# Data Management for HTC

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# Outline

- Common data patterns in HTC Applications.
- Storage architecture for HTC sites
- Strategies for Managing Data.
- Reliability and the Cost of Complexity
- Prestaging data on the OSG
- Advanced Data Management Architectures

# Common data patterns in HTC Applications

- I'm going to give a few common patterns for accessing data observed at HTC-centric sites.
- This is not meant to be exhaustive; for each "theme", there's a huge number of variations.
  - Not only variations of a single pattern, but several patterns in a workflow.

# Classifying Usage

- Ask yourself, per job:
  - Events in a job's life:
    - INPUT: What should be available when the job is starting?
    - RUNTIME: What is needed while the job runs?
    - OUTPUT: What output is produced?
  - Important quantities:
    - FILES: How many files?
    - DATA: How big is the "working set" of data? How big is the sum of all the files?
    - RATES: How much data is consumed on average? At peak?

# Simulation

- Based on different input configurations, generate the physical response of a system.
  - **Input**: The HTC application must manage many input files; one per job.
  - **Runtime**: An executable reads the input and later produces output. Sometimes, temporary scratch space is necessary for intermediate results.
  - **Output**: These outputs can be small [KB] (total energy and configuration of a single molecule) or large [GB] (electronic readout of a detector for hundreds of simulated particle collisions).
    - "Huge" outputs [TB] are currently not common in HTC.

# Searches

- Given a database, calculate a solution to a given problem.
  - **Input**: A database (possibly several GB) shared for all jobs, and an input file per job.
  - **Runtime**: Job reads the configuration file at startup, and accesses the database throughout the job's runtime.
  - **Output**: Typically small (order of a few MB); the results of a query/search.

# Data Processing

- Transform dataset(s) into new dataset(s). The input dataset might be re-partitioned into new logical groupings, or changed into a different data format.
  - **Input**: Configuration file. Input dataset
  - **Runtime**: Configuration is read at startup; input dataset is read through, one file at a time. Scratch space used for staging output.
  - **Output**: Output dataset; similar in size to the input dataset.

# Analysis

- Given some dataset, analyze and summarize its contents.
  - **Input**: Configuration file and data set.
  - **Runtime**: Configuration file is read, then the process reads through the files in the dataset, one at a time (approximately constant rate). Intermediate output written to scratch area.
  - **Output**: Summary of dataset; smaller than input dataset.

