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Spanish ATLAS Tier-2: facing up to LHC Run 2

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Abstract. The goal of this work is to describe the way of addressing the main challenges of Run 2 by the Spanish ATLAS Tier-2. The considerable increase of energy and luminosity for the upcoming Run 2 with respect to Run 1 has led to a revision of the ATLAS computing model as well as some of the main ATLAS computing tools. In this paper, the adaptation to these changes will be described. The Spanish ATLAS Tier-2 is a R&D project which consists of a distributed infrastructure composed of three sites and its members are involved in ATLAS computing progress, namely the work in different tasks and the development of new tools (e.g. Event Index).

1. Introduction

The Higgs boson discovery [1] acknowledged by the 2013 Nobel Prize in physics is a major Run 1 (data taking from 2010 to 2012) success for the experiments at LHC. Experiments like ATLAS [2] recorded 2 billion real events and 4 billion simulated events per year during 2011 and 2012. In addition, events were reprocessed and stored in several file formats, increasing numbers to 138 (10⁹) billion real event instances, and 93 billion simulated events in year 2012 alone. The Spanish ATLAS Tier-2 (ES-ATLAS-T2) operations and performances during this period were reported in [3,4].

During Run 2 (event collisions starting in 2015), the LHC physics program will continue its unprecedented research, exploring collisions at even higher beam energy and luminosity, and taking data at up to five times the rate compared to Run 1. This change of “scenario” in the operation of the LHC in the coming years (2015-2017) introduces a large uncertainty in the estimation of computational resources and data storage needed; changes in the computing technologies and protocols used may be required.

Section 2 of this paper presents an update of the ATLAS Computing Model for Run 2. In section 3 the current resources and the performance of the ES-ATLAS-T2 is reviewed. Section 4 discusses the changes needed to adapt our Tier-2 for the new Computing Model, such as to create multicore queues, and a Federated Data Storage System (FAX) to improve the use of computing resources and

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improvement of distributed analysis. Finally, in section 5, our participation in an important ATLAS R&D activity, the “Event Index project” in collaboration with other ATLAS groups is described.

2. Updates of the ATLAS Computing Model

During 2013 and 2014, the LHC machine underwent a period of maintenance and upgrades, with the aim of restarting operation in spring/summer 2015 (Run 2) at higher centre-of-mass energies (13 TeV for p-p collisions), a reduced bunch spacing (25 instead of 50 ns) and higher luminosities, leading to an average number of collisions per bunch crossing around 40. The data-taking rate will also increase up to 1 kHz on average in ATLAS.

The building blocks of the ATLAS Distributed Computing (ADC) architecture were designed and deployed before the start of LHC operations. The existing tools worked very well for ATLAS during Run 1 but at the same time showed some limitations: namely, the manpower required for operations was too high. The experience of Run 1 operations led to a redesign of workload management systems and to the addition of a few other services to help cope with increased data volumes and different kinds of computing resources [5]. ATLAS Computing Model changes are described in general in [6].

The Distributed Data Management (DDM) system was completely redesigned in 2013 and the new implementation Rucio [7] has been progressively deployed in 2014 and 2015. With respect to the previous DDM implementation, Rucio has data discovery based on name and metadata, no dependence on an external file catalogue, supports multiple data management protocols in addition to SRM (e.g. WebDAV, XRootD, proxis and gridftp) and smarter and more automated data placement tools.

Data access can be a bottleneck for data analysis. Some datasets can be very popular for short periods of time, with several analysis groups accessing them at the same time on the few sites where they are replicated. A way to ease the situation during peak request periods is to create a “data federation” in which data on disk at any site are directly accessible from jobs running at any other federated site. Evidently, the data access tools must be clever enough to choose the “best” data replica to access, depending on the bandwidth and latency between the destination and all possible data source sites. A data federation is needed also to allow remote access to data in case of unavailability of a given file in the local storage element, or sparse access to single events. FAX [8] is the ATLAS implementation of an XrootD based federation. It has two top-level redirectors, one in Europe and one in the US. It covers, so far, 56% of ATLAS sites, which contain 85% of data.

