CERES: Container-Based Elastic Resource Management System for Mixed Workloads

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Outline

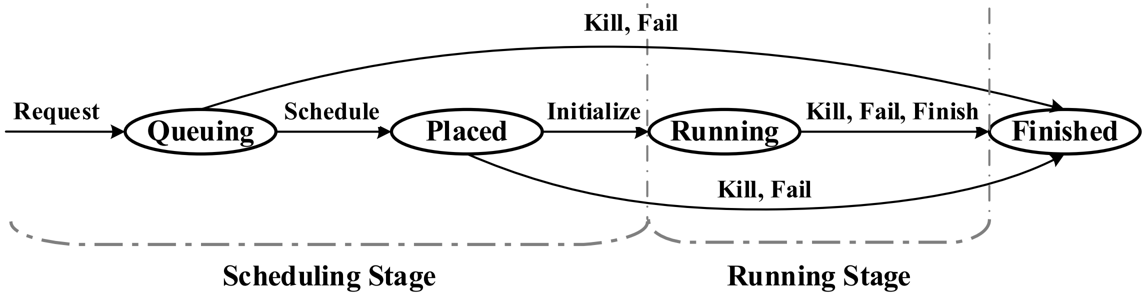
- Background and Motivation
- CERES
- Evaluation
- Conclusion

Workload Deployment Method

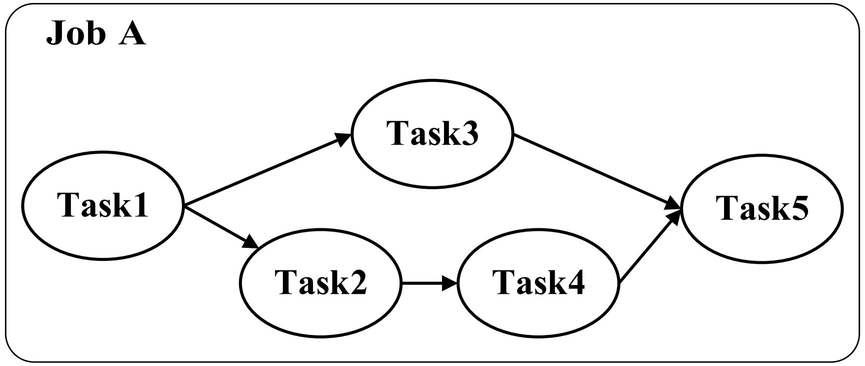
- Widespread use of emerging technologies
  - Increased difficulty in resource management
- Dedicated Cluster or Resource Reservation
  - Low resource utilization
  - High operation and maintenance costs
- Mixed Workload Deployment (MWD)
  - Deploy multiple workloads in one cluster
  - Widespread use
    - Alibaba, Bing, Google.
      - Latency-Sensitive Services (LSSs) & Batch jobs
  - Workload characteristics
    - Resource requirements
    - QoS

Details of Workload Processing

- Job
  - The logical entity of a workload
  - A job is handled by multiple tasks
- Task
  - The basic unit that does the actual work
  - The lifecycle
    - Task Scheduling Latency
      - Swollen task
        - Surplus resources
      - Few idle/allocable resources
        - Newly coming tasks queuing for resources
    - Task Running Time
      - Task dependency
      - Straggler task
        - Inter-task interferences or insufficient resources
        - Block the progress of tasks that depend on it
- *How to guarantee the QoS of LSSs in MWD Cluster?*



A. The lifecycle of a task



B. Task dependencies

Related Work

- Solutions to guarantee the task scheduling latency
  - Preempt the resources of batch jobs
    - PerfIso, BIG-C
  - *Preempt resources without considering surplus resources*
- Solutions to eliminate straggler tasks
  - Task Replicas
  - *Loss of task progress, increase in resource consumption*

