Using Xrootd to Federate Regional Storage

Presentation by Brian Bockelman
Representing work done by many others:
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Introductions
Scale Up, Scale Down

- The LHC experiments have thoroughly demonstrated the ability to scale up.

- Combined, we run around 100k cores a day, delivering petabytes to the local cluster, and about a petabyte over the WAN.

- What’s questionable is our ability to scale down to the needs of a single physicists.
The Woe of One Event

• If I want to read a single event, how do I get the data? Options:

  • **Run a grid job on that event**: best case, 15 minutes (create the job, submit it, have it run, fetch results). Worst case, hours of queue time.

  • **Download the file**: First you have to find it and setup the tools. If you’re lucky, only 5 minutes to download.
Direct Remote Access is Key

• We turned to the Xrootd project to provide remote, direct access to data stored at sites.

• Mature project for remote-I/O.

• Client almost always integrated into ROOT.

• Has the security mechanisms WLCG needs.

• Time to open event interactively is limited to network latency.
Introducing Federations

• Remote access gives us data for one site. We need a federation to access all sites.

• Definition of a **federated storage system**: 

  • A collection of disparate storage resources managed by cooperating but independent administrative domains transparently accessible via a common namespace.

* From the Lyon workshop on Federated Data Stores: [http://indico.in2p3.fr/conferenceProgram.py?confld=5527](http://indico.in2p3.fr/conferenceProgram.py?confld=5527)
Federating Xrootd

- The simplest kind of federation is illustrated below:

Federation overlays on top of existing storage
Federations, in practice

- The federation approach has been used by ALICE for many years; used ALIEN, not Xrootd to federate.
- USCMS started federating T2s in 2010; grew to all sites in 2011.
  - Project is named “Any Data, Any Time, Anywhere” or AAA.
- USATLAS started in 2011 and quickly grew to all sites.
  - Project named “Federated Atlas Xrootd”, or FAX.
- Equivalent projects in EU are being worked on.
AAA Deployment

• Currently, redirector at xrootd.unl.edu.
• Includes the FNAL T1 (dCache) and 8 T2s (5 HDFS, 1 dCache, 1 Lustre, 1 L-Store).
• During April, our monitoring recorded:
  • Over 300 unique users,
  • 900K file transfers
  • 300TB moved.
FAX Deployment

FAX is a 15PB federation, including ATLAS T3s and multiple layers of hierarchy.
Technical Concerns
Site Integration

- Most sites integrate via installing a plugin specific to their storage system.
  - This causes Xrootd to be a *proxy* to the outer world.
  - Anything with a C or POSIX interface can be integrated. E.g., HDFS or Lustre.
- A native Xrootd can do *direct integration* with the redirector.
- dCache has a few options besides proxying:
  - *Native implementation* of the Xrootd protocol, plus a standalone cmsd server for integration.
  - The *overlay* approach has a SLAC Xrootd server running on each dCache pool, reading out of dCache’s data directories.
Merging Namespaces

• To provide a uniform namespace, each site must export the *global* filename, not the *local* filename. This is achieved through a Xrootd plugin.

• For CMS, this mapping is achieved through a list of mapping rules and regular expressions.

• For ATLAS, this requires a MySQL database lookup. The higher overhead is partly ameliorated by aggressive caching.

• ATLAS namespace is currently evolving to something simpler.
Authorization

• While Xrootd has many security protocols, like SRM or GridFTP, GSI-based authentication is used in AAA/FAX.

• Xrootd has a plugin for mapping the GSI credentials to a username:
  • FAX uses a simple map file based on VOMS attributes.
  • AAA passes the DN and VOMS attributes to the site mapping service (GUMS).

• Once mapped, a separate file containing authorizations for each user determines file access.
Monitoring

• See poster 233, “Xrootd Monitoring for the CMS experiment,” in track 3.

• We have two streams of monitoring from Xrootd:
  
  • **Summary**: gives high-level statistics (# connections, failures, MB/s) per-server.
  
  • **Detailed**: a highly compressed trace of the user’s activities. Works at the per-open-file level.