The production and analysis workflows increased in number and complexity during Run 1, and are expected to increase and diversify further in the future. The system for defining and submitting tasks for the processing of event data had to be redesigned with a layered infrastructure; the new system, ProdSys2 [9], consists of four core components: the request interface allows production managers to define workflows; DEFT translates the user request into task definitions; JEDI generates the job definitions; and PanDA executes the jobs in the distributed infrastructure.

From the point of view of the software, running one ATLAS job per core will be difficult to sustain without memory limits on the worker node being reached and so less jobs will have to be allocated per worker node unless memory pressure can be mitigated. The most significant innovation has been the development of software that is able to run in parallel on different CPU cores. As a result, substantial memory is saved: a parallel job running on an 8-core CPU uses 8 times less memory than eight jobs running on that CPU, with an equivalent processing time. Most, if not all, data centres of the ATLAS Collaboration are equipped with multi-core platforms and they already set up a new batch queue for this purpose [9]. Even though this software has been tested successfully, the code must still be optimized to profit from additional features of modern compilers.

These upgrades have been tested on a large scale during an exercise called Data Challenge DC14 [5]. The sites of the ES-ATLAS-T2 performed its designated tasks and met the challenge successfully.

3. Maintenance and Operation of the Infrastructure

The ES-ATLAS-T2 has been built and is maintained to operate as an ATLAS Tier-2 Grid computing site. It can execute both data analysis and Monte Carlo event generation for the ATLAS experiment. According to the agreed commitment of Spain with the ATLAS experiment, the Tier-2 installations of the Spanish Groups must fulfil 5% of the total Tier-2 load. The infrastructure is integrated in the LHC Computing GRID following the Computing Model of the ATLAS Collaboration and will be ready to meet the requirements of Run 2. This Tier-2 has been developed in a distributed manner shared by the three Spanish institutes (all members of the ATLAS Collaboration) specifically: 50% IFIC (Valencia), 25% IFAE (Barcelona) and 25% UAM (Madrid). The fact that it is distributed leads to an increase of service redundancy, a faster response for problem solving, and optimises the use of existing computing expertise and human resources from the three institutes.

The following subsections give an overview of the evolution of the resources and performance, respectively, of the ES-ATLAS-T2 during the Run 1 and just before the start of Run 2.

3.1. Evolution of the resources

In that period (during Run 1 and before the start of Run 2), the ES-ATLAS-T2 has provided the hardware resources fulfilling the ATLAS requirement of the Resource Review Board of the LHCC committee, as is shown in the Table 1:

Table 1. Present resources (CPU and Disk) provided by the ES-ATLAS-T2

Site	CPU installed / pledge 2014 (HEP-SPEC06)	DISK installed / pledge 2014 (TB)
IFIC	10478 / 10300	1400 / 1400
IFAE	6600 / 5150	857 / 700
UAM	5100 / 5150	721 / 700

A Tier-2 must run round-the-clock every day of the year, and personnel must serve it 12 hours a day during working days (12h/5d). Disk space is managed by two distributed storage systems, namely dCache at IFAE and UAM, and Lustre+StoRM at IFIC. The Worker Nodes have at least 2 GB of RAM per CPU core to be able to run highly demanding ATLAS production jobs.

3.2. Performance of the ES-ATLAS-T2

ES-ATLAS-T2 availability and reliability metrics are calculated by the Service and Availability Monitoring system (SAM)[11], which runs a range of tests at regular intervals throughout the day. A site is considered to be available if a defined set of critical tests complete successfully. The availability and reliability metrics are defined as follows:

$$availability = \frac{U}{TT - TU}; reliability = \frac{U}{TT - D - TU}, \quad (1)$$

where U means uptime (time the site is available), TT is the total time, TU is the time when the status was unknown and D is the scheduled downtime.

The availability and reliability evolution for a four-year period (Run 1 and prior to Run 2) is shown in Figure 1. As can be seen, in both cases the average over all sites is always in the interval 90-100% since 2011.

