TopCoffea tutorial June 2021

TopCoffea with the work queue executor

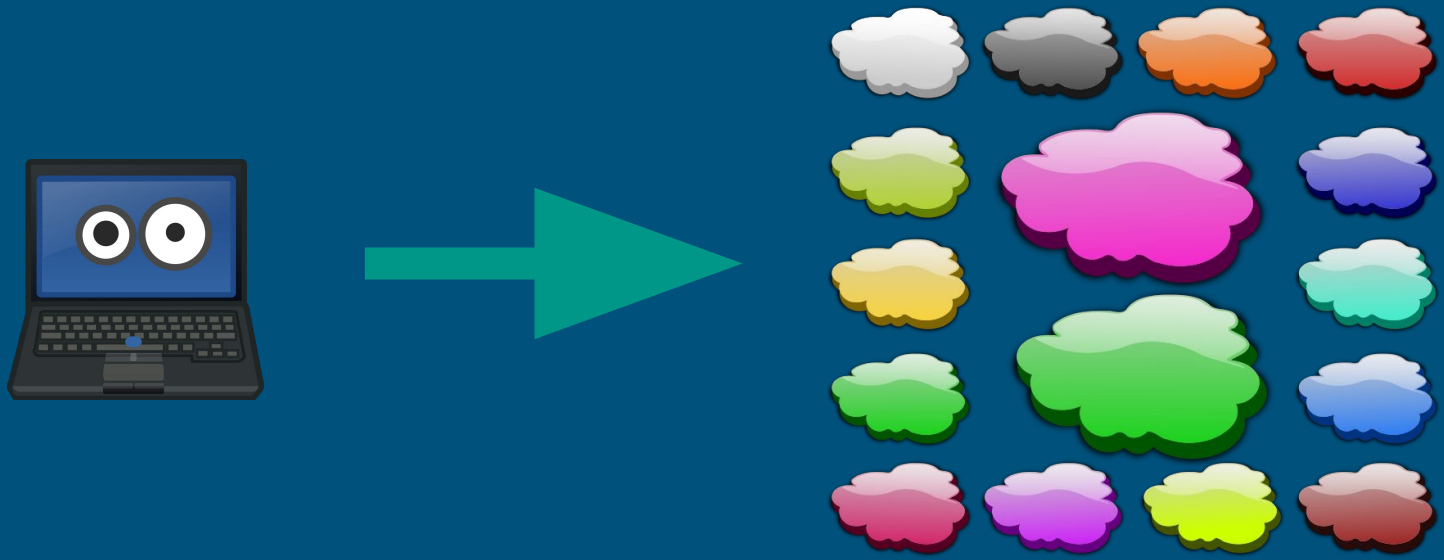
Ben Tovar
btovar@nd.edu

UNIVERSITY OF NOTRE DAME

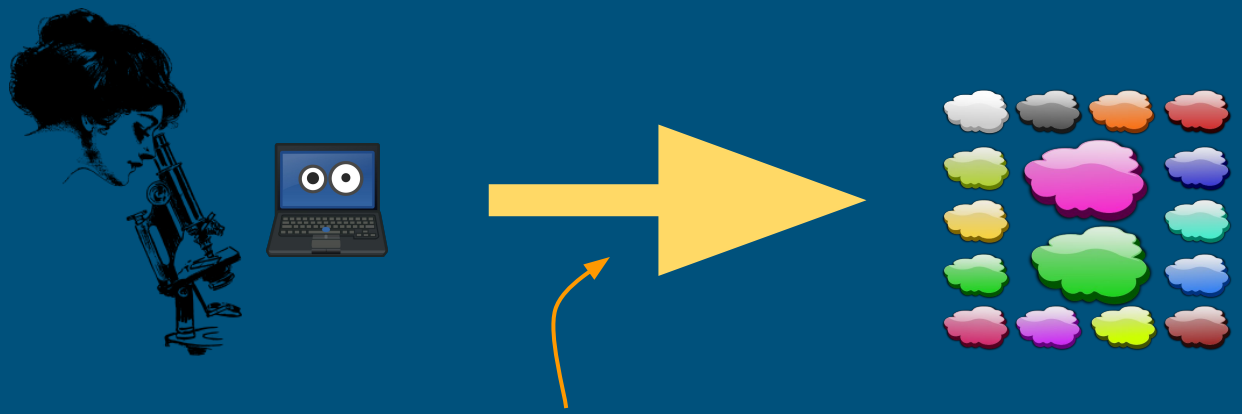
CCTools

where we are

"This demo topcoffea runs on my laptop, but I need much more for the real application. It would be great if we can run O(10K) tasks like this on this cloud/grid/cluster I have heard so much about."



where we want to be



Cooperative Computing Lab Tools (CCTools)

(work queue, resource monitor, ...)

CCTools Objectives

- Harness all the resources that are available: desktops, clusters, clouds, and grids.
- Make it easy to scale up from one desktop to national scale infrastructure.
- Provide familiar interfaces that make it easy to connect existing apps together.
- Allow portability across operating systems, storage systems, middleware…
- Make simple things easy, and complex things possible.
- No special privileges required.

CCTools

- Open source, GNU General Public License.
- Runs on Linux, MacOS*
- Interoperates with many distributed computing systems.
  - Condor, SGE, Torque, Globus, iRODS, Hadoop…

most used components

Makeflow: A portable workflow manager

What to run?

Work Queue: A lightweight distributed execution system

What to run and where to run it?

Chirp: A user-level distributed filesystem

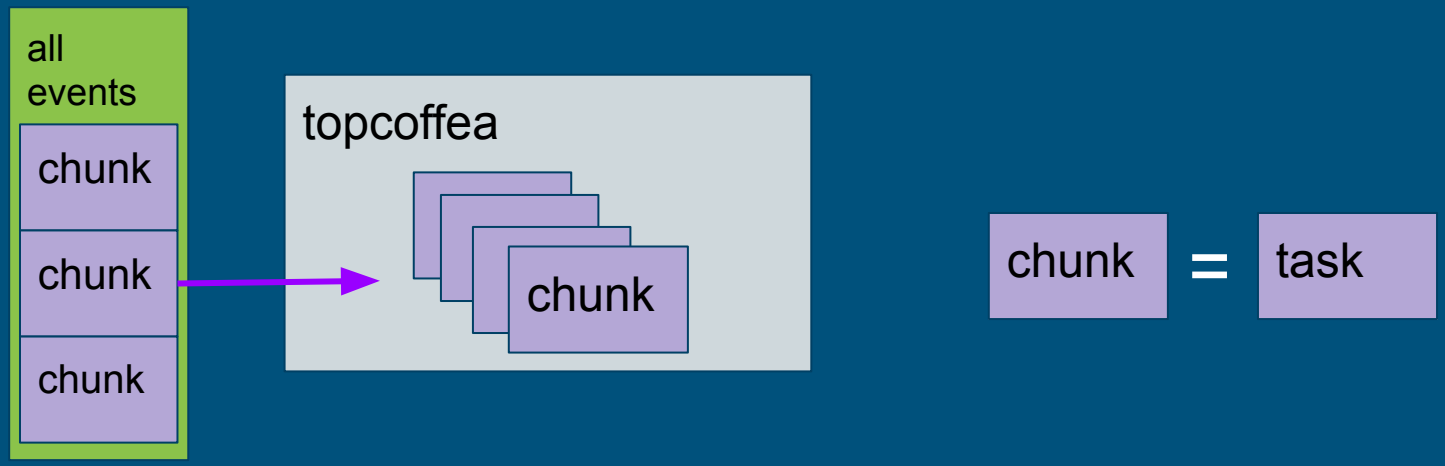
Where to get/put the data?

Parrot: A personal user-level virtual file system

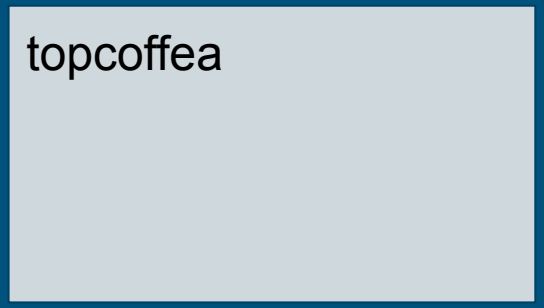
How to read/write the data?

