HTCondor Architecture and Administration Basics

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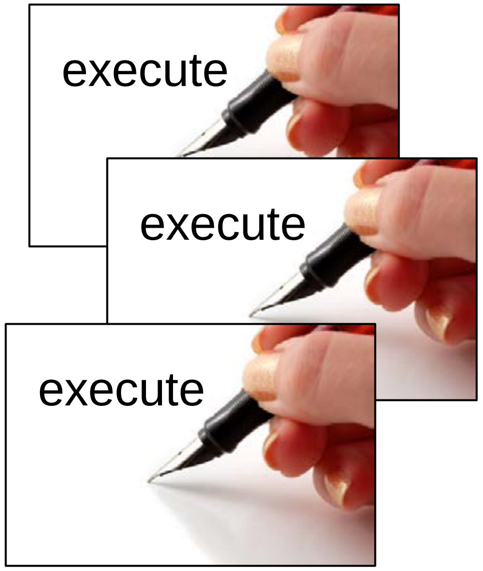
Two Big HTCondor Abstractions

- Jobs

- Machines



ClassAds: The *lingua franca* of HTCondor

What are ClassAds?

ClassAds is a language for objects (jobs and machines) to

- Express attributes about themselves
- Express what they require/desire in a “match” (similar to personal classified ads)

Structure : Set of attribute name/value pairs, where the value can be a literal or an expression. Semi-structured, no fixed schema.

Example

Pet Ad

```
Type   = “Dog”
Requirements =
   DogLover =?= True
Color = “Brown”
Price = 75
Sex = "Male"
AgeWeeks = 8
Breed = "Saint Bernard"
Size = "Very Large"
Weight = 27
```

Buyer Ad

```
AcctBalance  = 100
DogLover = True
Requirements =
 (Type == “Dog”)  &&
 (TARGET.Price <=
  MY.AcctBalance) &&
 ( Size == "Large" ||
   Size == "Very Large" )
Rank =
 100* (Breed == "Saint
 Bernard") - Price
. . .
```

ClassAd Values

- Literals
  - Strings (“RedHat6”), integers, floats, boolean (true/false), …
- Expressions
  - Similar look to C/C++ or Java : operators, references, functions
  - References: to other attributes in the same ad, or attributes in an ad that is a candidate for a match
  - Operators: +, -, *, /, <, <=,>, >=, ==, !=, &&, and || all work as expected
  - Built-in Functions: if/then/else, string manipulation, regular expression pattern matching, list operations, dates, randomization, math (ceil, floor, quantize,…), time functions, eval, …

Four-valued logic

- ClassAd Boolean expressions can return four values:
  - True
  - False
  - Undefined (a reference can't be found)
  - Error (Can't be evaluated)
- Undefined enables explicit policy statements *in the absence of data* (common across administrative domains)
- Special meta-equals (=?=) and meta-not-equals (=!=) will never return Undefined

```
[
  HasBeer = True
  GoodPub1 = HasBeer == True
  GoodPub2 = HasBeer =?= True
]
```

```
[
  GoodPub1 = HasBeer == True
  GoodPub2 = HasBeer =?= True
]
```

ClassAd Types

- HTCondor has many types of ClassAds
  - A "Job Ad" represents a job to Condor
  - A "Machine Ad" represents a computing resource
  - Others types of ads represent other instances of other services (daemons), users, accounting records.

The Magic of Matchmaking

- Two ClassAds can be matched via special attributes: Requirements and Rank
- Two ads match if both their Requirements expressions evaluate to True
- Rank evaluates to a float where higher is preferred; specifies the which match is desired if several ads meet the Requirements.
- Scoping of attribute references when matching
  - MY.name – Value for attribute “name” in local ClassAd
  - TARGET.name – Value for attribute “name” in match candidate ClassAd
  - Name – Looks for “name” in the local ClassAd, then the candidate ClassAd

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```

Daemons & Job Startup

The condor_master

- Every condor machine needs a master
- Like "~~systemd~~", or "init"
- Starts daemons, restarts crashed daemons
- Tunes machine for condor

