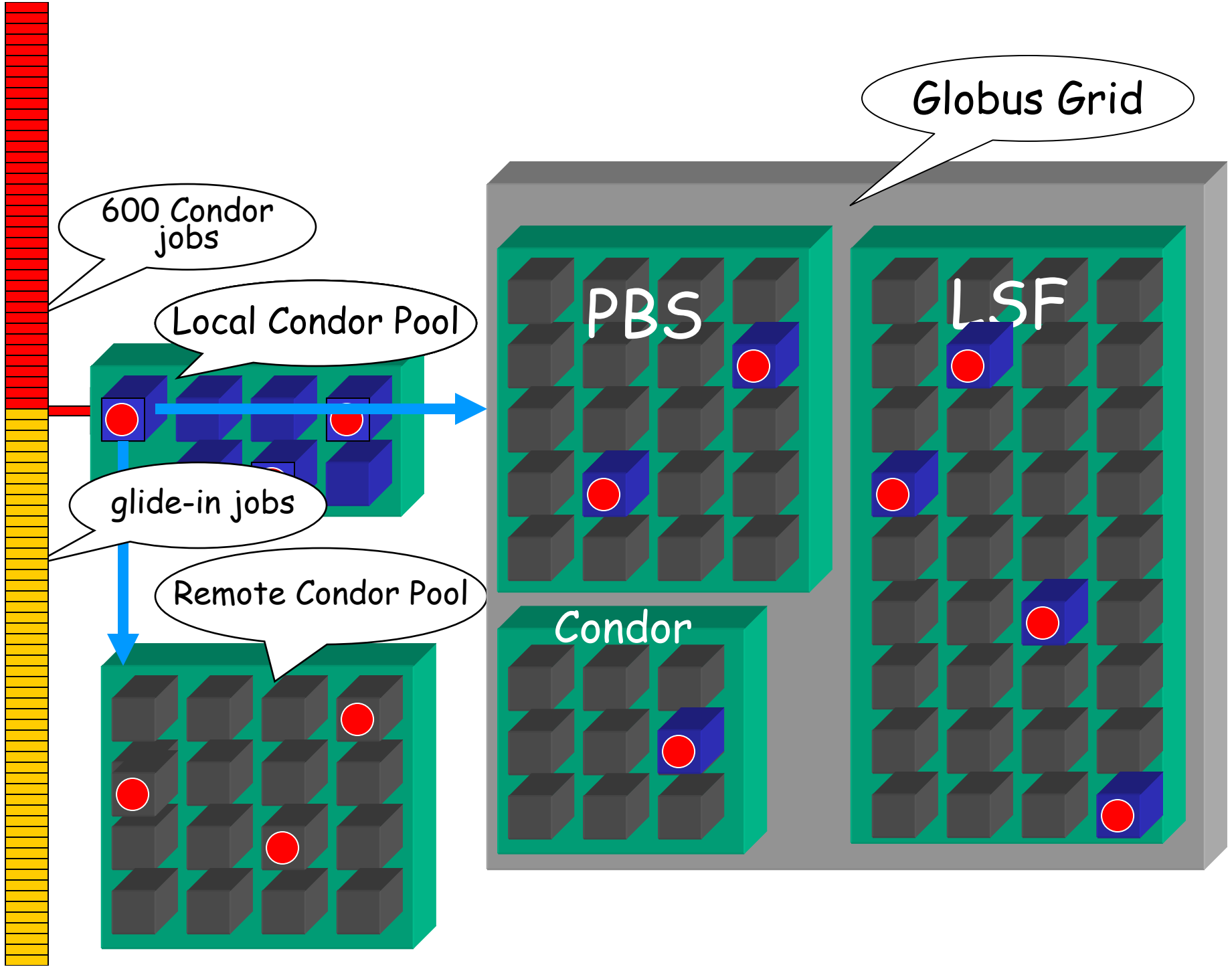
But Frieda Wants More…

- She wants to run standard universe jobs on Globus-managed resources
  - For matchmaking and dynamic scheduling of jobs
  - For job checkpointing and migration
  - For remote system calls