topcoffea as a manager-worker application

manager-worker application

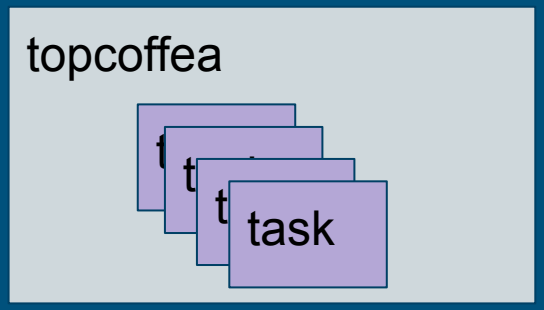


manager-worker application



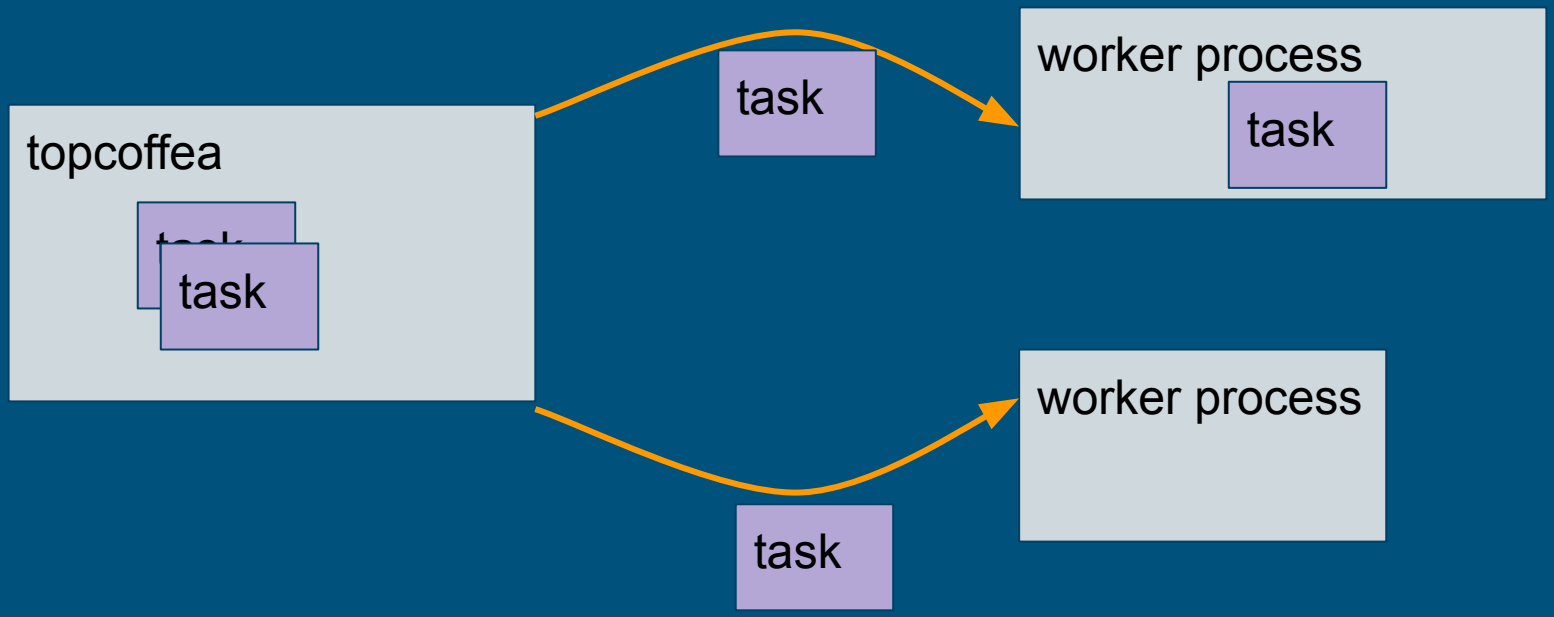
In a manager worker application...

manager-worker application



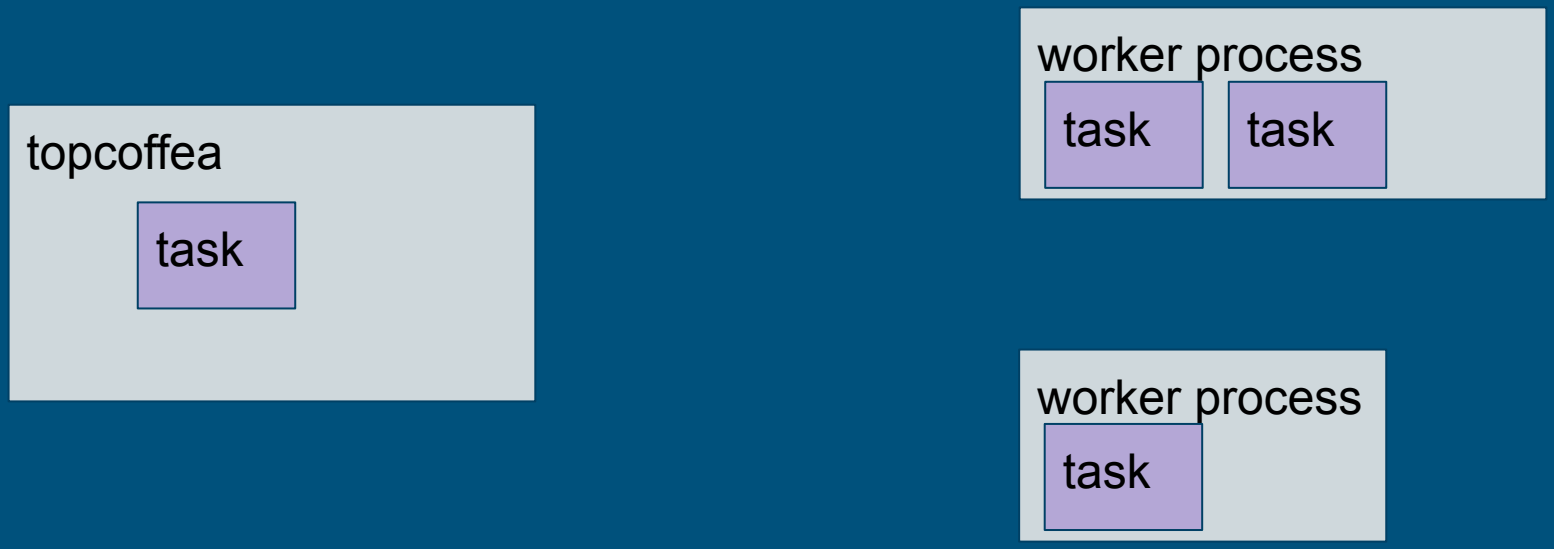
the manager process generates tasks, puts them in a queue...

manager-worker application



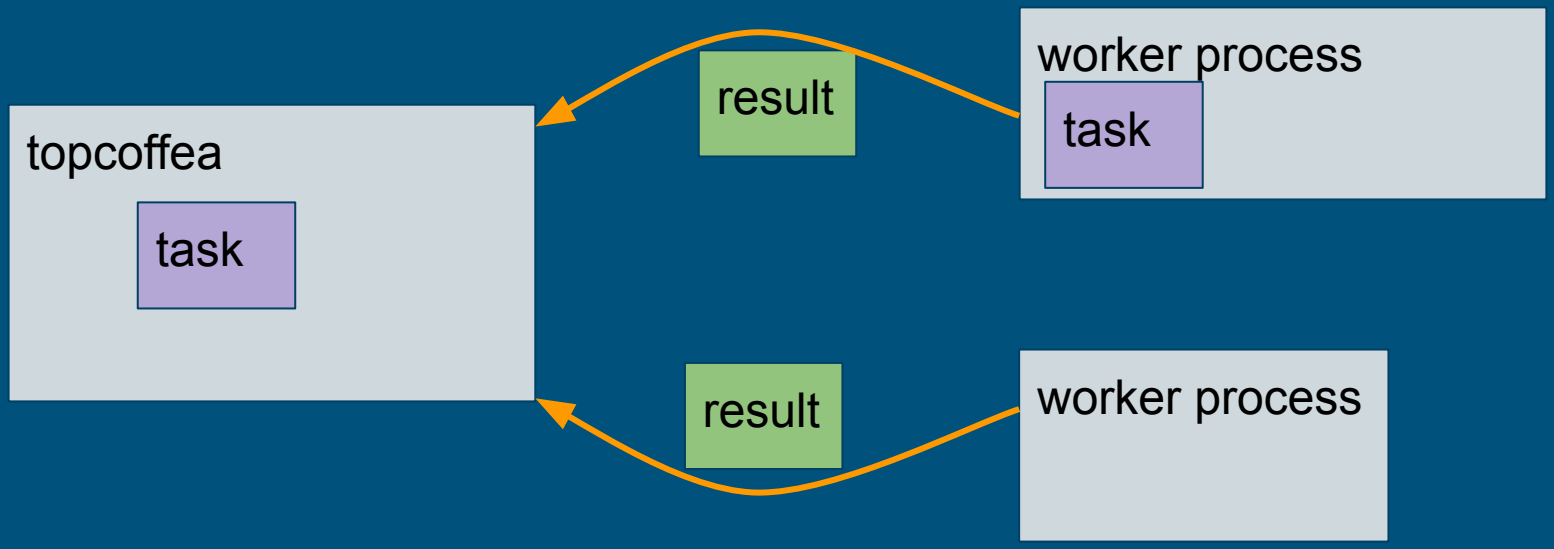
… delivers them to worker processes to execute...

manager-worker application



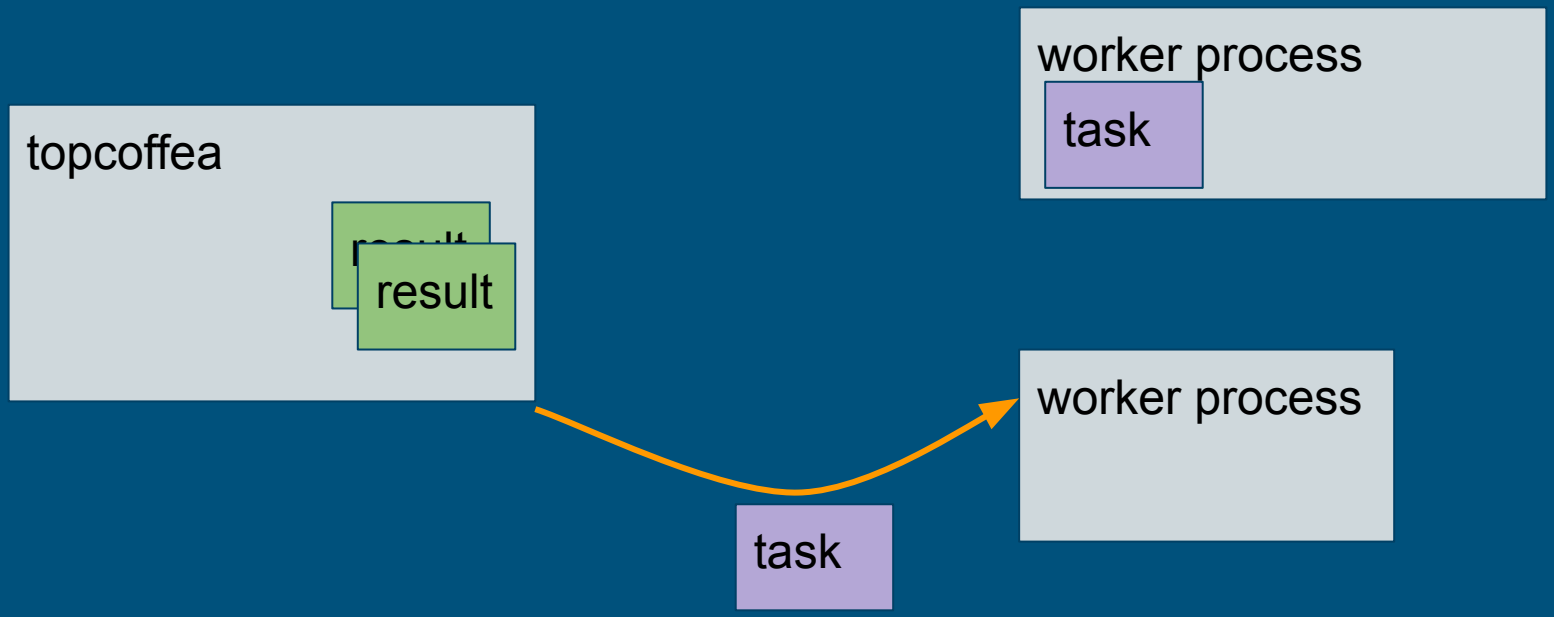
… waits for workers to execute tasks ...