Quick Review of Daemons

condor_master: runs on all machine, always

   plus a condor_procd, condor_shared_port

condor_schedd: runs on submit machine

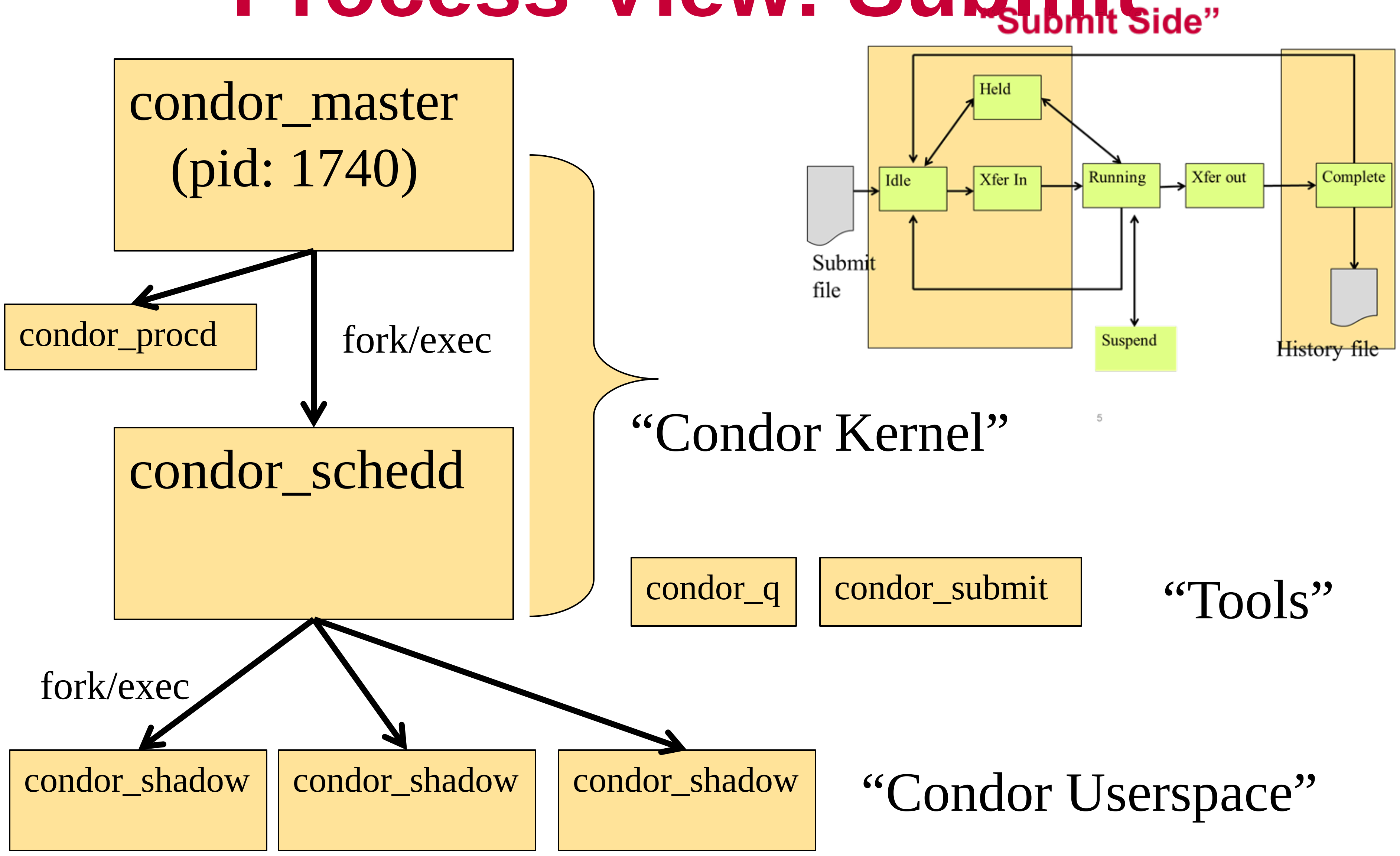
  condor_shadow: one per job

condor_startd: runs on execute machine

