Fine grained event processing on HPCs with the ATLAS Yoda system

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Motivation

- High Performance Computing (HPC) facilities present unique challenges and opportunities for HEP event processing
- The massive scale of many HPC systems means that fractionally small utilization can yield large returns in processing throughput
- Parallel applications, which can dynamically and efficiently fill any scheduling opportunities the resource presents, benefit both the facility (maximal utilization) and the (compute-limited) science

Challenges

- **Support fine-grained workloads** in order to be able to run efficiently with the variety of scheduling options (from back-filling to large time allocations)
  - ✔ Job granularity changes from files to individual events
  - ✔ Implemented by the **ATLAS Event Service** (see next slide)

- **Leverage MPI mechanisms** for running massively parallel applications on many compute nodes simultaneously
  - ✔ **Yoda** – MPI-based implementation of the Event Service designed specifically for running on HPC systems

- All this has been achieved without changing the existing ATLAS algorithmic code base

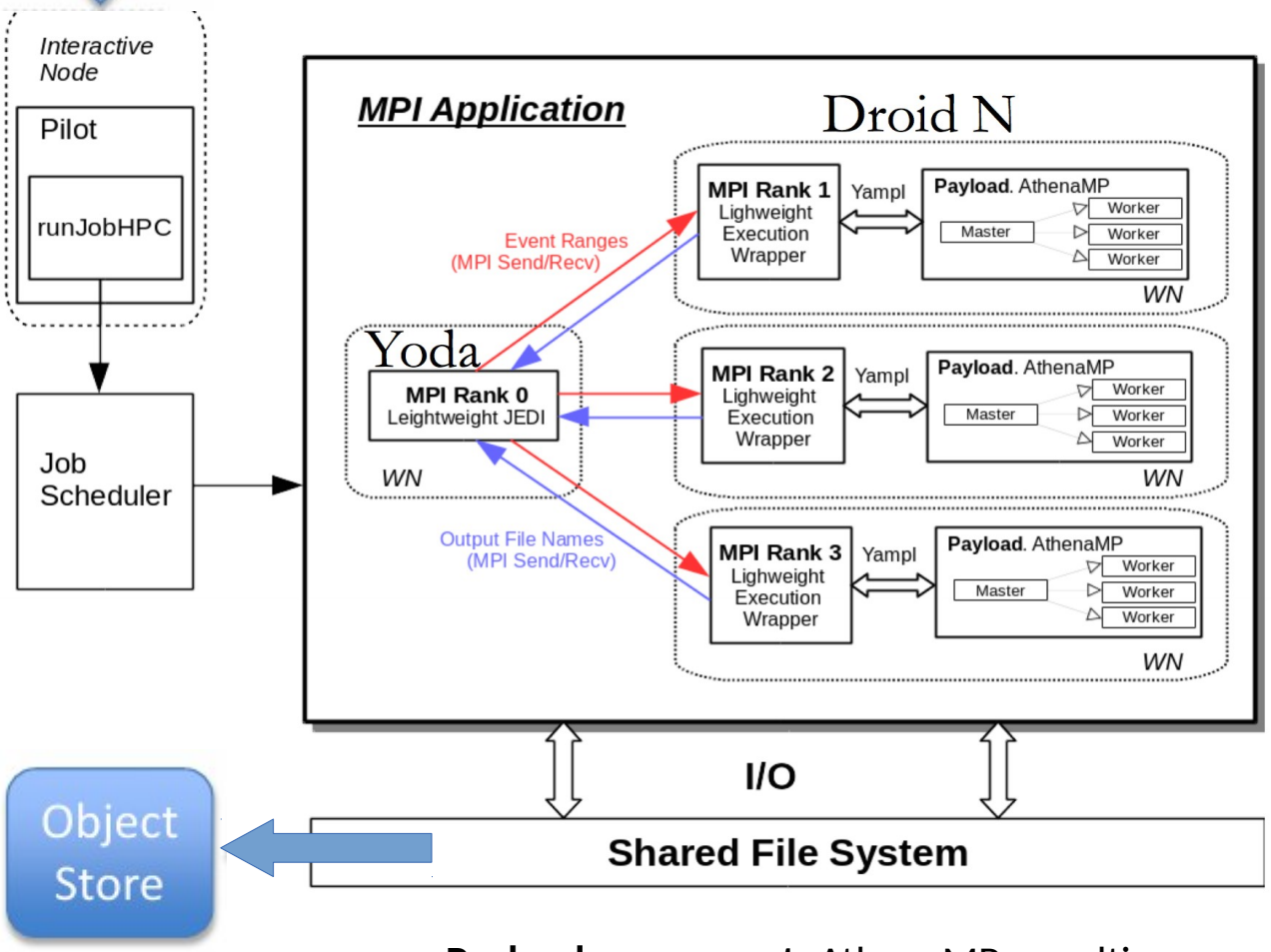
A fine grained Event Service

- **Minimize use of costly storage** in favor of strongly leveraging powerful networks
  - Deliver only those events to a compute node, which will be processed there by the payload application. Don't stage in entire input files
- Event Service is **agile and efficient in exploring diverse, distributed, potentially short-lived** (opportunistic) **resources**
  - 'Conventional resources' (Grid), HPCs, spot market clouds, volunteer computing
- **The job runs either until it uses the entire time slot allocated for it, or until it prematurely gets terminated (resource no longer available)**
  - Minimal data losses
- Applicable to any work-flow that can support fine grained partitioning of the processing and its outputs
- For more details see the presentation by Torre Wenaus at CHEP2015: *"The ATLAS Event Service: A new approach to event processing"* (Contribution #183)

Yoda. Event Service on HPCs

- The 'conventional' Event Service cannot run on most HPC systems
  - Various components of the 'conventional' Event Service communicate to one another over the network using HTTP
  - HPC compute nodes have no internet connection
- Reuse the code of the 'conventional' Event Service wherever possible, …
  - Keep the payload (event processing) component absolutely unchanged
- … just replace HTTP communications with MPI, …
- … and, as a result, we have **Yoda**: a MPI application capable to run within HPC systems with no internet connection
  - Relies on HPC Shared File System for retrieving all necessary input information and for producing outputs