One Solution: Condor-G GlideIn

- Frieda can use the Globus Universe to run Condor daemons on Globus resources
- When the resources run these GlideIn jobs, they will temporarily join her Condor Pool
- She can then submit Standard, Vanilla, PVM, or MPI Universe jobs and they will be matched and run on the Globus resources

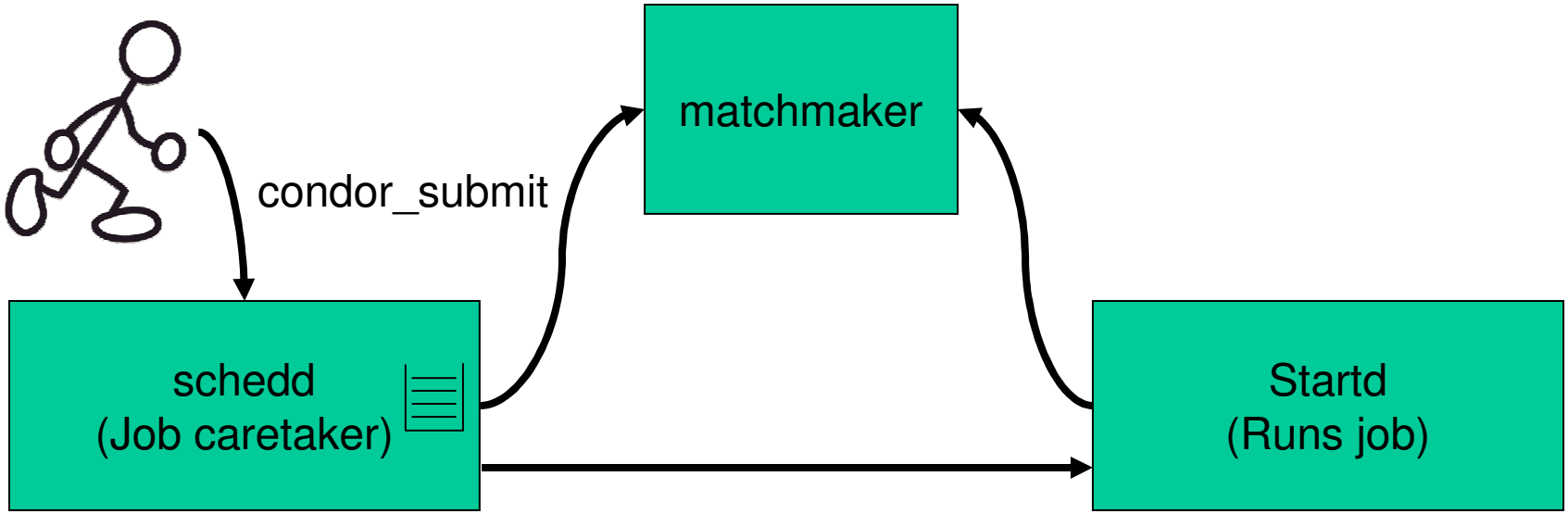

Globus Grid
600 Condor jobs
Condor Pool
PBS
LSF
glide-in jobs
Friendly Condor Pool
Condor


Globus Grid
600 Condor jobs
Local Condor Pool
PBS
LSF
glide-in jobs
Remote Condor Pool
Condor

