Evolving ATLAS Computing For Today’s Networks

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Abstract. The ATLAS computing infrastructure was designed many years ago based on the assumption of rather limited network connectivity between computing centres. ATLAS sites have been organized in a hierarchical model, where only a static subset of all possible network links can be exploited and a static subset of well connected sites (CERN and the Tier-1s) can cover important functional roles such as hosting master copies of the data.

The pragmatic adoption of such simplified approach, in respect of a more relaxed scenario interconnecting all sites, was very beneficial during the commissioning of the ATLAS distributed computing system and essential in reducing the operational cost during the first two years of LHC data taking.

In the mean time, networks evolved far beyond this initial scenario: while a few countries are still poorly connected with the rest of the WLCG infrastructure, most of the ATLAS computing centres are now efficiently interlinked. Our operational experience in running the computing infrastructure in the last years demonstrated many limitations of the current model: statically defined network paths are sometimes abused, while most of the network links are underutilized together with computing and storage resources at many sites, under the wrong assumption of limited connectivity with the rest of the infrastructure.

In this contribution we describe the various steps which ATLAS Distributed Computing went through in order to benefit from the network evolution and move from the current static model to a more relaxed scenario. This will include the development of monitoring and testing tools and the commissioning effort. We will finally describe the gains of the new model in terms of resource utilization at grid sites after many months of experience.
1. ATLAS computing and the MONARC model

The ATLAS collaboration [1] has been successfully running computing activities in distributed environments since its first data challenge in 2001. In a system which does not rely on centrally located resources, but rather on storage and CPUs spread across multiple computer centres in many countries (and continents), network connectivity is an essential component and does play a key role in defining the computing model. At the time of the first ATLAS Technical Proposal in 1994, institutes in Europe could generally rely on a 1Mb/s connection to CERN and Gb/s connections were foreseen by the start of LHC (after a 10 year period). The ATLAS computing TDR [2] assumed therefore not enough network bandwidth to accommodate a model of fully interconnected computer centres. The MONARC project [3] proposed therefore a multi-tier model with those constraints in mind:

- Computer centres are categorized into tiers, based on their role in the experiment computing model. The TIER-0 (CERN) is responsible for RAW data recording into mass storage systems, calibration and alignment and first-pass reconstruction of RAW into derived data. Tier-1s (10 centres in ATLAS, normally HEP laboratories or large IT infrastructures) provide the facility for storing a second custodial copy of the RAW data and for further data processing (both for detector and simulated data). Tier-2 sites (in ATLAS, approximately 100 universities or HEP laboratories) are responsible for end-user analysis as well as production of simulated events.

- The organization of tiers is hierarchical, as shown in Figure 1 on the left hand side. The topology is star-like, centred on the Tier-0. Tier-1 sites can exchange data with the Tier-0 or among themselves. Tier-2s are organized in clouds and each cloud is associated with a Tier-1. Tier-2s can exchange data with other Tier-2s of the same cloud, as well as with the Tier-1 of the cloud.

- The network topology follows directly the model. High bandwidth (10Gb/s) point to point connectivity is ensured between Tier-0 and Tier-1s as well as between Tier-1s by the Optical Private Network (OPN), as shown in Figure 1 on the right hand side. Other links rely on the General Purpose Networks and normally there is no QoS defined.

Figure 1: the ATLAS hierarchical tier model (left) and the LHC OPN (right)

The ATLAS computing model [4] embraced and implemented the MONARC model very strictly. ATLAS Tier-2s have been organized in 10 clouds, most of which group computing sites from a single country, but with noticeable exceptions. The ATLAS Distributed Data Management system (DDM) [5] delivers data to sites following the MONARC model restrictions on which network channels are
“allowed” or not. The ATLAS Production and Analysis framework (PanDA)[6] confines a single processing workflow to a single cloud. Such very pragmatic approach played a key role in the success of the ATLAS computing the first two years of data taking: the commissioning phase of the computing infrastructure could focus on a subset of transfer channel, reducing the manpower effort, from both the ATLAS central operations team and site administrators; transfer performances during data taking could be better monitored and possible issue could be tracked and solved in a timely manner. Finally, the cloud model provided a natural operational definition of responsibilities between tiers.