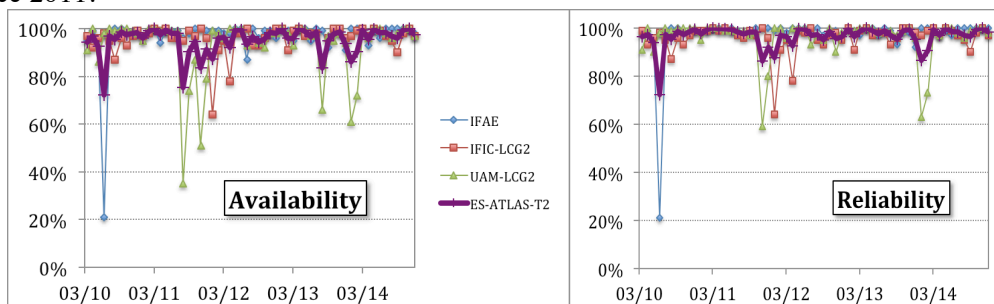


Figure 1. Availability and Reliability of ES-ATLAS-T2 for a four-year period.

Another useful metric is evaluated by ATLAS Computing operations. Sites are tested with typical analysis and Monte Carlo (MC) production jobs. Results from these Hammer Cloud (HC) tests are shown in Figure 2. It shows the average efficiency of the HC test is greater than 90% in the last four years for the ES-ATLAS-T2 sites.

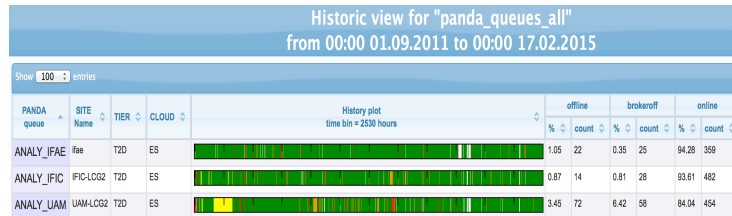


Figure 2. ATLAS availability for the ES-ATLAS-T2 analysis queues.

ES-ATLAS-T2 sites have been and are T2D category showing they have good connectivity among other Tier-1s and Tier-2s. In terms of connectivity, the concept of so-called T2D was introduced: those that fulfil a certain performance are then classified as T2D. At the moment, the performance limit is set to an overall transfer performance of at least 5MB/s to at least 80% of Tier-1s in ATLAS, for very large files (>1GB). This implies direct transfer from/to Tier-0 and all ATLAS Tier-1s and Tier-2s. It also means the execution of simulation and analysis jobs are favoured in our Tier-2. A T2D site must be stable enough to guarantee data processing and analysis. Figure 3(a) compares the number of jobs completed by the different ES-ATLAS-T2 sites. During Run 1 and before Run 2, the ES-ATLAS-T2 processed around 19 million jobs (analysis + production). The number of events processed related to these completed jobs is shown in Figure 3(b): around 93 million events.

In this period around 71 PB of data (both collision events and MC simulation jobs) have been processed in our Tier-2 and read from our storage systems, as shown in Figure 4(a). The ES-ATLAS-T2 sites are getting more datasets and around 100 PB of data have been transferred as is shown in Figure 4(b) from January 2012 to before Run 2.

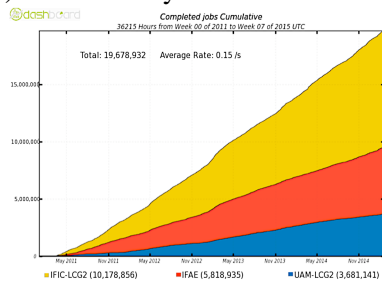


Figure 3(a). Completed jobs (50% analysis, 50% production) in the ES-ATLAS-T2 sites during Run 1 and before Run 2.

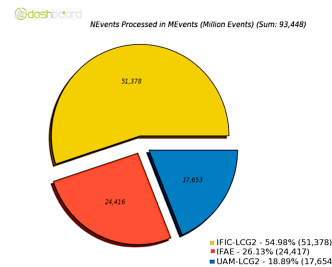


Figure 3(b). Number of events processed belonging to simulation (same as production) plus analysis jobs.

