Tier 1 Evolution in Response to Experiment Data Model Changes in LCG

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Abstract. Changes in experiment data models are having a significant impact on the operations of the Tier 1’s within WLCG. In this paper we look at how two sites, ASGC and RAL, have evolved to meet the specific request to separate the tape and disk systems for user jobs. We discuss the solutions chosen at the two sites, why the decisions were made and discuss the work required to implement, migrate to and support these solutions.

1. Introduction

The data distribution models used by experiments within WLCG [1] were originally designed based on the MONARC model [2], which foresaw a hierarchical, tiered model with a central data store (Tier 0) maintaining an archive copy of all data, and a second copy of the data being archived at one of a number of geographically distributed Tier 1’s. Each Tier 1 had a number of Tier 2’s which provided additional computing resources, obtaining data from the associated Tier 1 (which may itself need to get the data from another Tier 1 or the Tier 0 facility at CERN).

While this model has served well for a number of years, some inefficiencies have been observed. For instance, if a job running at a Tier 2 requires a specific dataset, it must always go to the Tier 1 to get that data, even if it is available at another Tier 2 in the associated cloud. This could mean recalling data from the tape archive held at the Tier 1 several times with a corresponding delay in meeting the job requirements. Both ATLAS and CMS are now moving away from the MONARC model to a mesh model where data is accessed directly from online copies if they are available on the grid, without the need for Tier 2’s to get their datasets from the Tier 1 ([3], [4]). This change in the model has some significant impact on the Tier 1s, particularly the access to tape. Some sites have made significant changes to their infrastructures in response to this change. This paper looks at two sites which had initially similar infrastructures and how they have evolved with the change in the models.

2. History

During the initial days of running WLCG, Tier 1 sites, for the most part, chose one of two hierarchical storage system (HSMs), dCache [5] and CASTOR [6]. Both these systems supported (either directly or indirectly) the concepts of disk only storage, where files are held on disks without necessarily any...
tape back-up, and a disk cache in front of the tape which held data either being written to or retrieved from the tape system ephemerally (so called Disk1Tape0 or analysis pools and Disk0Tape1 or archive pool solutions). Since then, the number of different storage solutions has expanded, but the overall goals of the Tier 1s has remained unchanged; to provide archive facilities for additional copies of LHC data sets and provide computational facilities for simulation, re-processing and other activities.

While most Tier 1s restricted direct access to the tape system for both reading and writing, jobs could access data from the disk cache in front of the tape, or from ‘disk-only’ storage. As part of the experiment evolution, both CMS and ATLAS have expressed a strong desire for a stricter disk and tape separation where user jobs are not allowed to access data from the archive pool, but only from analysis pool storage. Access to the tape system is still possible for production jobs, but user jobs requiring data which is only held near-line on tape must send a request to stage the data to a production manager who will optimise access to the tape system and will then move datasets from the archive pool to the analysis pool. In addition, data is normally written to the analysis pool and only when verified is it moved to the archive pool and put to tape. Thus the tape system is tending towards a true WORN (Write Once, Read Never) archive.

Until relatively recently, both Rutherford Appleton Laboratory (RAL), the UK Tier 1, and Academia Sinica Grid Computing (ASGC), the Tier 1 site for the Far East, used CASTOR to manage both the analysis and archive pools. Both support multiple experiments (RAL supporting all four of the major experiments and ASGC supporting ATLAS and CMS). These two sites have now diverged with ASGC physically splitting their storage and RAL performing a logical split. A further driver for ASGC was that at the time the split was being considered, the scheduler in CASTOR, which scheduled access to data, was not performant. It could take several seconds to schedule data access that was a significant fraction of, or even exceeded, the actual transfer time. The implication of these choices is described in the next section, along with improvements observed for production and analysis jobs.

3. Site Evolution
In this section we discuss the evolution of the infrastructure at two sites, ASGC and RAL, in response to the change in the WLCG data models for ATLAS and CMS. The advantages and disadvantages are also discussed. In these discussions, it is necessary to understand a number of terms and concepts which are used, and these are described in the following paragraphs.

When accessing data at a Tier 1, experiments use a middleware stack including FTS [7] to contact an 'end point' for the storage. Typically within WLCG this is a Storage Resource Manager (SRM), but it does not need to be. The SRM provides a common interface to a heterogeneous set of storage systems (both HSMs and disk only storage at Tier 2s). In addition, the SRMs provide a security layer based on X509 to protect the storage. In the new model of tape being infrequently used, FTS is the means by which data is moved from archive to analysis pools, which can then be strictly controlled.

It is also important to understand the difference between the archive and analysis pools at Tier 1s. The analysis pool is required for low latency, fast access to data which is already on spinning disk to maximize the CPU efficiencies for jobs running at a site. This analysis pool is managed by experiments, which have the responsibility of removing files and data sets which are no longer required from this pool. In contrast, the archive pool is designed for potentially high latency access which is managed by the HSM, with data being staged from tape to a disk cache, and data removed from the cache to ensure sufficient capacity to recall newer data sets and files.

Finally, the choice to make a physical rather than logical separation was done after significant analysis of alternative technologies including EOS[8], dCache, CEPH and HDFS.

3.1. Physical Separation of Storage
The ASGC Tier 1 has decided to split their analysis pool and storage pool to use completely different technologies. This has allowed ASGC to select the optimum technology for the two scenarios (analysis and archive) without the need to compromise on either, and allows for true disk/tape separation since it is not possible to read or write a file to tape using the analysis pool, since there is no
tape back end. ASGC have chosen to maintain CASTOR for the archive pool, but have switched to DPM [9] for the analysis pool. The two technologies are both highly optimised for their specific roles.

