HTC: Dealing with Data

Some friendly advice, some discussion

Brian Bockelman, 25 September 2024

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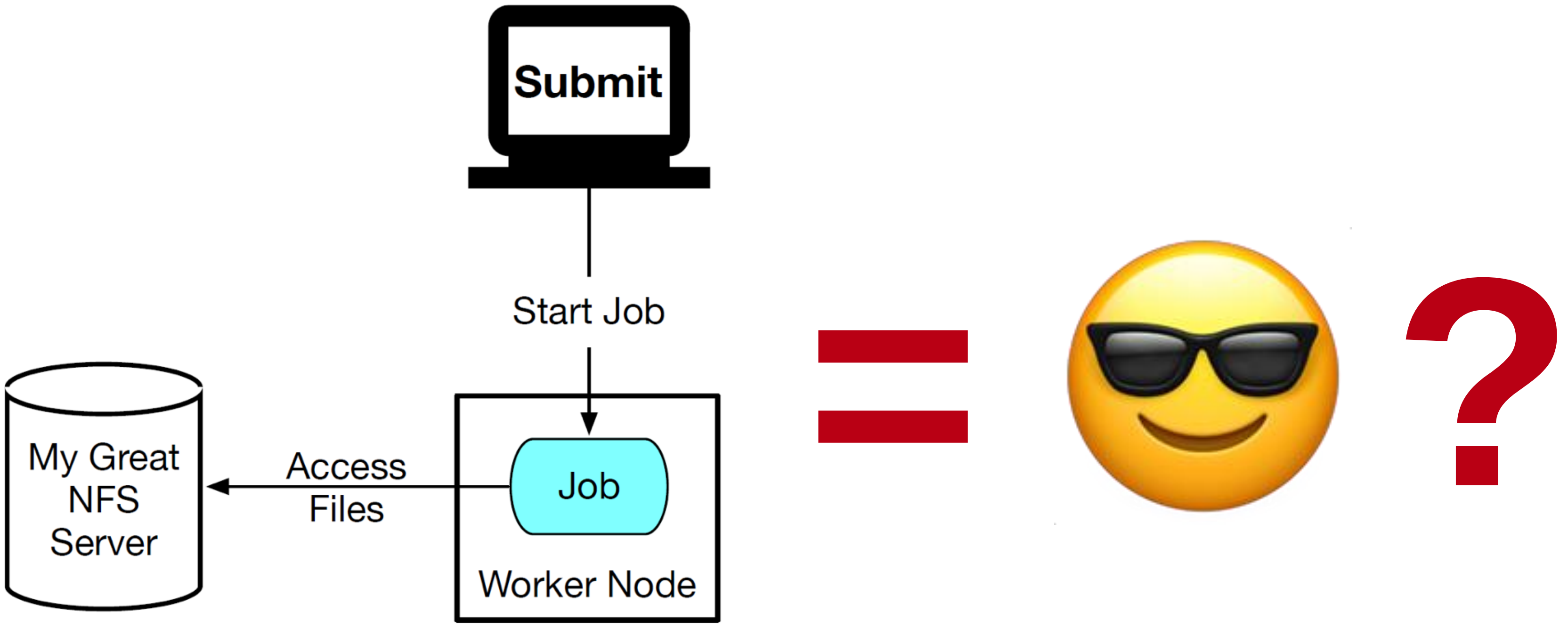
Why does HTCSS care about data?

Why is this even a talk?