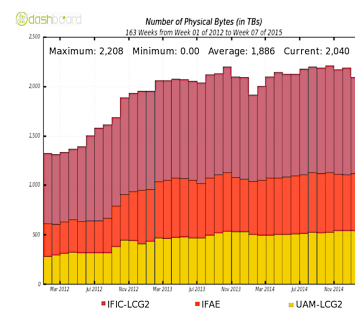
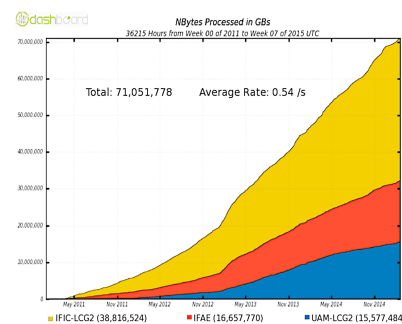


Figure 4(a). Number of physical bytes processed in the ES-ATLAS-T2 sites during Run 1 and before Run 2.

Figure 4(b). Data transfer in the ES-ATLAS-T2 sites during Run 1 (January 2012) and before Run 2.

4. Adaptation and involvement of the ATLAS Spanish Tier-2 in the new ATLAS computing model

The necessary upgrades and changes performed to handle the challenges of the ATLAS Computing Model for Run 2 related to our Tier-2 can be classified into different areas. The most important ones are detailed below.

4.1. Progress in Multicore

The ATLAS Software has been optimized to take advantage of the Multicore architectures so each site of ES-ATLAS-T2 has created a Multicore queue with several dedicated nodes. In some sites, static allocation for job resources has been configured based on the idea that the resources are only for multicore jobs; therefore no mix between Multicore or Monocore is possible in a CPU server. A usual approach is to assign 8 cores per job, with the same wall time restrictions as current ATLAS single core jobs. Currently, the number of Multicore jobs being processed is minimal, compared to Singlecore ones.

With time, the fraction of multicore-type jobs is expected to increase after technical problems (already explained in section 2) are resolved.

Figure 5(a) compares the number of Multicore jobs completed in different sites since March 2014, having processed around 20k completed jobs. The average efficiency of the HC test is between 66 to 86% since March 2014 for the ES-ATLAS-T2 sites as is shown in Figure 5(b).

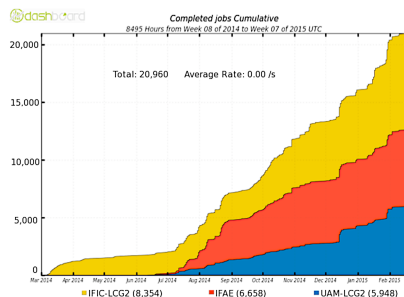


Figure 5(a). Completed multicore jobs in the ES-ATLAS-T2 sites since March 2014.

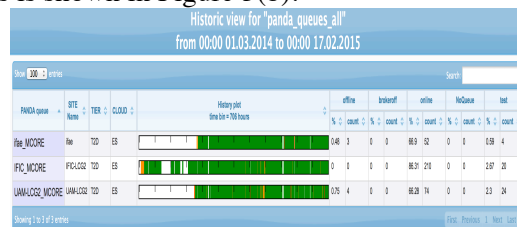


Figure 5(b). ATLAS availability for the ES-ATLAS-T2 multicore queues since March 2014.

4.2. Towards a Federated Data Storage System

Data federation using XRootD called FAX is a way to unify direct access to the diversity of storage services used by ATLAS. Since the start of the FAX initiative, several ATLAS sites belonging to different regions/clouds have joined the effort. Figure 6 shows the aggregated XRootD traffic at various Tier-2s.

FAX implementation in ES-ATLAS-T2 is as follows: the IFAE and UAM sites are serving their disk space within the ATLAS FAX federation, whilst IFIC will join in the upcoming months. In any case, for all sites of ES-ATLAS-T2, PanDA is using FAX when a local copy of the input file fails; in the case stage-in fails due to a temporary problem, FAX will re-attempt the stage-in in a second time after a few minutes.

