Evolution of User Analysis on the Grid in ATLAS

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ATLAS computing model – LHC Run 2

- New analysis data format: xAOD
  - Created on the basis of Run 1 experience with the AOD (Analysis Object Data)
  - Readable in both ROOT and Athena (ATLAS Software framework)

- Central production of Derived xAOD (DxAOD) for physics and performance groups
  - almost 100 formats
  - Data: *train model*, i.e. tasks with a single run as input are creating several output formats (*carriages*)
  - **Monte Carlo**: on request

See also *ATLAS Distributed Computing experience and performance during the LHC Run-2* [1]

[1] https://indico.cern.ch/event/505613/contributions/2230713/
Simulated data \(ightarrow\) Collider data \(ightarrow\) Reconstruction

**Central Production**

- **PBs** → **xAOD**
- **TBs** → **DxAOD**

**Distributed Analysis**

- **GBs** → **Private ntuple**

- **New analysis data format:** \(\text{xAOD}\)
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- **Central production of Derived xAOD** (\(\text{DxAOD}\))
  - for physics and performance groups
    - almost 100 formats
    - **Data:** *train model*, i.e. tasks with a single run as input are creating several output formats (*carriages*)
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- **ATLAS users can run** *any* step on the grid
  - However privately produced data/MC cannot be used in published results
  - Still useful for development, testing, validation of new workflows
ATLAS computing model – LHC Run 2

Thanks to our *working animals*

- Both completely redesigned for Run 2

**Distributed Data Management (DDM):** Rucio

**Job Workload Management:** PanDA

- Database Engine for Tasks (DEFT)
- Job Execution and Definition Interface (JEDI)

For more details, see

→ *Experiences with the new ATLAS Distributed Data Management System* [1]
→ *PanDA for ATLAS distributed computing in the next decade* [2],
→ *The ATLAS Production System Evolution. New Data Processing and Analysis Paradigm for the LHC Run 2 and High-Luminosity* [3]

[1] https://indico.cern.ch/event/505613/contributions/2230910/
[2] https://indico.cern.ch/event/505613/contributions/2230704/
[3] https://indico.cern.ch/event/505613/contributions/2230440/
[4] https://indico.cern.ch/event/505613/contributions/2230440/
Distributed computing activities

- **Analysis** share ranges from **10% to 20%** of running jobs
  - Driven by interplay of user and central production activities
- Stable load, except for big MC production or data reprocessing campaigns

Plot from [http://dashb-atlas-job.cern.ch/dashboard/request.py/dailysummary](http://dashb-atlas-job.cern.ch/dashboard/request.py/dailysummary)
Interlude

- The ATLAS analytics infrastructure based on Kibana/ElasticSearch has been used for the plots/numbers presented in the rest of the talk

- Analytics cluster at MWT2 (OpenCloud)
  - See Big Data Analytics Tools as Applied to ATLAS Event Data [5] for more details

- Combining data from two sources:
  - **PanDA** job archive
    - more than 100 fields available for each job: site, host, user, priority, input and output data, status, errors, memory, …
    - Available for all jobs from July 2014 to 30 minutes ago
  - **Rucio** storage element dumps
    - information of all datasets managed by Rucio, including storage element, size, data type, creation date, date of last access, owner…
    - Daily updated, available since Fall 2015

[5] https://indico.cern.ch/event/563611/
User jobs

Flat efficiency*: >80%

* Efficiency is defined as the ratio between successful and total (successful+failed) jobs

Up to 500 unique users per week
Number of unique users: ~1000
Average wall time/job: ~1 hour
Average queue time/job: ~2 hours
Average memory/job: 600 MB
Average number of jobs/user: 10k/month
Average number of events/user: 150M/month
Average input/job: 15 GB / 4 files / 15k events
Average output/job: 100 MB

Data reduction of a factor of 150!
Typical user workflows

June-August 2016

- **DxAOD-based** analysis most popular workflow
- Production-like workflows (event generation, simulation, reconstruction) more expensive in terms of resources

Plots from [http://atlas-kibana.mwt2.org:5601/app/kibana#/dashboard/FL-Analysis-Inputs-(for-CHEP)](http://atlas-kibana.mwt2.org:5601/app/kibana#/dashboard/FL-Analysis-Inputs-(for-CHEP))
User job priority

- **Priority** system among user jobs
  - User priority starts at **1000** and fairly rapidly decreases
  - *Authorized* users may have priority > **1000** for a limited period of time (urgent production)
  - Jobs submitted with working group privileges do not lower the personal user priority, but still compete with all other user jobs
  - Most users have priority > **–2000**

