THE ALICE PHYSICS DATA CHALLENGE 2004 AND THE ALICE DISTRIBUTED ANALYSIS PROTOTYPE

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Abstract

Since January 2004 the ALICE experiment is performing a large distributed computing exercise, the Physics Data Challenge '04, with two major objectives: to test the ALICE computing model, including distributed data analysis, and to provide Monte-Carlo data sample with various physics signal content for a refinement of the ALICE physics and detector studies. Simulation, reconstruction and analysis of approximately 1 million events were performed using the heterogeneous resources of tens of computer centres worldwide. These resources belong to different Grid systems and were steered by the AliEn (ALICE Environment) framework, acting as a meta-GRID. This exercise also served as a very thorough test of the middleware of AliEn and LCG (LCG-2 and grid.it resources) and their compatibility. During the past 9 months the average number of jobs executing in parallel was 500 with maximum up to 1500. More than 40 TB of data has been produced and stored in 20 different locations and subsequently analysed. The ALICE Grid analysis system is based on AliEn and ROOT and the jobs are controlled by an intelligent workload management system. The analysis starts with a metadata selection in the AliEn file catalogue, followed by a computation phase. Analysis jobs are sent to the sites where the data is located, thus minimizing the network traffic. Both batch and interactive jobs are fully supported. The latter are "spawned" on remote computing elements and report the results back to the user's workstation.

This paper describes the ALICE experiences during PDC'04 with the large-scale use of the Grid, the major lessons learned and the consequences for the ALICE computing model.

THE ALICE PHYSICS DATA CHALLENGE AND GRID COMPONENTS

The ALICE PDC'04 plan was to test and validate the experiment's data flow and all software components of the ALICE Offline computing model. For that purpose, the following goals were set:

- Large data volume: produce and analyse ~10% of the data sample collected in a standard data-taking year, following the logical data path during the experiment's normal data taking periods
- Software components test: do the production and analysis entirely on the Grid employing all off-line tools: AliEn [1], AliROOT [2], LCG [3] and PROOF [4]
- Physics analysis: The simulated data contains various physics signals, needed for detector studies and the ALICE Physics Performance Report (PPR)

The Data Challenge was logically divided in three distinct phases:

- Phase 1 - Production of underlying Pb+Pb events with different centralities (impact parameters) and production of p+p events
- Phase 2 - Mixing of signal events with different physics content into the underlying Pb+Pb events
- Phase 3 – Distributed analysis

All jobs have been run on the Grid, using the AliEn framework for access and control of the resources at the computing centres. These included 32-bit Intel and AMD and 64-bit Intel Itanium machines and various types of storage: NFS and NAS disk servers and CERN CASTOR MSS (at CERN and CNAF Bologna). The LCG Grid resources were accessed through an AliEn-LCG interface, thus AliEn was acting as a Meta-Grid provider.

AliEn Middleware and Job Handling

The AliEn middleware offers true Grid functionality: all jobs are inserted in a global queue system and distributed to the computing resources 'just-in-time' for optimal resource load. The middleware also offers a virtual file and metadata catalogue. A concept of a master job combined with job splitting mechanism allows the handling of large scale productions (bulk job submission with single command), for example for a Monte-Carlo production a single master job can be spawned into hundreds of sub-jobs with different random seeds. For jobs which require specific input structure, e.g. analysis tasks, the input data file list is taken as a base to split the jobs according to the file location.

AliEn Production Infrastructure

All AliEn core services run on four fast servers at CERN. Two additional servers are used as a scratch storage element and as a gateway and load-balancing entry point to three network servers. The latter are the front-end machines to three CERN CASTOR stagers with total capacity of 27 TB, used for storage of the underlying events (phase 1 of PDC). The complete AliEn core server system is shown in fig.1. On each external site, controlled directly by AliEn, there is one machine running the site computing element services and management tools for the local storage element.

