Data Storage & Access

Open Science Grid

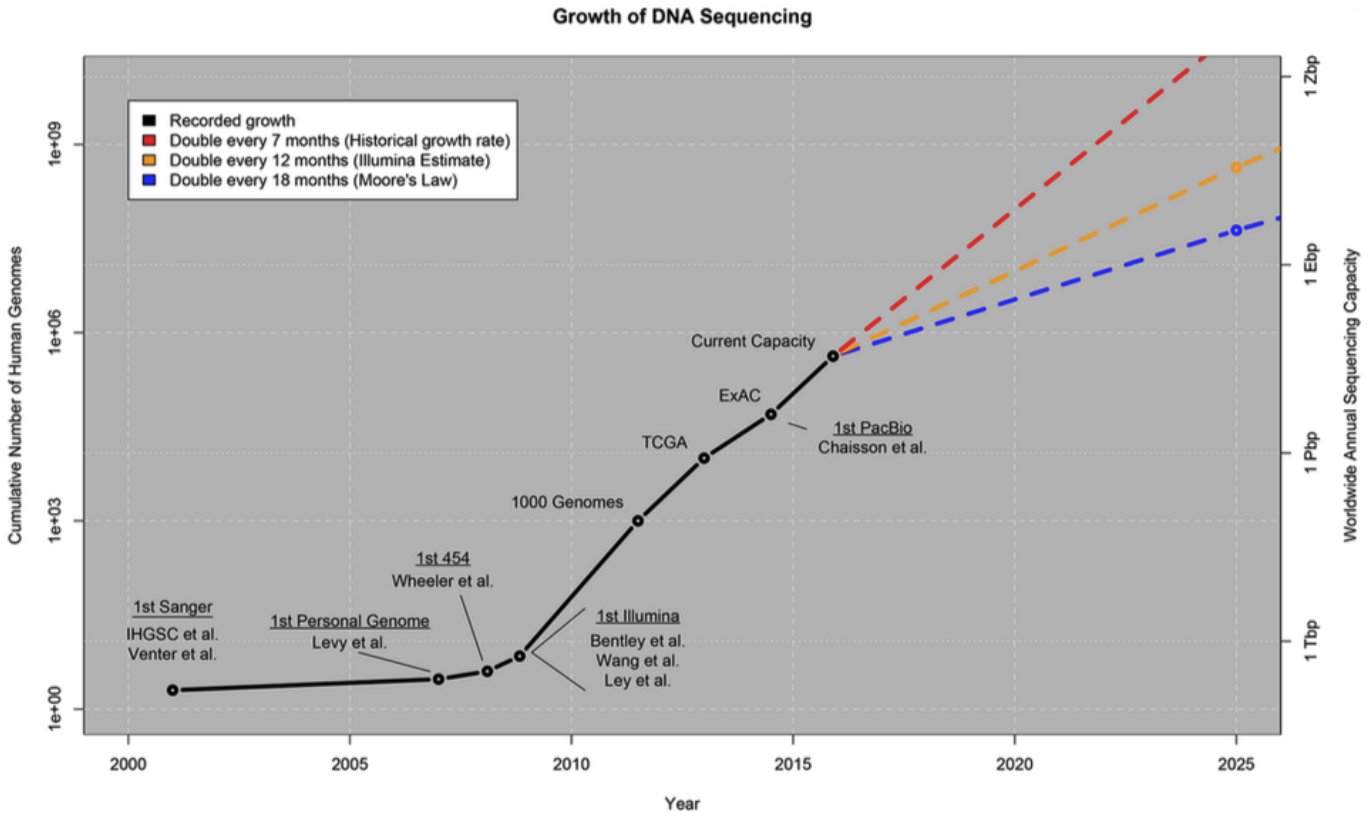
OSG Summer School
July 27-31, 2015

How big is Big?

Some examples of Big

- A single human genome
  - 200GB [1]
- Sloan Digital Sky Survey
  - 116 TB in Data Release 12 [2]
- ATLAS experiment at the LHC
  - 140 PB on disk in 2014 [3]
- Facebook’s data warehouse in 2014
  - 300 PB [4]

