Big Data and Extreme Computing Workshop
Architecture and Operation

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Outline

- Current State
- Motivation
- General
- Production Services
- Architecture
- Executive Summary

- We will not be talking about architectures in detail since
  - We just had three days of great talks
  - To first order – the BD and EC architecture choices are the same in this period
Current State

• In many ways, BD and EC have co-existed in the same facilities if not the same systems for many decades
• The perfect BD system shares many architectural attributes of the EC system
• Current Petascale EC resources have many examples of processing BD applications well
  • K machine is #1 of the Graph500 list
  • LSST analysis pipeline has been shown to run well and efficiently on Blue Waters
  • Examples of BD frameworks on EC file systems
  • Integrated EC and BD workflows exist
    • Ex – SCEC – Specfem3d + Cybershake – very large scale parallel phase and 100,000,000 job phase – co-exist on BW - published
  • The initial “user” member of Open Power Consortium was BD Google, and not that technology is what ORNL and LLNL will use for EC
    • Much EC technology now being used behind the scenes in cloud systems
  • EC resources in OSG
• Yet there remain significant differences between BD and EC
  • Actual and Perceived
Motivation

- Systems are expensive and not integrating misses opportunities
  - Leveraging investments and purchasing power
- Integration of Computation and Observation cycles implicitly requires convergence
- Expanded cross disciplinary teams of researchers are needed to explore the most challenging problems for society
- Data Consolidation trends span BD and EC
- Understand what benefits from Convergence and what does not
  - Categorization of Data
  - Structured, Semi-structured and Unstructured Data
  - Computer Generated and Observed Data
Real Motivation – Research is Changing

- Inference Spiral of System Science

- As models become more complex and new data bring in more information, we require ever increasing computational resources

Slide courtesy of T-Jordan – SCEC, Christian Ott- Caltech and Peter Nugent LBNL
## Differences and commonalities between EC and BD

### Difference

- **Cost and value models**
- **Project Approaches**
  - Commercial software like Oracle
  - Use VMs and cloud/grid methods
  - Do not like waiting for resources
  - Issues of data transport
  - Use of shared data machines
  - Aggregate I/O more important than individual IOPS
  - Longer term data storage because of original data creation
  - BD data sometimes unstructured
  - Programming models and languages (Fortran/C vs Java)
  - Parallelism and synchronization models
  - Integer vs floating point performance
  - Streaming data or data streaming over time
  - Consistency and correctness models
  - Data replication rather than protection
  - Workflow complexity and optimization

### Commonalities

- Interactivity is needed for BD as well as EC
- Many BD methods are computationally intensive
- BD has much pre-computing done in the style of EC
- **Energy Efficiency focus**
- Cost conscious focus
- **Time to solution focus**
- Use the basic underlying hardware features
- Different approaches in commercial and research
- Both EC and BD deal with millions and billions of files per system
  - EC is not large files
- SW Stacks
- Large amounts of data transfer
- High throughput use
  - ….
Technology game changer?

• Research that benefit both BD and EC, without need for convergence:
  • Processors that make use of 3D memory
  • high-capacity, high-bandwidth, cheap memory (what users want to see is a flat memory)
  • Accelerated computation (currently only FP)
  • high-speed interconnect (LAN and wide area)
  • high-speed to storage (bottleneck now is disk)
  • high-performance file systems

• Research to promote convergence:
  • speeds in/off the chip
  • data-aware algorithms
  • minimizing data movement, active storage
  • better use of SDN, virtualization
  • ability of software defined provisioning and management of resources
  • co-existing of VMs/containers in traditional EC systems/ Software and application stack control in EC
  • ease of validating applications in different environments
  • methods for co-location of computation and data
  • automated, optimal and easy use of deep memory hierarchies
  • on-the-fly data processing (percipient storage)
  • high-level abstractions for computation and data
  • benchmarks, application models, execution traces
  • efficient graph processing libraries
Effective Convergence of EC and BD Priorities

