A Unified Approach for Modeling and Optimization of Energy, Makespan and Reliability for Scientific Workflows on Large-Scale Computing Infrastructures

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Introduction

• Scientific workflows are often used to manage large-scale computations on HPC and HTC platforms
  • Several studies have been conducted to optimize workflow scheduling
  • However, most existing optimization techniques are limited to single or two objectives

• Research in green computing often address cooling and energy usage reduction in large data-centers
  • There are few studies on how resources are used by applications

• Green computing in scientific workflows
  • Studies are limited to the measurement of energy usage according to resource utilization
  • The energy consumption model is simplistic (e.g., homogeneous execution nodes)
Research Goals

• Development of an energy consumption model to address real large-scale infrastructure conditions
  • e.g., heterogeneity, resource availability, external loads
  • Validation of the model in a fully instrumented platform able to measure the actual temperature and energy consumed by computing, networking, and storage systems

• Development of a multi-objective optimization approach to explore workflow execution tradeoffs
Application Model: Scientific Workflows

- **Directed Acyclic Graph (DAG)**
  - Nodes denote tasks
  - Edges denote task dependencies

- **Tasks**
  - Command-line programs that read one or more input files and produce one or more output files
  - *Compute-intensive* or *data-intensive*

- **Data dependencies**
  - Result of output files from one program becoming input files for another program
System Model: Distributed Infrastructure

- Infrastructure as a Service (IaaS)
  - Data and task computations are stored/performed in the infrastructure

1: Application setup: provision of a set of parameters and input files uploading
2: Workflow task scheduling
3: Output data is stored on the storage server
4: Output data required by the user is downloaded from the storage server
Runtime and Reliability Models

• **At Workflow Level (Our Expertise)**
  - Collect and summarize performance metrics for workflow applications
  - e.g., *process I/O, runtime, memory usage, CPU utilization*
  - Profile data is used to build distributions of workflow applications

• **At Infrastructure Level (Looking for a Partner)**
  - Collect temperature and energy consumption from execution nodes, storage servers, and network systems
  - **Requires** a fully instrumented platform
Research Dimensions

• **Goal**: Multi-objective optimization of energy consumption, makespan, and reliability for scientific workflows

• **Monitoring**
  • Workflow profile data has been collected as part of the DOE dV/dt project (ER26110)
  • Temperature and energy consumption monitoring requires access to a fully instrumented infrastructure
Research Dimensions

• Multi-Objective Optimization
  • The improvement of one optimization criteria may imply in the deterioration of another criteria
  • Development of heuristics to reduce the large-search space of workflow executions

• Modeling (Dynamic Optimization)
  • Models will be constantly updated based on the profiling data collected during the workflow execution

• Workflow Execution
  • Conducted with the Pegasus WMS (OCI SI2-SSI #1148515)
Discussions

• Major Contribution
  • Multi-objective optimization of energy consumption, makespan, and reliability for scientific workflows on large-scale computing infrastructures

• Gaps in Current Research
  • There is no energy-aware profiling of scientific workflow applications
  • Research is focused on the optimization of a single or two objectives
  • Strong assumptions are made (e.g., homogeneous environments)

• Synergistic Projects
  • dV/dT: Accelerating the Rate of Progress Towards Extreme Scale Collaborative Science (DOE ER26110)
  • Pegasus WMS (OCI SI2-SSI #1148515)
  • DOE Sustained Performance, Energy and Resilience (SUPER) project
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Thank you.

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Mono-Objective Optimization

- Single optimization goal to improve workflow executions
  - e.g., makespan, cost, etc.
Multi-Objective Optimization

• The improvement of one optimization criteria may imply in the deterioration of another criteria
  • There is no single solution that is optimal with respect to all objectives

Determine the Pareto Front