At the same time, the operational experience demonstrated that while the rigid cloud model could serve the purpose so far, it is becoming now a limiting factor in facing new challenges in ATLAS computing, e.g.:

- The data distribution model based on pre-placement of data by determined computing model predictions on usage by data type has demonstrated its shortcomings (large volumes of data would be replicated and never accessed). Therefore ATLAS decided to move toward a mixed model where pre-placement is complemented by a more dynamic data caching system, where a minimal amount of datasets is pre-placed in repositories and extra copies are triggered based on usage and requests. Such dynamic model however looses a lot of flexibility if the replication can happen only within clouds or between Tier-1s as the MONARC model imposes.
- Data analysis benefits from computing resources in many sites (and many clouds). In ATLAS, the analysis outputs, stored locally at the processing site are often aggregated back at the institute of the physicist running the analysis. This is rather inefficient in a system, which does not allow Tier-2 to Tier-2 communication from any site to any site. In the same way, the ATLAS Monte Carlo production system is forced to confine one task to one cloud to facilitate the output aggregation at Tier-1s, but in this way one limits the capability of the system to expand to all possible computing resources in a flexible way.

In addition, one must recognize that the network infrastructure has changed quite heavily in the last 5 years. While the OPN still guarantees high bandwidth connectivity between Tier-0 and Tier-1s and across Tier-1s, a non-negligible network capacity now exists between Tier-1s and Tier-2s and also across Tier-2s not necessarily belonging to the same cloud (and therefore a lot of network capacity is today not explored). Finally, we should realize that for inter-cloud transfers, even in case of low available bandwidth, the connectivity is not always the limiting factor. For example, in case of transfers of small files (< 10MB), the overhead introduced by the storage frontend normally introduces penalties largely more considerable than the ones from missing network capacity.

2. The “relaxed” cloud model

Because of what stated in the previous section, ATLAS computing decided to relax the cloud model and allow direct transfers between sites not belonging to the same cloud. As in the past, the approach has been very pragmatic, and rather that investing an enormous effort in commissioning channels between the full mesh of ATLAS sites, we decided to focus on a subset of channels, based on the following considerations:

- Not all Tier-2s in ATLAS provide the same amount of storage and computing resources. We decided to focus on the largest (in terms of capacity) Tier-2s since this is where most of the data traffic goes through anyway.
- Some ATLAS sites play a special role in ATLAS computing: calibration Tier-2s, repositories of physics-groups’ data, centres for trigger studies. Those sites should have priority in respect of others, when commissioning new networks paths.
• While Tier-2 to Tier-2 connectivity is very important for some use cases, the main advantage comes from connecting Tier-2s to Tier-1s of different clouds.

We defined therefore a new category of Tier-2s, called Tier-2D (directly connected), for which transfers between the Tier-2 and any Tier-1 are allowed; we built a list of candidates Tier-2Ds, based on the criteria expressed in the bullets above and commissioned the network channels between Tier-2D candidates and Tier-1s.

3. The ATLAS network commissioning framework

We decided to setup an automated machinery for the network commissioning activity, so that we could reduce the manpower needed in the long term and we would gain a persistent infrastructure to be used for network monitoring once the commissioning phase would be over. The framework relies heavily on the ATLAS DDM subscription system, which has been properly modified and extended to cover the additional use case.

Figure 2: the ATLAS network-commissioning framework

The building blocks are shown in Figure 2 and briefly described below:

• A set of scripts, the “Sonar”, acts as load generator for network traffic. Three datasets of 5 files each have been pre-placed at each ATLAS site. Files of each datasets are of different size: Small (10MB/file), Medium (100MB/file) and Large (1GB/file), representing the different sized for different dataset types in ATLAS. Once per week, the transfer of those 3 dataset is triggered from any site to any site, probing therefore each possible network channel.
The ATLAS DDM Transfer Service treats the subscriptions. In the backend, the Transfer Service scheduling agent delegates the point-to-point data transfer to the WLCG File Transfer Service (FTS).

The DDM Transfer Services polling agent obtains from FTS the information about the time of transfer of each file and stores it via a callback mechanism into the ATLAS DDM Dashboard, which offers a platform for calculating transfer statistics and exposing them programmatically through an HTTP interface.