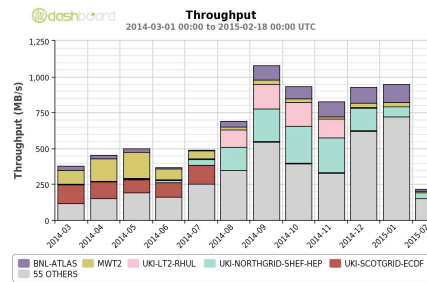


Figure 6. Aggregated XRootD Traffic at various Tiers of ATLAS.

4.3. Distributed Analysis in Run 2

Distributed Analysis (DA) has worked very well during Run 1 but several improvements are needed to speed-up the workflow and to profit from the more powerful computer architectures now available. Figure 7(a) shows the completed jobs in our Tier-2 by activity where analysis jobs comprise 55%. The Derivation Framework, see Figure 7(b), is the key to the success of the Run 2 Analysis Model. The framework performs bulk data processing for the majority of physicists, producing targeted samples, which physics groups and users will later process themselves. In Run 1 if one or more variables were missing from a particular private end-user collection of collision physics data, it had to be recreated from scratch, wasting time and resources. The new analysis model attempts to tackle this problem by producing automatically common data collections for all physics groups as soon as new data are produced or a new version of the data processing software is available. The Derivation Framework is the chain of jobs that are executed regularly that produce either one or several common group data collections for a given input provided by the detector or a simulation. The data to be analysed is created with an initial calibration alignment which is the best known at the time of producing the files, but later can be recalibrated and realigned and will keep up-to-date all of the necessary variables. The computing resource constraints for Run 2 motivate a limit of the number of outputs of approximately ten. The target output size for a derived dataset is 1–10 TB, based on feedback on group workflows summing over the 2012 dataset and MC samples. This output volume fits well with the computing resource constraints. Data reduction can be achieved either by skimming (removing events) or slimming (removing per event information). Book-keeping tools will record the sum of the weights of events removed.

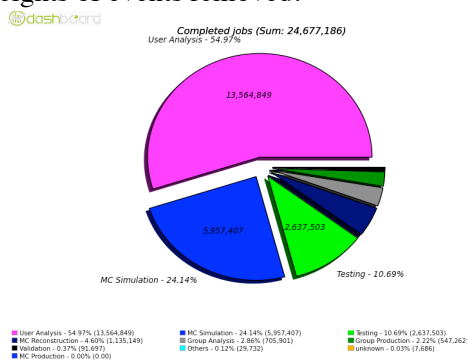


Figure 7(a). Completed jobs in the ES-ATLAS-T2 by activity before the Run 2.

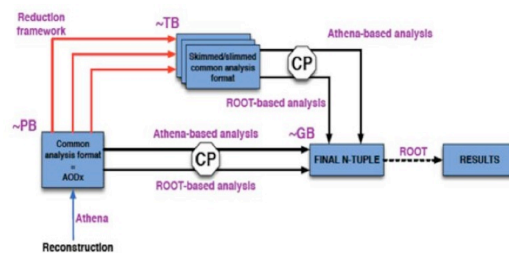


Figure 7(b). Data Analysis Model for ATLAS Run 2 Derivation Framework.

ES-ATLAS-T2 through the IFAE has contributed to the coordination of DA for two years and now the same person is the Grid Distributed Production (GDP) coordinator.

5. The Event Index Project

The Event Index Project [12] consists of the development and deployment of a complete catalogue of events for experiments with large amounts of data, such as the ATLAS experiment. Data to be stored

in the Event Index are produced by all production jobs that run at CERN or on the GRID; for every permanent output file, a snippet of information, containing the unique file identifier and the relevant attributes for each event, is sent to the central catalogue. The estimated insertion rate during the LHC Run 2 is about 80 Hz of file records containing ~15 kHz of event records.