Genomics - projected 10 year growth

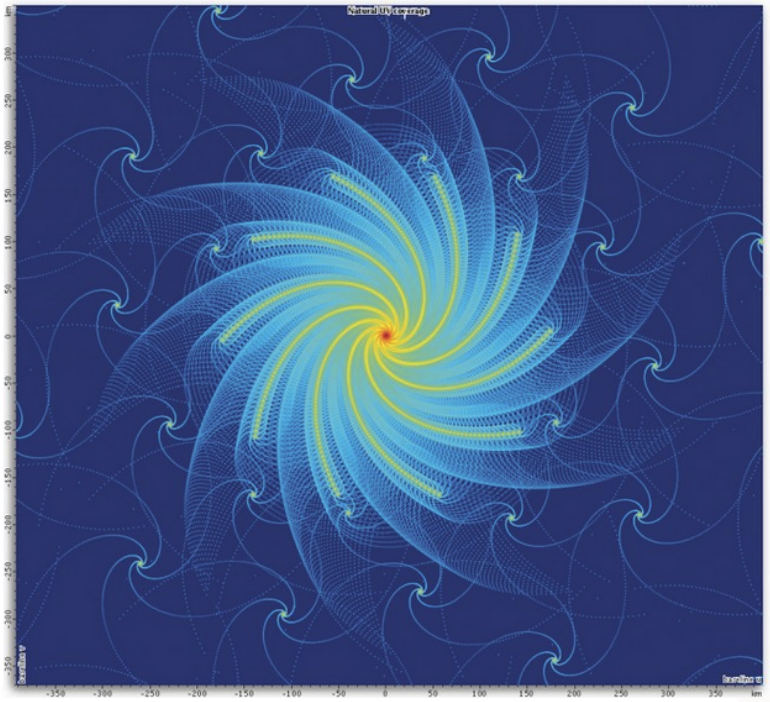


> 1 Ebp/year (base pairs) ⇒

1-40 EB/year

PLOS Biology | DOI:10.1371/journal.pbio.1002195 July 7, 2015

Square Kilometer Array (www.skatelescope.org)



2 / 2 A pretty picture, and, if you must know, a map of SKA sensitivty at certain radio wave frequencies based on the antenna geometry. (Flickr/SKA)

7 EB/y to disk in 2022 projected
(~ 1 EB/day raw!)

http://arxiv.org/pdf/1101.1355.pdf

Storage systems

- Most university HPC centers provide storage to users, at various costs depending on type
  - Cheaper, slower ➔ high capacity
  - Other applications may require fast (e.g. SSD) storage
  - Tape systems can be used for archival, but rarely within live computational workflows
- National cyberinfrastructure centers also offer storage with varying characteristics and costs
- AWS storage - S3

- What good is all of this “big data” if you can’t move it around?
- Many things to think about:
  - How much data does my application need?
  - How fast can I move it?
  - How quickly can my application consume it?
  - How to access my data on a remote worker?
  - What changes as I scale up?

Getting started

Data transfer basics

- Standard tools like `scp`, `rsync` work well for moving data to submit nodes
  - Does **not** (usually) work inside a job!
- Also consider: Where to put data?
  - `/home` often has quotas in place.
  - Usually some dedicated storage in place
  - If in doubt, ask your system operator.

Dealing with larger datasets

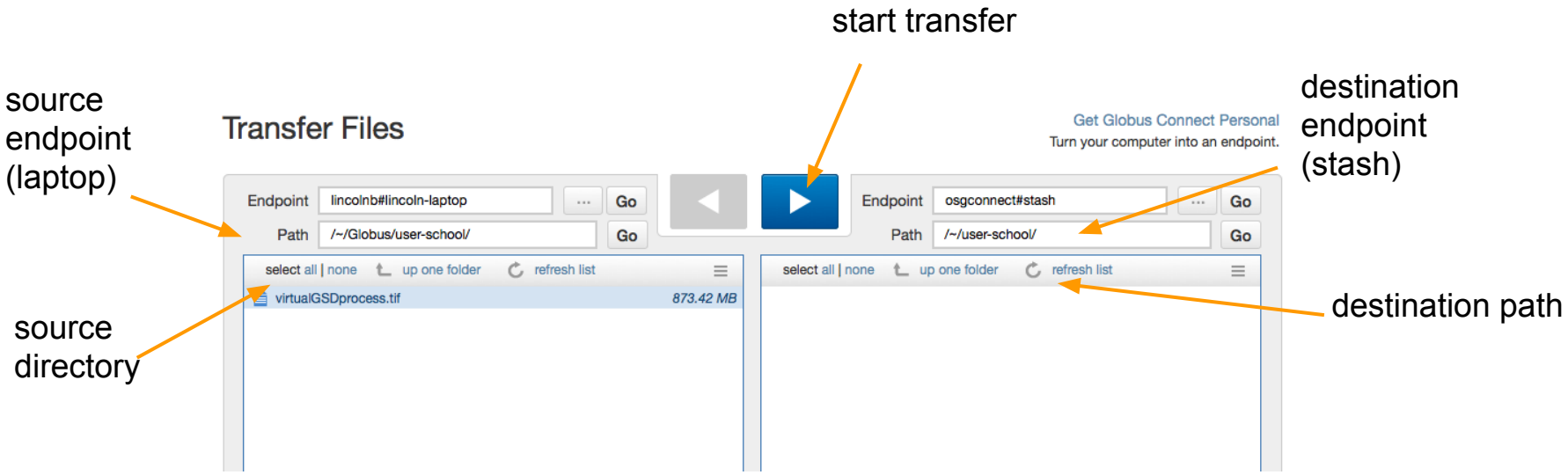
- Many datasets are too large to keep a local copy
- How to move these around?
  - We recommend Globus
    - Web-based platform for moving data between facilities or workstations
  - Access via http://portal.osgconnect.net if using OSG Connect