- New APIs and integrated execution models
- Ease of movement between cloud and extreme scale EC/BD resources
- More flexible, High-performance file/storage systems/repositories
  - Many files – not just a few large files
  - Multiple personalities/APIs?
  - Neither EC nor BD will be using strict POSIX
  - Virtualized I/O capability
  - Design for a common storage capability
- Fine grained resource management
  - EC resource managers can today integrate long large jobs with modest length (O(10 minutes) small jobs – this works for thinks like structured data analysis pipelines (HEP, Genomics, …)
  - BD also has high throughput sub minute jobs that need new integration steps
  - Affinity for job steps
  - Need a way to specify the mix of resources that you need and the system would allocate them
  - Need for a malleable schedulers
  - Fast, lightweight launch
  - User Experience focus (scale vs time to complete, planned (batch) vs asynchronous immediate, …)
  - Container support with low jitter
- Approaches to what to optimize
Effective Convergence of EC and BD Priorities

- Software Defined Resources
  - dynamic integration of memory and storage resources and associated API
  - runtime system that automate data movement between memory and storage
  - Network and topology configurations
  - Virtualized memory and storage systems with open APIs for transparent data movement and on-the-fly processing

- Energy efficient resource management

- More collaboration between EC and BD researchers
  - benchmarks for EC and BD workloads
  - Technology discussions between research centers and cloud service providers
  - Work with a selected group of application, understand them and make them work in heterogeneous environments
    - Machine learning, Graph Analysis, etc.
    - Establish partner relationship with major “data creator” projects (LSST, SKA, next gen LIGO..)

- Understand cost models of BD and EC and use appropriately

- Allocation, Authorization and Authentication
  - Not really a firewall, etc.
Executive Summary
Statements

• General:
  • We need to identify different levels of BD-EC convergence and evaluate their benefits.
    • Not all BD and EC has to, nor should converge – maybe driven by types of BD
  • We need to conduct a cost benefit analysis to determine where and how convergence would benefit the user communities and how to best prioritize the activities in a way that reflects the needs of the user community and the priorities of the funding organizations.
  • Address trans-national policies to encourage collaborations and flexible, efficient resources allocations. Exploit new synergies between countries and organizations.

• Architecture:
  • Both BD and EC will use the same architectural components (processors, memory technologies, interconnects, …) So the key issue are cost effective system balances and system software architectures.
  • More robust and dynamic methods to move the data where they are needed
  • Ensure I/O and storage technology research and productization targeting need of convergent system should receive sufficient focus and funding

• Operations:
  • We have a clear need for convergence of resource allocation and management mechanisms and services (that accommodate both styles of applications).
  • Set up a repository of reference components and workflow systems useful for EC and BD applications.
  • Encourage resource providers to adopt a user-centric model that includes support for convergent BD/HPC applications.
Bill’s Additional Thoughts

• The basic technology building blocks will be the same for BD and EC systems
  • That does not imply the cost of the building blocks should be the same for BD and EC
  • Hence, the major challenges will be
    • System balances
    • System Software
    • How resources are managed
• It should not be a goal that all BD and all EC needs to use the same systems and services
• Many BD and EC uses are on same resources
• Really good low hanging fruit – workflow optimizations
  • Many inefficient components that are connected (often via files)
• Inconsistent funding models for large scale BD creators and large scale EC resources
• Reward metrics need to be similar for BD and EC
  • Methods developers
• Cultural and work methods pose at least as big a challenge as technical architecture challenges
• Need new resource management benchmarks – not just discrete application benchmarks
Bill’s Additional Thoughts

- Architectural decisions are always multi-variate optimization choices
  - Often expressed via benchmarks and Best Value
- Need to impedance match scale and complexity
- Both BD and EC need not data repository solutions
  - Lustre and GPFS – 15 years and still being made to work
  - Google changes their data repository every 2 years
- Convergence of EC and BD could take several paths
  1. Opportunistic use of resources and services
  2. An overall optimization across all both communities
  3. Sub-select areas of BD and/or EC that can efficiently leverage co-optimized architectures.
    - Examples:
      - BD/EC resources can exist with structured and semi-structure BD that need computational intensive analysis
      - May be reasonable to EC/BD cover HTC for O(10 minutes), but not O(10 second) sessions can easily co-exist
- Technology risks are across both EC and BD