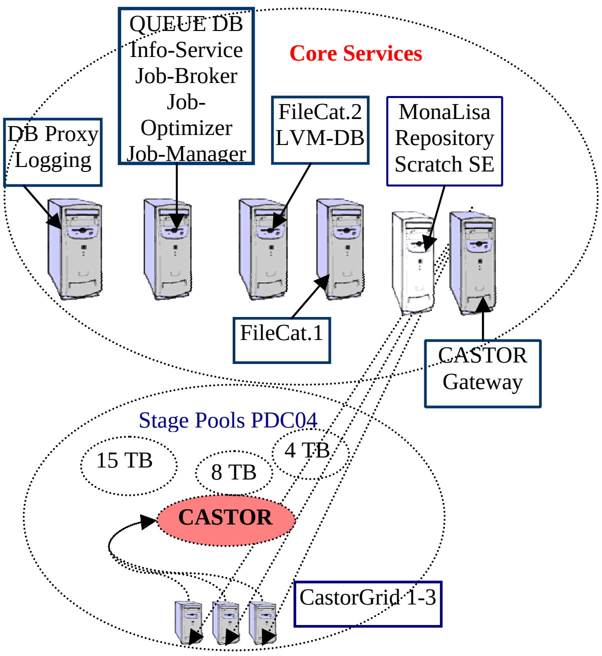

Figure 1: AliEn core infrastructure and CERN storage

The Data Challenge Timeline

The duration of Phase 1 was 4 months: from mid-February to June 2004. Three weeks in June were devoted to preparation of for Phase 2 – adding functionality to the AliEn code and preparing additional storage capacity at CERN and at the remote computing centres. Phase 2 started in early July and was finished on the 1st of October. From October on phase 3 is running with the analysis prototype of AliEn and a migration to the EGEE [5] End-to-End analysis prototype and the gLite [6] middleware is foreseen. This phase is planned to last until the end of 2004. Fig. 2 shows the phases of PDC'04 on a plot with number of jobs executed as a function of time until the time of publication of this paper.

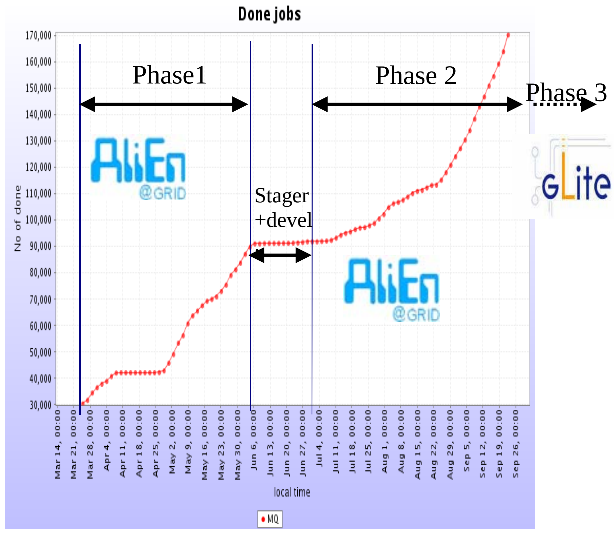

Figure 2: Timeline of PDC '04.

PHASE 1 – DISTRIBUTED PRODUCTION

Phase 1 simulates the experiment's data taking process in reverse – data are transferred from the remote computing centres to CERN. Underlying Pb+Pb events with different centralities (impact parameters) and p+p events are generated using the AliROOT framework. One production job consists of the following steps:

- Simulation of Pb+Pb events in 6 centrality bins
  - central 1 events
  - peripheral 1-5 events
- Reconstruction of the simulated event
- Validation of the simulation and reconstruction output files
- Storage of event data in CERN CASTOR

For each centrality bin, 20.000 events have been generated, distributed over 56.000 jobs, with the job durations as follows:

- 22.000 8.5 hour jobs (central 1)
- 22.000 5 hour jobs (peripheral 1)
- 12.000 2.5 hour jobs (peripheral 2-5)

The total amount of CPU work was 285 MSi2K hours. The amount of CPU provided by the LCG resources was 67 MSi2K hours.

Each job produced 36 output files, 23 of them were stored in the CASTOR storage element. 13 others (log files and book-keeping information) were recorded in the CERN scratch storage element. In total, 2 million files (representing 4 million catalogue entries – pair of LFN and PFN for each file) have been stored in the AliEn file catalogue, without any noticeable performance degradation. The total data volume stored in the CASTOR stagers was 26 TB.