Moving data with Globus

- Move data to/from:
  - OSG Connect (Stash)
  - XSEDE or Blue Waters HPC centers
  - your local research computing facility
  - local resources (e.g., laptop)
- Restarts failed/incomplete transfers, manages data integrity, designed for high-throughput transfers

Globus Online Example

- Transferring files from laptop to Stash



Transferring data to a job

- OSG does not have a shared filesystem!
  - Jobs must transfer their input files to the remote worker.
- `scp`, `rsync`, etc typically will not work here
- Basic mechanism: HTCondor file transfer
  - `transfer_input_files = …`
  - Can also recursively copy directories, transfer via other protocols such as HTTP (see later)

HTCondor File Transfer Example

- Print the contents of `hello_world.txt`:

```
universe = vanilla

output = job.out
error = job.err
log = job.log

transfer_input_files = hello_world.txt
executable = /bin/cat
arguments = hello_world.txt

queue
```

Getting data back out

- HTCondor monitors the job sandbox.
  - Files created within the sandbox will get transferred back out to the user.
- Can also explicitly create a list of outputs with `transfer_output_files`
  - Useful when working on scratch disk

I/O Considerations

- Bandwidth is not infinite!
- Most workers connected at 1Gb/s (125MB/s)
- Realistically expect to copy data at rates of 1MB/s to 50MB/s
  - May be more or less depending on disk, local network, filesystem configuration, # of concurrent transfers, and external network

I/O Considerations

- Disks tend to be anywhere from 40-80MB/s
  - Varies for sequential vs random reads
  - Remember: shared resource!
- How fast can your application consume data?
  - e.g., typical ATLAS analysis job processes data at approximately 40MB/s
  - No good rule of thumb, experiment and find out.

File size vs number of files

- Two important dimensions of a transfer task:
  - Average file size and the number of files
- Is one 1GB file the same as 10^6 1KB files? **No!**
- The difference is in the filesystem metadata
  - a million 1KB files -> a lot of overhead
  - gets worse as you start moving them around
    - overhead for the transfer services

Dealing with small files

- We know that large amounts of small files are bad
- How to handle this?

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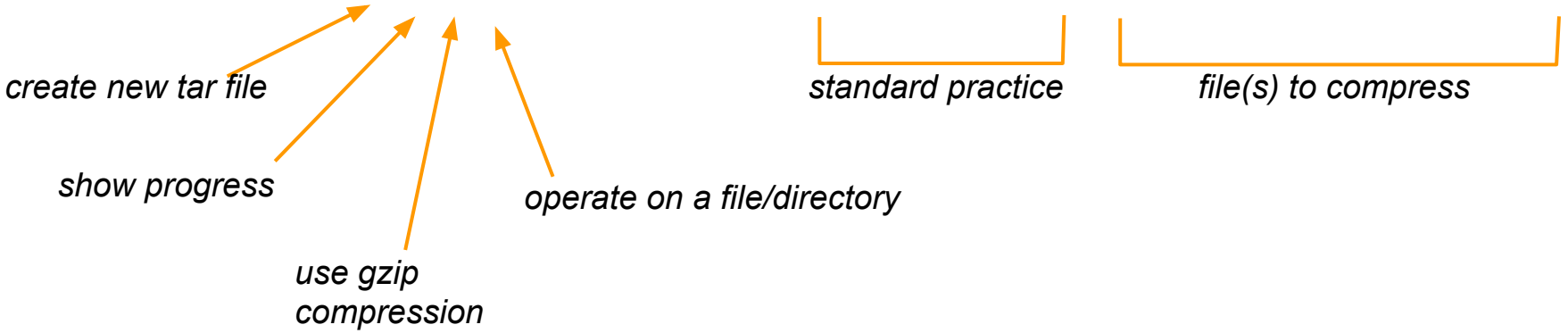
- We know that large amounts of small files are bad
- How to handle this?
  - Archive (zip/tar) small files.
- Compression saves a lot of time with small performance penalties
- Tools like `zcat(1)` can read out of compressed files on the fly