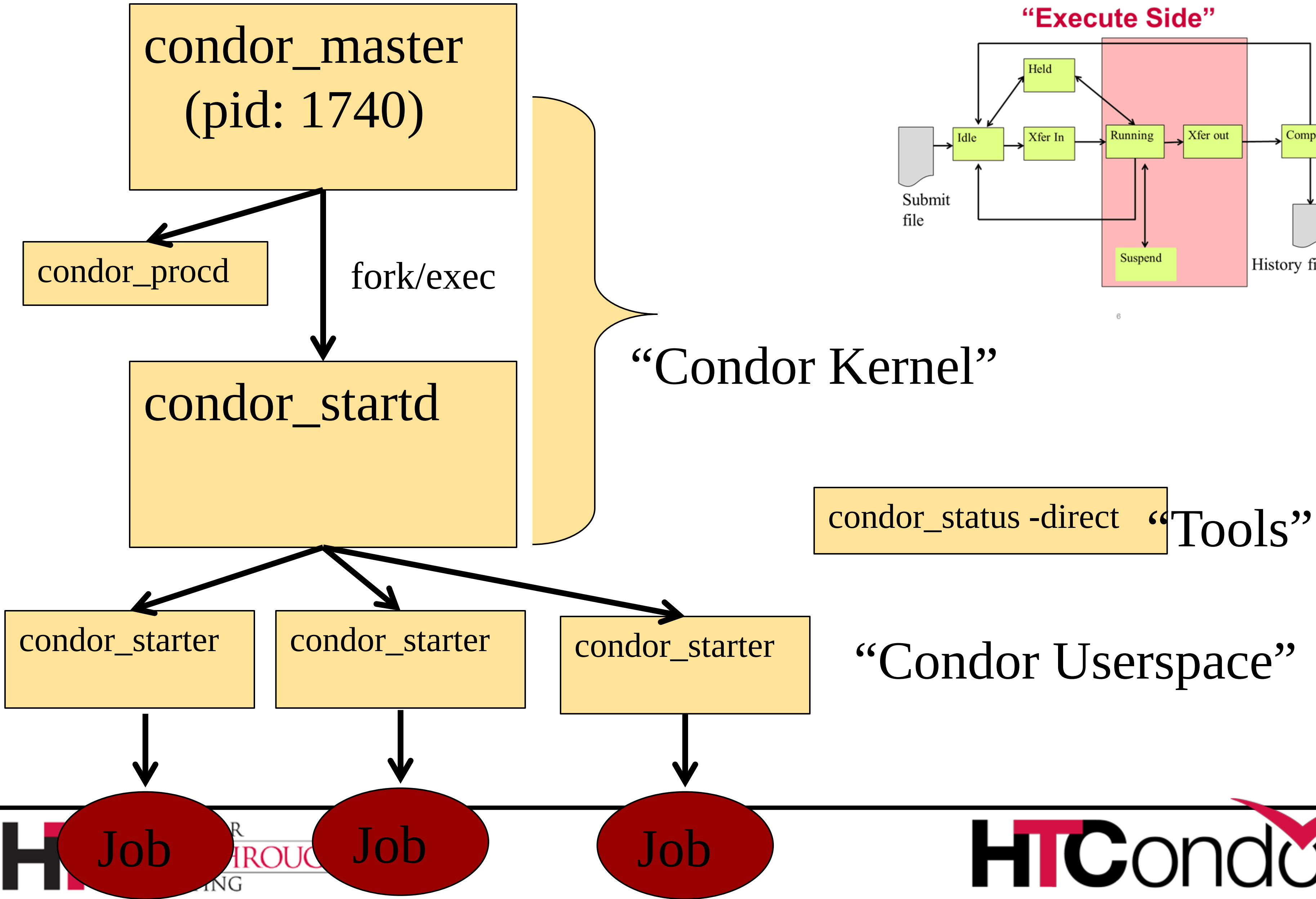
   condor_starter: one per job

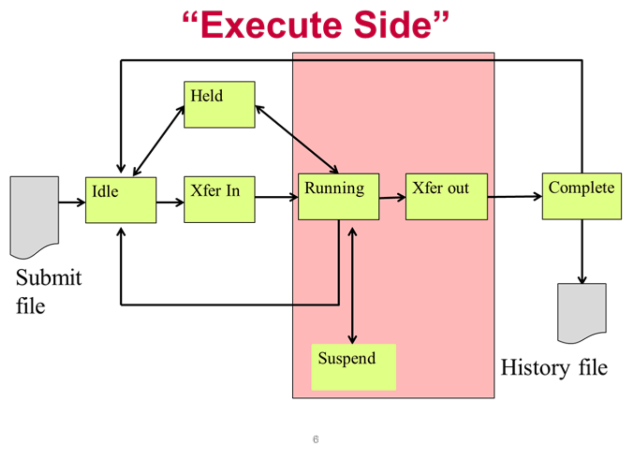
condor_negotiator/condor_collector

Process View: Submit

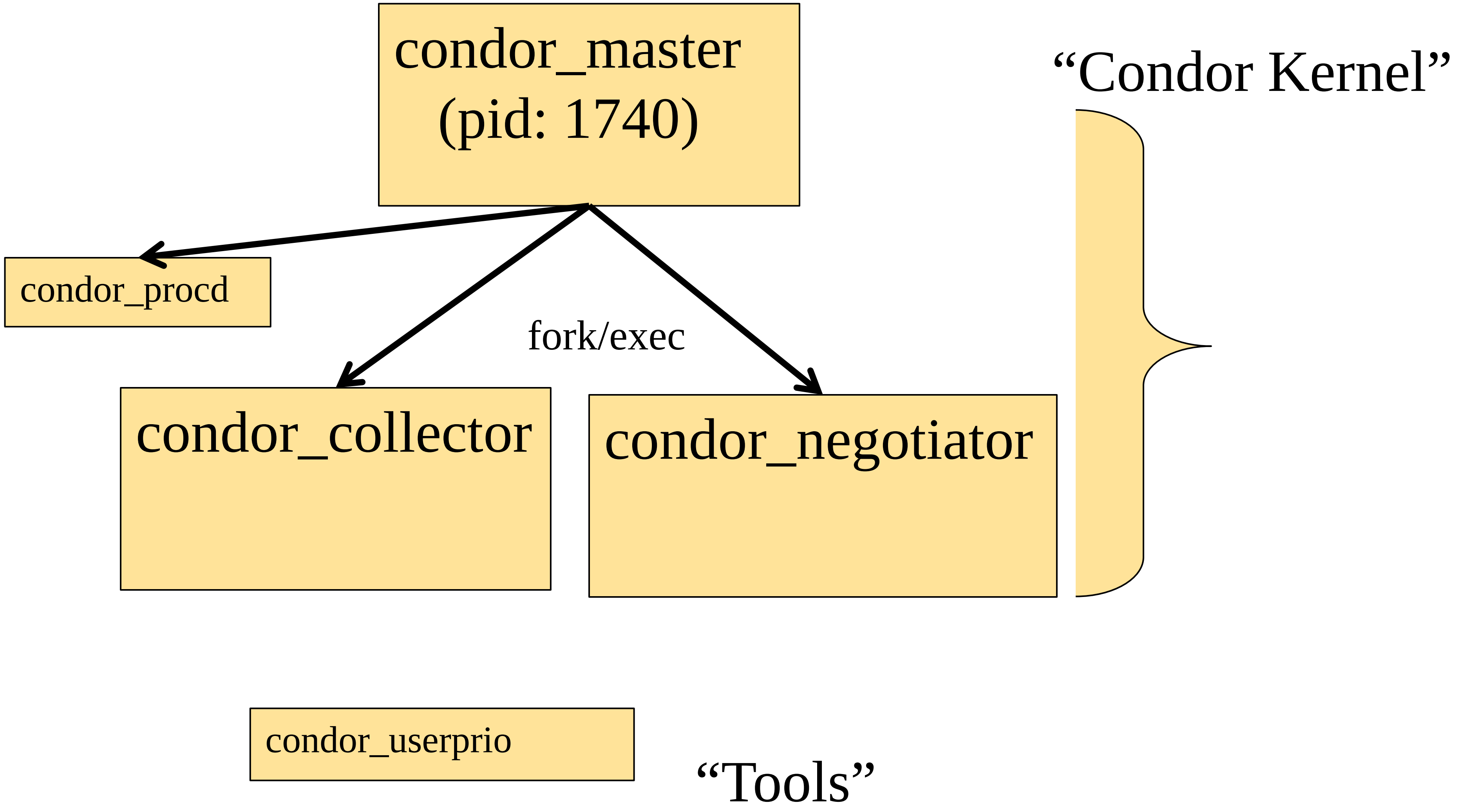


Process View: Execute

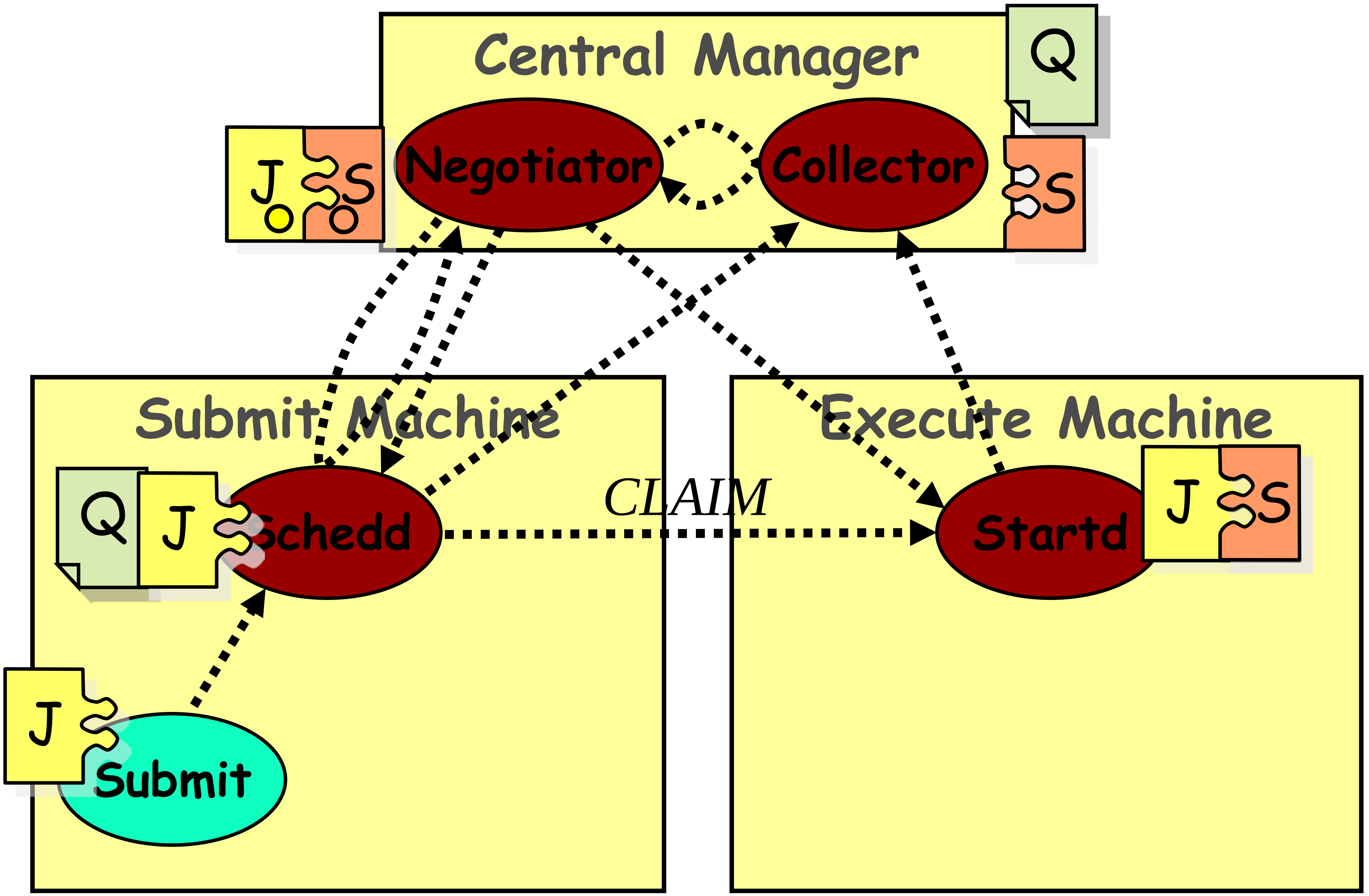