Yoda. Schematic view

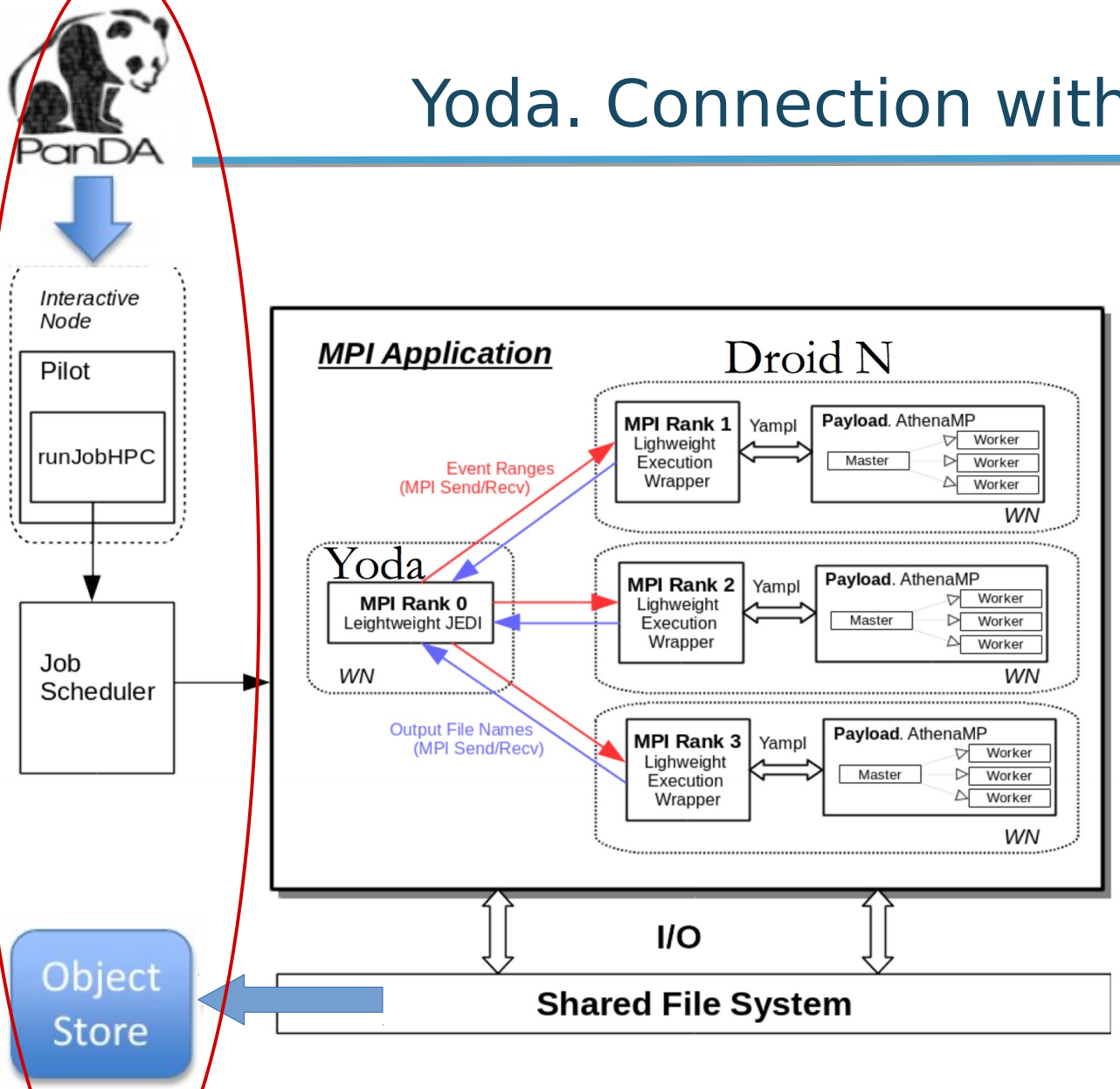


- **MPI application implementing master – slave architecture**
- **Rank 0 (Yoda, master).** Distributes workload between slave ranks
- **Fine grained workload:** individual events or event ranges
- **Rank N (Droid, slave).** Occupies entire compute node;
  Processes assigned workload;
  Saves outputs to the shared file system;
  Asks for the next workload …

- **Payload component:** AthenaMP – multi-process version of the ATLAS simulation, reconstruction and data analysis framework Athena

V.Tsulaia, ATLAS, CHEP2015

Yoda. Connection with PanDA



- **Special implementation of the PanDA Pilot – RunJobHPC – runs on the HPC Interactive Node**
- **Pulls job definitions and input data from the PanDA Server**
- **Submits Yoda jobs to the HPC Batch Scheduler**
- **Streams output files from the Shared File System to the Object Store for final merging**

Job scheduling options

- Yoda is flexible in defining duration and size of MPI jobs
- It offers the efficiency and scheduling flexibility of **preemption** without the application needing to support or utilize checkpointing
  - ✔ AthenaMP payload writes to the disc new output file for each event range
  - ✔ This allows for stopping the job at any time during event processing with minimal losses
- Which means we can run Yoda jobs in the **back-filling mode**
  - ✔ Grab the compute nodes as soon as they become available and use them for the entire duration of their availability
  - ✔ Big 'full' HPCs are full of large hulking rocks; they still have plenty of room for sand for those able to efficiently poor fine-grained work into the cracks