Submit

Start Job

My Great NFS Server

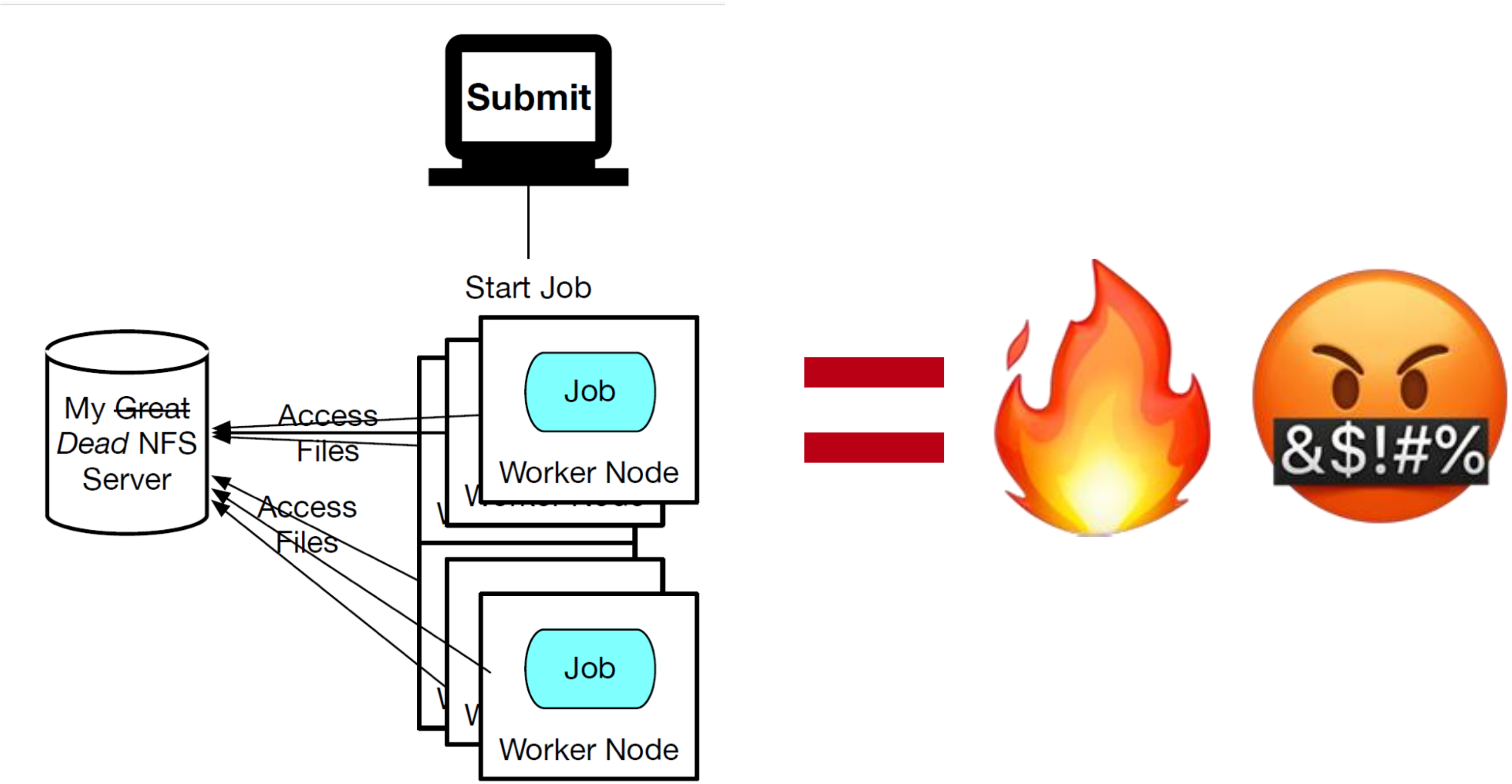
Access Files

Job

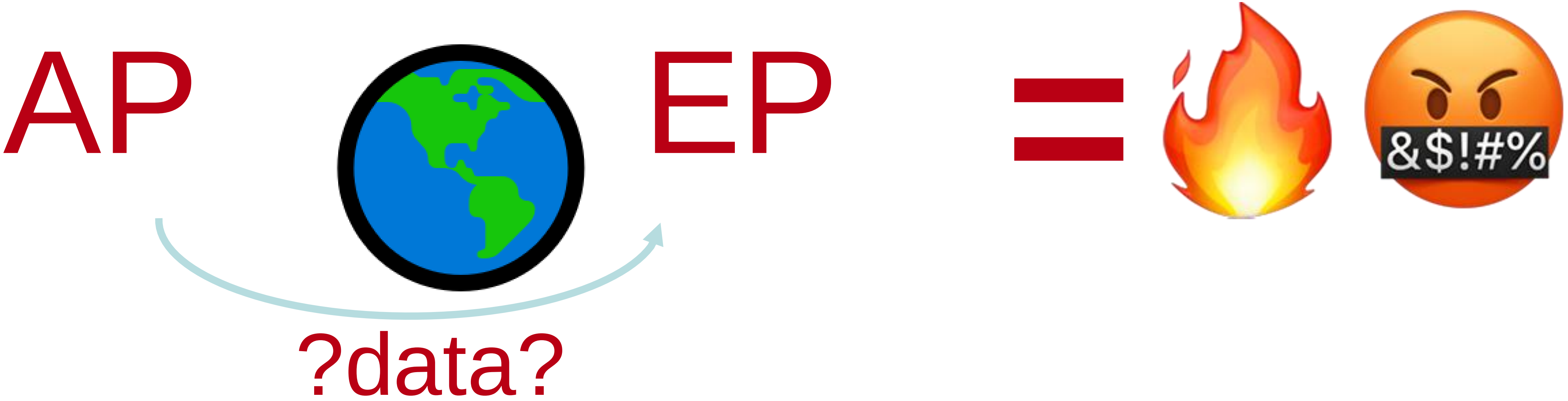
Worker Node

= 😎 ?

Why? This is why…



It only gets worse…



AP 🌎 EP = 🔥🤬

?data?