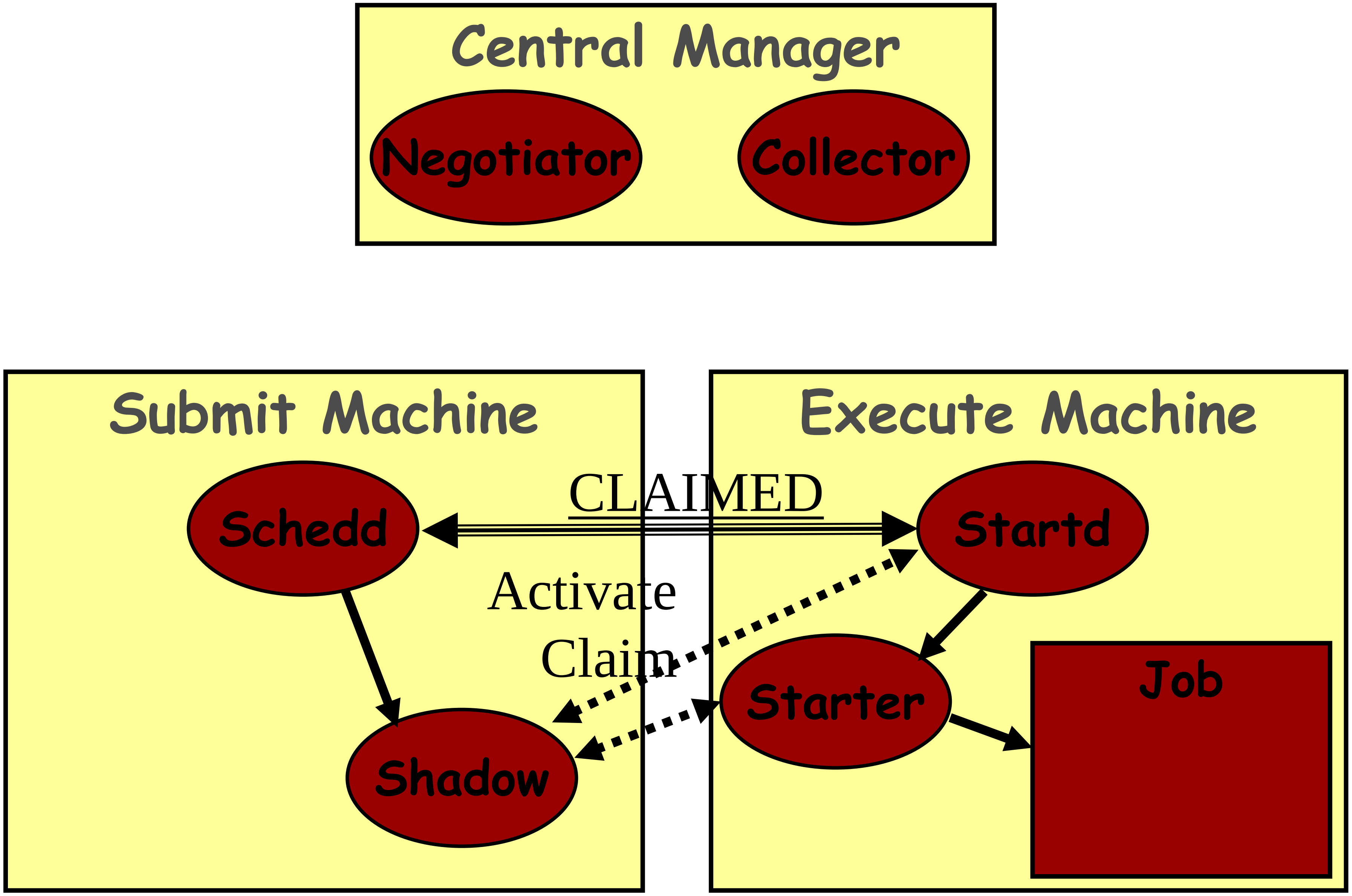
Process View: Central Manager



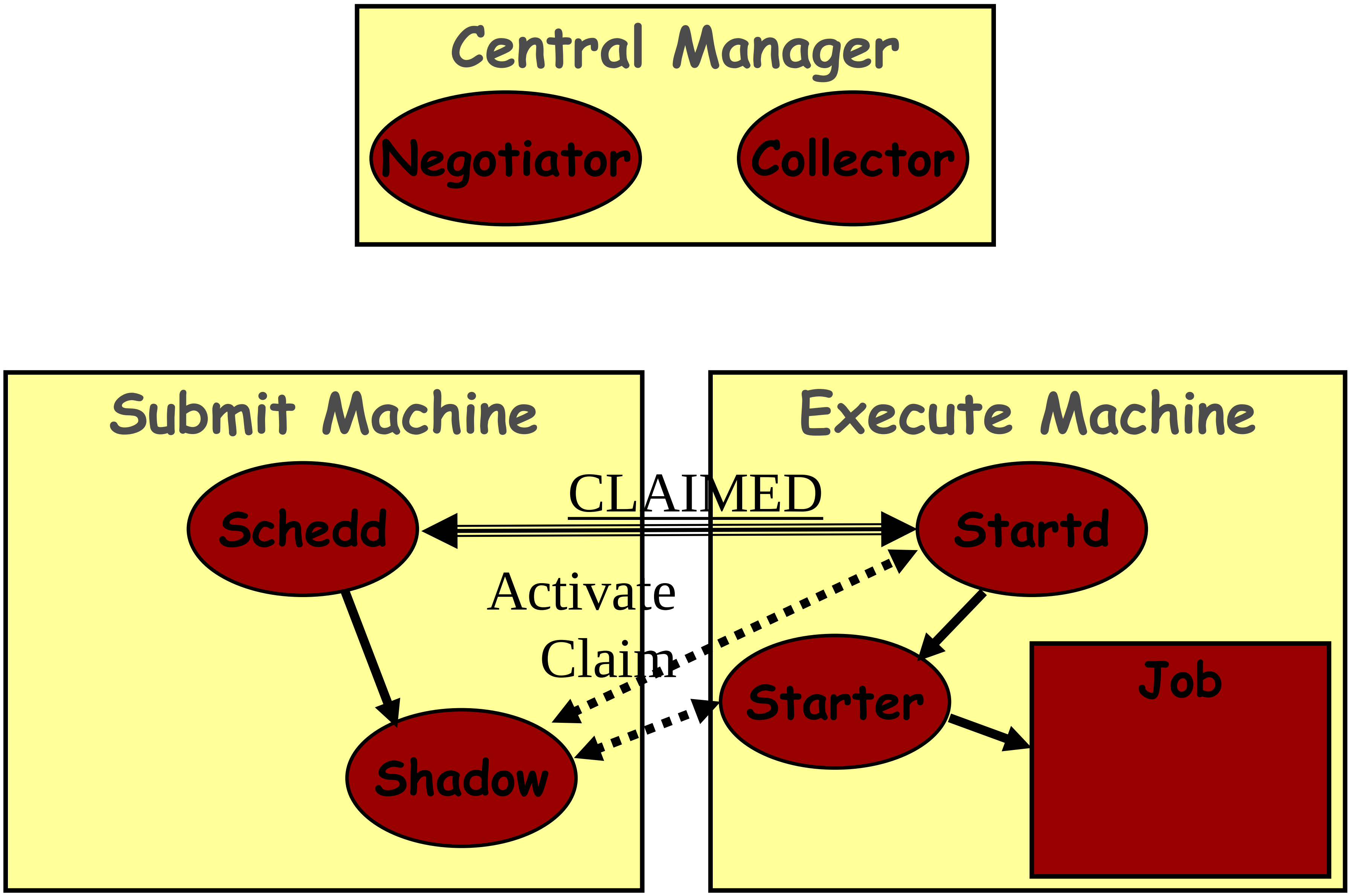
Claiming Protocol



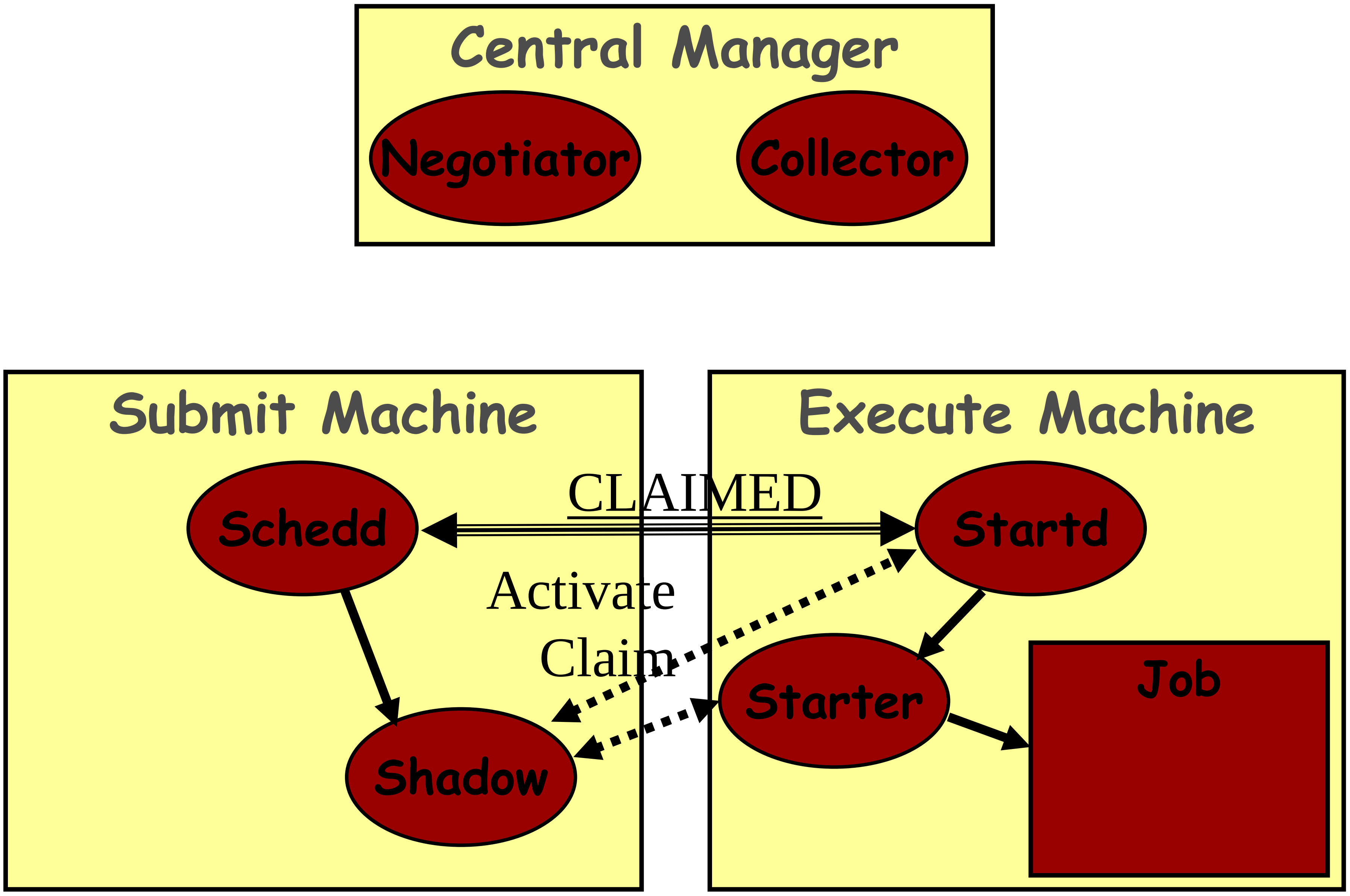
Claim Activation



Repeat until Claim released



Repeat until Claim released



When is claim released?

