Site report:
Colliding High Energy Physics With HPC, Cloud, and Parallel Filesystems

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Agenda

• What is CERN?
• The CERN IT agile environment
• HPC at CERN
• How we use SLURM
• Future work, our plans for our HPC infrastructure
CERN was founded 1954: 12 European States
“Science for Peace”

Currently 22 member states and 8 Associate member states from Europe and beyond
The mission of CERN

Probing the fundamental structure of the universe using the world's largest and most complex scientific instruments to study the basic constituents of matter – the fundamental particles.
LHC accelerator and detectors

LHC ring: 27 km circumference
Collisions Produce 1PB/s

• Event filtering – down to 6Gb/s today
• Data reconstruction
• Data analysis
• Find the interesting events

Simulations
• Particle beam trajectories
• Theory behind events
• Events and detectors...
CERN Data Centre: Primary Copy of LHC Data

- 90k disks
- 15k servers
- > 200 PB
- on tapes

Data Centre on Google Street View
CERN Data Centre: Private OpenStack Cloud

- Over 500,000 physics jobs/day on over 300,000 cores
**WLCG: LHC Computing Grid**

About WLCG:
- A community of 10,000 physicists
- ~250,000 jobs running concurrently
- 600,000 processing cores
- 700 PB storage available worldwide
- 20-40 Gbit/s connect CERN to Tier1s

**Tier-0 (CERN)**
- Initial data reconstruction
- Data recording & archiving
- Data distribution to rest of world

**Tier-1s (14 centres worldwide)**
- Permanent storage
- Re-processing
- Monte Carlo Simulation
- End-user analysis

**Tier-2s (>150 centres worldwide)**
- Monte Carlo Simulation
- End-user analysis

170 sites Worldwide
> 10000 users
CERN batch compute

- The bulk of computing at CERN is done via High Throughput Computing (HTC) facilities via Grid or local
- CERN local batch system
  - 1-8 cores for a single job for maximum efficiency
  - 16-48 cores for applications with special requirements
- Also volunteer computing (LHC@home) for high CPU/low I/O simulations
HPC at CERN

- Applications and use cases that do not fit the standard batch High Throughput Computing (HTC) model.
- About 250 nodes, 5000 cores.
- Integration with Agile environment
HPC user community

Beams and technology

- Plasma and beam simulations for LHC and smaller experiments
  - Gdfdl - field calculations for RF cavities
  - Picmc - plasma simulation
  - PyOrbit - Objective Ring Beam Injection and Tracking

Theoretical Physics

- OpenQCD - Lattice QCD simulations

Safety and Engineering

- Safety and fire simulations
  - FDS (Fire Dynamics Simulator)
- Computational Fluid Dynamics
  - Ansys-Fluent
  - OpenFOAM
- Structural analysis
  - Ansys
  - LS-Dyna

WLCG

- Worldwide LHC Computing Grid
- Backfill with Grid jobs via HTCondor to increase cluster utilization
Agile vs. HPC

Agile Methodologies
- High automation and frequent changes
- Shared configuration
- No room for special cases

HPC
- Long-running jobs (several weeks)
- Stability
- Few interventions and changes
- Performance tuning
Agile + HPC

- Keep high level of automation, frequent changes
- Separate testing and production environments
- Perform extensive testing before rolling out to production
- Almost never need to drain all nodes
- Repository snapshotting to control changes
SLURM setup

- Four partitions covering two clusters
- Configuration done by puppet module
- Smaller replicated setup for QA/testing
  - Management nodes (VMs) + 2-5 QA workernodes

Challenges

- Automating the setup and choosing plugins
- Integrating with HTCondor for backfill
SLURM setup

- Submitnode
- Submitnode
- Submitnode
- Headnode
- Headnode (backup)
- DBnode
- DBnode (backup)

HPC Batch
- Short partition
- Long partition

HPC BE
- Short partition
- Long partition
SLURM puppet module

- Configurable and customisable setup for SLURM
- Supports SLURM versions 16.* onwards
- Available at: https://github.com/cernops/puppet-slurm
- Contributions welcome!
SLURM plugins and tools

- Fairly basic setup with VMs and bare-metal
  - Separate MySQL instance for accounting
  - Munge, X11, cgroups, multifactor priority...
- STUBL tools: [https://github.com/ubccr/stubl](https://github.com/ubccr/stubl)
- NHC: [https://github.com/mej/nhc](https://github.com/mej/nhc)
- Tried Slurm-web: [https://github.com/edf-hpc/slurm-web](https://github.com/edf-hpc/slurm-web)
HPC Containers in SLURM

Singularity containers

- Environment and libraries shipped with application
- Fulfill specific application requirements
- Easier to reuse, refer to and share job configurations
OpenStack Ironic bare-metal provisioning

- Access to raw resources without hypervisor isolation or overhead
- No resource sharing among tenants
- Faster context switching, no hypercalls, less cache flushes, less overhead (latency!)
- PMU access
- Possibility to optimize low-level BIOS and kernel settings
- Full advantage of fast Infiniband interconnects
HPC ❤️ CephFS

HPC workernodes

- Intel Xeon E5 2630 v3
- 128GB Memory 1600Mhz
- RAID 10 SATA HDDs
- Low-latency Chelsio T520-LL-CR
- Communication iWARP/RDMA CM

CephFS Jewel

- 3x replication
- Per-host replication
- Shared file POSIX consistency model
- Mon, MDS live in cloud

Legacy bare-metal provisioning

VMs on OpenStack
HPC ❤ CephFS

Hyperconverged
Compute + Storage

- Intel Xeon E5 2630 v4
- 128GB 2400Mhz 18ASF2G72PDZ-2G3B1
- 4x 960GB Intel S3520 SATA3
- RDMA Interconnect (compute)
- Mellanox MT27500 ConnectX-3 56Gb/FDR
- 10Gb Ethernet (storage)

- CephFS Luminous 12.2.5
- Network-local
- Pinned MDS
- OSDs on compute nodes
- 2x replication
- Rack-aware replication
- Lazy I/O relaxed POSIX

IO500 SCORE:
Throughput: 3.77 GB/s
Metadata: 8.20k IOPS
Best Score: 5.56
(On 10Gb Ethernet)
Future Work

- Increase resource utilization
- Increase workload power and performance efficiency
- Improve data gathering and analysis of HPC workloads
Highlights

• CERN runs a relatively small HPC site that integrates with a very large HTC infrastructure
• We run an HPC facility on SLURM in an agile and cloud-based environment
• We’re open sourcing our puppet-slurm module on GitHub.
• We are run CephFS as a shared and parallel filesystem for both production and experimental use cases.
• We look forward to discuss similar scenarios and use cases with you!
Our interests

- How to integrate engineering applications with SLURM?
  - Ansys-Fluent - how do you run on your site?
  - Commercial applications rely on ssh, do you restrict ssh in any way? \texttt{pam\_slurm\_adopt} or other solutions?

- Resource booking
  - Plugin or software for booking resources?

- Alerting and job performance statistics
  - Recommended solutions?
Questions and discussion
Credits

References:
Minimizing Thermal Variation Across System Components, Zhang et al., IPDPS 2015.

Image sources:
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