File compression how-to

- Use the `tar` utility:

```
$ tar -cvzf  my_file.tar.gz  my_directory/
```



Compression example

- Wikipedia public data dump.
  - Contains all articles and changes to articles
- 168 compressed (7z) XML files
  - One compressed file: 127 MB
  - Same file, uncompressed: 14 GB
- ~110:1 compression ratio!
  - Not all files will compress this well

Scratch disks

- In the previous example, decompressed file was 14GB
  - Put this in scratch if available!
  - Scratch location: `$OSG_WN_TMP`
- Why scratch?
  - Job sandbox is often restricted in size
  - Scratch is usually on separate/faster disks

More on scratch

- Scratch won't necessarily be cleaned automatically
  - clean up after yourself.
- `$OSG_WN_TMP` also not necessarily defined
  - Need a little if…then…else in your wrapper

Scratch example

```
#!/bin/bash

if [ -n $OSG_WN_TMP ]; then
     MY_SCRATCH=$(mktemp --tmpdir=$OSG_WN_TMP XXXXX)
else
     MY_SCRATCH=$(mktemp --tmpdir=$(pwd) XXXXX)
fi

...(move data to $MY_SCRATCH, do work)...

rm -rf $MY_SCRATCH
```

- Exercise 1
  - Refresher of scp, rsync,
  - introduction to Globus
- Exercise 2
  - Transferring files in and out using HTCondor’s built-in file transfer

Caching infrastructures

- Remember what is a good fit for OSG:
  - Jobs lasting 1-12 hours
  - Less than 2GB of memory
  - Input/out less than 10GB
- Data needed per job..
  - can influence all of the above
  - is determined on a case-by-case basis

- Would a single job with 100GB of input data be a good fit for OSG?

- Would a single job with 100GB of input data be a good fit for OSG?
- Assume the worst: 100GB / 1MB/s
  - Over a day just to transfer data
- Can we improve this job?
  - Does the data need to be read in its entirety, or just parts?
  - Can we compress the data?

- HTTP
- Caching / StashCache
- Remote I/O
- Pre-staging / OSG Storage Element

More on HTCondor File Transfer

- When using `transfer_input_files`, the data goes through the submit node
  - Potentially a bottleneck
- Suppose you have 1000 jobs starting simultaneously, each transferring 1GB input files. If the submit node has a 1Gbps connection, how long will it take?
  - (Hint: 1Gbps = 125MB/s; 1GB = 1024MB)

HTCondor File Transfer Plugins

- HTCondor also supports various plugins for file transfer
- To use the HTTP plugin, for example, simply:
  - `transfer_input_files = http://<path to file>`
- Takes the network load off of the submit host
  - Scalability problems moved to web server developers/operators :)

Simple HTTP plugin example

- Example that prints the contents of ‘hello.txt’:

```
universe = vanilla

output = job.out
error = job.err
log = job.log

transfer_input_files = http://s3-us-west-2.amazonaws.com/osg-user-school/hello.
txt
executable = /bin/cat
arguments = hello.txt

queue
```

More on scaling up

- Do you transfer the same input data with each job?
  - Two options: caching or remote staging