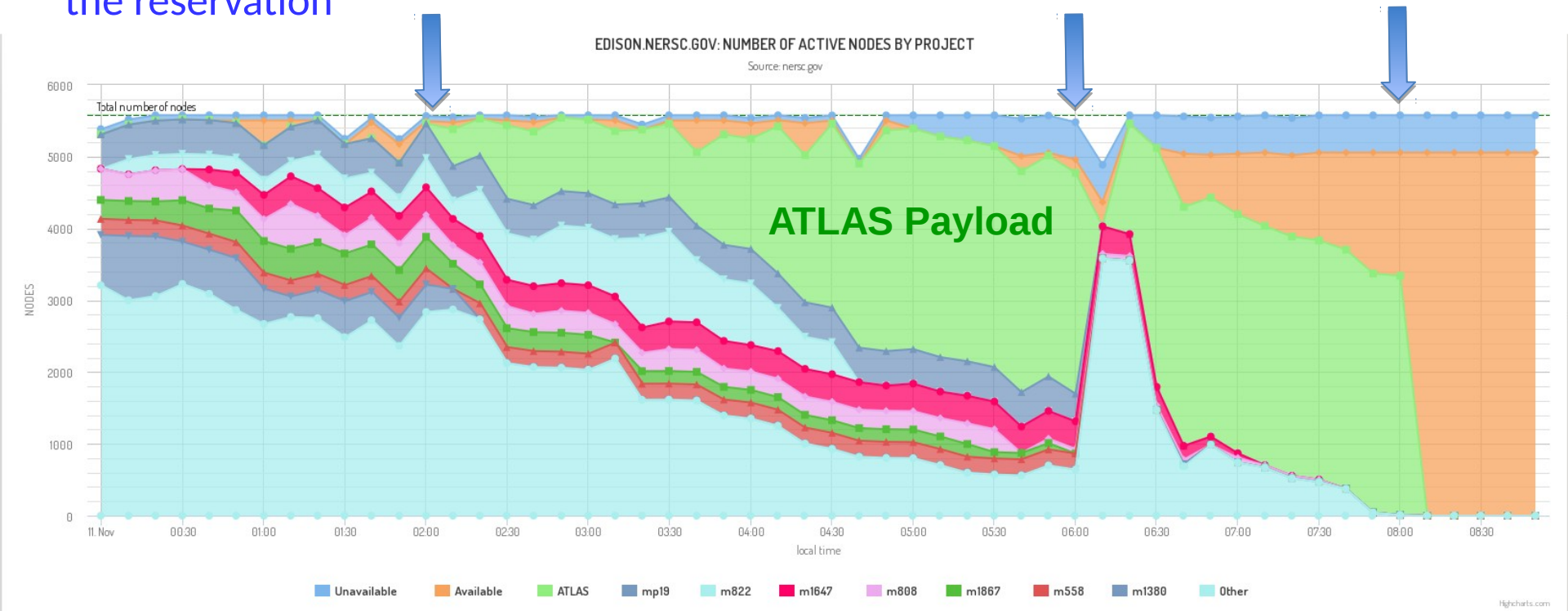
Yoda scavenging resources

- **Edison supercomputer at NERSC (Berkeley, USA)**
- As the machine is emptied either for downtime or for large usage block (**“reservation”**), a **“killable”** queue makes transient cycles available
- Yoda sucks them up and processes the events until the moment they vanish
- … and refills them when they appear again