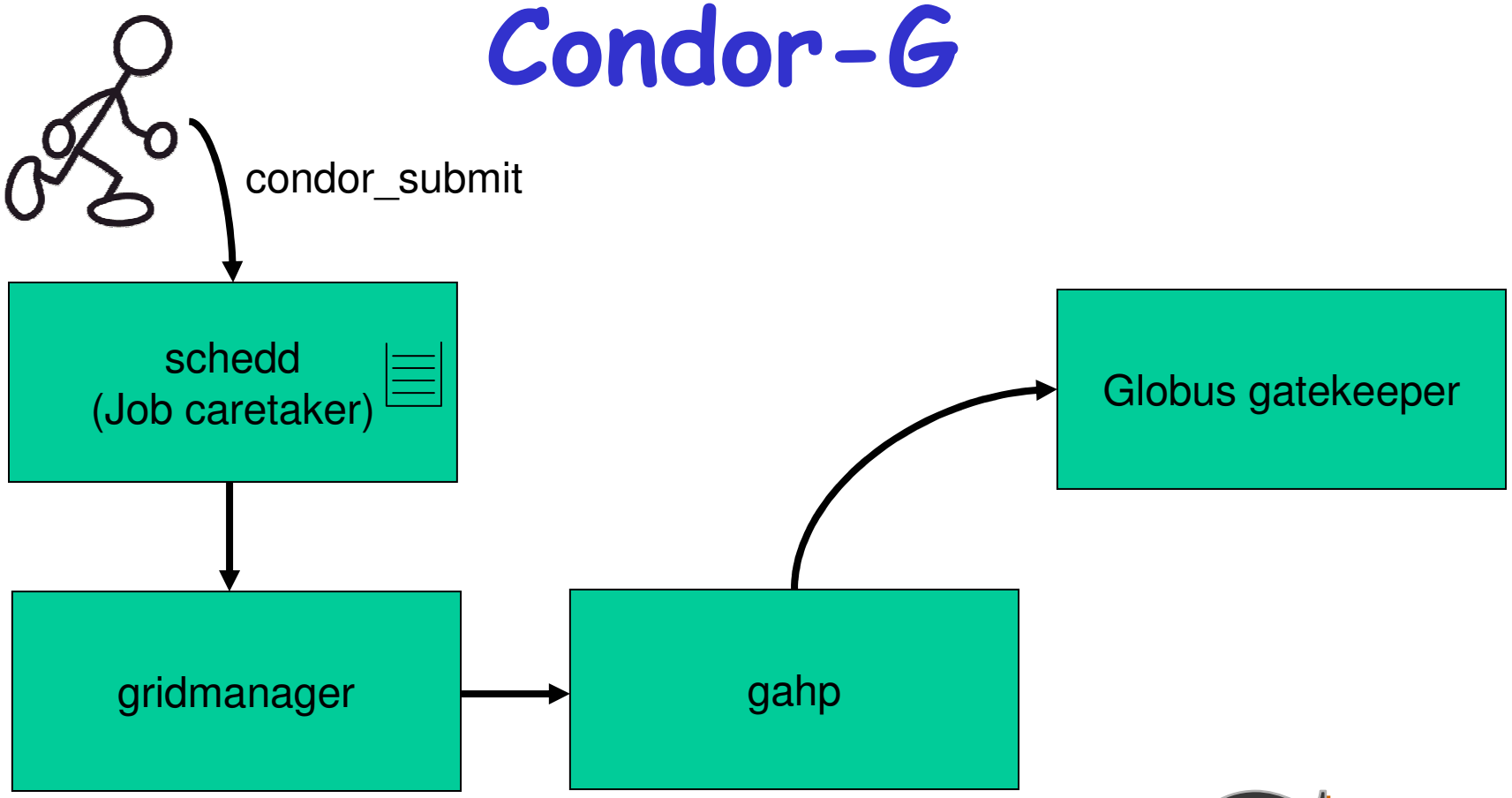
GlideIn Concerns

- What if a Globus resource kills my GlideIn job?
  - That resource will disappear from your pool and your jobs will be rescheduled on other machines
  - Standard universe jobs will resume from their last checkpoint like usual
- What if all my jobs are completed before a GlideIn job runs?
  - If a GlideIn Condor daemon is not matched with a job in 10 minutes, it terminates, freeing the resource