manager-worker application



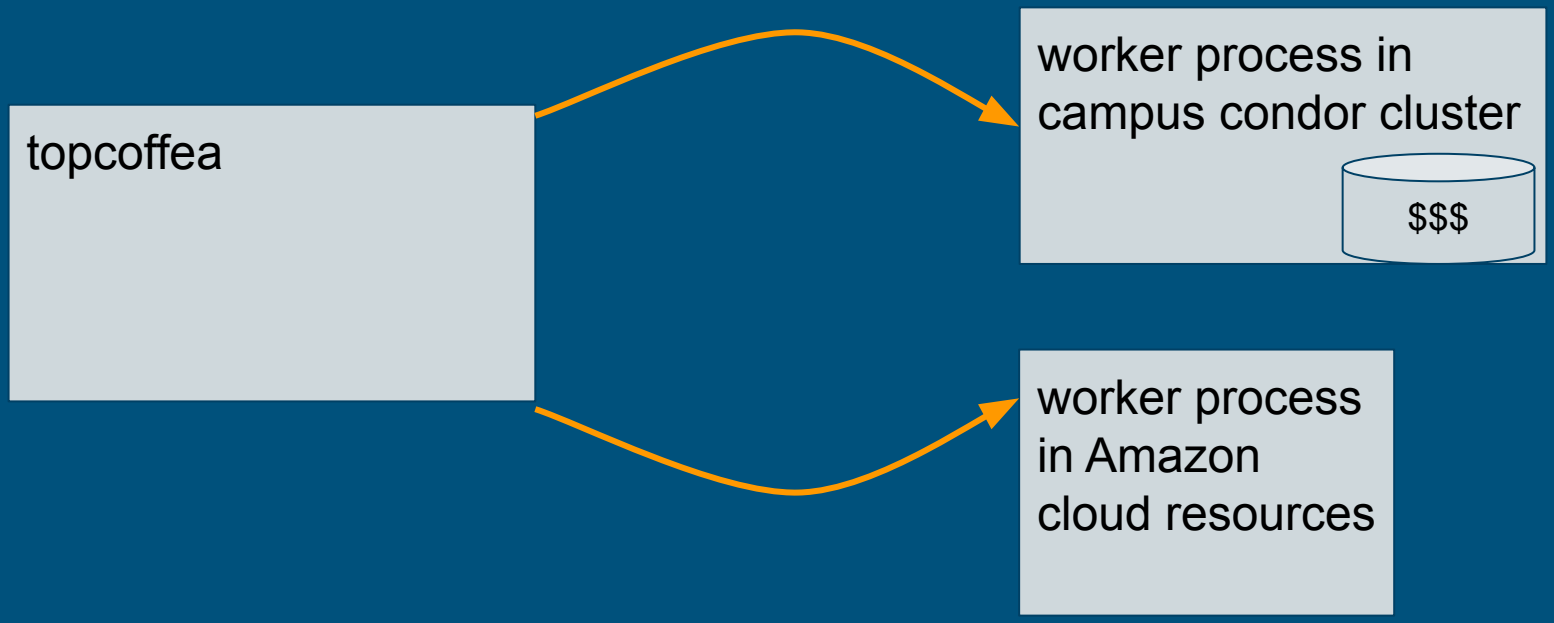
and gathers the results on completion.

manager-worker application

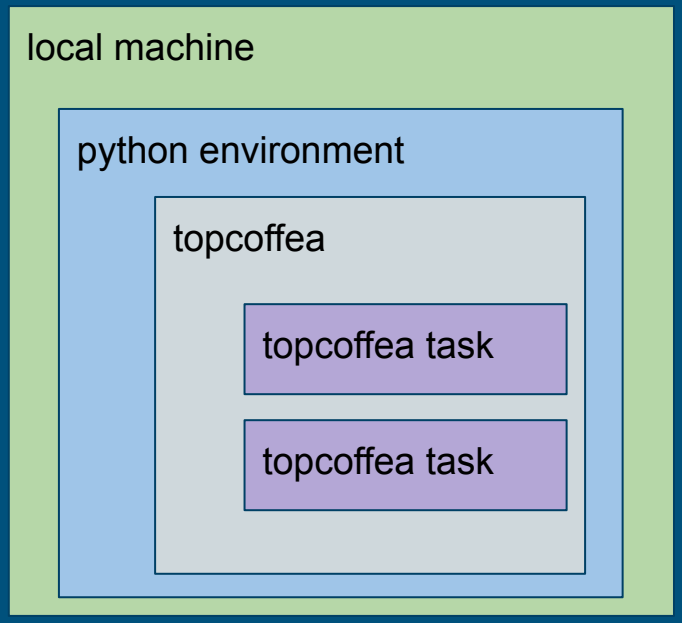


and on and on until no more tasks are generated.

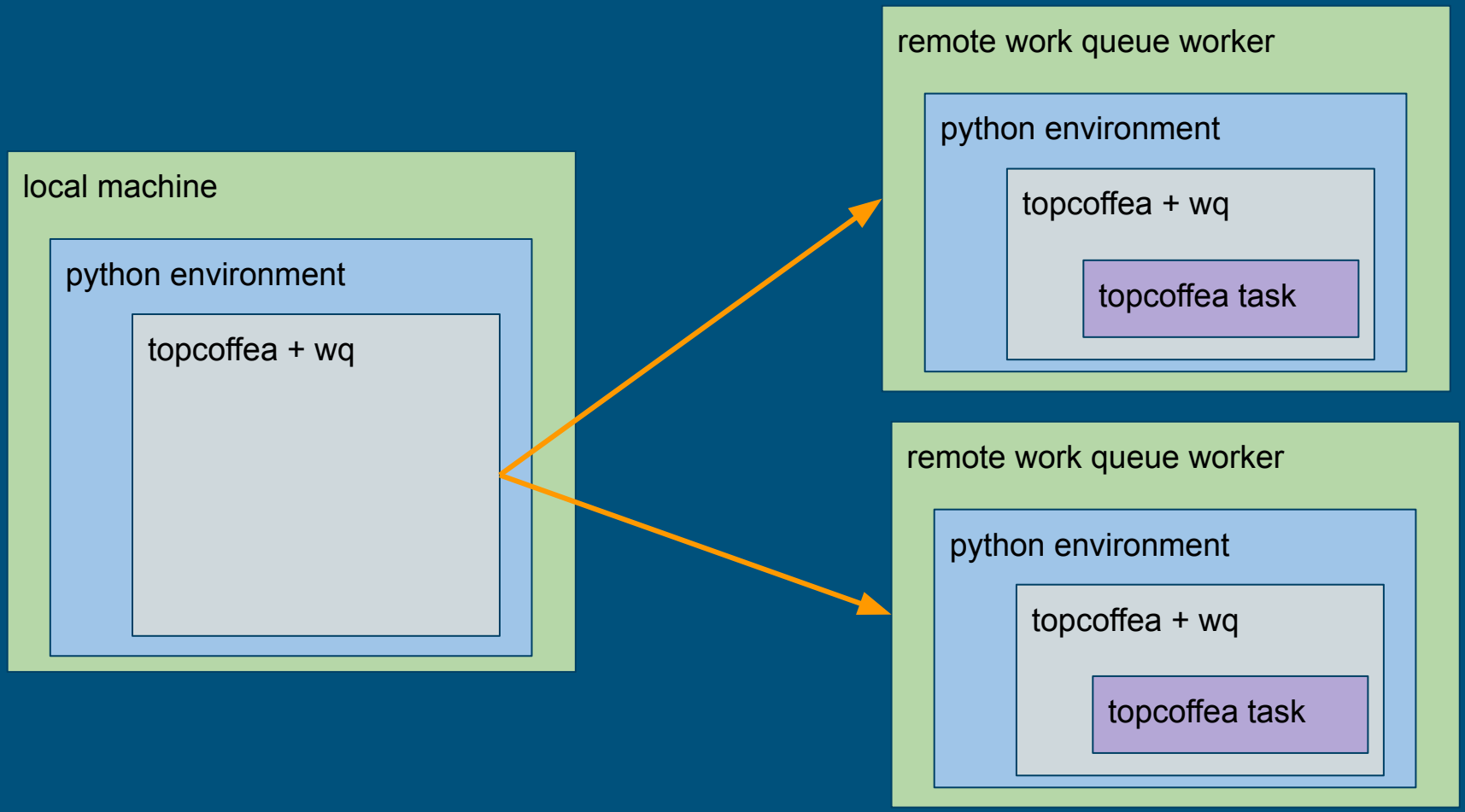
manager-worker application



TopCoffea without work queue



Need to replicate environment at workers

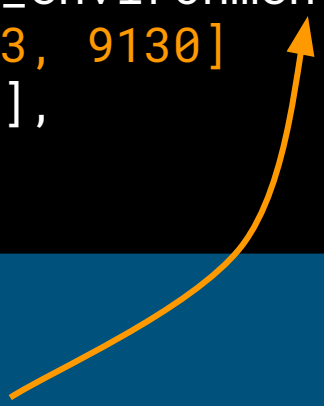


using the work queue executor

```
# topcoffea/analysis/topEFT/work_queue_run.py

...
# minimum executor arguments:

executors_args = {
    'schema': NanoAODSchema,
    'master-name': '{}-wq-coffea'.format(os.environ['USER']),
    'environment-file': topeftenv.get_environment(),
    'port': 9123,    # or a range [9123, 9130]
    'extra-input-files': ["topeft.py"],
}
...
```