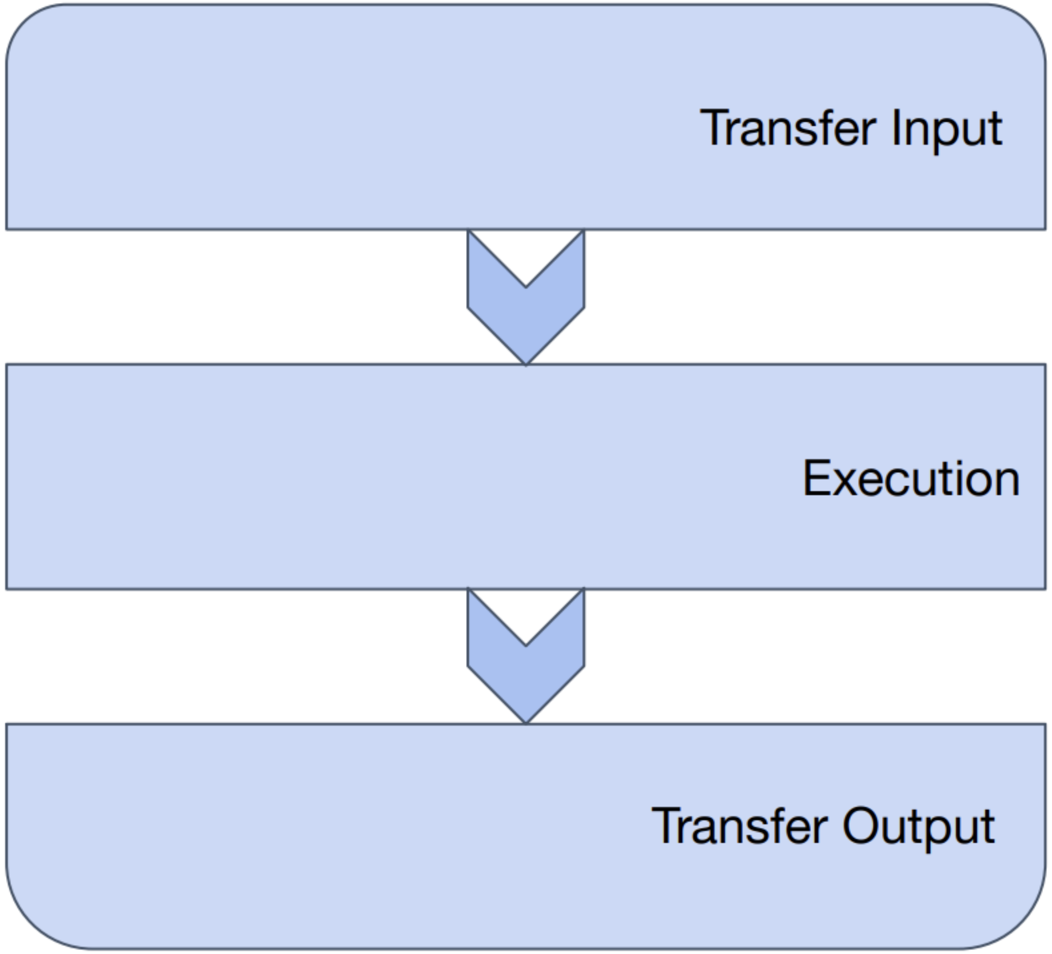
Dealing with Data

- What are the important parts of “dealing with data”?
  - Understanding data dependencies between tasks.
  - Detecting failures & handling retries.
  - Managing finite resources (storage, I/O).
  - And yes, moving data quickly.
- What’s perhaps the least of these? **Data transfer rates**!
- What is a user or site to do?
  - **Power through with hardware**: Pay enough money so you can assume the hardware never fails and is never the bottleneck.
  - **Do it yourself**: Provide all the functionality yourself (or use a workload manager layered on top of HTCSS).
  - Let the HTCondor Software Suite help!

Managing workloads = managing data

- HTCSS needs to manage your data to manage your workloads:
  - **I/O capacity**: Limit the I/O load (MB/s, IOPS) experienced by the remote service. Managed via limiting the transfer concurrency.
    - Can consider read and write activity separately.
  - **Retry policy**: What to do when a transfer fails?
    - Should we consider it permanent or transient?
    - Run the job at a different site?
    - Have the AP start avoiding the EP in general?
  - **Portability**: Run the job at a wider range of resources, not just local to the AP/EP's site.
- Can you skip this? Sure! But then you're in charge…

HTCondor breaks the job into stages



transfer_input_files = input1.dat, input2.dat

executable = my_processor.py

transfer_output_files = complete.dat

If HTCondor manages the I/O, it can delineate these stages!