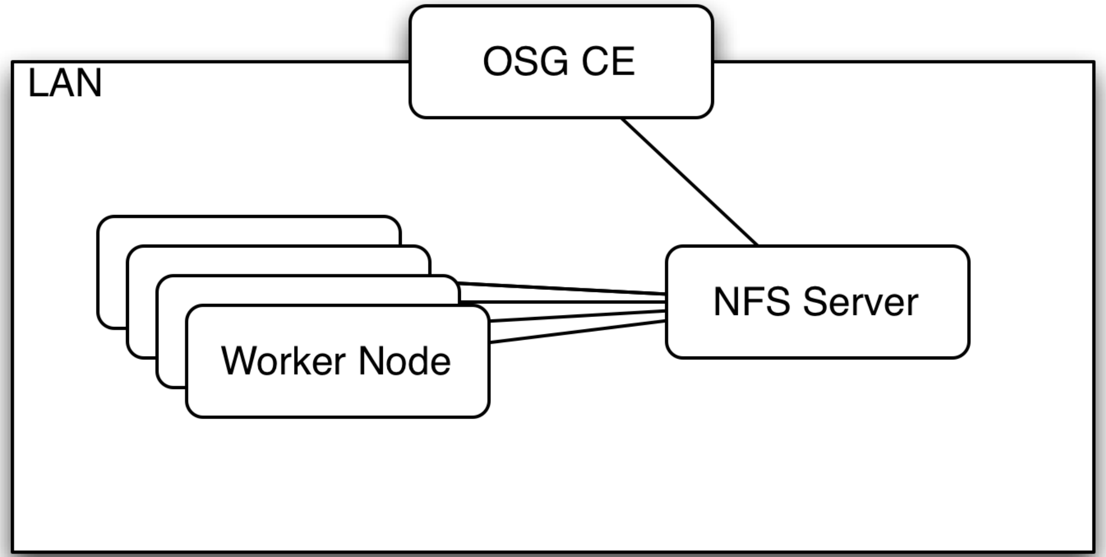
# OSG Anti-Patterns

- Just as we want to identify common successful patterns, we want to identify common patterns that are unsuccessful on OSG.
  - Files larger than >5GB.
  - Requiring a (POSIX) shared file system.
  - Lots of small files (more than 1 file per minute of computation time).
  - Jobs consuming more than 10GB per hour, or needing scratch space more than 5GB.
  - Locking, appending, or updating files.
- When using OSG resources opportunistically, the effective limitations may be more restrictive than above!

# Storage Architectures on the OSG

- Given the previous problems patterns, I want to discuss common solution patterns.
  - Before that, we need a short primer on how storage is architected on the OSG.

# Storage at OSG CEs




- All OSG sites have some kind of shared, POSIX-mounted storage (typically NFS).* This is almost never a distributed or high-performance file system
- This is mounted and writable on the CE.*
- This is readable (sometimes read-only) from the OSG worker nodes.

*Exceptions apply! Sites ultimately decide

# Why Not?

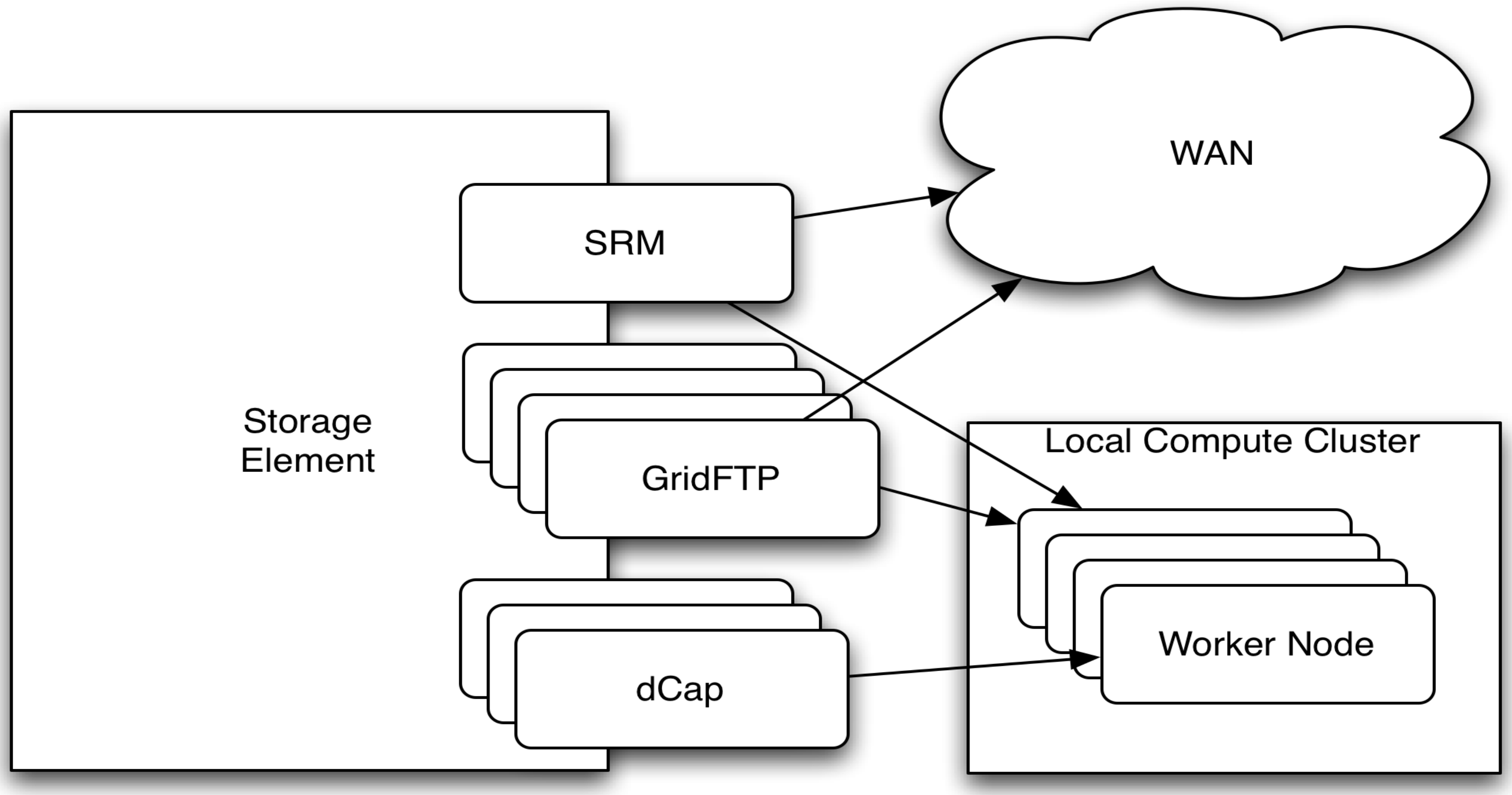
- This setup is called the "classic SE" setup, because this is how the grid worked circa 2003.
  - ***Why didn't this work*?**
- High-performance filesystems not reliable or cheap enough.
- Scalability issues.
- Difficult to manage space.