`'environment-file': topeftenv.get_environment(),`

- get_environment() generates a python environment that can easily be transferred to workers.
- the environment is created once per the latest git commit in the topcoffea directory.
- if there are unstaged changes, the environment is regenerated everytime!
  - (this is expensive, so remember to commit your changes)
- last three environments are kept in: `topcoffea/analysis/topEFT/envs`

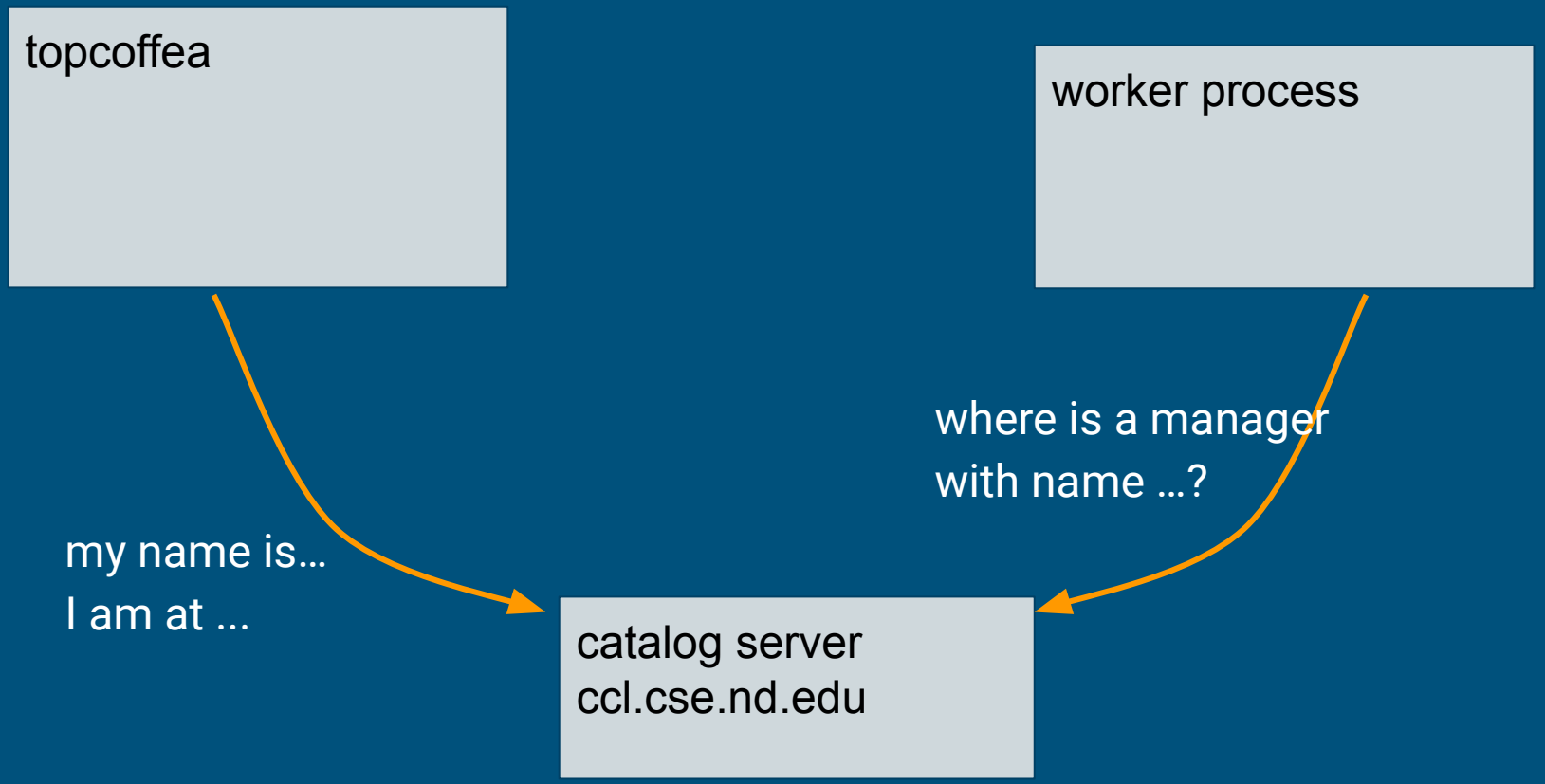
running work queue

```
$ conda activate topcoffea-env
$ cd topcoffea/analysis/topEFT
$ python work_queue_run.py --chunksize 10000
../../topcoffea/cfg/mycfg.cfg

# in some other terminal, launch a worker for that manager
# workers don't need PYTHONPATH set.
# -M my-manager-name to serve managers with that name
# it could be a regexp.

# --single-shot to terminate after serving one manager
# In general workers may serve many managers in their
# lifetime, but only one at a time.
$ conda activate topcoffea-env
$ work_queue_worker -M $USER-wq-topcoffea --single-shot
```

how do workers find the manager?



work_queue_status

```
$ work_queue_status
PROJECT                HOST                        PORT WAITING RUNNING COMPLETE WORKERS
geomeTRIC              128.120.146.3               9000     823       0      761       0
geomeTRIC              128.120.146.3               8999     793       0      791       0
btovar-wq-topcoffea    earth.crc.nd.edu            9123      10       0        0       0
lobster_kmohrman_EFT   earth.crc.nd.edu            9000    2680     899   125466     565
lobster_rgoldouz_L1A   earth.crc.nd.edu            9001       0       7       79      11
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20003     365       0        0       0
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20007     365       0        0       0
EEMT_LARGE-cc5858845   vm65-195.iplantcollabor     20015     365       0        0       0
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20001     365       0        0       0
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20012     365       0        0       0
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20008     365       0        0       0
EEMT-cc58588456b17c2   vm65-195.iplantcollabor     20000     365       0        0       0
```

chosen manager name

create a worker in condor

```
# using \ to break the command in multiple lines
# you can omit the \ and put everything in one line

# run 3 workers in condor, each of size 1 cores, 2048 MB
# of memory and 4096 MB of disk,
# to serve ${USER}-my-makeflow
# and which timeout after 60s of being idle.

$ condor_submit_worker  --cores 1              \
                        --memory 2000          \
                        --disk   4000          \
                        -M my-manager-name      \
                        --timeout 60           \
                        3
```

work queue resource management

resources contract:
running several tasks in a worker concurrently

```
Worker has
available:

i cores
j MB of memory
k MB of disk
```

```
Task needs:



m cores
n MB of memory
o MB of disk
```

Task runs only if it fits in the currently available worker resources.

resources contract example

```
Worker has
available:

8 cores
512 MB of memory
512 MB of disk
```

```
Task a:

4 cores
100 MB of memory
100 MB of disk
```

```
Task b:

3 cores
100 MB of memory
100 MB of disk
```

Tasks a and b may run in worker at the same time.
(Work could still run another 1 core task.)

Beware!
tasks use all worker on missing declarations

```
Worker has
available:

8 cores
512 MB of memory
500 TB of disk
```

```
Task a:

4 cores
100 MB of memory
```

```
Task b:

3 cores
100 MB of memory
```

Tasks a and b may NOT run in worker at the same time.
(disk resource is not specified.)

specifying tasks resources

```
# categories are groups of tasks with the same
# resource requirements

# specify resources in executor args:

executors_args = {
    'schema': NanoAODSchema,
    'master-name': '{}-wq-coffea'.format(os.environ['USER']),
    'environment-file': topeftenv.get_environment(),
    'port': 9123,    # or a range [9123, 9130]
    'extra-input-files': ["topeft.py"],

    'cores': 1,
    'memory': 2000, # in MB
    'disk': 4000,    # in MB
}
```

managing resources

Do nothing (default if tasks don't declare cores, memory or disk):

One task per worker, task occupies the whole worker.

Honor contract (default if tasks declare resources):

Task declares cores, memory, and disk (the three of them!)

Worker runs as many concurrent tasks as they fit.

Tasks **may** use more resources than declared.

Monitoring and Enforcement:

Tasks fail (permanently) if they go above the resources declared.

Automatic resource labeling:

Tasks are retried with resources that maximize throughput, or minimize waste.

