ATLAS I/O Performance Optimization in As-Deployed Environments

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Introduction

- ATLAS produces huge amounts of data during physics data taking periods
- Grid sites deploy a wide variety of storage technologies → require also a wide range and reliable ways to access data for prompt physics analysis
- ATLAS has established a working group to address a range of areas related to I/O performance
  - Monitoring, measurement, and data collection of I/O performance, both in cleanroom(local) and Grid environments
  - Evaluate implications for decision-making on many fronts → persistent data organisation, caching, best practices, framework interactions with underlying service layers, and settings at many levels (application code, Grid sites,...)
  - Improving robustness of distributed data access → failover mechanisms for error recovery → proper propagation of non-recoverable errors
- This talk will only present a portion of this work today

Range of Analysis Computing in ATLAS

- Local processing
- Distributed data analysis
  - Running on Grid sites using PanDA
  - Running on batch systems
- Access patterns
  - Remote access protocols → dcap, XRootD, WebDAV (Talk by Johannes Elmsheuser)
  - Copy-to-scratch
  - Local disk access

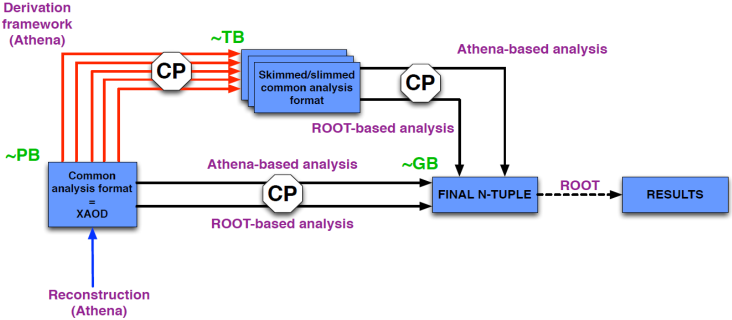
Instrumentation for Performance Monitoring

- Local tests
  - Direct (manual) way to test performance
  - Allows to test on a very basic level, but does not necessarily represent the way how a data analysis is run in reality
  - Can be easily modified for other access cases
- Hammercloud
  - Automated system to run stress and functional tests on Grid sites
  - Allows implementation of tests to monitor performance
- Analysis environments for new Event Data Model (EDM)
  - "Enforce" centralisation of analysis usage
  - Provide hooks for central monitoring

The New ATLAS xAOD Event Data Model in a Nutshell

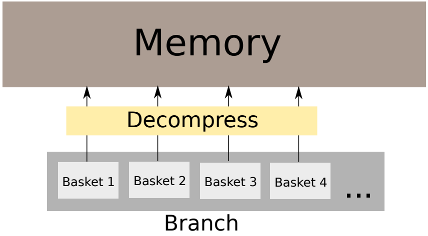
- Problems with Run I analysis model
  - Disconnect between data reconstruction output (AOD - Analysis Object Data) and data format used by physics analyses (DPD - Derived Physics Data)
  - Huge amount of data/software duplication
- Requirements for Run II
  - Prepare for increased data rates ($\sim 2\times$ that of Run I)
  - Provide similar I/O performance for physics analyses
  - In general homogenisation $\rightarrow$ less steps from data preparation to physics results
- Development of new data model (Talk by Scott Snyder)
  - Merging of AOD and DPD to new format called xAOD
  - Class based information storing $\rightarrow$ directly analysable in ROOT and ATLAS software framework Athena

The New ATLAS Analysis Model in a Nutshell



- Data preparation after reconstruction → DxAOD recommended data format
  - Centrally produced, trimmed down xAOD
  - Heavily reduced content, customised to the needs of different physics groups
  - Talk by James Catmore on the Derivation Framework