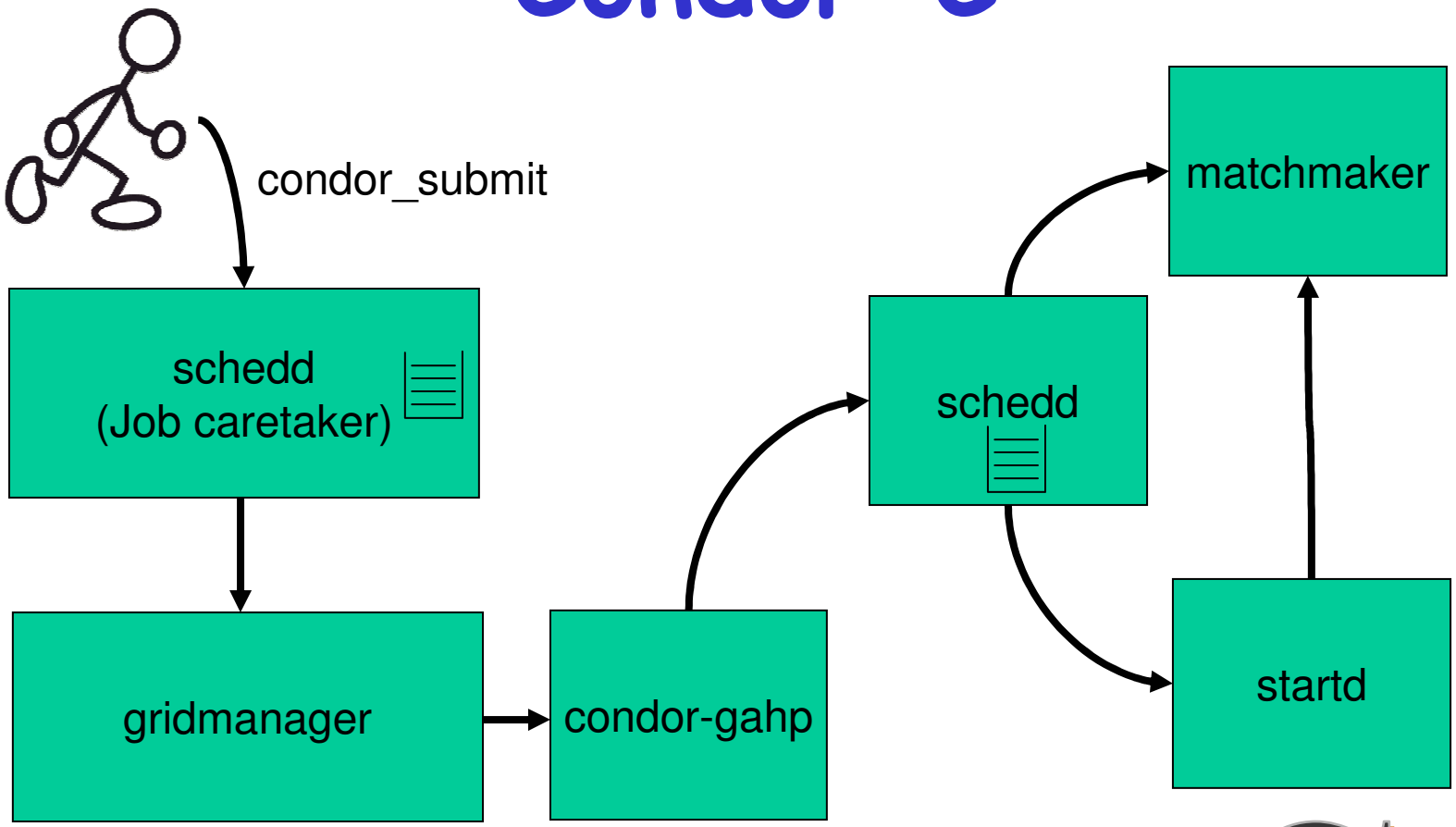
The Route to Condor-C: Condor



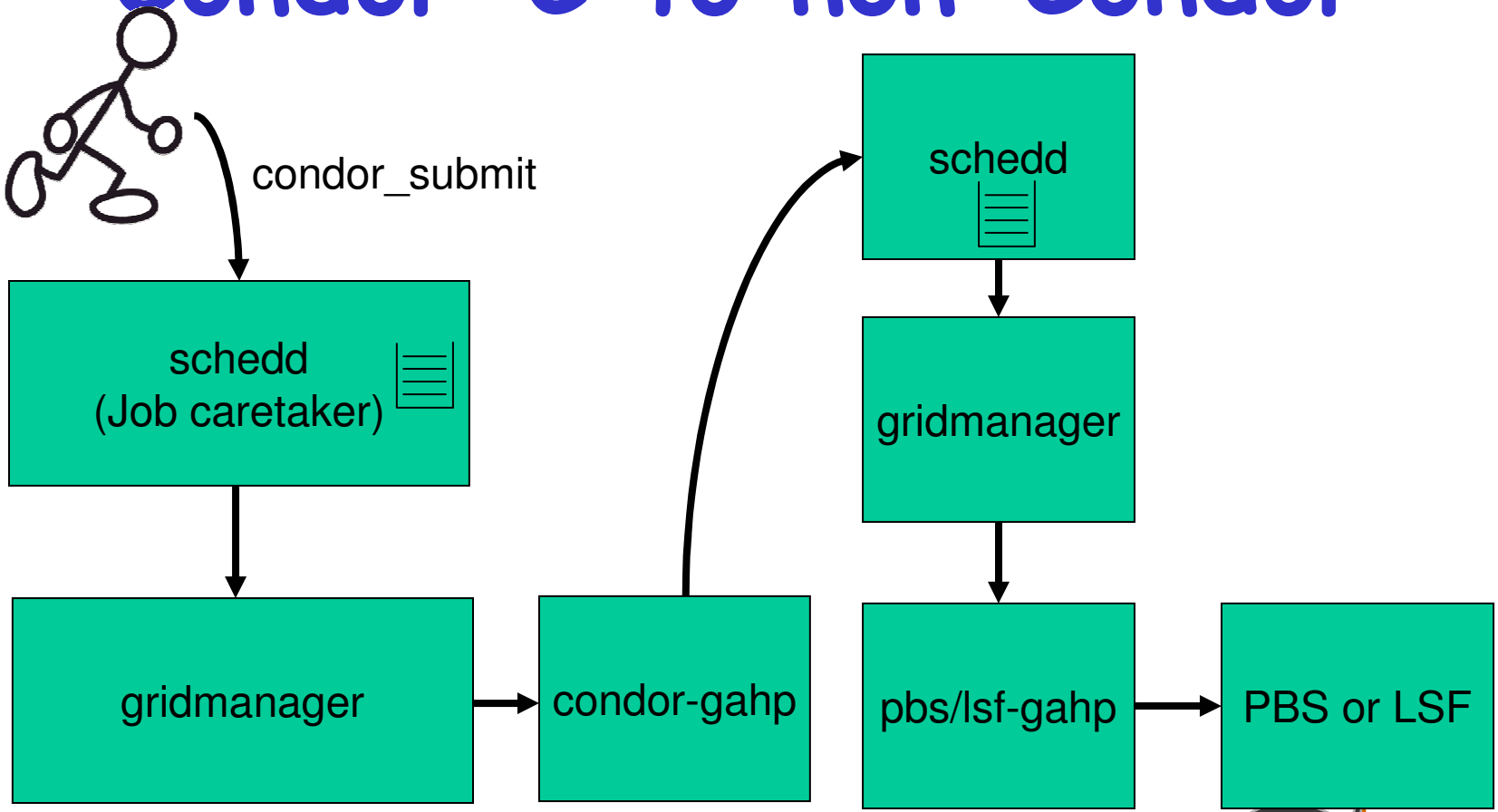