# Storage Elements

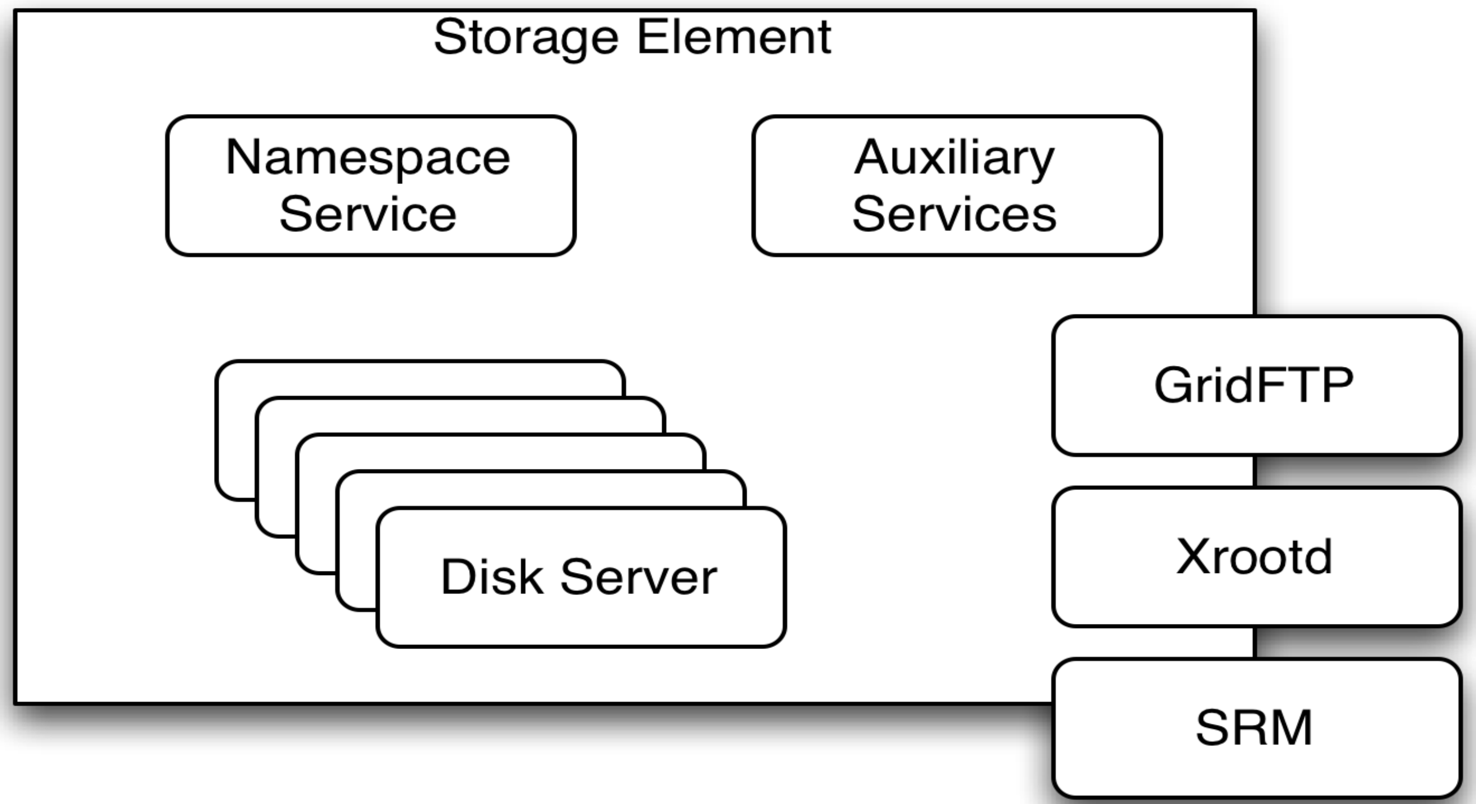
- In order to make storage and transfers scalable, sites set up a separate system for storage (the *Storage Element*).
- Most sites have an attached SE, but there's a wide range of scalability.
- These are separated from the compute cluster; normally, you interact it via a get or put of the file.
  - Not POSIX!