- When relinquished by one of the following
  - lease on the claim is not renewed
    - Why? Machine powered off, disappeared, etc
  - schedd
    - Why? Out of jobs, shutting down, schedd didn't "like" the machine, etc
  - startd
    - Why? Policy re claim lifetime, prefers a different match (via Rank), non-dedicated desktop, etc
  - negotiator
    - Why? User priority inversion policy
  - explicitly via a command-line tool
    - E.g. condor_vacate

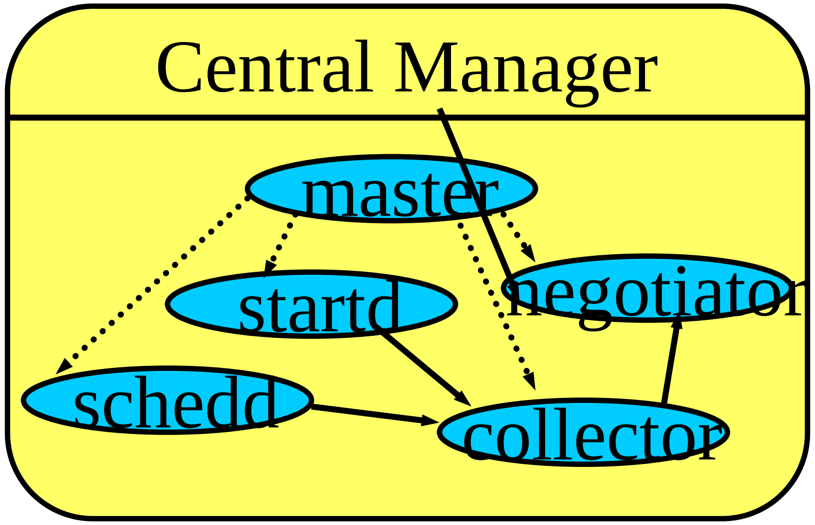
Some items to notice

- Machines (startds) or submitters (schedds) can dynamically appear and disappear
  - A key for expanding a pool into clouds or grids
- Scheduling policy can be very flexible (custom attributes) and very distributed
- Central manager just makes a match, then gets out of the way
  - CM not consulted at job boundaries, only when moving a slot from one user to another
- Lots of network arrows on previous slides
  - Reflects the P2P nature of HTCondor

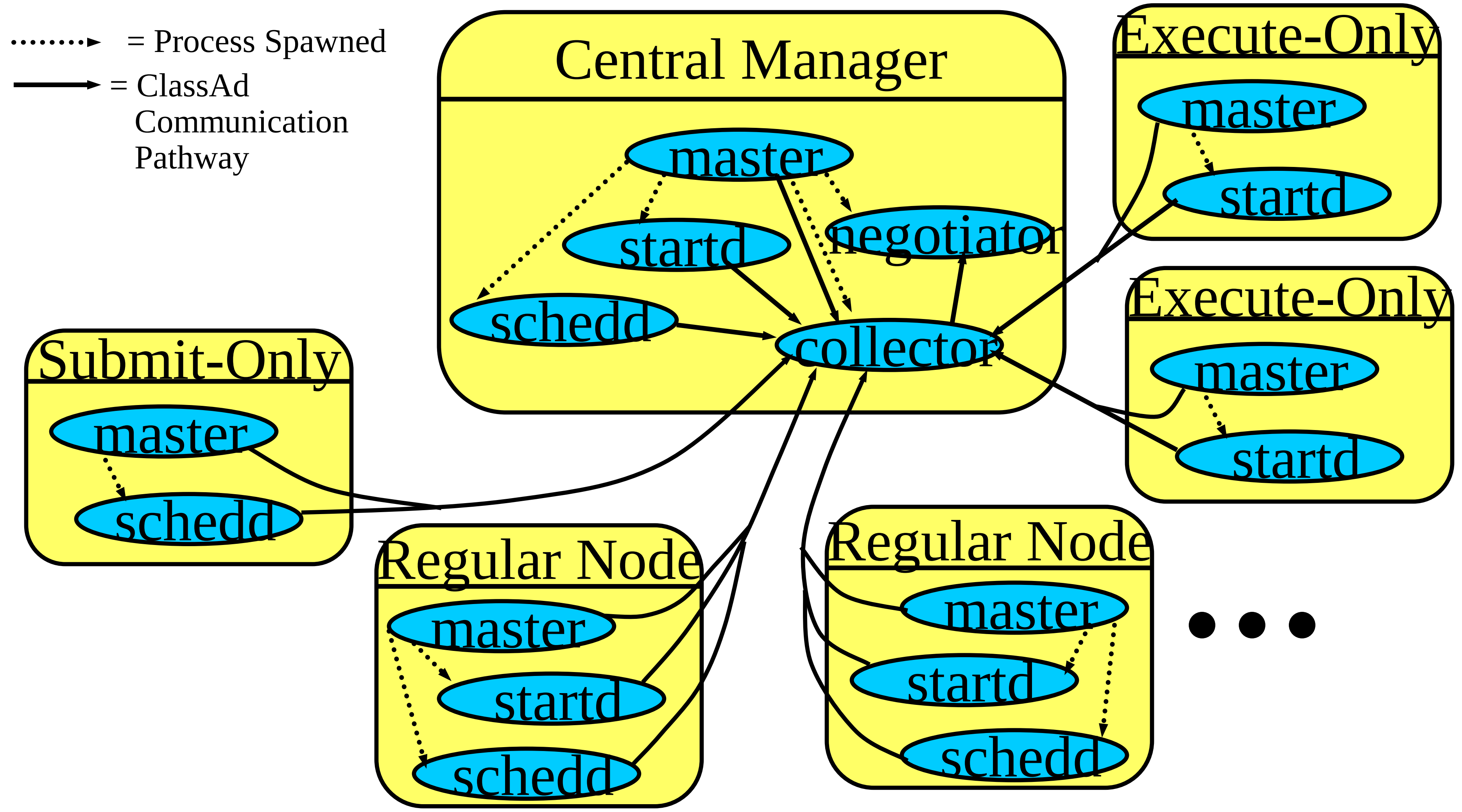
Layout of a Personal Condor Pool

⋯⋯⋯► = Process Spawned

———► = ClassAd Communication Pathway



Layout of a General Condor Pool



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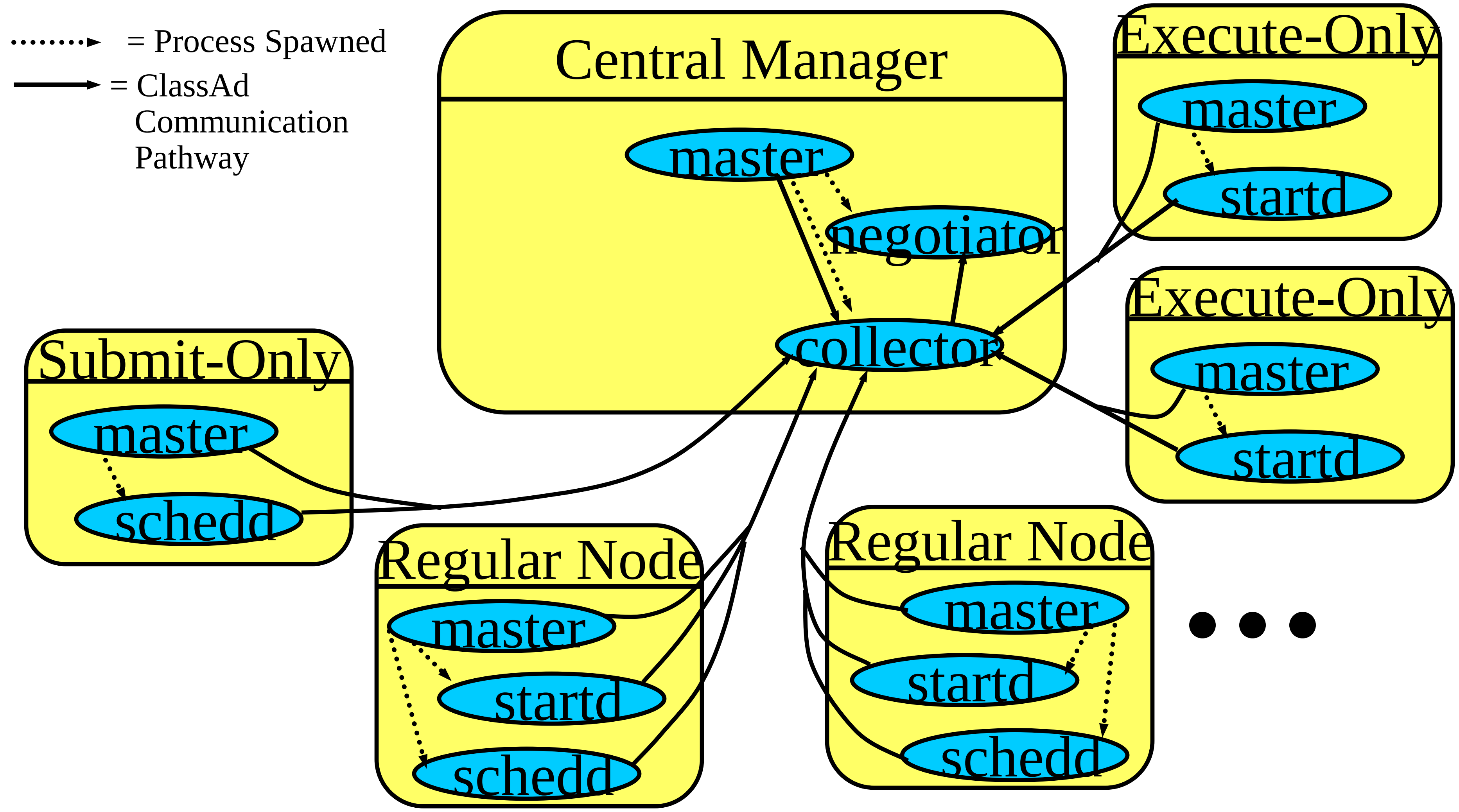