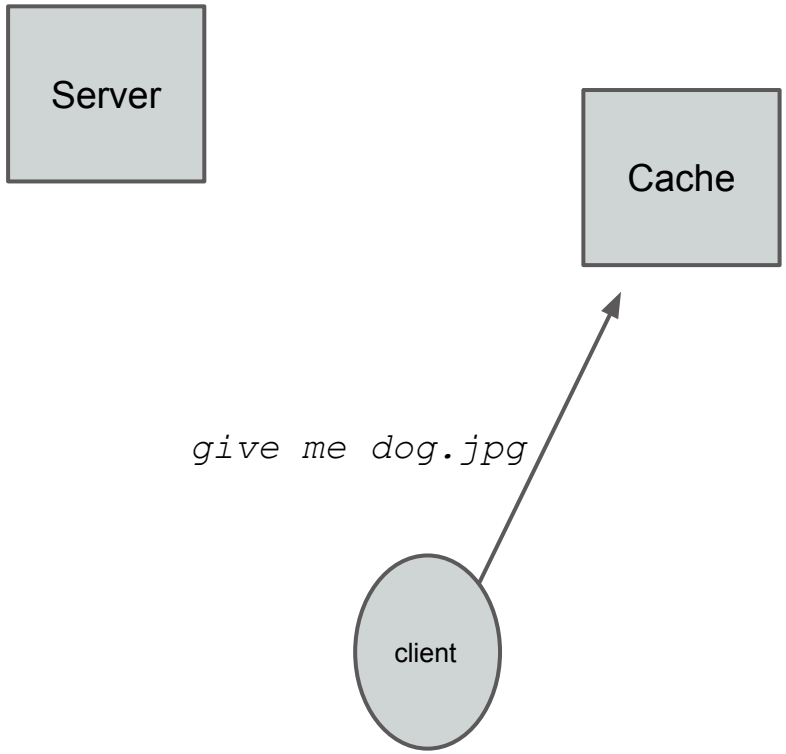
Caching and CDNs

- Imagine you own a popular website like YouTube, Netflix, Reddit, or Facebook
- Users are complaining that their videos load very slowly
- How would you get files to your users faster?

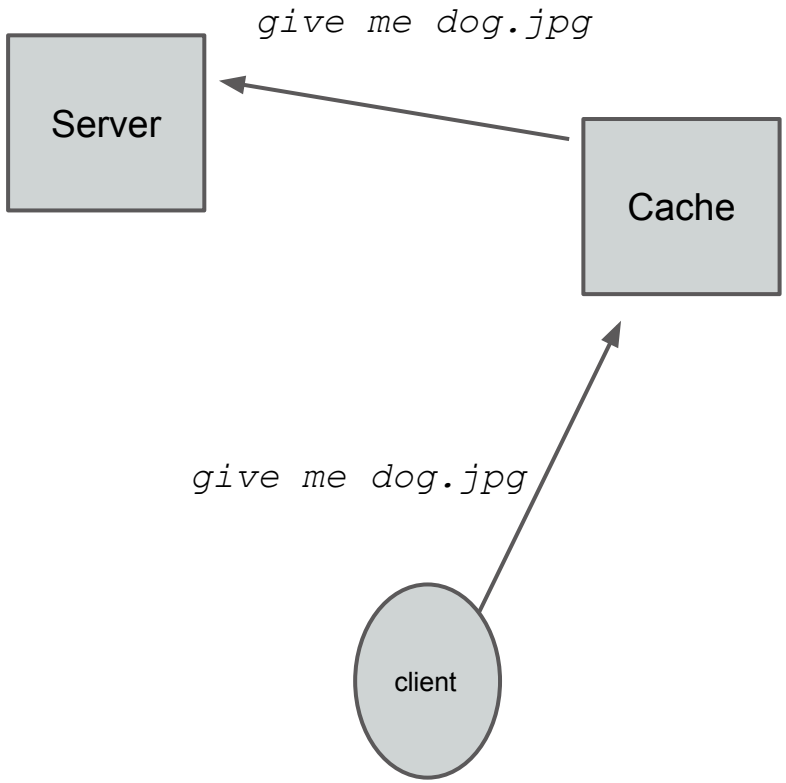
Caching and CDNs

- Build a distributed caching infrastructure
  - Frequently accessed files stored on nearby caches
  - Each cache is as fast or faster than the source server
  - Source server only talks to the caches, not the end-users