# Storage Elements on the OSG

User point of View!



# SE Internals



# GridFTP in One Slide

- An set of extensions to the classic FTP protocol.
- Two most important extensions:
  - **Security**: Authentication, encryption, and integrity provided by GSI/X509. Use proxies instead of username/password.
  - **Improved Scalability**: Instead of transferring a file over one TCP connection, multiple TCP connections may be used.

# SRM

- SRM = Storage Resource Management
- SRM is a web-services-based protocol for doing:
  - Metadata Operations.
  - Load-balancing.
  - Space management.
- This allows us to access storage remotely, and to treat multiple storage implementations in a homogeneous manner.

# Data Access Methods

- To go with our archetypical problems, we'll have a few common approaches to implementing solutions:
  - Job Sandbox
  - Prestaging
  - Caching
  - Remote I/O
- A realistic solution will combine multiple methods.
- Descriptions to follow discuss the common case; there are always exceptions or alternates.

# Job Sandbox

- Data sent with jobs.
- The user generates the files on the submit machines.
- These files are copied from submit node to worker node.
  - With Condor, a job won't even start if the sandbox can't be copied first. You can always assume it is found locally.
- What are the drawbacks of the job sandbox?

# Prestaging

- Data placed into some place “near” to where the jobs are run.
- By increasing the number of locations of the data and doing intelligent placement, we increase scalability.
  - In some cases, prestaging = making a copy at each site where the job is run.
  - Not always true; a single storage element may be able to support the load of many sites.

# Caching

- A cache transparently stores data close to the user process. Future requests can be served from the cache.
  - User must place file/object at a source site responsible for keeping the file permanently. Cache must be able to access the file at its source.
  - Requesting a file will bring it into the cache.
  - Once the cache becomes full, an eviction policy is invoked to decide what files to remove.
  - The cache, not the user, decides what files will be kept in the cache.

# Remote I/O

- Application data is streamed from a remote site upon demand.  I/O calls are transformed into network transfers.
  - Typically, only the requested bytes are moved.
  - Often, data is streamed from a common source site.
  - Can be done transparently so the user application doesn’t know the I/O isn’t local.
- Can be effectively combined with caching to scale better.