Policy

- "Don't even think about it" by Kat

Policy Expressions

- Policy Expressions allow jobs and machines to restrict access, handle errors and retries, perform job steering, set limits, when/where jobs can start, etc.

Assume a simple setup

- Lets assume a pool with only one single user (me!).
    - no user/group scheduling concerns, we'll get to that later…

We learned earlier…

- Job submit file can specify Requirements and Rank expressions to express constraints and preferences on a match

```
Requirements = OpSysAndVer==“RedHat6”
Rank = kflops
Executable = matlab
queue
```

- Another set of policy expressions control job status

Job Status Policy Expressions

- User can supply job policy expressions in the job submit file. See condor_submit man page.
- These expressions can reference any job ad attribute.

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

Job Policy Expressions

- Do not remove 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 =
  ( ExitCode =!= 0 ) ||
  ( (time() - JobStartDate) < 3600)
```

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

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

Job Policies by the Admin

- Admins can also provide supply periodic job policy expressions in the condor_config file.
- These expressions impact all jobs submitted to a specific schedd.

```
system_periodic_remove = <expression>
system_periodic_hold = <expression>
system_periodic_release = <expression>
```

- **What is the period? Frequency of evaluation is configurable via a floor (1 minute), max (20 minutes), and schedd timeslice (1%).**

Startd Policy Expressions

- How do you specify Requirements and Rank for machine slots?
- Specified in condor_config
- Machine slot policy (or ‘startd policy’) expressions can reference items in either the machine or candidate job ClassAd (See manual appendix for list)

Administrator Policy Expressions

- Some Startd Expressions (when to start/stop jobs)
  - START = <expr>
  - RANK = <expr>
  - SUSPEND = <expr>
  - CONTINUE = <expr>
  - PREEMPT = <expr>   (*really means evict)*
    - And the related WANT_VACATE = <expr>

Startd's START

- START is the primary policy
- When FALSE the machine enters the Owner state and will not run jobs
- Acts as the Requirements expression for the machine, the job must satisfy START
  - Can reference job ClassAd values including Owner and ImageSize

Startd's RANK

- Indicates which jobs a machine prefers
- Floating point number, just like job rank
  - Larger numbers are higher ranked
  - Typically evaluate attributes in the Job ClassAd
  - Typically use + instead of &&
- Often used to give priority to owner of a particular group of machines
- Claimed machines still advertise looking for higher ranked job to preempt the current job
  - LESSON: *Startd Rank creates job preemption*

Startd’s PREEMPT

- Really means vacate (I prefer nothing vs this job!)
- When PREEMPT becomes true, the job will be killed and go from Running to Idle
- Can “kill nicely”
  - WANT_VACATE = <expr>; if true then send a SIGTERM and follow-up with SIGKILL after MachineMaxVacateTime seconds.

Startd’s Suspend and Continue

- When True, send SIGSTOP or SIGCONT to all processes in the job

Default Startd Settings

- Always run jobs to completion

```
START = True
RANK  = 0
PREEMPT = False
SUSPEND  = False
CONTINUE  = True
```

OR

use policy: always_run_jobs

Policy Configuration

- I am adding special new nodes, only for simulation jobs from Math. If none, simulations from Chemistry. If none, simulations from anyone.

Prefer Chemistry Jobs

```
START = KindOfJob =?= “Simulation”
RANK  =
   10 * Department =?= “Math” +
   Department =?= “Chemistry”
SUSPEND = False
PREEMPT = False
```

Policy Configuration

- *Don’t let any job run longer than 24 hrs, except Chemistry jobs can run for 48 hrs.*

Settings for showing runtime limits

```
START = True
RANK = 0
PREEMPT = TotalJobRunTime >
  ifThenElse(Department=?=“Chemistry”,
                  48 * (60 * 60),
                  24 * (60 * 60) )
```

Note: this will result in the job going back to Idle in the queue to be rescheduled.

Runtime limits with a chance to checkpoint

```
START = True
RANK = 0
PREEMPT = TotalJobRunTime >
  ifThenElse(Department=?=“Chemistry”,
                 48 * (60 * 60),
                 24 * (60 * 60) )
WANT_VACATE = True
MachineMaxVacateTime = 300
```

Wonder if the user will have any idea why their jobs was evicted….

Runtime limits with job hold

```
START = True
RANK = 0
TIME_EXCEEDED = TotalJobRunTime >
  ifThenElse(Department=?=“Chemistry”,
                48 * (60 * 60),
                24 * (60 * 60) )
PREEMPT = $(TIME_EXCEEDED)
WANT_HOLD = $(TIME_EXCEEDED)
WANT_HOLD_REASON =
   ifThenElse( Department=?=“Chemistry”,
   “Chem job failed to complete in 48 hrs”,
   “Job failed to complete in 24 hrs” )
```

```
C:\temp>condor_q


-- Submitter: ToddsThinkpad : <127.0.0.1:49748> : ToddsThinkpad
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD
   1.0   tannenba        12/5  17:29   0+24:00:03 H  0   0.0  myjob.exe

1 jobs; 0 completed, 0 removed, 0 idle, 0 running, 1 held, 0 suspended

C:\temp>condor_q -hold


-- Submitter: ToddsThinkpad : <127.0.0.1:49748> : ToddsThinkpad
 ID      OWNER            HELD_SINCE  HOLD_REASON
   1.0   tannenba        12/6  17:29 Job failed to complete in 24 hrs

1 jobs; 0 completed, 0 removed, 0 idle, 0 running, 1 held, 0 suspended
```

Custom Slot Attributes

- Can add attributes to a slot’s ClassAd, typically done in the local configuration file

```
INSTRUCTIONAL=TRUE
NETWORK_SPEED=1000
STARTD_EXPRS=INSTRUCTIONAL,
  NETWORK_SPEED
```

Custom Slot Attributes

- Jobs can now specify Rank and Requirements using new attributes:

```
Requirements = INSTRUCTIONAL=!=TRUE
Rank = NETWORK_SPEED
```

- Dynamic attributes are available; see **`STARTD_CRON_*`** in the manual

Further Machine Policy Information

- For further information, see section 3.5 "Policy Configuration for the *condor_startd*" in the HTCondor manual
- htcondor-users mailing list

  http://research.cs.wisc.edu/htcondor/mail-lists/

Condor Installation Basics

Let’s Install HTCondor

› Either with tarball (good if non-root)
  • tar xvf htcondor-8.6.2-redhat6

› Or native packages (RPM, DEB) if root install

```
$ rpm --import https://research.cs.wisc.edu/htcondor/yum/RPM-GPG-KEY-HTCondor