PHASE 2 – EVENT MIXING

In this phase, the underlying events produced during Phase 1 are mixed with signal events with various physics contents. The resulting event mix is subsequently reconstructed. This phase simulates the standard event reconstruction schema. All production jobs have been running outside CERN and for each mixed event an underlying event is exported from the CERN storage to the remote centre. The output data of Phase 2 jobs was stored in local storage elements at the remote sites.

62 different job conditions (see fig. 3) were executed during Phase 2. They were grouped in 340k jobs, totalling 15.2 million events. The output data volume, stored at the remote SEs, was 10 TB. 200 TB of input data was exported from CERN.

Signal	No.of signal events per underlying	Number of jobs			
Jets (un- and quenched) cent 1			**PHOS**	**cent 1**	
Jets PT 20-24 GeV/c	5	1666	Jet-Jet PHOS	1	20000
Jets PT 24-29 GeV/c	5	1666	Gamma-jet PHOS	1	20000
Jets PT 29-35 GeV/c	5	1666	Total signal	40000	40000
Jets PT 35-42 GeV/c	5	1666	**D0**	**cent 1**	
Jets PT 42-50 GeV/c	5	1666	D0	5	20000
Jets PT 50-60 GeV/c	5	1666	Total signal	100000	20000
Jets PT 60-72 GeV/c	5	1666	**Charm & Beauty**	**cent 1**	
Jets PT 72-86 GeV/c	5	1666	Charm (semi-e) + J/psi	5	20000
Jets PT 86-104 Gev/c	5	1666	Beauty (semi-e) + Y	5	20000
Jets PT 104-125 GeV/c	5	1666	Total signal	200000	40000
Jets PT 125-150 GeV/c	5	1666	**MUON**	**cent 1**	
Jets PT 150-180 GeV/c	5	1666	Muon coctail cent1	100	20000
Total signal	399840	39984	Muon coctail HighPT	100	20000
Jets (un- and quenched) per 1			Muon coctail single	100	20000
Jets PT 20-24 GeV/c	5	1666	Total signal	6000000	60000
Jets PT 24-29 GeV/c	5	1666	**MUON**	**per 1**	
Jets PT 29-35 GeV/c	5	1666	Muon coctail per1	100	20000
Jets PT 35-42 GeV/c	5	1666	Muon coctail HighPT	100	20000
Jets PT 42-50 GeV/c	5	1666	Muon coctail single	100	20000
Jets PT 50-60 GeV/c	5	1666	Total signal	6000000	60000
Jets PT 60-72 GeV/c	5	1666	**MUON**	**per 4**	
Jets PT 72-86 GeV/c	5	1666	Muon coctail per4	5	20000
Jets PT 86-104 Gev/c	5	1666	Muon coctail single	100	20000
Jets PT 104-125 GeV/c	5	1666	Total signal	2100000	40000
Jets PT 125-150 GeV/c	5	1666			
Jets PT 150-180 GeV/c	5	1666			
Total signal	399840	39984	Grand total	15239680	339968

Figure 3: Phase 2 job conditions.

The total amount of CPU work was 500 MSi2K hours with 65 MSi2K hours on LCG resources. The number of files registered in the AliEn file catalogue (combined Phase 1 and 2) was approximately 9 Million after the completion of Phase 2.

COMPUTING CENTRES PARTICIPATION

Phase 1 and 2 jobs were executed on computing capacity provided by 17 centres, controlled directly through AliEn and through an interface, the LCG Grid. Fig. 4 shows the relative contribution of all remote participating centres to the successfully completed jobs and storage capacity in Phases 1 and 2, with the exception of CNAF Bologna, which provided additional 6.2 TB of CASTOR stage pool space for a production of set of special events.