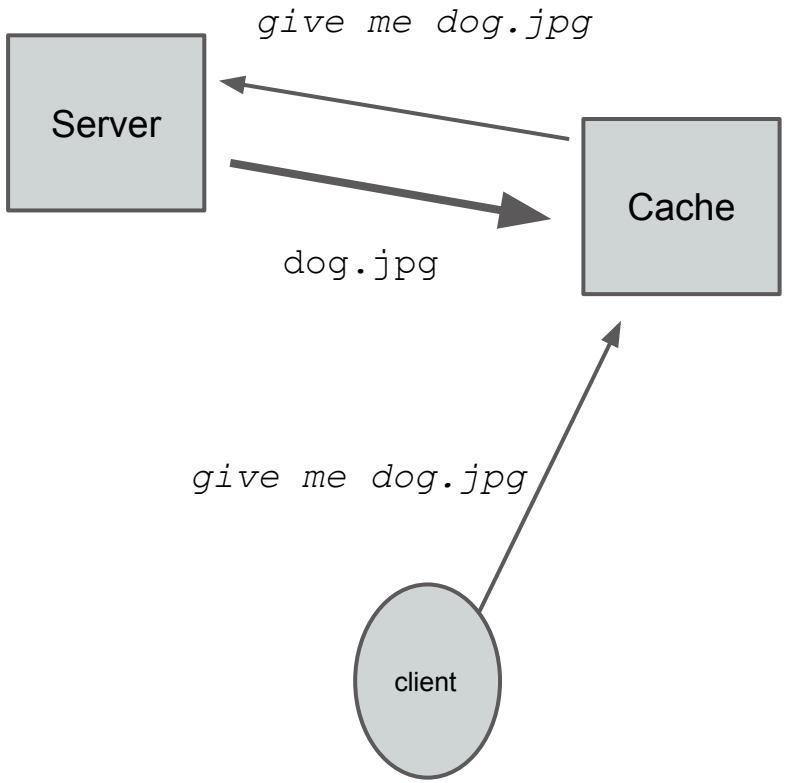
Caching example



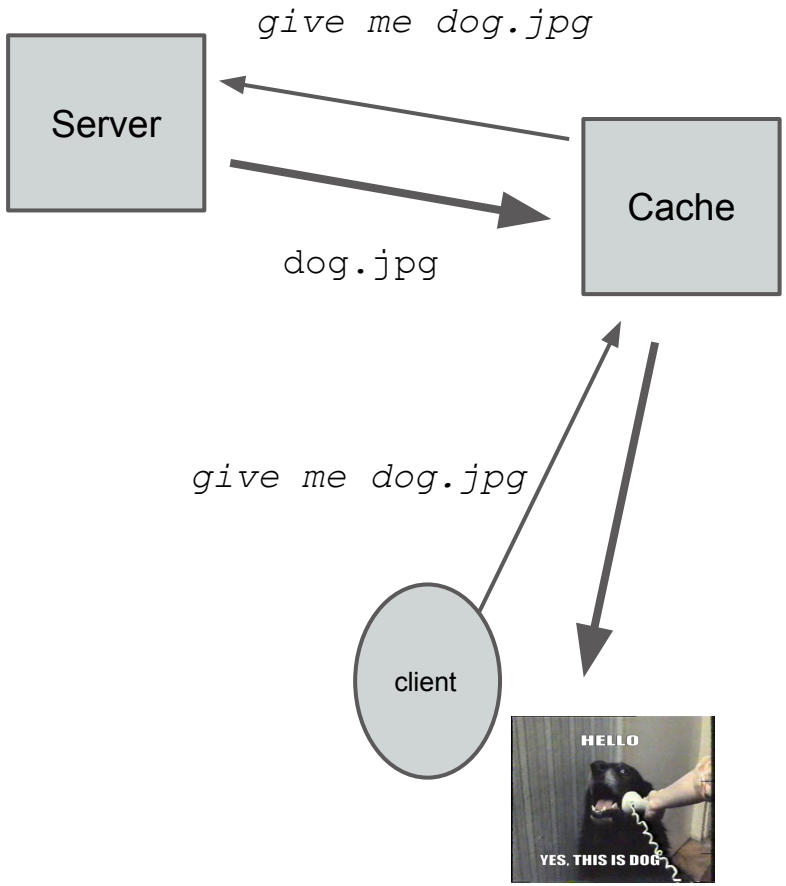
Caching example



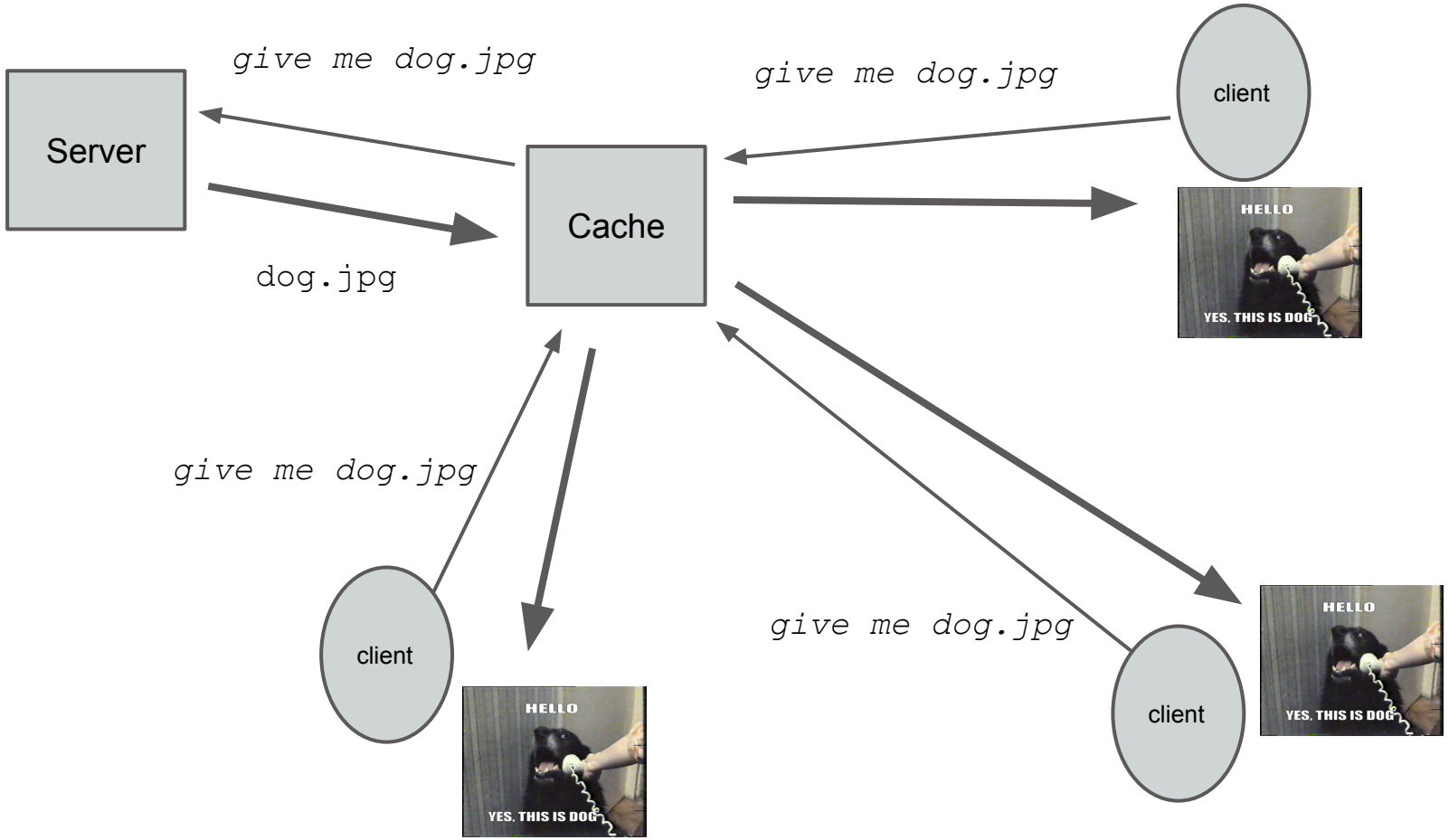
Caching example



Caching example



Caching example



HTTP Caching on OSG

- We can use the same technology to speed up data access
- OSG sites have local Squid servers for this reason
- Effective if:
  - You need the same dataset frequently
  - Cached files are reasonably small
    - Why?

Using HTTP caches on OSG

- To access data via cache, need to set the environment variable `http_proxy`
- `curl`/`wget` tools automatically respect `http_proxy` if set
- Most OSG sites have a pointer to their local cache via `OSG_SQUID_LOCATION`

Cache usage example

- Example script using `wget`

```
#!/bin/bash
export http_proxy=$OSG_SQUID_LOCATION

wget http://stash.osgconnect.net/+dbala/random_words
```

StashCache

- Caching technology being developed by OSG for staging in larger datasets
  - 1GB - 1TB dataset sizes
- Files cached can be orders of magnitude larger than those in HTTP caches
- Designed with the opportunistic user in mind
- HTCondor transfer plugin and direct file access will be available.

Exercises

- Exercise 3
  - Using HTTP and caching on OSG

Remote I/O and the OSG Storage Element

Dealing with *really* large datasets

- In some cases, the input dataset is too large to either:
  - transfer in a reasonable amount of time
  - store on a worker node.
- How do to deal with such datasets?
  - Two techniques: Split the data up, or use remote I/O

Technique 1: Splitting up data

- No general recipe for this, some tips:
  - Unstructured text files can be manipulated simply with the standard UNIX tools (awk, sed, cut, etc)
  - Tar files can be extracted and reorganized
  - Tools like ImageMagick can split images

Technique 2: Remote I/O

- Remote I/O allows a job to read remote data locally
- Either needs to be built into the protocol (e.g., XRootD) with a supporting client application (e.g., ROOT)
- Or user applications have to be tricked into thinking remote files are actually local
  - via trapping & redirecting system calls