HTCondor Submit Files

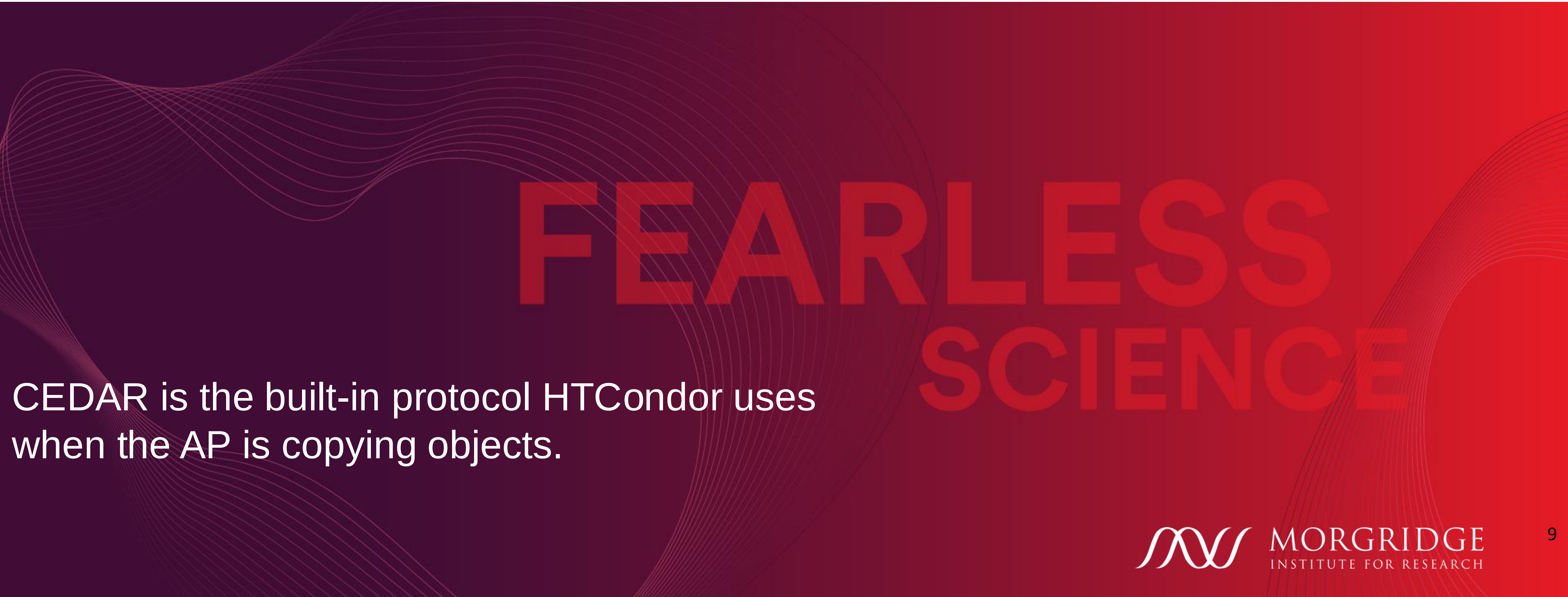
By declaring your jobs' inputs and outputs to HTCondor, you:

- Allow HTCondor to manage the movement of files.
- Allow HTCondor to prepare your job environment.
- HTCondor knows to not even start your job if the input is unavailable.
- Can make your job portable to other infrastructures.

In the simplest - and most common - case, HTCondor will also perform the file transfer.

```
universe = vanilla
executable = science.exe
arguments = $(Process)
transfer_input_file = \
              input.txt
output = science.out
error = science.err
log = science.log
queue
```

All about CEDAR



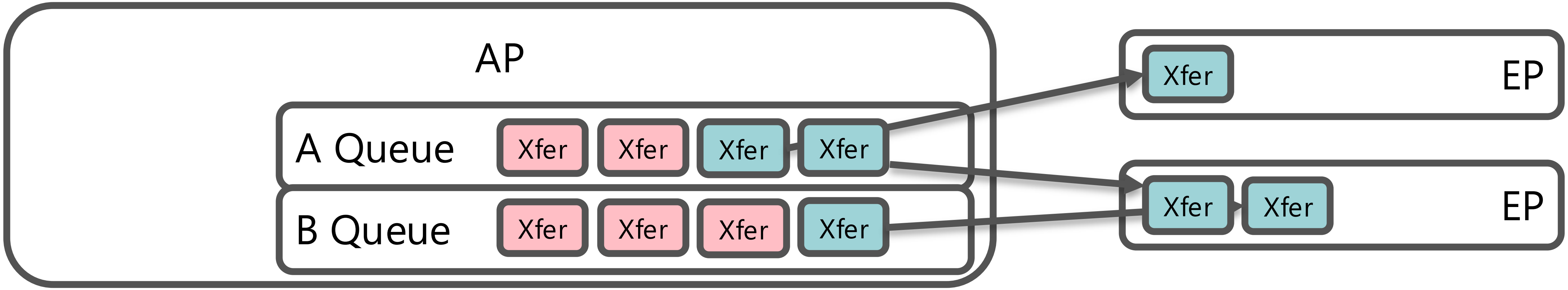
CEDAR is the built-in protocol HTCondor uses when the AP is copying objects.

CEDAR Transfers

- CEDAR is HTCondor’s internal binary protocol for transferring files.
- Uses the TCP connection established between client and server:
  - E.g., between AP and EP.
  - Can use HTCondor’s connection broker to reverse connections if server is behind a firewall.
  - Can only read/write local files to the AP/EP.
  - Effective: minimal use of round-trip blocking during transfers: can move a directory of small files, even with large network latencies.
  - No optimizations around object reuse: no caching if the same file is moved repeatedly.
  - “Plays well” with firewalls.
- Effective, simple, no setup required: the baseline for users.