Edison is getting ready for the reservation

Reservation time

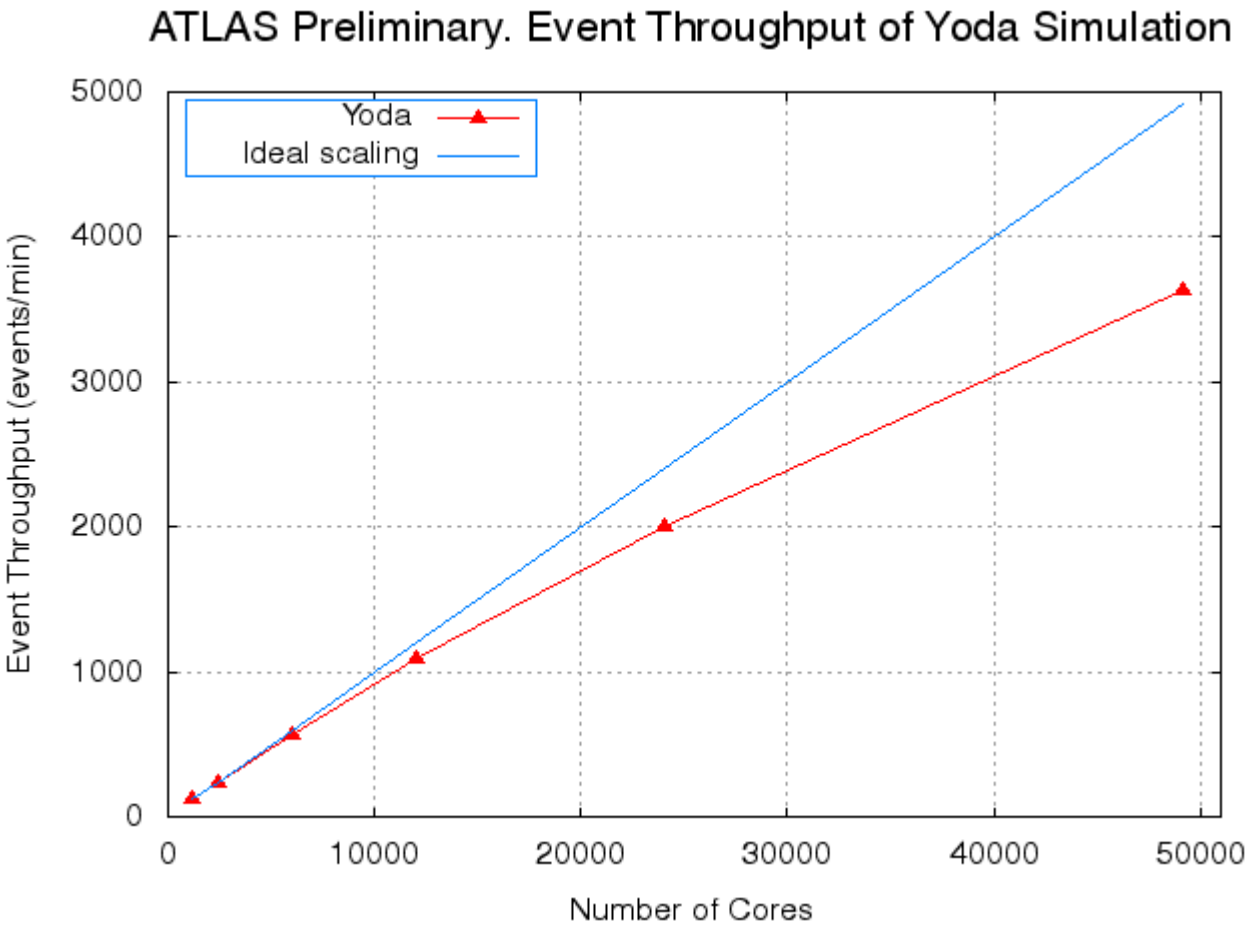
Machine Downtime



Status

- ATLAS Geant4 simulation has been chosen as a first use-case
  - ✔ The biggest return for the least investment
  - ✔ CPU-intensive job with minimal I/O requirements. Meta-data handling relatively simple
- By reusing the code of the conventional Event Service, we were able to very rapidly go from the concept of Yoda to its first implementation in fall 2014
- In November Yoda was demoed at Supercomputing 2014 as DOE ASCR Demo
- Since then we have been focused on preparation for large-scale productions
- As part of this process we successfully validated for physics the simulation output produced by Yoda jobs

Performance scaling tests



- Recent tests on Edison HPC at NERSC demonstrated that Yoda scales well with the number of parallel processes (cores)
- Although there is still room for improvement
- Simulation of full ATLAS physics events was used for these tests
- **Yoda running with 50K parallel processes simulated 220K events in 1 hour**

Summary

- Yoda – MPI-based Event Service – is our approach to running ATLAS-specific workloads on HPCs
- Thanks to its flexible architecture, Yoda allows for efficient usage of available HPC resources by running the jobs either in large time allocations or in back-filling mode
- Yoda went very rapidly from the concept to the first implementation, which has already been validated for physics, …
- … **and now it is ready for running in production**