• In addition, external server health checks - Nagios and RSV.
### Frequently Asked Questions

#### Host: atl-prod09.slac.stanford.edu (atl-prod09.slac.stanford.edu)

| Metric                                | Last Executed       | Enabled? | Next Run Time       |
|---------------------------------------|---------------------|----------|---------------------|
| org.usatlas.xroottd.grid-xrdcp-compare| 2012-05-08 19:50:03 CDT | YES      | 2012-05-08 20:05:00 CDT |
| org.usatlas.xroottd.grid-xrdcp-direct | 2012-05-08 20:05:01 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.grid-xrdcp-fax    | 2012-05-08 20:05:00 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.ping              | 2012-05-08 20:05:02 CDT | YES      | 2012-05-08 20:20:00 CDT |

#### Host: atlas29.hep.anl.gov (atlas29.hep.anl.gov)

| Metric                                | Last Executed       | Enabled? | Next Run Time       |
|---------------------------------------|---------------------|----------|---------------------|
| org.usatlas.xroottd.ping              | 2012-05-08 20:05:02 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-compare     | 2012-05-08 20:05:01 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-direct      | 2012-05-08 20:05:02 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-fax         | 2012-05-08 20:05:01 CDT | YES      | 2012-05-08 20:20:00 CDT |

#### Host: atlgridftp01.phy.duke.edu (atlgridftp01.phy.duke.edu)

| Metric                                | Last Executed       | Enabled? | Next Run Time       |
|---------------------------------------|---------------------|----------|---------------------|
| org.usatlas.xroottd.ping              | 2012-05-08 20:05:01 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-compare     | 2012-05-08 20:05:00 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-direct      | 2012-05-08 20:05:02 CDT | YES      | 2012-05-08 20:20:00 CDT |
| org.usatlas.xroottd.xrdcp-fax         | 2012-05-08 20:05:01 CDT | YES      | 2012-05-08 20:20:00 CDT |

#### Host: dcdoor09.usatlas.bnl.gov (dcdoor09.usatlas.bnl.gov)

| Metric                                | Last Executed       | Enabled? | Next Run Time       |
|---------------------------------------|---------------------|----------|---------------------|
| org.usatlas.xroottd.ping              | 2012-05-08 20:05:02 CDT | YES      | 2012-05-08 20:20:00 CDT |
Use Cases

• Our initial goals tended toward interactive use, but we have found several other compelling use cases for a federation.
Fallback

• If a grid job fails to open a file, don’t fail the application. Instead, have it try again, reading from the redirector.

• Loss of efficiency, but the job doesn’t crash.

• Great for “breaking in” new federations.

• The job was going to fail anyway; even an unreliable federation is better than nothing.
Storage Healing

• Fallback prevents jobs from failing. Taking it one step further, we can use the federation as a source to re-download the broken file.

• Still an R&D topic. Issues:
  • How to handle failure “bursts” (all files in your storage fail for 10 minutes).
  • How do you determine whether the file should be there?
Overflow

- See poster 232, “Controlled overflowing of data-intensive jobs from oversubscribed sites,” in track 3.
- If jobs are queued for a long time, we can purposely send the job to the “wrong” site if
  - Fallback is enabled at the destination.
  - One data source is in the federation.
- This forced fallback allows us to “backfill” otherwise-idle CMS analysis CPUs, work around non-optimal data distribution.
File Caching

- Remote I/O is expensive in terms of WAN bandwidth, especially if the file is re-read many times.
- Instead of asking the redirector for the file, ask a local Xrootd install.
- On the file open failure, the local Xrootd will stage the file to a local disk. On next access, file will be local.
- Using this at the BNL T3, and under investigation at Duke.
- Work needed to make it more fault tolerant. Cache management - which files to evict - is a deep, difficult topic.
Parting Remarks

- We’ve been doing this for several years now, and Xrootd-based federations are starting to enter large-scale, day-to-day use for CMS. ATLAS is quickly hardening FAX.

- We’ve found the **major issues are** not making the federation deliver data, but **covering the failure cases** - esp. within the client.

- The ability to do wide-area, direct Xrootd access is dependent on the application code’s ability to handle large network latency.

- Effort by the experiment is a prerequisite to many of these use cases work.
Questions?
Backup Slides
XrdReport for link traffic on UNL

May 2012

red-gridftp1  red-gridftp10  red-gridftp11  red-gridftp12  red-gridftp2  red-gridftp3  red-gridftp4  red-gridftp5  red-gridftp6  red-gridftp7
red-gridftp8  red-gridftp9  xrootd
Volume of Gigabytes Transferred By Facility
13 Days from 2012-04-09 to 2012-04-22