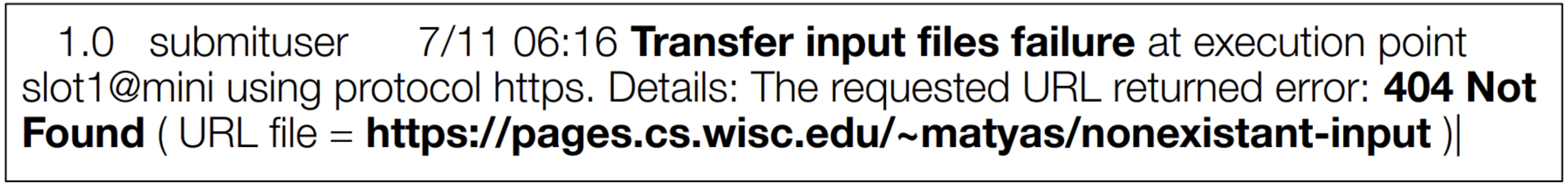
Resource management: CEDAR

- Before any transfer starts, the source side enters a transfer queue at the AP.
  - This allows the AP to understand the concurrency of currently-running transfers.
- The queue entered defaults to the owner's HTCondor identity.
  - When it is ready to start a new transfer, the AP will round-robin between queues.
  - Transfer queue is a ClassAd expression: can be based on the EP's sit ename.
- The AP records the time spent in I/O and adjusts the concurrency based on a high-/low-watermark algorithm:
  - Number of transfers is slowly increased until a high-water load limit is reached.
  - The concurrency is decreased until the low-water limit is reached.

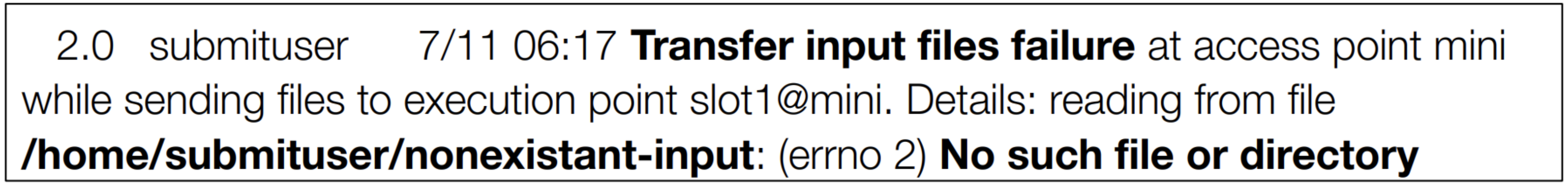


Working on error messages

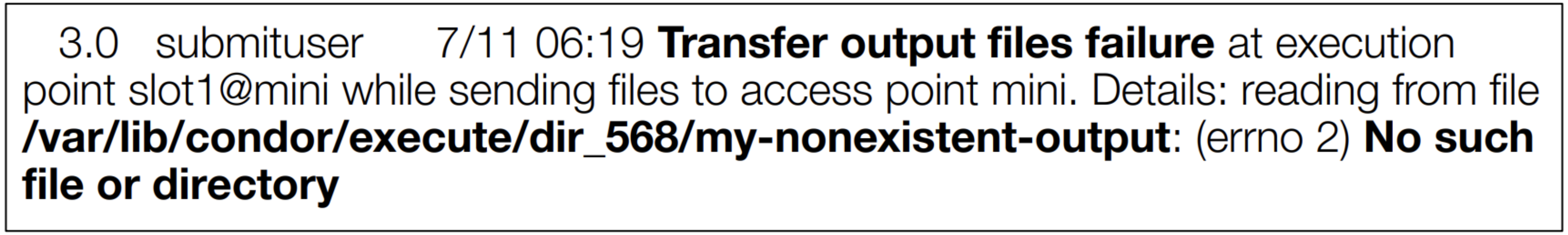
- During the course of HTCondor 23, we’ve tried to cleanup CEDAR errors messages:
  - Fewer repetitions.
  - User-centric, not admin-centric.



1.0 submituser 7/11 06:16 **Transfer input files failure** at execution point slot1@mini using protocol https. Details: The requested URL returned error: **404 Not Found** (URL file = **https://pages.cs.wisc.edu/~matyas/nonexistant-input**)|



2.0 submituser 7/11 06:17 **Transfer input files failure** at access point mini while sending files to execution point slot1@mini. Details: reading from file **/home/submituser/nonexistant-input**: (errno 2) **No such file or directory**



3.0 submituser 7/11 06:19 **Transfer output files failure** at execution point slot1@mini while sending files to access point mini. Details: reading from file **/var/lib/condor/execute/dir_568/my-nonexistent-output**: (errno 2) **No such file or directory**

Arcane Knowledge…

For Users:

- If you use the **-spool** option, HTCondor will make a copy of your input files to a private directory. This allows you to make changes locally while your jobs are running.
- The **stream_output** submit file command will cause HTCondor to stream output back to the submit host while the job is running. Useful - but use sparingly (consider condor_tail or condor_ssh_to_job as well).
- **max_transfer_output_mb** allows you to put a maximum cap on the data you transfer back; a useful sanity check if your job produced 100GB when you expected 100KB.
- **encrypt_input_files** allows you to force some files to be encrypted in flight - even if HTCondor would not otherwise do this.
- The **transfer_output_remaps** command allows you to provide arbitrary mappings from files in the job execute directory

For Admins:

- **MAX_CONCURRENT_UPLOADS** / **MAX_CONCURRENT_DOWNLOADS** provide an absolute limit on the number of files being transferred at a time
- **FILE_TRANSFER_DISK_LOAD_THROTTLE** will further lower the number of concurrent file transfers based on the I/O load measured on the submit host's storage.
- **MAX_TRANSFER_OUTPUT_MB** sets the schedd-wide default for maximum data transfers per jobs (users can override).
- **MAX_TRANSFER_QUEUE_AGE** is the maximum time, in seconds, that a transfer is allowed to proceed before it is killed.