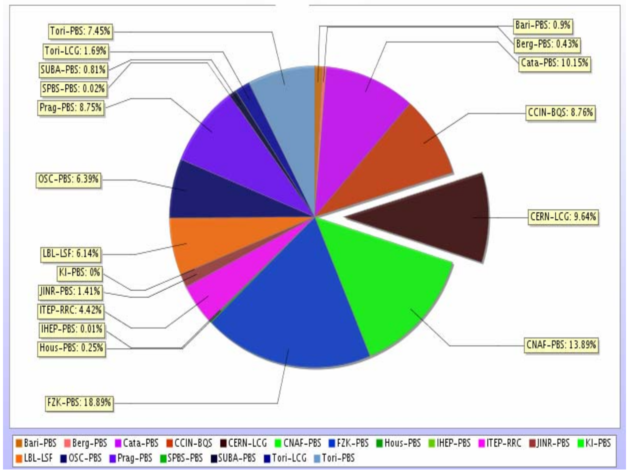

Figure 4: Phase 2 relative site participation in job production and storage capacity

EXPERIENCES FROM PHASE 1 AND 2

Monitoring Tools

Essential element of the production running and debugging process was a comprehensive monitoring system. Due to the long duration of the Data Challenge a tool with a good history data presentation was needed. For PDC'04, ALICE used the MonALISA [7] framework. The repository was modified to use the AliEn internal monitoring tools and the presentation formats were changed to follow the existing job structure. About 900 parameters, both running and cumulative, were continuously monitored. The parameters were split in logical groups:

- For each computing centre: e.g. running jobs, SE occupancy, completed jobs, error conditions
- For the core AliEn servers: e.g. memory utilisation, number of proxy connections, load factors

- Derivative summaries: efficiencies, task completion
- Global system view: dynamically updated geographical maps, tabular real-time processes and tasks view

The monitoring allowed identifying problems and bottlenecks quickly, thus minimizing the downtime. Additionally to the MonALISA, the built-in AliEn monitoring tools were also enriched gradually both for bulk and single job real-time information. The latter allowed identifying problems down to a WN level, for example job failing due to a missing application software directory, full scratch space disk or insufficient memory.

Production Running and Remote Centres

The production running was surveyed by a small number of experts centrally, relying exclusively on the information extracted from the MonALISA and the native AliEn monitoring tools. For every remote computing centres there was also an expert assigned, typically located at the centre. The problems arising at the centres were directly discussed between the people running the production and the computing centre experts. This has proven to be an extremely efficient method, which minimized further the downtime of the resources and allowed for quick inclusion of additional resources and new sites. For the LCG Grid operational issues, ALICE relied on the CERN IT/GD experts and used the adopted LCG reporting tools.

MSS Limitations

A major problem during phase 1 and 2 was the hard limit on the number of files that could be stored in one CASTOR stager. With the present implementation, a stage pool cannot handle more than 500K files, therefore several pools had to be configured to handle the number of files stored in Phase 1. In Phase 2, a zip archive containing all output files of a job was implemented in AliEn in order to overcome this limitation. The new CASTOR software, currently under development in the CERN IT department will no longer have this limit.

PHASE 3 – DISTRIBUTED ANALYSIS

Phase 3 is dedicated to the distributed analysis of the data produced in Phases 1 and 2. This corresponds to the normal analysis scheme envisioned in the ALICE computing model. The analysis can be done in two ways: ordered and chaotic. The ordered analysis is essentially analogous to the standard data production, where the analysis jobs are pre-defined in scope and are run by small number of people in a predetermined fashion, typically in a batch mode. The chaotic analysis is performed by multiple users without a defined plan amongst them and the jobs can be both batch and interactive. All analysis tasks will depend on the Grid middleware and will use the End-to-End distributed analysis prototype. The analysis phase will provide a test of gLite as a multi-user Grid platform.

The Distributed Analysis Prototype

The basic premise of the distributed analysis prototype is to process the data close to the place where it is located. Therefore the jobs are executed using the Grid middleware services at sites with direct access to the input data SE.

The analysis prototype includes two operational modes: Interactive Analysis with PROOF and Batch Analysis using ROOT. Both modes will be transparent to the user - the procedures are identical in both analysis modes and also for local file processing. The interactive analysis offers feedback during processing while in batch mode, the feedback is provided only on completion of all sub-tasks. Both modes are invoked from the ROOT prompt. The Analysis macros have to be provided as ROOT macros and are executed using the AliROOT framework. All other functionalities, like the metadata and file catalogues, workload management services, job splitting etc. are provided by the Grid middleware. The concept of the end-to-end analysis prototype is illustrated in fig. 5.