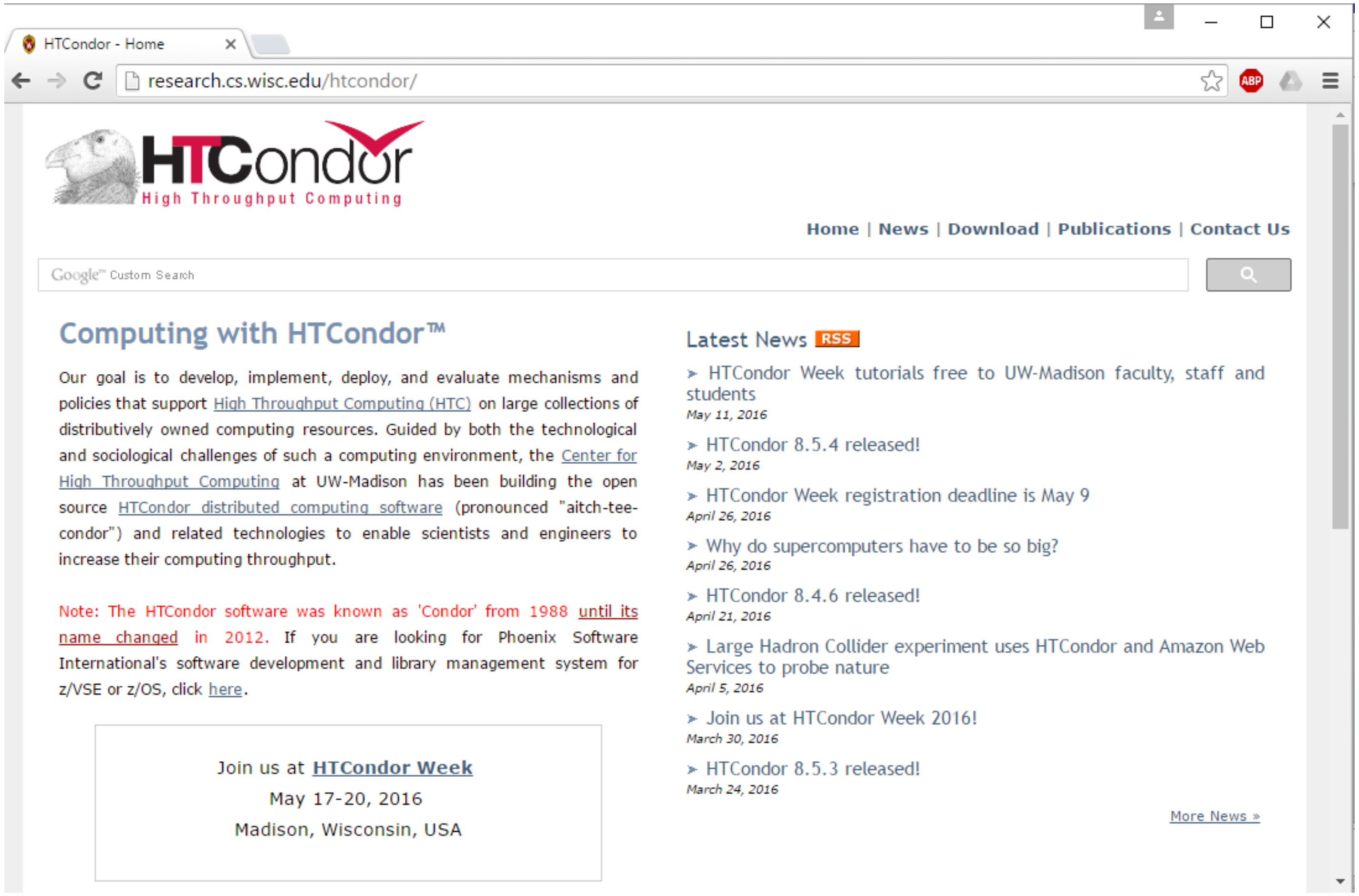
$ yum-config-manager --add-repo
https://research.cs.wisc.edu/htcondor/yum/repo.d/htcondor-development-rhel7.repo

$ yum install -y condor-all

$ systemctl start condor

$ systemctl enable condor
```

http://htcondorproject.org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Computing with HTCondor™

Our goal is to develop, implement, deploy, and evaluate mechanisms and policies that support High Throughput Computing (HTC) on large collections of distributively owned computing resources. Guided by both the technological and sociological challenges of such a computing environment, the Center for High Throughput Computing at UW-Madison has been building the open source HTCondor distributed computing software (pronounced "aitch-tee-condor") and related technologies to enable scientists and engineers to increase their computing throughput.

Note: The HTCondor software was known as 'Condor' from 1988 until its name changed in 2012. If you are looking for Phoenix Software International's software development and library management system for z/VSE or z/OS, click here.

Join us at HTCondor Week
May 17-20, 2016
Madison, Wisconsin, USA

Latest News RSS

- HTCondor Week tutorials free to UW-Madison faculty, staff and students
  May 11, 2016
- HTCondor 8.5.4 released!
  May 2, 2016
- HTCondor Week registration deadline is May 9
  April 26, 2016
- Why do supercomputers have to be so big?
  April 26, 2016
- HTCondor 8.4.6 released!
  April 21, 2016
- Large Hadron Collider experiment uses HTCondor and Amazon Web Services to probe nature
  April 5, 2016
- Join us at HTCondor Week 2016!
  March 30, 2016
- HTCondor 8.5.3 released!
  March 24, 2016

More News »

Version Number Scheme

- Major.minor.release
  - If minor is even (a.b.c): Stable series
    - Very stable, mostly bug fixes
    - Current: 8.6.x
    - Examples: 8.4.5, 8.6.3
  - If minor is odd (a.b.c): Developer series
    - New features, may have some bugs
    - Current: 8.7
    - Examples: 8.7.1, 8.7.2

The Guarantee

- All minor releases in a stable series interoperate
  - E.g. can have pool with 8.4.0, 8.4.1, etc.
  - But not WITHIN A MACHINE:
    - Only across machines
- The Reality
  - We work really hard to do better
    - 8.4 with 8.2 with 8.5, etc.
    - Part of HTC ideal: can never upgrade in lock-step

Let’s Make a Pool

- First need to configure HTCondor
- 1100+ knobs and parameters!
- Don’t need to set all of them…

Default file locations

```
BIN = /usr/bin
SBIN = /usr/sbin
LOG = /var/condor/log
SPOOL = /var/lib/condor/spool
EXECUTE = /var/lib/condor/execute
CONDOR_CONFIG =
/etc/condor/condor_config
```

Configuration File

- `(Almost)`all configure is in files, “root”
  - **`CONDOR_CONFIG env var`**
  - **`/etc/condor/condor_config`**
- This file points to others
- All daemons share same configuration
- Might want to share between all machines (NFS, automated copies, puppet, etc)

Configuration File Syntax

```
# I’m a comment!
CREATE_CORE_FILES=TRUE
MAX_JOBS_RUNNING = 50
# HTCondor ignores case:
log=/var/log/condor
# Long entries:
collector_host=condor.cs.wisc.edu,\
    secondary.cs.wisc.edu
```

CENTER FOR HIGH THROUGHPUT COMPUTING

HTCondor

Other Configuration Files

- **`LOCAL_CONFIG_FILE`**
  - Comma separated, processed **in order**

```
LOCAL_CONFIG_FILE = \
   /var/condor/config.local,\
/shared/condor/config.$(OPSYS)
```

- **`LOCAL_CONFIG_DIR`**
  - **`Files processed IN LEXIGRAPHIC ORDER`**

```
LOCAL_CONFIG_DIR = \
   /etc/condor/config.d
```

Configuration File Macros

- You reference other macros (settings) with:
  - `A = $(B)`
  - `SCHEDD = $(SBIN)/condor_schedd`
- Can create additional macros for organizational purposes

Configuration File Macros

- Can append to macros:

```
A=abc
A=$(A),def
```

- Later macros in a file overwrite earlier ones
  - B will evaluate to 2:

```
A=1
B=$(A)
A=2
```

Configuration File Macros

› **Can have "config templates"**