Delegated Transfers

AKA, “URL-Based Transfers”

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Bringing your friends along for the ride…

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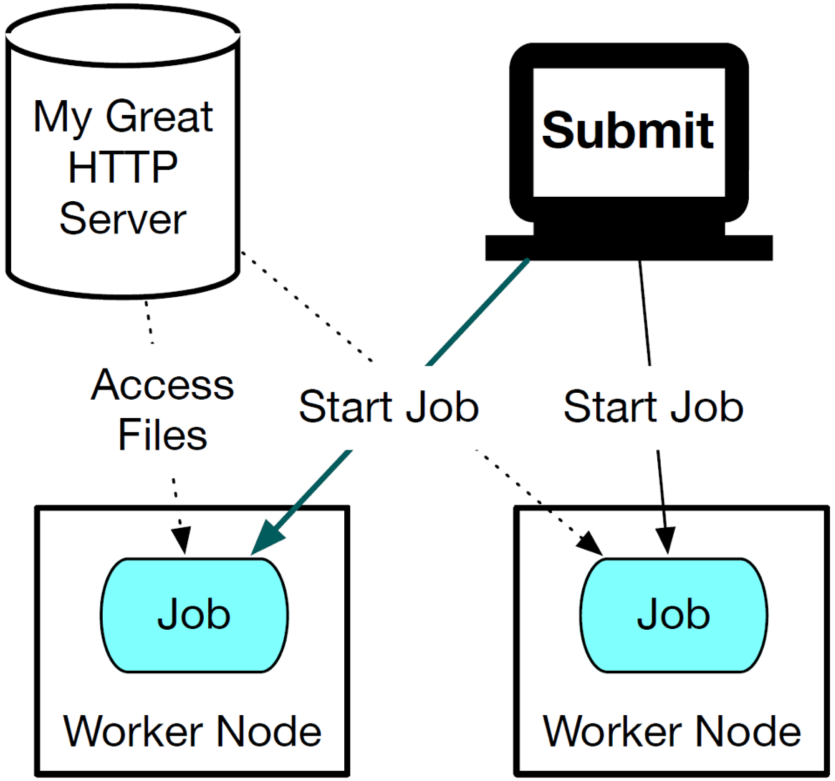
What are Delegated Transfers?

- Delegated transfers* are transfers that are initiated by HTCSS but performed by some other component.
  - We typically call these “URL-based transfers” but I feel the fact they’re specified by URL secondary.
- There’s an enormous world of transfer tools and protocols out there. Delegated transfers are how HTCSS taps into that for the input/output sandbox.
- Shipped with HTCSS:
  - HTTP, FTP, HTTPS, DAVS, file (basically, anything that libcurl supports!)
  - data:// - base64-encode the data in the URL itself.
  - osdf:// (and soon, pelican:// !) – transfer with a data federation.

* Still searching for a good name here – suggestions welcome!

Delegated Transfers

```
universe = vanilla
executable = science.exe
arguments = $(Process)
transfer_input_file = \
 https://example.co/input
output = science.out
error = science.err
log = science.log  queue
```



I can do that!

- Wait, why not call curl inside my job? I can do that!...
- As we say at CHTC, **Miron has a lot of questions**:
  - Are you sure you call curl correctly?
  - Did you pass the right headers to make caching work?
  - Did you discover the right proxy?
  - Did you set timeouts appropriately?
  - Did you fine-tune your retry policy?
  - When the transfer fails, is this reflected correctly in the job status?
- If HTCondor doesn’t know about it, HTCondor can’t schedule it!
- Same as with normal file transfers, HTCondor can do the hard work and (difficult) management if it is told what URLs are needed.

Your own delegated transfers!

- The world is a lot larger than the supported mechanisms that ship with HTCondor.
- *Don't see your preferred schema? You can write your own plugin…*
  - "You" applies to both users and EP admins.
- The plugin must:
  - Specify the schemes it supports (gs://, box://, gdrive://, etc).
  - Take an input file describing a list of transfers to perform.
  - (Actually perform the transfers, of course!)
  - Produce an output file describing the results of the transfer.
- HTCSS will group the transfers so the plugin is invoked *once* per URL schema.
  - Optimize to your heart's content