In Run 1, the ATLAS experiment had a catalogue of all real and simulated events in the database (TAGDB), implemented in Oracle, with the main purpose of the selection of events on the basis of physical variables, the identification of files that contain a list of events already selected by other means, and consistency checks on the completeness of event processing. Nevertheless the TAGDB is slow, complex, unreliable [13] and has scaling problems when the number of events exceeds 10^9 .

The new catalogue (Event Index Project) is based on the previous work on the TAGDB, but improving it to reach good performance. The most innovative part of this project is the adaptation and application of the NoSQL technologies for cataloguing data of a large experiment. They are cheaper, easier to use and faster for sparse searches over large amount of data, so the Event Index project is using them for the event cataloguing system. The contents of this new catalogue for each reconstruction campaign and for each data format are event identifiers, online trigger pattern and hit counts and references (pointers) to the events at each processing stage in all permanent files on the storage. Basically the use cases that Event Index is addressing are the following:

- Event picking: give me the reference (pointer) to “this” event in “that” format for a given processing cycle.
- Production consistency checks: technical checks that processing cycles are complete (event counts match).
- Event service: give me the references (pointers) for “this” list of events, or for the events satisfying given selection criteria, to be distributed individually to processes running on (for example) HPC or cloud clusters.

The system design [12], as is shown in Figure 8, is highly modular, so that its components (data collection system, storage system based on Hadoop, and query web service) could be developed separately and in parallel. The Event Index is in operation for the start of LHC Run 2.

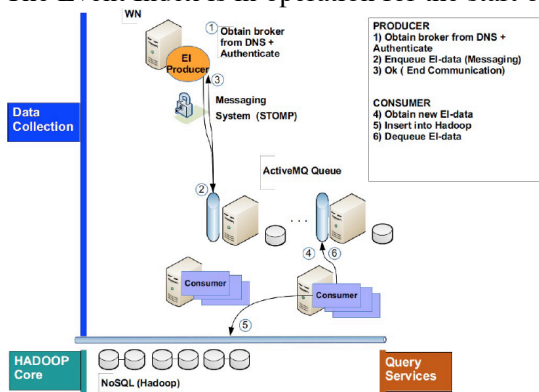


Figure 8. Event Index architecture

ES-ATLAS-T2 is participating actively in the Distributed Data Collection task [14] as a pure R&D task contained in the Tier-2 project. The Event Index contains records of all events processed by ATLAS; these records include the reference to the files containing each event (the GUID of the file) and the internal “pointer” to each event in the file. This information is collected by all jobs that run at Tier-0 or on the GRID and process ATLAS events. Each job produces a snippet of information for each permanent output file (producer architecture). This information is packed and transferred to a central broker at CERN using an ActiveMQ messaging system (consumer architecture), and then is unpacked, sorted and reformatted in order to be stored and catalogued into a central Hadoop server.

The Event Index infrastructure at IFIC consists in a Hadoop cloudera cluster composed by 8 machines with 2 quad core Intel Xeon E5420@2.5GHz processors and 16 GB DDR2@667 MHz of RAM memory and a hardware by 2 SAS drives of 146 GB @ 10 Krpm. The purpose is to work on Event

Index developments (e.g. optimize queries from event service) and have another implementation for checking and comparison.

6. Conclusions and perspectives

Run 2 data taking will begin in Spring/Summer 2015 and the ATLAS experiment is ready to address new challenges in Computing and Data Management. For this purpose the ATLAS computing model has been updated.

The goals of every Tier-2 are to satisfy the revised computing requirements (disk and CPU) and the daily maintenance and operation. Moreover, the ES-ATLAS-T2 is adopting the necessary changes to address the new ATLAS Run 2 challenges. In particular: to apply several improvements in the Distributed Analysis and the Derivation Framework; to provide multicore queues to serve the multicore jobs; and to implement the Federated Data Storage System, ATLAS FAX.

Moreover, the ES-ATLAS-T2 sites are leading the ATLAS Event Index Project, thus also embracing R&D. The tasks performed within this project, and ready for Run 2, are: automation of all the procedures; loading all Run 1 data; tuning of the system and providing a thorough monitoring system. Applying previous improvements will solve most of the new challenges mentioned at the introduction.

7. References

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Acknowledgments

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