The DDM FTS monitor fetches statistics from the DDM dashboard and provide transfer performance history plots for each pair of storage endpoints.

Such machinery has been operating since more than one year now without any need for major intervention and it is currently at the basis of the ATLAS network links commissioning effort.

4. Network links commissioning and Tier-2Ds

The main visualization of the network link commissioning relies of the Site Status Board (SSB) technology [7]. A special “Sonar” view in the ATLAS SSB instance has been defined and is regularly filled with the summaries of the last two weeks of transfers. A snapshot of the Sonar SSB view can be seen in Figure 3. For each channel, one can see topology information such as source and destination site, cloud and tier level, together with the average per file transfer rate in the last 15 days for all the three file sizes. A “priority” field also indicates for each channel how important that channel is for ATLAS operation (Tier-0 to Tier-1 channels have maximum priority 10, while Tier-2 to Tier-2 channels have rather low priority). The SSB offers functionalities such as sorting and filtering, which help shift teams and management to visualize the subset of information they need. Given a pair of sites, the network channel between those 2 sites is considered “healthy” if the three conditions below are all satisfied:

1. More than 5 small files were transferred through the channel at more than 0.1MB/s in average
2. More than 4 medium files were transferred through the channel at more than 2MB/s in average
3. More than 3 large files were transferred through the channel at more than 15MB/s in average

The SSB Sonar view reports measurements for any transfer in a given network channel, which includes the load from the sonar load generator as well as the production activity. Therefore many channels count largely more than the 15 file transfers per week injected by the generator. One should also remember that while we talk about “transfer rates”, we do not refer to network only, but to network + storage access overheads. Since the storage overhead does not depend on the file size, we can conclude that for large files the transfer times are dominated by network components, for small files they are dominated by storage overheads. If we want to measure purely the network performance we need a different set of probes, such as the PerfSONAR framework [8], discussed elsewhere in this conference. Finally, network channels are not necessarily symmetric. Therefore we cannot expect the same results if we measure transfer performance from SiteA to SiteB or from SiteB to SiteA. Therefore we measure both and we take both pieces of information into account.
A Tier-2D candidate can be promoted to Tier-2D if for at least 3 consecutive weeks the links between the candidate and at least 8 Tier-1s (out of 10) are healthy. Once a Tier-2 is promoted to Tier-2D, the ATLAS site topology is modified so that it can start exchanging data directly with all Tier-1s. At the moment 37 out of 65 Tier-2s have been promoted to Tier-2Ds. Figure 4 visualizes the transfer statistics in a 4-hours window between Tier-1s and the Napoli Tier-2D. As one can see from the table at the top of the figure, Napoli is receiving data from all Tier-1s rather than only from CNAF, which is the Tier-1 of the cloud Napoli belongs to (and that in the non relaxed cloud model would be the only possible Tier-1 data source for Napoli). The plot at the bottom of the figure instead shows how many files Napoli is importing from the various Tier-1s. Interestingly, most of the traffic comes from BNL rather than CNAF, which shows clearly the benefits of the relaxed cloud model.
Figure 4: transfer statistics in a 4-hours window between all Tier-1s and the Napoli Tier-2D. The table at the top shows the transfer rates, the efficiencies and the number of successful and failed transfers. The bottom plot shows the breakdown per source Tier-1 of the number of successful transfers to Napoli.

5. Conclusions and future work

The ATLAS network commissioning initiative and the campaign to relax the cloud model with the introduction of Tier-2Ds has been only the first step toward a more flexible usage of distributed computing resources. The definition of the topology is still quasi static, while the aim is to progress toward a quasi real time utilization of the best possible network connections and routing between sites. For this we need a more fine-grained sampling possibility than the weekly sonar tests. The global deployment of PerfSONAR would be a step forward in this direction. From the infrastructure point of view, major improvements are foreseen in the next few years thanks to the LHCONE initiative [9], which should provide a more controlled environment for connecting Tier-2 sites. Ultimately, utilization of Tier-2s and Tier-1s should be fully transparent from the network perspective. Only at this point ATLAS will be able to utilize all storage and computing resources in the most elastic way.

6. References

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