Arcane Knowledge…

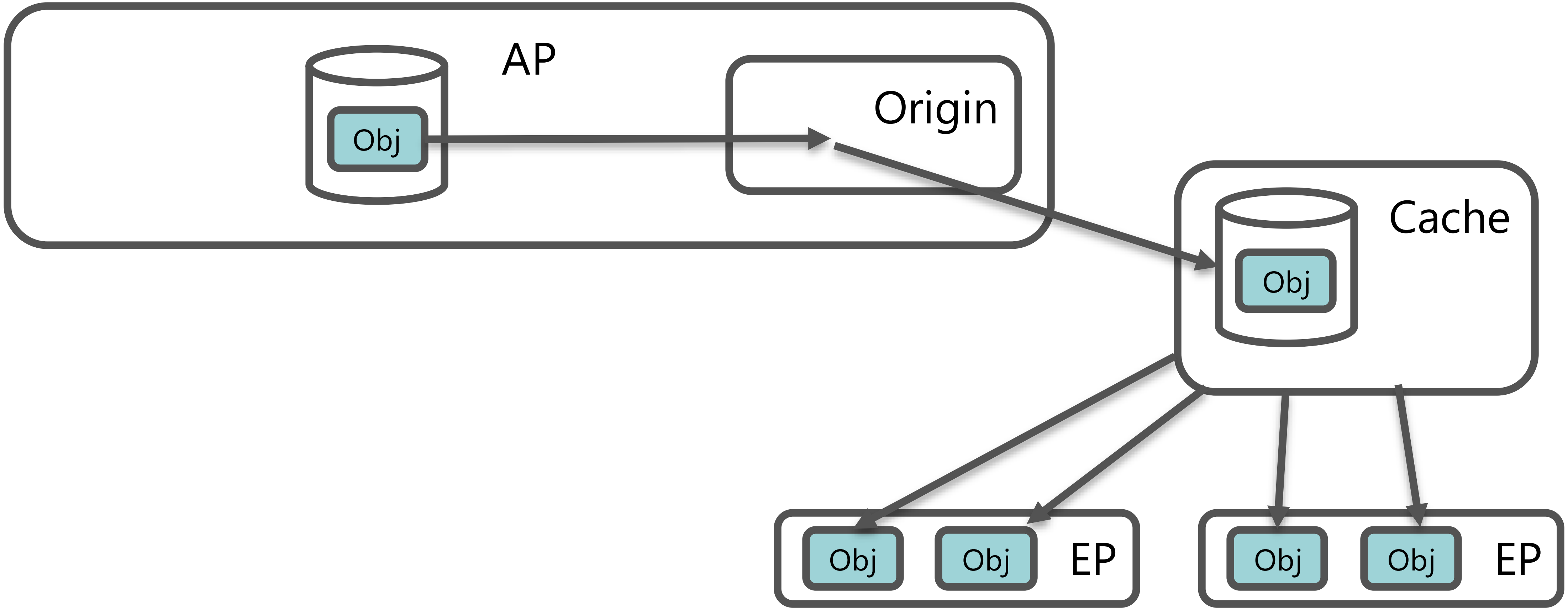
- HTCSS now keeps statistics on these transfers. You can see how many bytes were moved, how many files, number of successes.
  - Also the file transfer stage is present in the job's event log.
- CEDAR transfers are done first for the job input sandbox and last for the job output sandbox:
  - Delegated transfers can rely on configuration sent via CEDAR; they can drop files that are returned via CEDAR.
- The s3:// URLs are special: instead of transferring the S3 credentials to the EP, it will automatically create a signed URL on the AP. This https:// URL is then sent to the EP for transfer.
  - The EP only receives a single URL, not your credentials! Minimizes risk of a malicious EP.

Off into the future – Managing Delegated Transfers

- Originally *all* transfers for a job were done with an active token in the transfer queue.
  - This made no sense: we are not managing the AP’s I/O resources while transferring with a 3rd party!
- In 9.x, we changed this so no transfer tokens were held.
  - Which also makes no sense! That means delegated transfers are completely unmanaged.
- Soon-to-appear: the AP manages a separate queue for delegated transfers.
  - Targeting services that AP has a close relationship with.
  - Others (think AWS…) may not need to be managed by the AP.