Monitoring resource usage

```
#
executors_args = {
    'schema': NanoAODSchema,
    'master-name': '{}-wq-coffea'.format(os.environ['USER']),
    'environment-file': topeftenv.get_environment(),
    'port': 9123,    # or a range [9123, 9130]
    'extra-input-files': ["topeft.py"],

    'cores': 1,
    'memory': 2000, # in MB
    'disk': 4000,    # in MB

    'resource-monitor': True,     # does not work in OSX
    'verbose': True
}
```

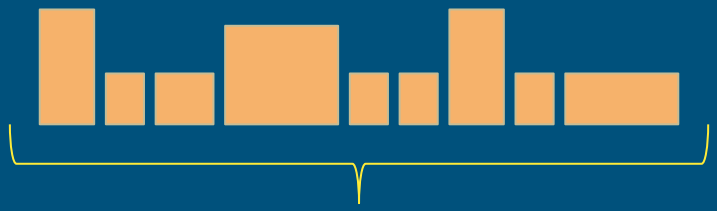
Monitoring resource usage

```
Task (id #1) complete: ./certs_wrapper.sh --environment full_env_d7122b27_HEAD.tar.gz --unp
nction.p item_0.p output_0.p (return code 0)
Allocated cores: 1, memory: 2000 MB, disk: 4000 MB, gpus: 0
Measured cores: 1, memory: 631 MB, disk 408 MB, gpus: 0, runtime 39.550364
```

Tasks fail permanently on resource exhaustion

```
Task (id #1) complete: ./certs_wrapper.sh --environment full_env_d7122b27_HEAD.tar.gz --unpack-to
nction.p item_0.p output_0.p (return code 143)
Allocated cores: 1, memory: 2 MB, disk: 2 MB, gpus: 0
Measured cores: 1, memory: 1 MB, disk 391 MB, gpus: 0, runtime 0.003314
Task id #1 failed with code: 16
```

automatic resource labeling
when you don't know how big your tasks are

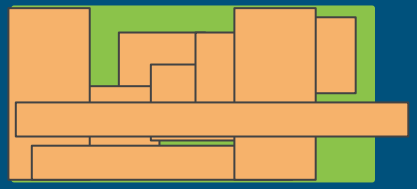


Tasks which size
(e.g., cores, memory, and disk)
is not known until runtime.

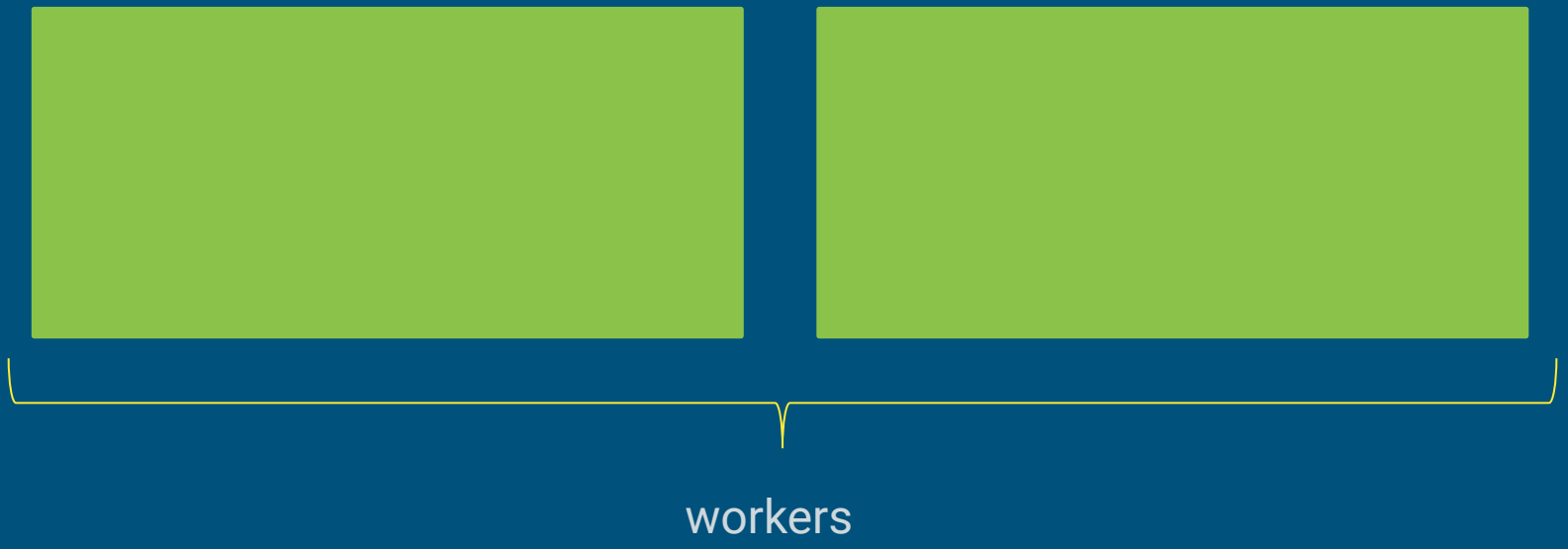
workers

One task per worker:
Wasted resources, reduced throughput.

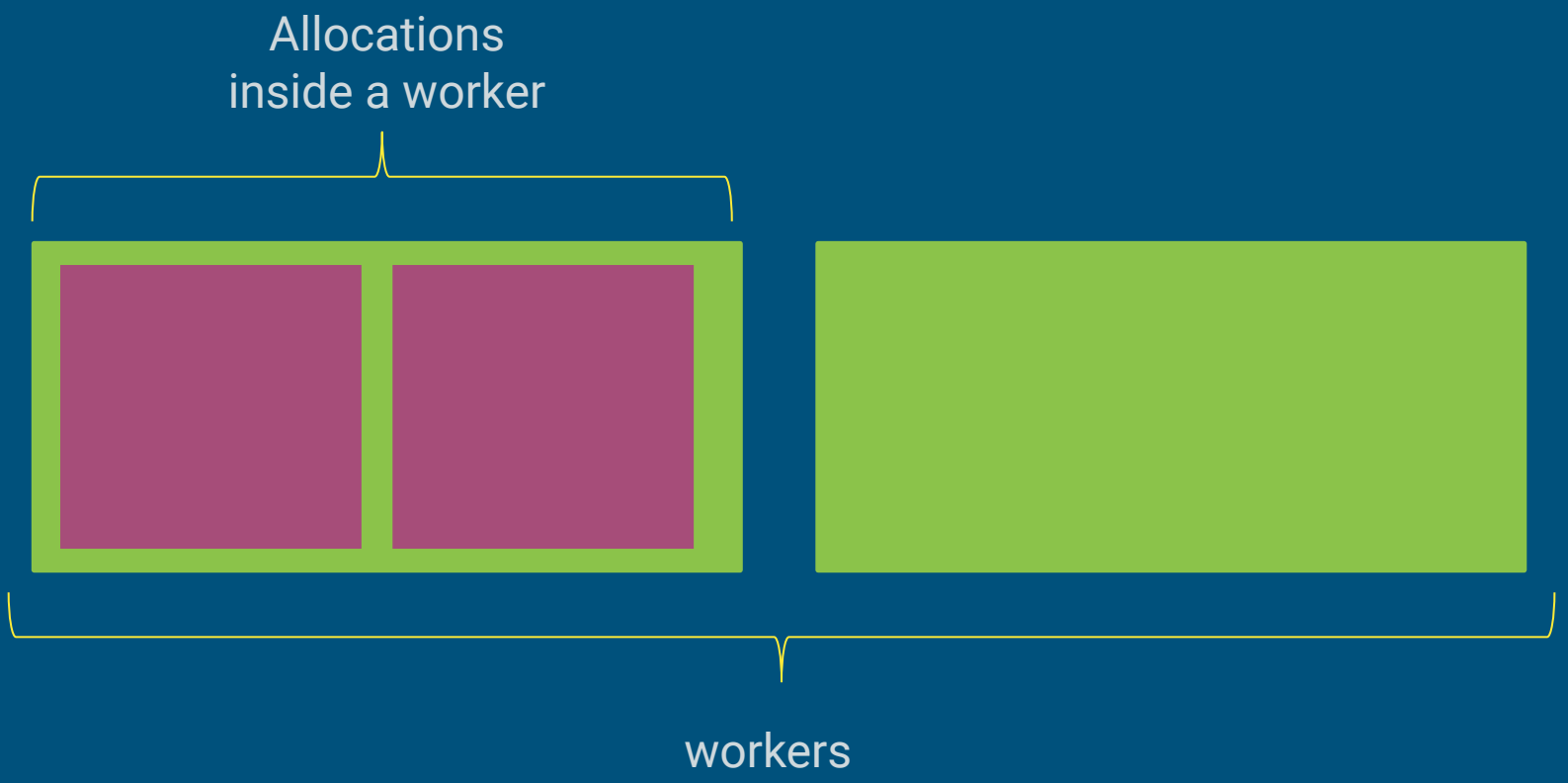
Many tasks per worker:
Resource contention/exhaustion, reduce throughput