Tools for remote I/O

- Parrot
  - Intercepts system calls and rewrites them on the fly via the kernel debugging interface (ptrace)
- Chirp
  - Lightweight I/O protocol used by Parrot
  - Also available via condor_chirp (see exercise)

Parrot Diagram

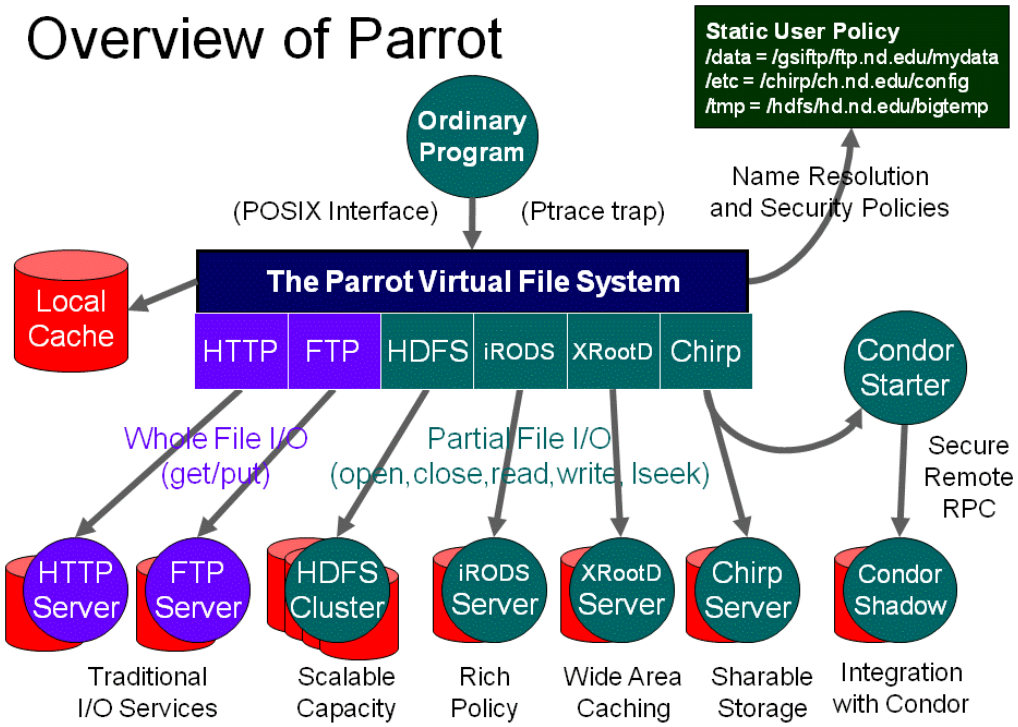


Diagram shamelessly stolen from: http://ccl.cse.nd.edu/software/parrot/

Parrot and Chirp caveats

- Does not work with some workloads
- Rewriting system calls on the fly can affect performance

The OSG Storage Element (SE)

- The traditional OSG storage solution
- Jobs and data co-located at the same OSG site
- Multi-TB to multi-PB of storage space
- Works well for large collaborations (CMS, ATLAS, etc)
- Typical protocols: SRM, GridFTP, XRootD

The OSG Storage Element (SE)

- Doesn’t work so well for opportunistic use
- Why?
  - Need to know *a priori* where jobs will go in relation to data
  - No auto-expiration of old data

A whirlwind tour through GridFTP/SRM

- GridFTP
  - extends the venerable File Transfer Protocol (FTP)
  - adds support for X509 authentication, fault tolerance, parallel transfers, etc

A whirlwind tour through GridFTP/SRM

- Storage Resource Manager (SRM)
  - sits on top of GridFTP
  - adds quotas (space tokens), manages pools of GridFTP servers, etc

When should I use the standard SE?

- SE currently most effective for staging large (multi-GB to TB) amounts of data in/out of a site
- However:
  - Using an SE requires an X509 certificate and some special setup.
  - If you think this applies to you, come talk to us.

Summary

- Many ways to access data on OSG
  - HTCondor's built-in file transfer, external protocols (e.g. HTTP), caching, remote I/O
- The "best" access method will depend on your application requirements.

References

- [1] http://recode.net/2015/04/22/the-third-phase-of-big-data/
- [2] http://www.sdss.org/dr12/data_access/volume/
- [3] https://indico.cern.ch/event/214784/session/6/contribution/262/material-old/paper/0.pdf
- [4] https://code.facebook.com/posts/229861827208629/scaling-the-facebook-data-warehouse-to-300-pb/