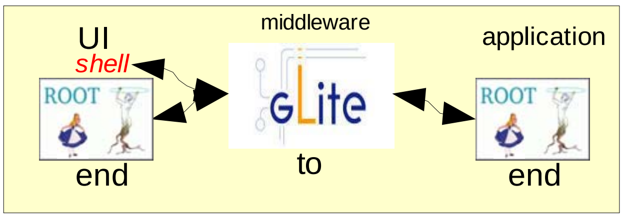

Figure 5: The End-to-End prototype schema.

Interactive Analysis

The PROOF system has been extended to support interactive analysis in a distributed environment. PROOF itself is implemented in a master-slave configuration schema: a master is distributing in a load-balanced way small packets of work to the slaves.

In a Grid environment the needed master-slave connectivity cannot be fulfilled: a common computing centre policy is that the worker nodes (where the slaves are running) have none or only outbound connectivity. To achieve the master-slave implementation on the Grid, the initial setup is changed in the following way: the PROOF slaves connect to a central master multiplexer who opens for every slave a virtual port on the master machine and forwards connections to these virtual ports directly to the connected slave machines. Non-multiplexed connection forwarding is not feasible, since the system has to scale to thousands of slave machines.

A session management system, PROOF STEER, enables the use of PROOF for multiple users in a Grid environment. It assigns available slaves for a limited time period to a specific user. This assignment takes into account the data location and the user computing quota.

A typical setup procedure of an interactive user PROOF session consists of the following steps:

- Dataset query of the file catalogue or use of a prepared dataset
- Requesting slaves for a session at a specific time and for the dataset, resulting from the query
- Invoking a connection from the client session to a session PROOF master
- The session PROOF master connects to multiplexed virtual slave ports on the master host
- The user processes an analysis macro on a fraction or on the complete dataset. The master distributes the work over all slaves in a balanced fashion
- At the end of the processing, the user histograms and analysis objects are returned
- The users destroys the session master

Batch Analysis

The batch analysis follows a similar processing scheme:

- Dataset query of the file catalogue or use of a prepared set
- Submission of a master analysis job, which contains the complete dataset to the job queue
- The job optimizer splits the master analysis job into sub-jobs taking into account the location of input data.
- The sub-jobs are submitted by the job optimizer
- The user can inspect the job splitting process and request the status of the sub-jobs
- The user can fetch back the results of the completed sub-jobs and merge them on the fly
- Upon completion of all sub-jobs, the master job is followed up by a job, which combines the sub-job results into a final set of output files

SUMMARY

The ALICE Physics Data Challenge is running successfully since February 2004. Its main goals are to validate the experiment's off-line computing model and to produce simulated physics data for detector and physics studies. PDC'04 has been run entirely on the Grid using the resources of tens of computing centres steered by the AliEn middleware and at the LCG resources, accessed through an interface.

Overall the AliEn system demonstrated its modularity and scalability to changing requirements and could be quickly adapted to accommodate the many unexpected problems encountered in the 9 months of running. For handling of many thousands jobs, master jobs have been introduced, capable of encapsulating hundred of sub-jobs with similar parameters. For failed jobs a fast resubmission mechanism has been introduced which operates on the master job ID re-submits all sub-jobs belonging to this ID. To allow a resource sharing between several users a priority scheduler with user specific resource quotas has been implemented. The job queue has been directly connected to the MonALISA repository for easy status view and production control. AliEn was successfully interfaced to the LCG resources, thus demonstrating its capability to act as a meta-Grid provider.

ACKNOWLEDGEMENTS

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REFERENCES

[1] P. Saiz, L. Aphecetche, P. Buncic, R. Piskac, J.-E. Revsbech and V. Sego, "AliEn-Alice environment on the GRID", Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 502, Issues 2-3, 21 April 2003, Pages 437-440. See also http://alien.cern.ch

[2] http://aliweb.cern.ch/offline/

[3] http://lcg.web.cern.ch/LCG/

[4] http://root.cern.ch

[5] http://egee-intranet.web.cern.ch/egee-intranet/gateway.html

[6] http://glite.web.cern.ch/glite/

[7] http://MonALISA.cacr.caltech.edu