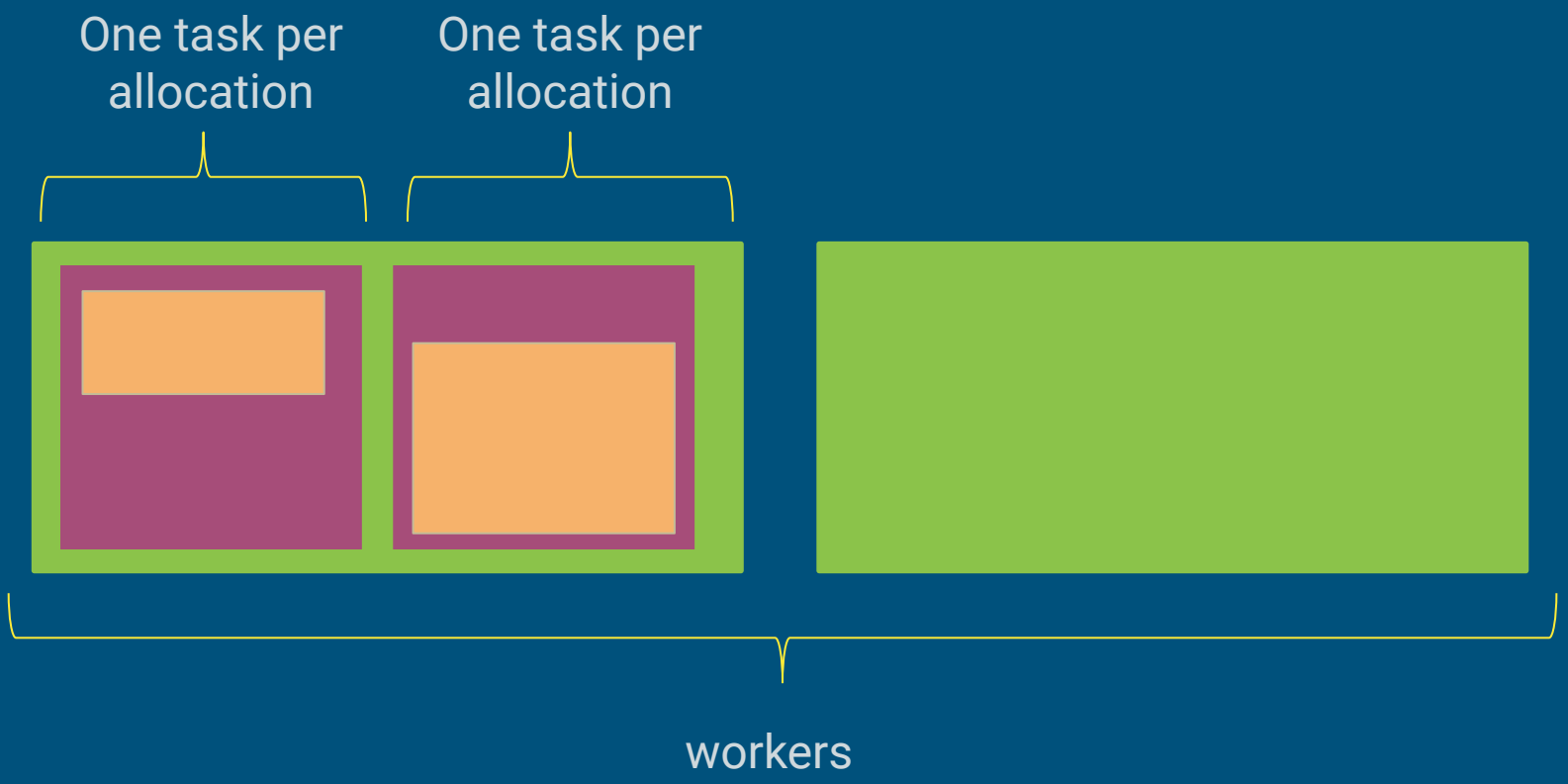
Task-in-the-Box



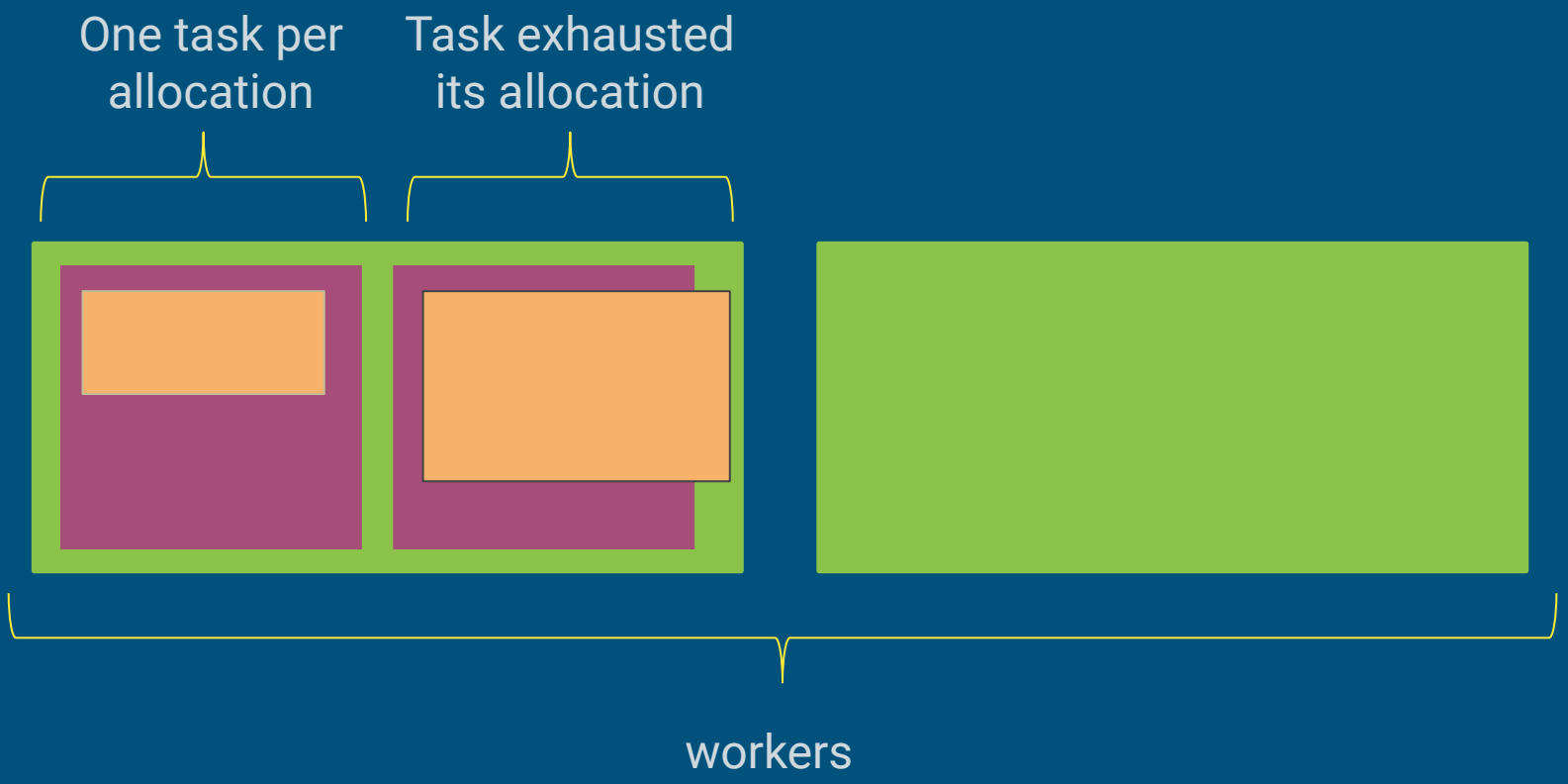
Task-in-the-Box



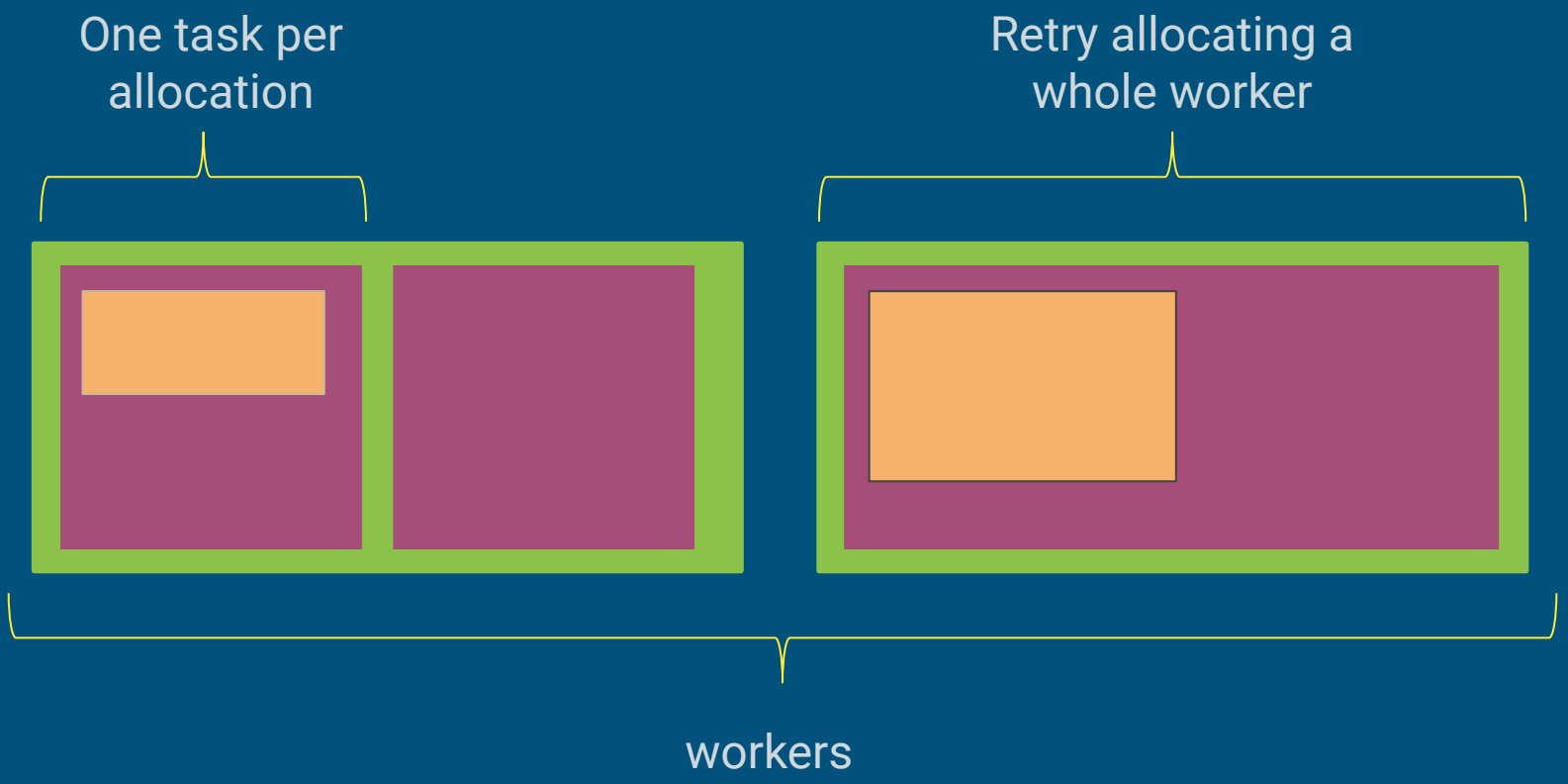
Task-in-the-Box



Task-in-the-Box



Task-in-the-Box



automatic resource labeling

```
#
executors_args = {
    'schema': NanoAODSchema,
    'master-name': '{}-wq-coffea'.format(os.environ['USER']),
    'environment-file': topeftenv.get_environment(),
    'port': 9123,    # or a range [9123, 9130]
    'extra-input-files': ["topeft.py"],

    'cores':  2,     # now resources are maximum allowed
    'memory': 4000, # in MB
    'disk':   4000, # in MB

    'resource-monitor': True,
    'resources-mode': 'auto',
    'verbose': True
}
```

what work queue does behind the scenes

1. Some tasks are run using full workers.
2. Statistics are collected.
3. Allocations computed to maximize throughput, or minimize waste.
    a. Run task using guessed size.
    b. If task exhausts guessed size, keep retrying on full (bigger) workers, or a specified `cores`, `memory` or `disk` is reached.
4. When statistics become out-of-date, go to 1.