Maximum: 17,992 GB, Minimum: 3,300 GB, Average: 8,304 GB, Current: 3,916 GB
| File A          | User Hash      | Server Domain | Client Domain | Open Ago   | Update Ago  | Read [MB] | Read [%] | Rate |
|----------------|----------------|---------------|---------------|------------|-------------|-----------|----------|------|
| /store/mc/Fall11 | 6DB2B1B7       | hep.wisc.edu  | unl.edu       | 25:37:11   | 21:22:11    | 2728.245  | 68.827   | 0.030|
| /store/mc/Summer11 | 3C12BE84   | fnal.gov      | unl.edu       | 01:06:03   | 00:05:23    | 2523.107  | 62.609   | 0.637|
| /store/data/Run2012A | 3D8C2B76    | fnal.gov      | t2.ucsd.edu   | 04:30:43   | 00:08:38    | 2498.118  | 54.639   | 0.154|
| /store/data/Run2012A | 3D8C2B76    | fnal.gov      | t2.ucsd.edu   | 03:15:18   | 00:01:08    | 2474.463  | 57.433   | 0.211|
| /store/data/Run2012A | 3D8C2B76    | fnal.gov      | t2.ucsd.edu   | 04:00:37   | 00:01:42    | 2442.054  | 57.521   | 0.169|
| /store/mc/Summer11 | 3C12BE84    | fnal.gov      | unl.edu       | 00:51:58   | 00:00:58    | 2429.944  | 64.505   | 0.779|
| /store/mc/Summer11 | 3C12BE84    | fnal.gov      | t2.ucsd.edu   | 02:14:36   | 00:04:21    | 2420.094  | 59.497   | 0.300|
| /store/data/Run2012A | 3C12BE84    | fnal.gov      | t2.ucsd.edu   | 01:26:01   | 00:04:41    | 2413.841  | 63.327   | 0.468|
| /store/data/Run2012A | 3C12BE84    | fnal.gov      | t2.ucsd.edu   | 01:31:55   | 00:00:50    | 2366.587  | 64.929   | 0.429|
| /store/data/Run2011A | 3C12BE84    | ihepa.ufl.edu | unl.edu       | 03:52:41   | 00:01:56    | 2365.060  | 59.156   | 0.169|
| /store/data/Run2012A | 3AC086B     | fnal.gov      | t2.ucsd.edu   | 01:17:18   | 00:00:18    | 2320.691  | 62.855   | 0.500|
| /store/data/Run2012A | 3D8C2B76    | hep.wisc.edu  | t2.ucsd.edu   | 04:00:47   | 00:10:22    | 2411.461  | 52.835   | 0.167|
| /store/data/Run2012A | 3D8C2B76    | hep.wisc.edu  | t2.ucsd.edu   | 04:01:48   | 00:00:23    | 2212.339  | 59.802   | 0.152|
| /store/mc/Summer11 | 3C12BE84    | hep.wisc.edu  | ultralight.org| 02:02:28   | 00:16:48    | 2170.151  | 54.353   | 0.295|
| /store/data/Run2011A | 3AC086B     | ihepa.ufl.edu | unl.edu       | 03:52:41   | 00:11:16    | 2101.871  | 52.162   | 0.151|
| /store/data/Run2012A | 3D8C2B76    | fnal.gov      | t2.ucsd.edu   | 04:20:26   | 00:00:56    | 1991.785  | 61.253   | 0.127|
| /store/data/Run2012A | 3AC086B     | ihepa.ufl.edu | t2.ucsd.edu   | 08:41:15   | 00:00:05    | 1976.205  | 62.562   | 0.063|
| /store/mc/Spring11 | 3C12BE84    | unl.edu       | ultralight.org| 01:17:14   | 00:10:34    | 1953.870  | 53.664   | 0.422|
| /store/mc/Fall11  | B83B3C94     | hep.wisc.edu  | ultralight.org| 11:32:01   | 02:49:41    | 1944.444  | 52.812   | 0.047|
| /store/data/Run2012A | 3D8C2B76    | hep.wisc.edu  | t2.ucsd.edu   | 03:17:33   | 00:02:03    | 1919.433  | 64.035   | 0.162|
| /store/data/Run2011A | 3C12BE84    | ihepa.ufl.edu | unl.edu       | 03:38:01   | 00:00:01    | 1908.636  | 50.158   | 0.146|
Sample Daily Report

Xrootd Summary for 2012-05-09 | 59.92 TB | 37% increase

| Source Site     | Volume GB | # of Transfers | Yesterday Diff | One Week Diff |
|-----------------|-----------|----------------|----------------|--------------|
| GLOW            | 1,080     | 1,223          | 55%            | 1908%        |
| GLOW_Internal   | 46,053    | 38,388         | 65%            | 32%          |
| MIT             | 4,950     | 11,460         | 103%           | 95800%       |
| Nebraska        | 4,195     | 9,118          | -43%           | 65%          |
| Purdue          | 415       | 2,168          | 279%           | 374%         |
| T2_IT_Bari      | 0         | 6              | Unknown        | -96%         |
| UCSD            | 551       | 4,245          | -65%           | 927%         |
| UFL             | 1,138     | 2,066          | 945%           | 1250%        |
| USCMS-FNAL-WC1  | 1,521     | 2,222          | -57%           | -32%         |
| Vanderbilt      | 14        | 746            | 400%           | 598%         |