```
use feature: gpus
```

› **Can have conditionals**

```
if $(IsMaster)
  …
endif
```

› **Can have includes**

```
include: /path/to/file
```

› **Can come from stdout of a script**

```
include command: /path/to/script args
```

› **Very enabling! E.g. config from git**

http://htcondor.org/HTCondorWeek2016/presentations/Grasmick_GitConfig.pdf

Config file defaults

- CONDOR_CONFIG “root” config file:
  - /etc/condor/condor_config
- Local config file:
  - /etc/condor/condor_config.local
- Config directory
  - /etc/condor/config.d

Config file recommendations

- For “system” condor, use default
  - Global config file read-only
    - /etc/condor/condor_config
  - All changes in config.d small snippets
    - /etc/condor/config.d/05some_example
  - All files begin with 2 digit numbers

- Personal condors elsewhere

condor_config_val

- condor_config_val [-v] <KNOB_NAME>
  - Queries config files
- condor_config_val -set name value
- condor_config_val -dump

- Environment overrides:
- export _condor_KNOB_NAME=value
  - Trumps all others (so be careful)

condor_reconfig

- Daemons long-lived
  - Only re-read config files condor_reconfig command
  - Some knobs don't obey re-config, require restart
    - DAEMON_LIST, NETWORK_INTERFACE
- condor_restart

Got all that?

Let’s make a pool!

- “Personal Condor”
  - All on one machine:
    - submit side IS execute side
  - Jobs always run
- Use defaults where ever possible
- Very handy for debugging and learning

Minimum knob settings

Role

What daemons run on this machine

CONDOR_HOST

- Where the central manager is

Security settings

- Who can do what to whom?

Other interesting knobs

```
LOG = /var/log/condor
```

Where daemons write debugging info

```
SPOOL = /var/spool/condor
```

Where the schedd stores jobs and data

```
EXECUTE = /var/condor/execute
```

Where the startd runs jobs

Minimum knobs for personal Condor

› In `/etc/condor/config.d/50PC.config`

```
# All daemons local
Use ROLE : Personal

CONDOR_HOST = localhost
ALLOW_WRITE = localhost
```

Does it Work?

```
$ condor_status
Error: communication error
CEDAR:6001:Failed to connect to <128.105.14.141:4210>


$ condor_submit
ERROR: Can't find address of local schedd


$ condor_q
Error:
Extra Info: You probably saw this error because the
condor_schedd is not running on the machine you are
trying to query…
```

Checking…

```
$ ps auxww | grep condor_
$
```

Starting Condor

- condor_master

  or
- service start condor

```
$ ps auxww | grep [Cc]ondor
$
Condor 19534  50380           Ss   11:19   0:00 condor_master
root   19535  21692           S    11:19   0:00 condor_procd -A …
condor   19557  69656         Ss   11:19   0:00 condor_collector -f
condor   19559  51272         Ss   11:19   0:00 condor_startd -f
condor   19560  71012         Ss   11:19   0:00 condor_schedd -f
condor   19561  50888         Ss   11:19   0:00 condor_negotiator -f
```

Notice the UID of the daemons

Quick test to see it works

```
$ condor_status
# Wait a few minutes…
$ condor_status
Name                OpSys      Arch   State     Activity LoadAv Mem

slot1@chevre.cs.wi LINUX      X86_64 Unclaimed Idle      0.190 20480
slot2@chevre.cs.wi LINUX      X86_64 Unclaimed Idle      0.000 20480
slot3@chevre.cs.wi LINUX      X86_64 Unclaimed Idle      0.000 20480
slot4@chevre.cs.wi LINUX      X86_64 Unclaimed Idle      0.000 20480

-bash-4.1$ condor_q
-- Submitter: gthain@chevre.cs.wisc.edu : <128.105.14.141:35019> :
chevre.cs.wisc.edu
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD

0 jobs; 0 completed, 0 removed, 0 idle, 0 running, 0 held, 0 suspended
$ condor_restart # just to be sure…
```

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Brief Diversion into daemon logs

- Each daemon logs mysterious info to file
- $(LOG)/DaemonNameLog
- Default:
  - /var/log/condor/SchedLog
  - /var/log/condor/MatchLog
  - /var/log/condor/StarterLog.slotX
- Experts-only view of condor

Let’s make a “real” pool

- Distributed machines makes it hard
  - Different policies on each machines
  - Different owners
  - Scale

Most Simple Distributed Pool

- Requirements:
  - No firewall
  - Full DNS everywhere (forward and backward)
  - We’ve got root on all machines

- HTCondor doesn’t require any of these
  - (but easier with them)

What UID should jobs run as?

- Three Options (all require root):
  - Nobody UID
    - Safest from the machine's perspective
  - The submitting User
    - Most useful from the user's perspective
    - May be required if shared filesystem exists
  - A "Slot User"
    - Bespoke UID per slot
    - Good combination of isolation and utility

UID_DOMAIN SETTINGS

```
UID_DOMAIN = \
same_string_on_submit
TRUST_UID_DOMAIN = true
SOFT_UID_DOMAIN = true
```

If UID_DOMAINs match, jobs run as user, otherwise “nobody”

Slot User

```
SLOT1_USER = slot1
SLOT2_USER = slot2
…
STARTER_ALOW_RUNAS_OWNER = false
EXECUTE_LOGIN_IS_DEDICATED=true
```

Job will run as slotX Unix user

FILESYSTEM_DOMAIN

- HTCondor can work with NFS
  - But how does it know what nodes have it?
- WhenSubmitter & Execute nodes share
  - `FILESYSTEM_DOMAIN` values
    - e.g `FILESYSTEM_DOMAIN = domain.name`
- Or, submit file can always transfer with
  - `should_transfer_files = yes`
- If jobs always idle, first thing to check

3 Separate machines

- Central Manager
- Execute Machine
- Submit Machine

Central Manager

```
Use ROLE : CentralManager
CONDOR_HOST = cm.cs.wisc.edu
ALLOW_WRITE = *.cs.wisc.edu
# to use a non-default port
# default is 9618
#COLLECTOR_HOST=$(CONDOR_HOST):1234
# ^- set this for ALL machines…
```

Submit Machine

```
Use ROLE : submit
CONDOR_HOST = cm.cs.wisc.edu
ALLOW_WRITE = *.cs.wisc.edu
UID_DOMAIN = cs.wisc.edu
FILESYSTEM_DOMAIN = cs.wisc.edu
```

Execute Machine

```
Use ROLE : Execute
CONDOR_HOST = cm.cs.wisc.edu
ALLOW_WRITE = *.cs.wisc.edu
UID_DOMAIN = cs.wisc.edu
FILESYSTEM_DOMAIN = cs.wisc.edu
# default is
#FILESYSTEM_DOMAIN=$(FULL_HOSTNAME)
```

Now Start them all up

- Does order matter?
  - Somewhat: start CM first
- How to check:
- Every Daemon has classad in collector
  - condor_status -schedd
  - condor_status -negotiator
  - condor_status -any

condor_status -any

```
MyType              TargetType          Name

Collector           None                Test Pool@cm.cs.wisc.edu
Negotiator          None                cm.cs.wisc.edu
DaemonMaster        None                cm.cs.wisc.edu
Scheduler           None                submit.cs.wisc.edu
DaemonMaster        None                submit.cs.wisc.edu
DaemonMaster        None                wn.cs.wisc.edu
Machine             Job                 slot1@wn.cs.wisc.edu
Machine             Job                 slot2@wn.cs.wisc.edu
Machine             Job                 slot3@wn.cs.wisc.edu
Machine             Job                 slot4@wn.cs.wisc.edu
```

Debugging the pool

- condor_q / condor_status
- condor_ping ALL –name machine
- Or
- condor_ping ALL –addr ‘<127.0.0.1:9618>’

What if a job is always idle?

- Check userlog – may be preempted often
- run condor_q -better-analyze job_id

Whew!

Tools for admins

condor_off

- Three kinds for submit and execute
- -fast:
  - Kill all jobs immediate, and exit
- -gracefull
  - Give all jobs 10 minutes to leave, then kill
- -peaceful
  - Wait forever for all jobs to exit

condor_restart

- Restarts all daemons on a given machine
- Can be run remotely – if admin priv allows

condor_status

- -collector
- -submitter
- -negotiator
- -schedd
- -master

condor_userprio

- Condor_userprio –allusers
  - Whole talk on this,

condor_fetchlog

- Remotely pulls a log file from remote machine
- condor_fetchlog execute_machine STARTD

Thank You and Additional Resources

- Talk to us!
- http://htcondor.org
- Nice HTCondor FAQs, examples, and documentation from our friends in Canary Islands:

https://is.gd/TjRvY8

- Email list:

http://htcondor.org/mail-lists/

- HTCondor HOWTO Recipes has FAQ on job submission

http://wiki.htcondor.org/index.cgi/wiki?p=HowToAdminRecipes