- **Job concurrency:**
  - Number of cores per user limited to **10k**
  - *Separate fair share* at sites from production jobs
Waiting time

User jobs with **low priority** (<-2000)
Average queue time: **2.3 hours**

User jobs with **normal priority** (>2000)
Average queue time: **1.4 hours**

Low priority jobs will run quickly if:
→ grid is empty
→ input datasets at empty sites or event generation (can run anywhere)
Failed user jobs

Top 5 pilot exit codes

- Get error: 1,099
- Killed from batch system: 1,201
- Put error: 1,137
- Put error: 1,165
- Batch system time limit: 1,213

Top 5 application exit codes

- Application crash: 40
- Unspecified error: 1
- Core dump: 2
- Input file error: 9
- Core dump or timeout: 134

- **Walltime** consumption of failed jobs:
  - ~50% application errors
  - ~50% infrastructure: storage errors and batch system kills
Future developments

- **Global shares** for all distributed computing activities
  - Optimize resource usage
  - Eases central operations

- Differentiate **analysis queues** to better cope with different workflows
  - *Standard* queues with uniform limits on job duration, memory usage, etc
  - *Special* queues with specific requirements: high memory, multi-core, long jobs

- Dynamic **data placement**
  - Distribute popular formats to offload busy sites

For more details, see also:

→ *How to keep the Grid full and working with ATLAS production and physics jobs* [6]
→ *C3PO - A Dynamic Data Placement Agent for ATLAS Distributed Data Management* [7]

[6] http://indico.cern.ch/event/505613/contributions/2230712/
[7] http://indico.cern.ch/event/505613/contributions/2230956/
Conclusions

- Several changes to **ATLAS** computing for **LHC Run 2**:
  - New *production* and *data management* systems
  - New *data format* for analysis

- Move was a **SUCCESS!**
  - Distributed analysis performances stable, **80% job efficiency**
  - User workflows are heterogeneous:
    - Creation of **final ntuples** before publication-ready results
      - New **DxAOD** most popular analysis format
    - Production-like workflows also popular, mainly for testing/validation:
      - event generation, simulation, reconstruction
    - Load balancing achieved through priority system
      - Most user jobs waiting time ~1 hour
Backup
Waiting time

User jobs with **group production privileges**
Average queue time: 1.5 hours

User jobs with **low priority**
Average queue time: 2.3 hours

User jobs with **normal priority**
Average queue time: 1.4 hours
Distributed computing activities

Plots from http://dashb-atlas-job.cern.ch/dashboard/request.py/dailysummary

Start of 2016 data taking
Reprocessing of 2015 data and MC

New MC simulation campaign
CPU efficiency

Plots from http://atlas-kibana.mwt2.org:5601/app/kibana#/dashboard/FL-Analysis

Any executable (mostly ROOT)

Athena analysis

Average ~45% CPU efficiency

Production-like workflows
HammerCloud

- Tool for automatic site testing
  - both functional and stress tests
  - Used by ATLAS, CMS, LHCb
  - Crucial tool to test new deployments (JEDI, Rucio) before going to production/exposing changes to users
  - Used also for R&D of new workflows
  - Fully integrated in ATLAS Grid Information System (AGIS)

- Suite of 3 AFTs, Analysis Functional Tests, mimicking typical user analysis are used for automatic exclusion of sites failing the tests from brokerage
  - Typical efficiency of analysis functional tests: 95% → constant over time, clouds, ...
Distributed Analysis Support Team (DAST)

- User support with dedicated mailing list
  - expert shifters covering 16 hours/day (American and European time-zones)
  - Critical to help users to solve grid issues fast

- Established in October 2008, more than 1000 users

- Covered by DAST:
  - Rucio and Jedi clients
  - Site services/Issues
  - Physics analysis tools
  - Monitoring systems
User job priority in PanDA

Job priority

Job priorities are calculated for each user by using the following formula. When a user submits a job which is composed of $M$ subJobs,

\[ Priority(n) = 1000 - \frac{T + n}{5} - W \times (U - Q) \times H(x = (U - Q)) \]

where

- $Priority(n)$ … Priority for $n$-th subJob ($0 \leq n \leq M$)
- $T$ … The total number of the user's subJobs existing in the whole queue. (existing = job status is one of defined, activated, running)
- $W$ … Weight = 100, can be changed on a per-user basis. Needs approval
- $U$ … CPU usage for last 24 hours (in kSl2kday)
- $Q$ … CPU quota = 500, can be changed on a per-user basis. Needs approval
- $H(x)$ … Heaviside step function ($0: x \leq 0$, $1: x > 0$)

$T$ is set to 0 for jobs submitted with group production privileges