# Scalability

- For each of the four previous methods (sandboxes, prestaging, caching, remote I/O), how well do they scale?
  - What are the limitations on data size?
  - What resources are consumed per user-process?
  - What are the scalability bottlenecks?

# The Cost of Reliability

- For each of the four previous methods, what must be done to create a reliable system?
  - What's the cost for tracking the location of files?
  - What recovery must be done on failures?
    - What must be done manually, or require extra infrastructure?
  - What is the most critical bottlenecks or points of failure?
    - How do these tie into the job submission system?

# Comparing Compute and Storage

- The “shared resource” for computing is the gatekeeper.
  - One badly behaving user can overload the gatekeeper, preventing new jobs from starting.
  - However, once jobs are started, they are mostly independent.
    - There are some shared aspects: what are they?  Why am I not concerned about them?

# Comparing Compute and Storage

- Storage is different:
  - It is often used throughout the job's lifetime, especially for remote I/O.
  - One badly behaved user can crash the storage resource – or at least severely degrade.
  - Opportunistic usage of storage via prestaging does not automatically have a limited lifetime.
    - Most users assume that data, once written to a SE, will be retrievable.

# Prestaging Data on the OSG

- Prestaging is currently the most popular data management method on the OSG, but requires the most work.
  - Requires a **transfer system** to move a list of files between two sites. Example systems: Globus Online, Stork, FTS.
  - Requires a **bookkeeping system** to record the location of datasets. Examples: LFC, DBS.
  - Requires a mechanism to **verify** the current validity of file locations in the bookkeeping systems. Most systems are ad-hoc or manual.

# Exercise Break

- https://twiki.grid.iu.edu/bin/view/Main/CSE435GridStorage
- Note:  To complete this exercise, you must fill your user name into the form and hit "Customize".