The Route to Condor-C: Condor-G



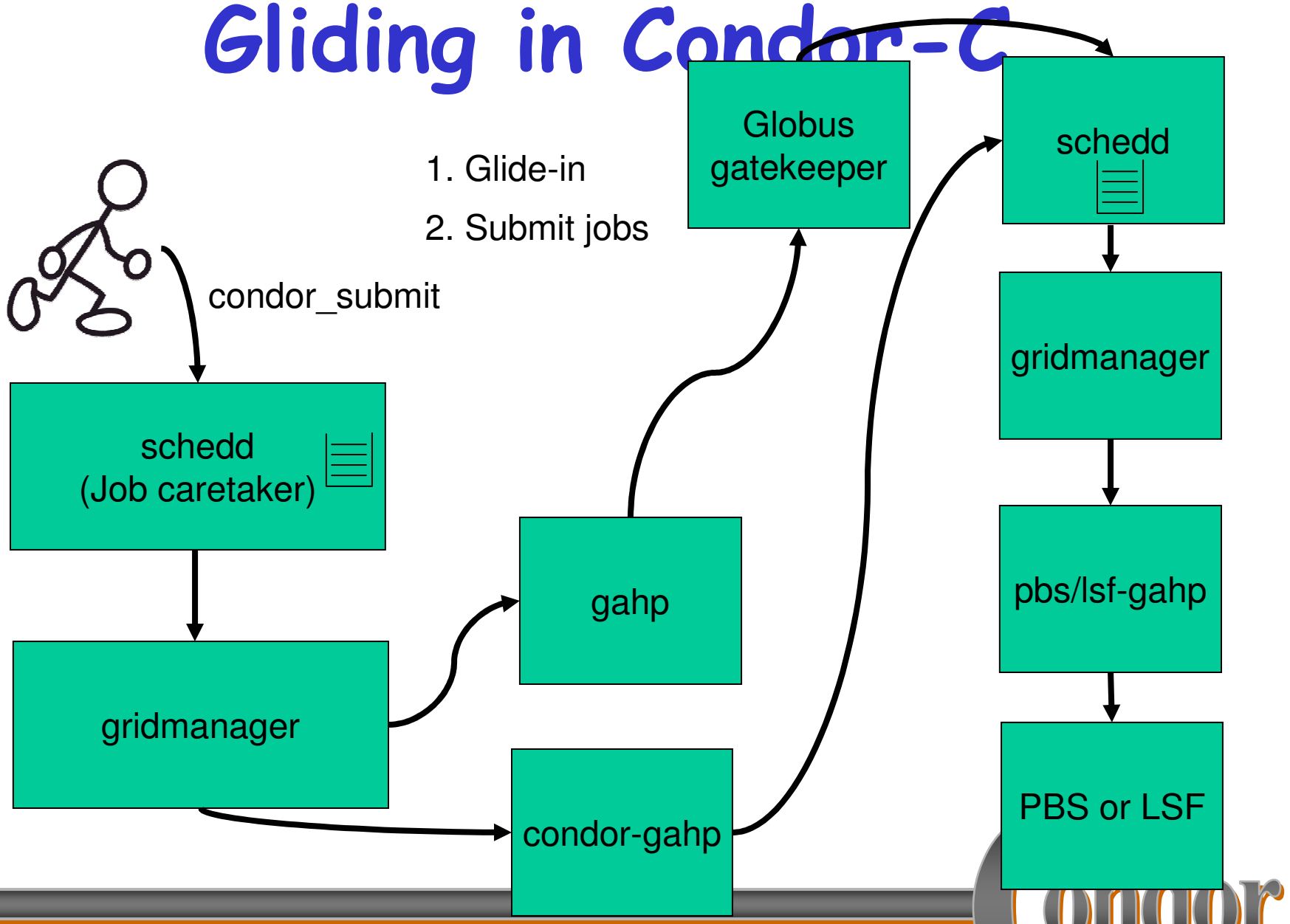
Condor-C


condor_submit
schedd
(Job caretaker)
gridmanager
condor-gahp
schedd
matchmaker
startd