While this solution does meet the experiment requirements, it necessarily comes with some overheads. It requires staff to have a good understanding of two different technologies and be able to support both to the levels required by WLCG. While DPM is designed to be easy to configure and manage, it still requires expertise to optimise its behaviour at different sites. However, unlike CASTOR, it has a large pool of expertise, being deployed at over 200 sites which aids the support effort. This separation has also allowed for a much simpler deployment of CASTOR, now requiring only a single pool of disk servers to act as a tape in front of cache.

With two separate technologies there are additional overheads which must be considered. Both have their own upgrade schedules and will require testing separately, which potentially means increased staff effort at peak times. If test systems are required to test upgrades and patches, then clearly it is necessary to maintain two of these which has implications on hardware and power costs within the ASGC data centre. It also means maintaining two separate set of templates within the configuration management system. Physical separation also makes optimising the hardware placement more difficult; if disk server need to be moved from the archive to the analysis pool (or vice versa), then all components of one technology need to be removed and replaced with the new technology. In the case of ASGC’s choice of technology, this is a particular issue since both CASTOR and DPM support the \texttt{rfio} protocol, but the implementations are incompatible.

When splitting the pools like this, it was necessary to interrupt access to the analysis pool, since the disk servers from the analysis pool would have to be cleared of data and reconfigured to go into the pool in DPM. Any data previously staged on these servers would need to be repopulated once the DPM end point is commissioned and ready. This clearly has a knock-on impact on the experiment, at least while the data required for analysis is moved. However, after this initial disruption, the experiments have seen better performance from the two optimised solutions.

In terms of overall performance, while there was no change in the overall network load, the scheduling overhead was significantly reduced, from several seconds to tens of milliseconds. While this did not have a significant impact on the storage itself, user analysis and production jobs run on the compute farm became significantly more efficient due to the improved data access rates, with efficiencies increasing from about 80% to 90% or more.

3.2. Logical Separation of Storage

The UK Tier 1 [10] at RAL has decided to maintain a single HSM, CASTOR and perform logical separation of the analysis and archive pools. CASTOR has the concepts of service classes and file classes. The service class, as configured at RAL, is associated with a set of disk servers and defines whether the disk pool behaves as a system managed cache or a user managed space. The file class determines whether a particular file will go to tape and is associated with the namespace of the file. Thus writing to tape can be fairly easily protected. However, it is quite possible to recall a file from tape onto the analysis pool by specifying the recall to go to a specific service class, and it is this that must be prevented. Within CASTOR this is achieved using a combination of VO role mapping and Access Control Lists (ACLs). Production users are mapped to specific accounts and the ACLs ensure only jobs submitted by production users can access files in this part of the namespace. To move data from the archive pool to the analysis pool involves an FTS transfer and a change in the namespace of the file (for example, in the case of CMS, the namespace changes from \texttt{.../store} to \texttt{.../disk}). Setting up ACLs where none existed before is of course a risky operation and required significant testing and review before it was implemented and applied recursively to existing directories under the archive namespace. Now this is done, all new directories created under this namespace inherit the ACLs of the parent directory and so needs no ongoing maintenance. It is important to note that this is only possible because CASTOR itself does not support deduplication; two copies of a file in different disk pools are treated independently. For a system that does support this functionality, it would treat the two copies as identical and may remove one of the copies.
Performing a logical separation like this has several advantages in terms of managing the service. Having only one system to manage the storage means staff only need an understanding of the one system and effort can be spent in optimizing it. In terms of hardware deployment, it is also easier to move physical hardware between the analysis and archive pools since the same software is used between the two. In both cases one simply needs to drain existing data from a disk server to other hardware and tell the system the disk server now belongs to the other pool. Of course there are also downsides with this approach. Until recently, CASTOR relied on a commercial scheduler that introduced significant latency in accessing files on the analysis pool. This has largely been addressed in later releases with a dedicated scheduling engine to direct transfer requests. This new scheduler has brought similar overheads seen in DPM (q.v. above), but meant jobs at STFC could be quite inefficient, particularly short jobs accessing small files. A further possible issue is that both the analysis and archive pools need to be upgraded concurrently; while this makes the job of the storage system administrator easier, it does require more careful scheduling with the users to avoid periods of peak activity. One final point is that even with the precautions taken with ACLs, it is possible for a production user to submit a non-production job using their production role and access the archive namespace directly, possibly pulling data from the tape system in a somewhat uncontrolled manner.

4. Conclusion
In this paper we have looked at two methods for achieving the goal of disk/tape separation. Which system is most appropriate for a site is down to a number of factors and it is impossible to say which solution is correct for any site. While we have discussed some of the factors affecting which decision is correct, such as staff training and ease of migration, these are not exhaustive. We have not discussed in this paper issues such licensing costs, the impact of hardware choice or agreements with vendors, expertise needed to maintain the storage systems (for example, CASTOR requires an experienced Oracle Database Administrator) or support.

What we can say is that looking at the two sites in this paper is that having started from the same point in terms of storage solutions, they have chosen to evolve in very different ways. RAL had significantly more staff running their storage and have been actively involved in the development of CASTOR that has given an in-depth knowledge that has reduced the need for external support. They have looked at possible alternative disk-only (analysis) solutions, but did not identify a compelling candidate that outperformed CASTOR and would justify the effort of learning and supporting a second system. ASGC on the other hand have significantly fewer support staff and were less involved in the development of CASTOR. Moving their analysis pool to DPM, which is well supported and widely used within WLCG has given them additional resources to call upon for support and has reduced their dependence on Oracle, upon which CASTOR is based, with the commensurate reduction in expertise needed and licensing costs.

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