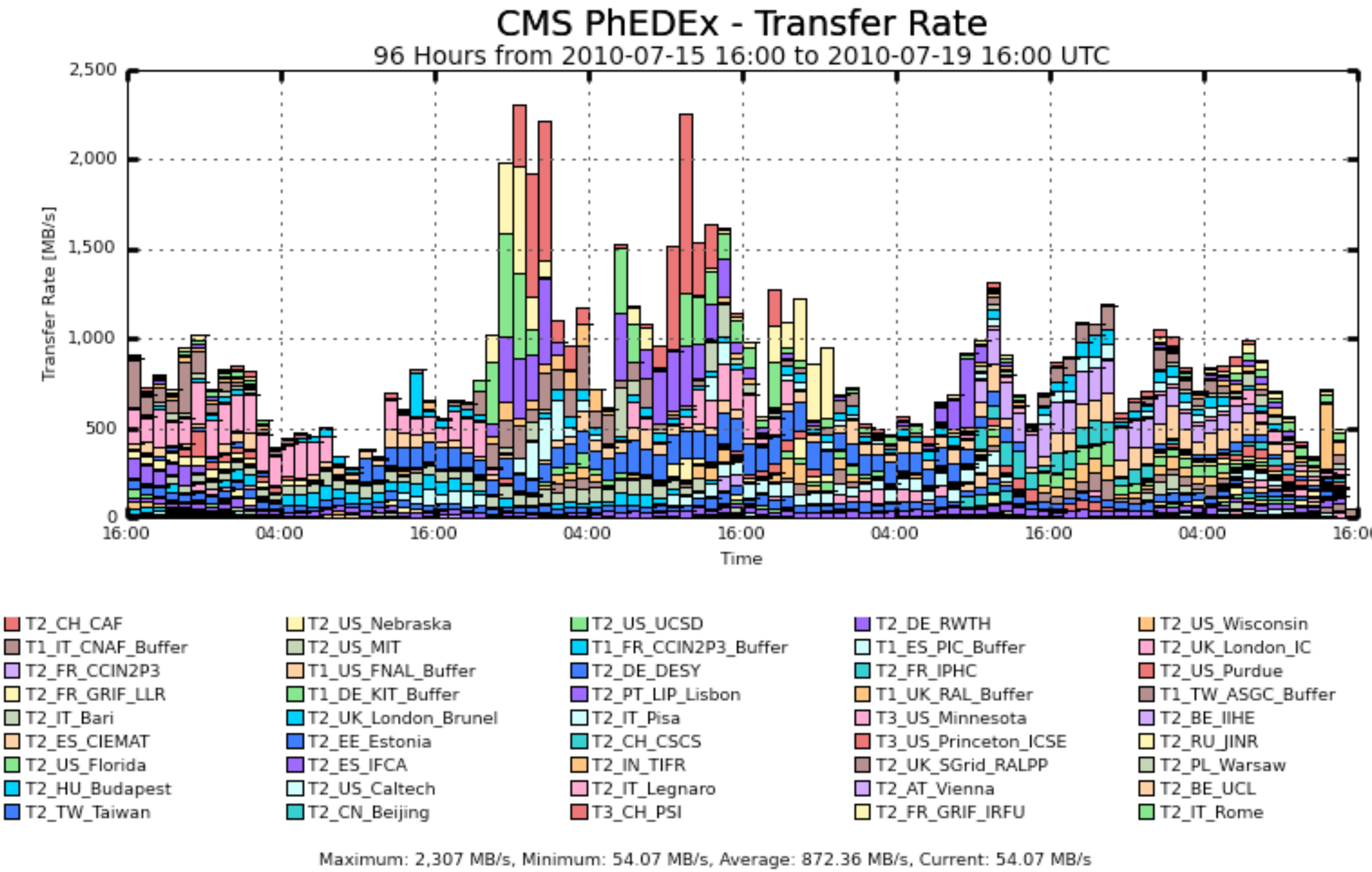
# Example Solution: PhEDEx

- PhEDEx is the CMS data transfer system.
- Transfers are done using FTS.
- Bookkeeping is done via a custom Oracle system.
- Destination sites are subscribed to datasets by users.
- Source sites are selected per-file by intelligent routing mechanisms.

# PhEDEx

- Each site runs a set of processes called Agents to manage the download activity.
  - Requires admin time at each participating site.
- Full-featured monitoring via the PhEDEx website.
- Resulting system is highly effective, extremely scalable, but probably requires a large amount of effort.