work_queue_status -A HOST PORT

information about waiting tasks and resources

```
CATEGORY RUNNING WAITING FIT-WORKERS  MAX-CORES MAX-MEM MAX-DISK
default        2      20           2          1   >1024    ~2000
```

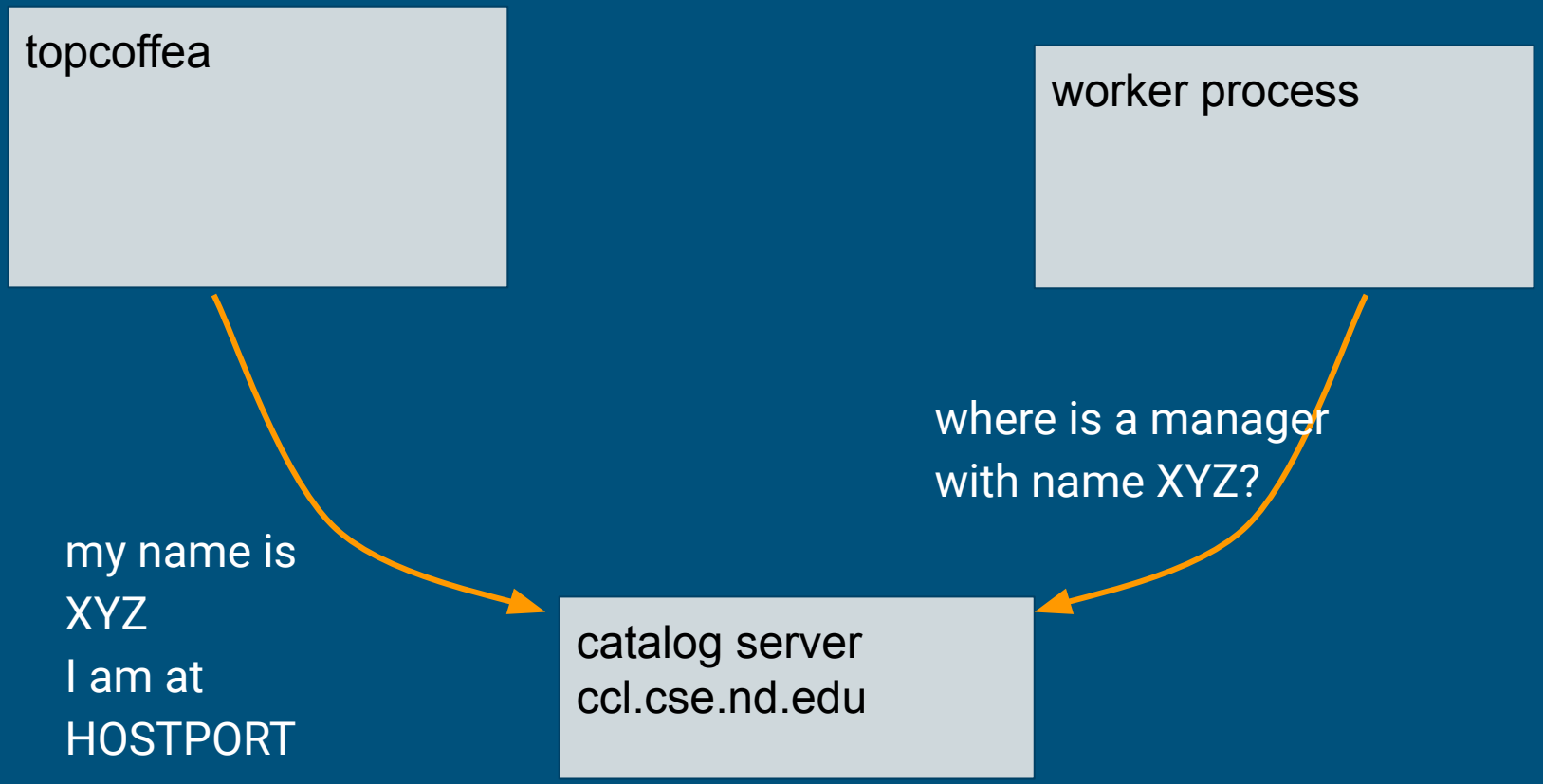
fixed resource

~ no fixed resource set, and all tasks have run under this value

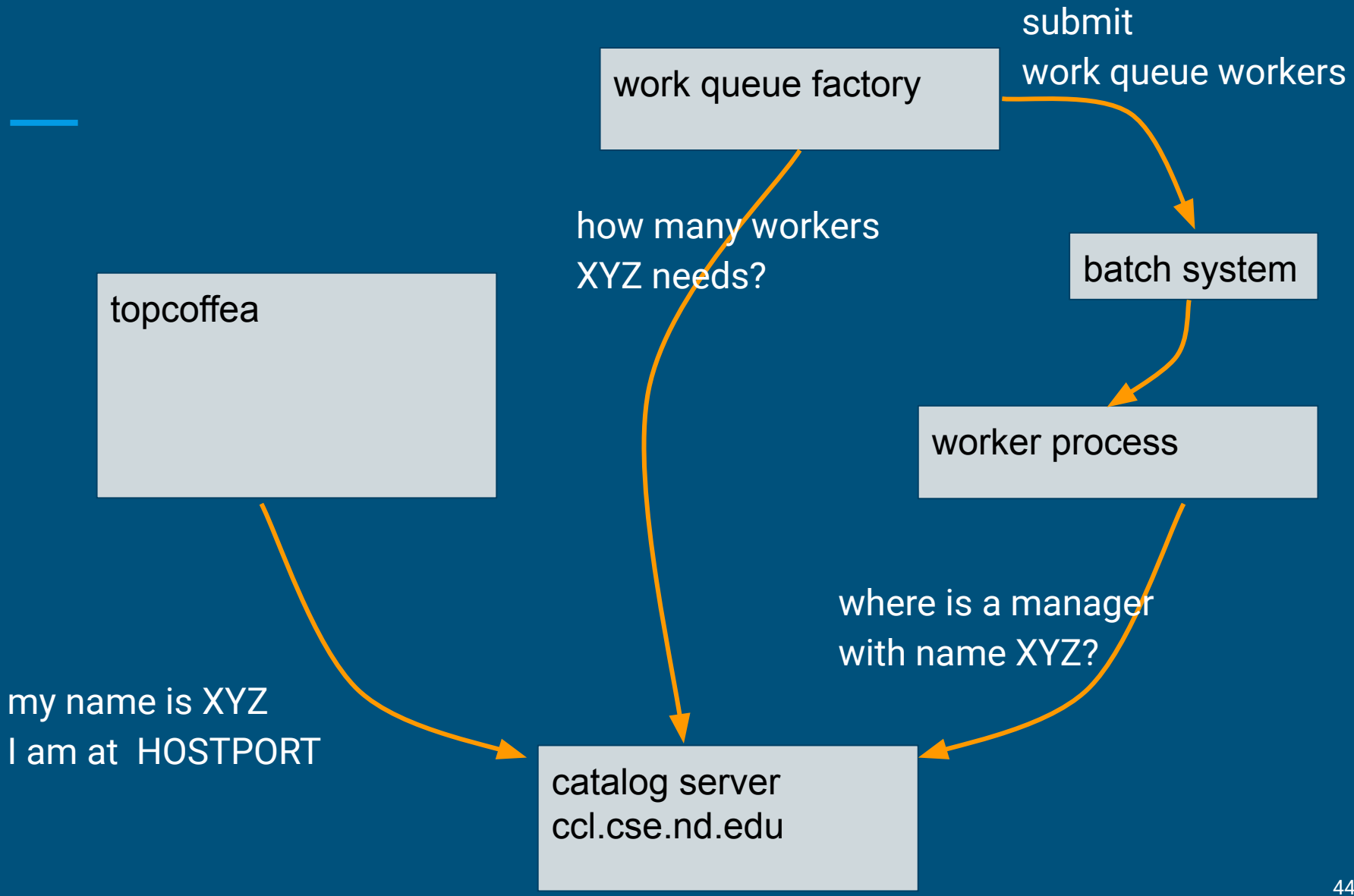
> At least one task that is now waiting, failed exhausting these much of the resource.

other work queue capabilities

how many workers do I submit?