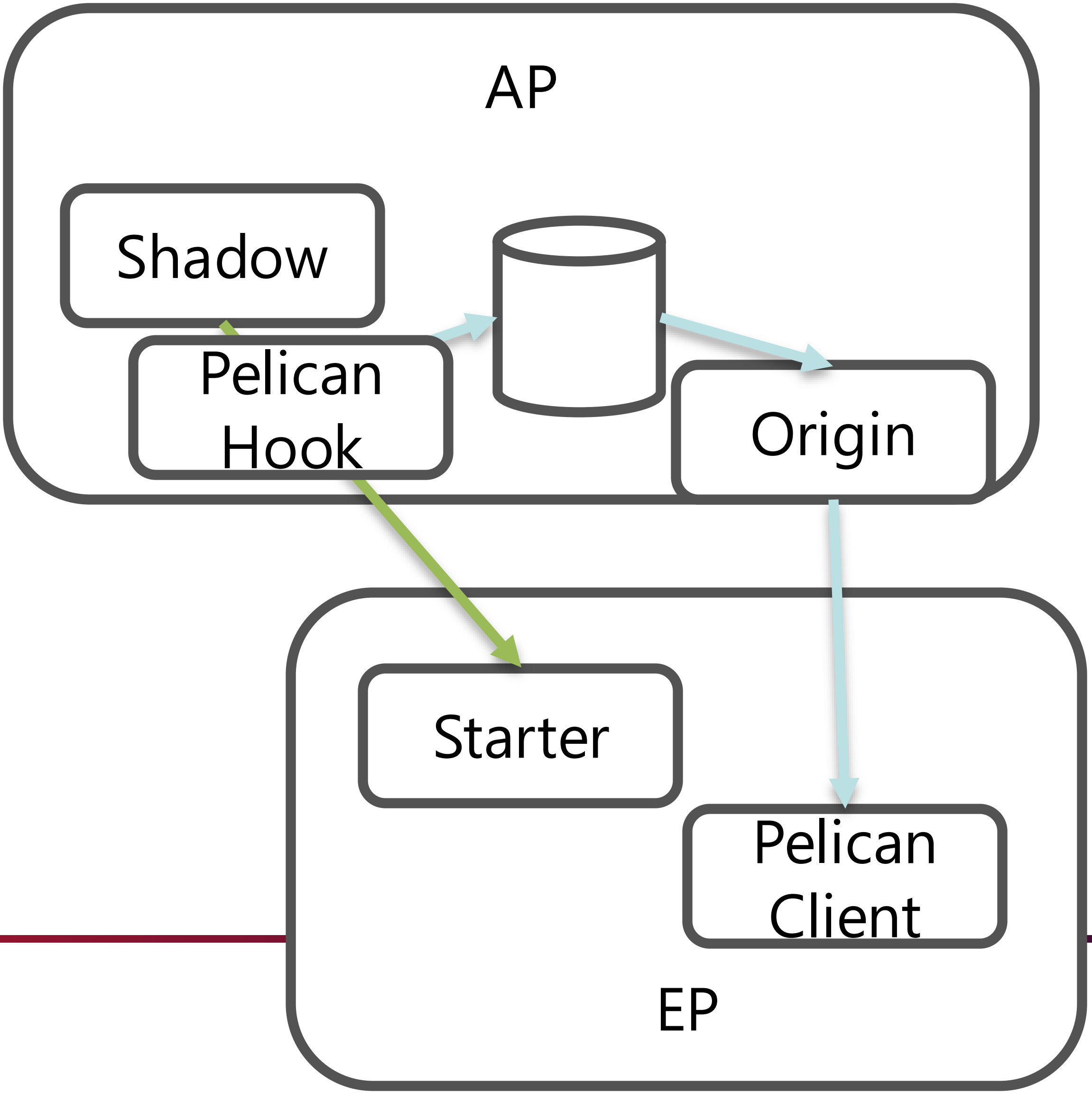
Example - Pelican

The Pelican plugin allows for reuse at the content distribution network. **More later today!**



Arcane Knowledge…

- “Well-hidden” in HTCSS is the shadow job hook.
  - Arbitrary code invoked by the condor_shadow process before sending a job’s ClassAd to the condor_starter.
    - Receives the shadow’s copy of the job ClassAd and any credentials for the job.
    - Output is updates to the ClassAd.
- **Opportunity**: Can transform the input sandbox.
  - Example: The Pelican shadow hook will examine large files, upload them to a local origin, and then instruct the starter to use the Pelican copy of the file.



Coming up soon…

Integration with the LotMan library (part of the Pelican Platform):

- LotMan performs accounting for storage.
    - Finally (!) can ask HTCSS questions like “how much spool is Brian using?”
- Can ask jobs to provide estimates of input/output sandbox needs.
    - Don’t schedule a job with 1TB output if the user doesn’t have 1TB of space allocated!
- First step in the ability to set policies for storage.
    - As with I/O, users should not get a blank check for storage.

Common Pitfalls / Challenges

Why do folks manage their own data?

- **Data volume**: The volume of data the job will read is larger than the local scratch space.
- **Streaming / subsets**: The application reads a small subset of the data and CEDAR moves the entire file.
- **Unknown application dependencies**: The user is utilizing a community-developed application and has little insight into what data is needed.
- **Workflow engine assumptions**: The user is running a workflow engine that assumes a shared filesystem.

Common Pitfalls: Approaches

Why do folks manage their own data?

- **Data volume**: The volume of data the job will read is larger than the local scratch space.
  - **Approach**: Consider splitting into smaller jobs, each with less data volume.
  - **Approach**: Still declare dependencies, let HTCSS know the filesystem requirements. Can still use the policy/retry engine!
- **Streaming / subsets**: The application reads a small subset of the data while CEDAR moves the entire file.
  - **Approach**: Move subsetting step into job creation time or an earlier node in DAG.
  - **Approach**: Delegate subsetting into a custom transfer plugin.
- **Unknown application dependencies**: The user is utilizing a community-developed application and has little insight into what data is needed.
  - **Approach**: Provide interactive host, run inside a container.
- **Workflow engine assumptions**: The user is running a workflow engine that assumes a shared filesystem.
  - **Approach**: Search for a “AWS mode”; any HTCondor integration is more like AWS than SLURM.

Parting Thoughts

- Rely on HTCSS to manage your data and you get:
  - **Policy engine**: Clear phases for transfer and ever-improving policies for failure.
  - **Capacity management**: Concurrency limits in the AP and queue management implements management of the I/O capacity of the AP.
  - **Portability**: Jobs are not tied to the local shared filesystem and can moved to anywhere!
- Using HTCSS relies on you building a knowledge of the data dependencies of your workload:
  - This does not come “for free”: new users often struggle with understanding their workload.
  - <u>Worthwhile</u>: good for the hygiene of the workload, opens doors with HTCondor!

Questions?

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