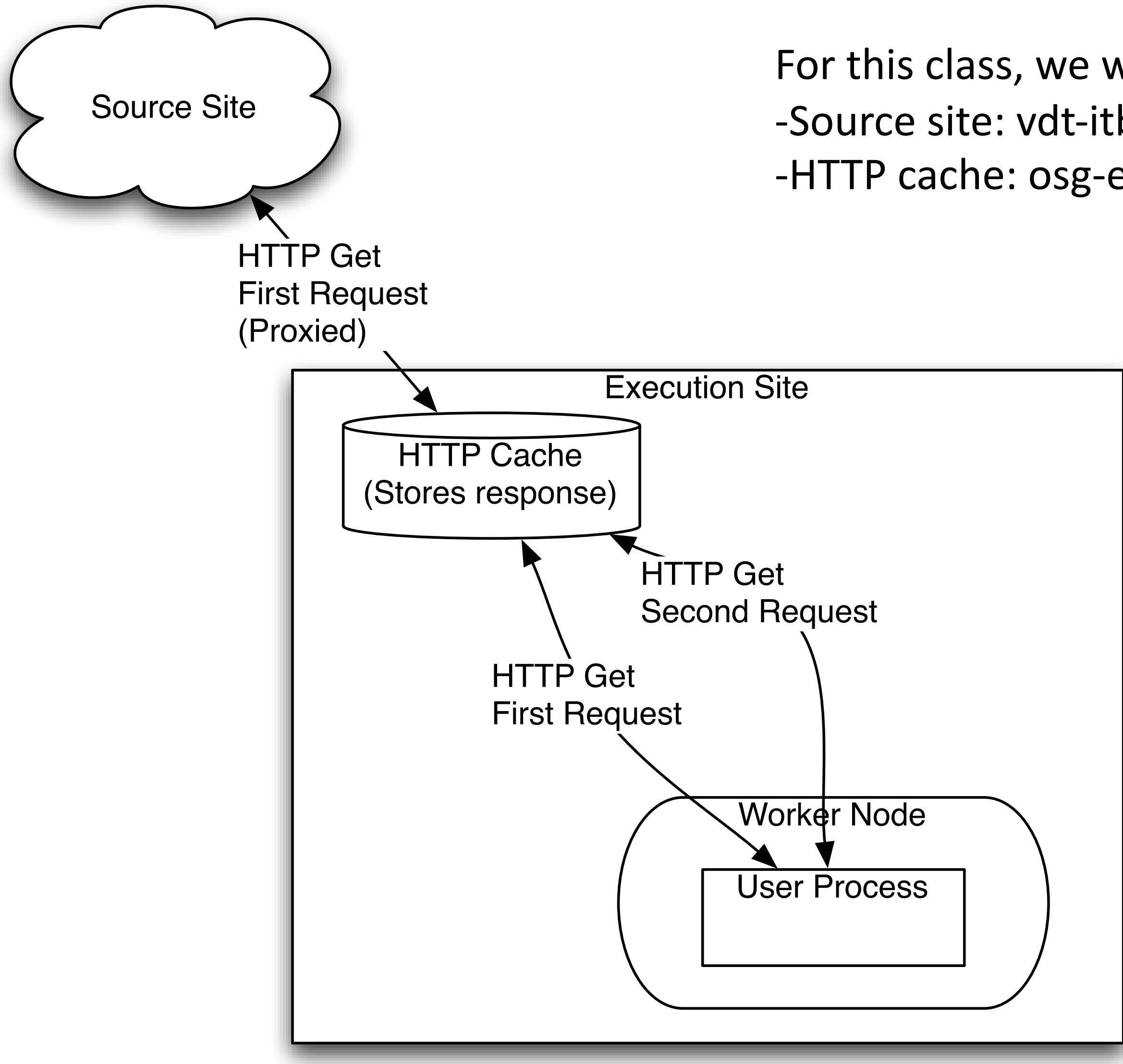
# PhEDEx Snapshot



# HTTP Caching

- The HTTP protocol is perhaps the most popular application-layer protocol on the planet.
- Built-in to HTTP 1.1 are elaborate mechanisms to use HTTP through a proxy and for caching.
- There are mature, widely-used command-line clients for the HTTP protocol on Linux.
  - Curl and wget are the most popular; we will use wget for the exercises.
    - Oddly enough, curl disables caching by default.

# HTTP Cache Dataflow




For this class, we will use:
-Source site: vdt-itb.cs.wisc.edu
-HTTP cache: osg-edu-se.cs.wisc.edu

# Proxy Request

- Here's the HTTP headers for the request that goes to the proxy osg-edu-se.cs.wisc.edu:

**GET** http://vdt-itb.cs.wisc.edu/dm_exercises_part3/bbockelm/yeast.aa.psq HTTP/1.0
User-Agent: Wget/1.11.4 Red Hat modified
Accept: */*
**Host: vdt-itb.cs.wisc.edu**

# Proxy Response

- Here is the response headers from osg-edu-se.cs.wisc.edu:

HTTP/1.0 200 **OK**
Date: Fri, 24 Jun 2011 22:43:53 GMT
Server: Apache/2.2.3 (Scientific Linux)
Last-Modified: Fri, 24 Jun 2011 22:43:10 GMT
ETag: "2f89a4-2d79f1-4a67ced0c3b80"
Accept-Ranges: bytes
Content-Length: 2980337
Content-Type: text/plain; charset=UTF-8
Age: 7
**X-Cache: HIT from osg-edu-se.cs.wisc.edu**
**Via: 1.0 osg-edu-se.cs.wisc.edu:3128 (squid/2.6.STABLE23)**
Proxy-Connection: close