Condor-C to non-Condor



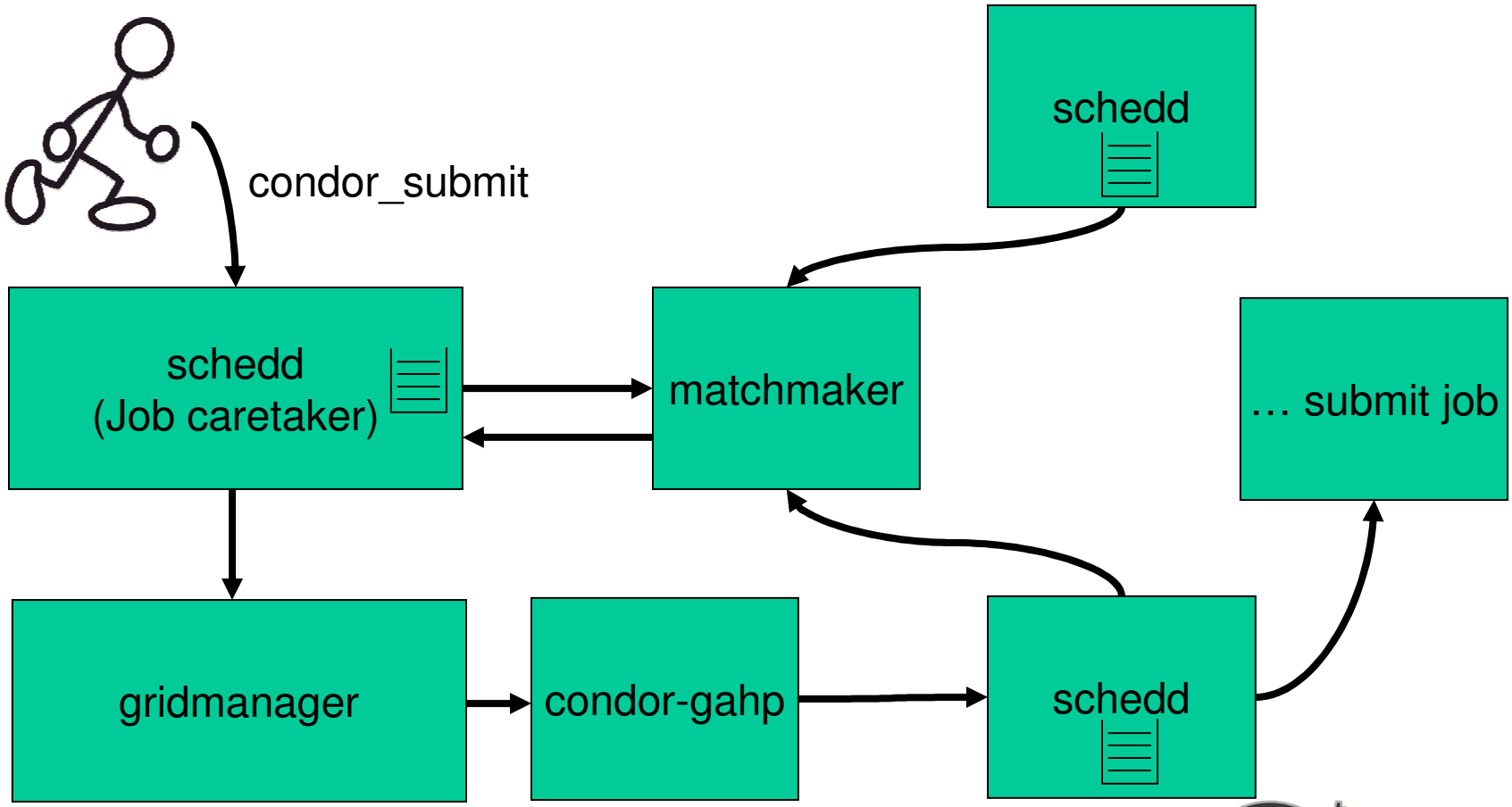
Gliding in Condor-C



Matchmaking with Condor-C

- In all of these examples, Condor-C went to a specific remote schedd
- This is not required: you can do matchmaking

Matchmaking with Condor-C



Using Condor-C

```
# minimal submit file for a Condor-C job
universe = grid
grid_type = condor
executable = myjob
output = myoutput
error = myerror
log = mylog
remote_pool = machine1.example.com
remote_schedd = joe@remotemachine.example.com
+remote_jobuniverse = 5 # vanilla
+remote_requirements = True
queue
```

Condor-C is in development

- Condor-C is in **active** development
- You can get it in Condor 6.7.3
- Authentication is limited, coming very soon
- Remote schedd must not be root (coming soon)
- Fancier setups may require experimentation and/or handholding

Thank you!