the work queue factory



the work queue factory

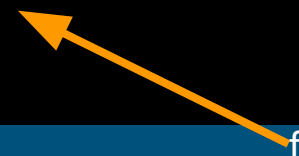
Factory creates workers as needed by the manager:

```
$ work_queue_factory -Tcondor \
 -M ${USER}-wq-topcoffea
 --min-workers 5
 --max-workers 200
 --cores 1 --memory 4096 --disk 10000
```

the work queue factory -- conf file

to make adjustments the configuration file can be modified once the factory is running

```
$ work_queue_factory -Tcondor -C my-conf.json
$ cat my-conf.json
{
    "manager-name": "btovar-wq-topcoffea",
    "max-workers": 200,
    "min-workers": 5,
    "workers-per-cycle": 5,
    "cores":  4,
    "disk":   10000,
    "memory": 4096,
    "timeout":   900,
    "tasks-per-worker": 4
}
```



for topcoffea, set to number of cores of workers

configuring runtime logs

We recommend to always enable all the logs.

```
executors_args = {
    'schema': NanoAODSchema,
    'master-name': '{}-wq-coffea'.format(os.environ['USER']),
    'environment-file': topeftenv.get_environment(),
    'port': 9123,    # or a range [9123, 9130]
    'extra-input-files': ["topeft.py"],

    'cores':  2,     # now resources are maximum allowed
    'memory': 4000, # in MB
    'disk':   4000, # in MB

    'resource-monitor': True,
    'resources-mode': 'auto',
    'verbose': True

     'debug-log': 'debug.log',
     'transactions-log': 'tr.log',
     'stats-log': 'stats.log',
}
```

transactions log

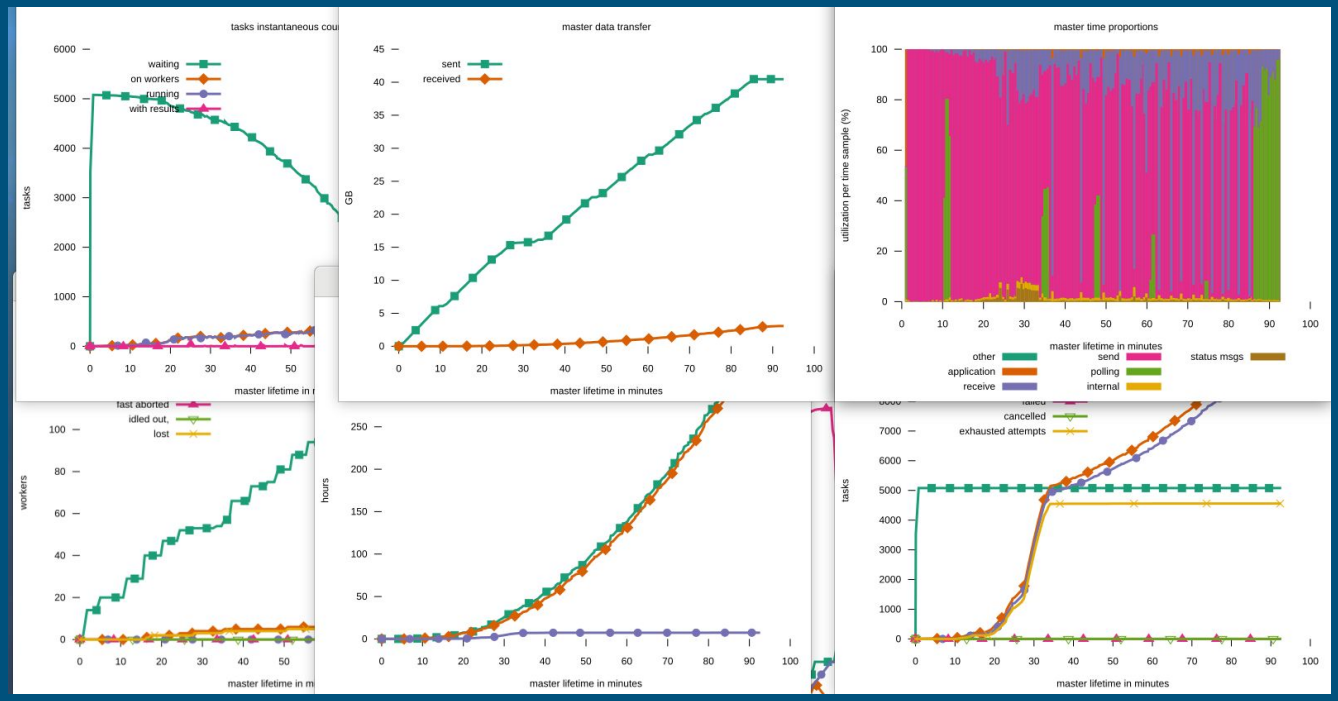
```
$ grep '\<TASK 1\>' tr.log
```

```
1550697985850270 9374 TASK 1 WAITING my-tasks FIRST_RESOURCES {"cores":[1,"cores"]}
1550698004105770 9374 TASK 1 RUNNING 127.0.0.1:40730  FIRST_RESOURCES {"cores":[1,"cores"],"memory
,"MB"]}
1550698004473367 9374 TASK 1 WAITING_RETRIEVAL 127.0.0.1:40730
1550698004475215 9374 TASK 1 RETRIEVED RESOURCE_EXHAUSTION {"disk":[20,"MB"]} {"start":[155069800
698004259680,"us"],"cores_avg":[0.989,"cores"],"cores":[1,"cores"],"wall_time":[0.14619,"s"],"cpu_
x_concurrent_processes":[1,"procs"],"total_processes":[1,"procs"],"memory":[1,"MB"],"virtual_memo
":[0,"MB"],"bytes_read":[0.00138569,"MB"],"bytes_written":[0,"MB"],"bytes_received":[0,"MB"],"byt
dth":[0,"Mbps"],"total_files":[7,"files"],"disk":[201,"MB"],"machine_cpus":[8,"cores"],"machine_l
1550698004475384 9374 TASK 1 WAITING my-tasks MAX_RESOURCES {"cores":[1,"cores"],"memory":[1,"MB"
1550698046053626 9374 TASK 1 RUNNING 127.0.0.1:40734  MAX_RESOURCES {"cores":[1,"cores"],"memory"
"MB"]}
1550698046444043 9374 TASK 1 WAITING_RETRIEVAL 127.0.0.1:40734
1550698046445440 9374 TASK 1 RETRIEVED SUCCESS {"start":[1550698046079981,"us"],"end":[155069804
[0.989,"cores"],"cores":[1,"cores"],"wall_time":[0.146097,"s"],"cpu_time":[0.144457,"s"],"max_con
ocs"],"total_processes":[1,"procs"],"memory":[1,"MB"],"virtual_memory":[6,"MB"],"swap_memory":[0,
38569,"MB"],"bytes_written":[0,"MB"],"bytes_received":[0,"MB"],"bytes_sent":[0,"MB"],"bandwidth":
[7,"files"],"disk":[201,"MB"],"machine_cpus":[8,"cores"],"machine_load":[0.31,"procs"]}
1550698046445762 9374 TASK 1 DONE SUCCESS {"start":[1550698046079981,"us"],"end":[155069804622607
9,"cores"],"cores":[1,"cores"],"wall_time":[0.146097,"s"],"cpu_time":[0.144457,"s"],"max_concurre
,"total_processes":[1,"procs"],"memory":[1,"MB"],"virtual_memory":[6,"MB"],"swap_memory":[0,"MB"]
,"MB"],"bytes_written":[0,"MB"],"bytes_received":[0,"MB"],"bytes_sent":[0,"MB"],"bandwidth":[0,"M
iles"],"disk":[201,"MB"],"machine_cpus":[8,"cores"],"machine_load":[0.31,"procs"]}
```

statistics log

Use work_queue_graph_log to visualize the statistics log:

```
$ work_queue_graph_log stats.log
$ display my_stats.*.svn
```



other ways to access statistics

```
$ work_queue_status -l HOST PORT
{"name":"cclws16.cse.nd.edu","address":"129.74.153.171","tasks_total_di
sk":0,...
```

Work Queue API

http://ccl.cse.nd.edu/software/manuals/api/python

http://ccl.cse.nd.edu/software/manuals/api/perl

http://ccl.cse.nd.edu/software/manuals/api/C

thanks!

questions:
btovar@nd.edu

forum:
https://ccl.cse.nd.edu/community/forum

manuals:
http://ccl.cse.nd.edu/software

repositories:
https://github.com/cooperative-computing-lab/cctools
https://github.com/cooperative-computing-lab/makeflow-examples

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CCTools

extra slides

using the work queue executor: setup

```
# install miniconda from #
https://docs.conda.io/en/latest/miniconda.html

$ conda create --yes --name topcoffea-env python=3.8 dill
$ conda activate --yes topcoffea-env
$ conda install --yes -c conda-forge coffea ndcctools xrootd

$ git clone https://github.com/TopEFT/topcoffea.git
$ cd topcoffea
$ pip install -e .

$ cd topcoffea/analysis/topEFT
```

Stand-alone resource monitoring

```
resource_monitor -L"cores: 4" -L"memory: 4096" -- cmd
```

```
cclws16  ~ > resource_monitor -i1 -Omon --no-pprint -- /bin/date
Thu May 12 20:27:21 EDT 2016
cclws16  ~ > cat mon.summary
{"executable_type":"dynamic","monitor_version":"6.0.0.9edd8e96","host":"cclws16.cse.nd.edu
","command":"/bin/date","exit_status":0,"exit_type":"normal","start":[1463099241605723,"us
"],"end":[1463099243000239,"us"],"wall_time":[1.39452,"s"],"cpu_time":[0.002999,"s"],"core
s":[1,"cores"],"max_concurrent_processes":[1,"procs"],"total_processes":[1,"procs"],"memor
y":[1,"MB"],"virtual_memory":[107,"MB"],"swap_memory":[0,"MB"],"bytes_read":[0.0105429,"MB
"],"bytes_written":[0,"MB"],"bytes_received":[0,"MB"],"bytes_sent":[0,"MB"],"bandwidth":[0
,"Mbps"],"total_files":[90546,"files"],"disk":[11659,"MB"],"peak_times":{"units":"s","cpu_
time":1.39452,"cores":0.394445,"max_concurrent_processes":0.394445,"memory":0.394445,"virt
ual_memory":1.39428,"bytes_read":1.39428,"total_files":1.39428,"disk":1.39428}}%
```

http://ccl.cse.nd.edu/software/manuals/resource_monitor.html

(does not work as well on static executables that fork)