Simplified Picture of Data Storage in ROOT Files

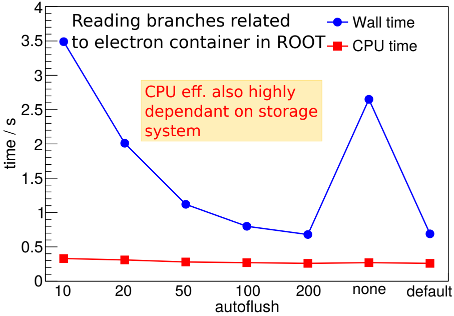


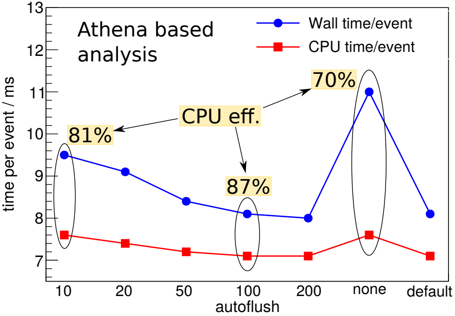
- Properties(e.g. electron p_T, eta, phi, ...) are stored in separate branches
- Information within branches is stored in multiple, separate baskets
- Accessing a property contained in a given basket $\rightarrow$ whole basket is loaded into memory $\rightarrow$ process has to wait until I/O operation is completed

Autoflushing as a Handle on Number of Baskets

- Number of baskets heavily affects reading speed if all events are accessed
- Using Autoflush to steer number of baskets $\rightarrow$ while writing, flush buffered data to disk
  - after a certain number of events have been processed
  - after a certain amount of bytes have been processed
- Has been found to be a very effective handle in the past $\rightarrow$ value of 10 found to be most practical for old AOD format
- Old AOD ($\sim$300 branches) $\leftrightarrow$ new xAOD ($>$2000 branches) $\rightarrow$ requires higher autoflush setting
- Re-optimisation needed for new xAOD format to adapt to new requirements

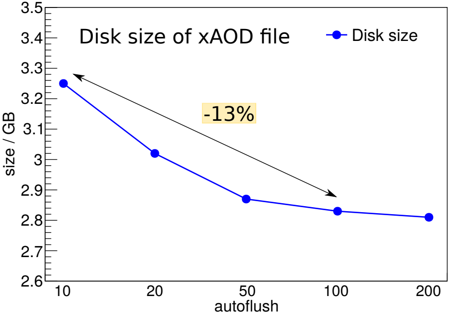
Impact of Autoflush on I/O





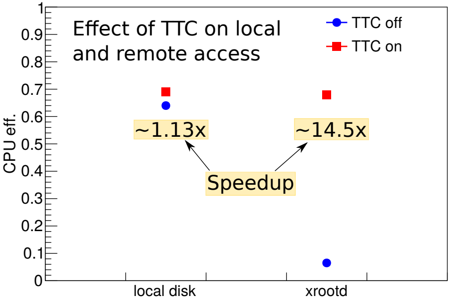
- Noticeable impact of Autoflush configuration on reading speed
  - "None": no autoflushing, number of baskets determined by default basket size
  - "Default": flushing according to amount of bytes in buffer (30MB)
- Old Autoflush setting of 10 clearly not suitable for new xAOD format

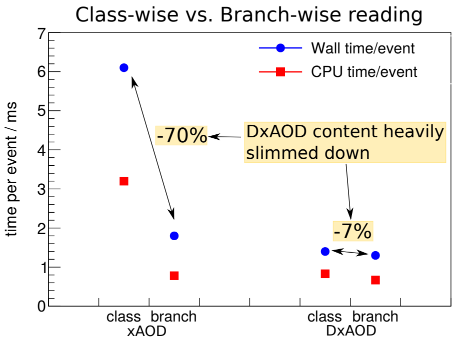
Further Observations



- Higher Autoflush values also reduces the disk size of the xAOD file
  - More compressable data per basket
  - Higher compression rates
- Slight increase in Virtual Memory foot print → acceptable tradeoff
- New Autoflush value of 100 is used for (D)xAODs

Additional Handles - TTC & Branch-wise Reading





- Pre-caching of data via the TTreeCache (TTC) feature of ROOT
  - In general beneficial to analysis speed
  - Very important for remote access → running on Grid sites
- Feature in xAOD EDM to toggle access mode for ROOT access
  - Class-wise → all branches connected to the container are read
  - Branch-wise → branches are read when respective properties are accessed

Conclusions

- New ATLAS analysis model and data format introduced in preparation for next period of data taking
- Old configurations and handles on I/O performance need to be revisited and re-optimised
- First improvements already found their way in the new xAOD format
- Further plans
  - Investigate benefit from more differentiated settings (xAOD $\leftrightarrow$ DxAOD)
  - Extend monitoring of data access patterns and performance in user jobs
    - Integrate with production job reporting
    - Integrate with ATLAS analytics infrastructure for decision support
  - Further establish monitoring via Hammercloud