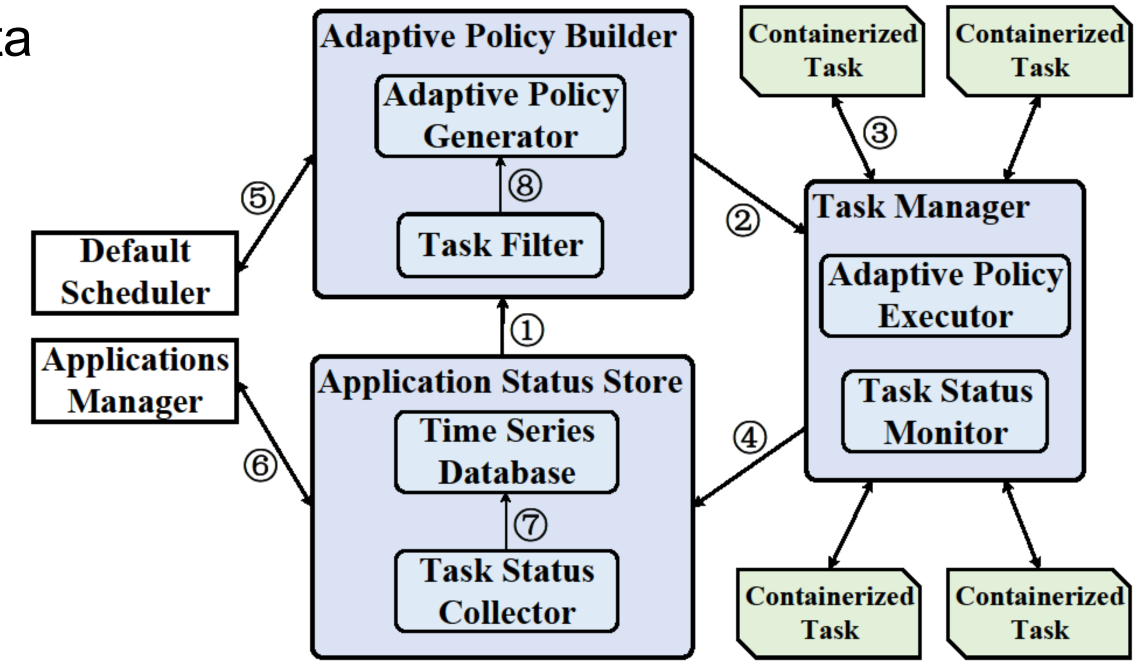
Goals and Challenges

Resource Management Mechanism for MWD

• **Goals**	• **Challenges**
• Enough allocable resources to avoid long scheduling latency	• Accurate identification of swollen tasks and on-demand resource reclamation
• Minimize the performance impact of straggler tasks	• Accurately identify and eliminate straggler tasks
• Minimize the performance loss to batch jobs	• Reduce resource preemptions

CERES

- Application Status Store (ASS)
  - Task Status Collector & Time-series Database
  - collecting, processing, and storing task status data
- Adaptive Policy Builder (APB)
  - Task Filter
    - screen out swollen tasks and straggler tasks;
  - Adaptive Policy Generator
    - make adaptive resource decisions
- Node Task Manager (NTM)
  - Adaptive Policy Executor
    - execute task resource adjustments;
  - Task Status Monitor
    - obtain task status data on the node;



Task Filter

- Swollen tasks from batch jobs
  - Get task resource limits and the maximum used resources
  - Compute the actual maximum resource utilization
  - Determine whether the task is swollen or not
- Straggler task from latency-sensitive services
  - Get the monitoring data of the last three monitoring time points
  - Compute the current and previous processing speed
  - Estimate the task completion time
  - Determine whether the task is a straggler or not

Adaptive Policy Generator

- Adaptive Policy Generator
  - Get cluster idle resources;
  - Count the total resource requirements of new latency sensitive tasks and straggler tasks;
  - Idle resources cannot meet task resource requirements
    - Reclaim resources from swollen tasks;
    - Preempt resources from other batch tasks;
  - When there are enough allocable resources
    - If straggler tasks exist, expand resources for them;
    - If there are no reclaiming or preempting operations, restore resources for preempted tasks.

Node Task Manager

- Adaptive Policy Executor
  - Receive adaptive policies;
  - Perform the policies on tasks
    - Call the Docker Engine API based on Cgroups;
    - Achieve container migration with CRIU;
- Task Status Monitor
  - Obtain task status information
    - Resource usage, processing process, running time, etc.
  - Report the monitoring data to ASS;

Evaluation Setup

- Cluster
  - Composed of 26 servers
    - One manager node, 25 worker nodes;
    - 32 CPU cores, 128GB memory, 12Gbps Ethernet
- Metrics
  - Task Scheduling Latency (TSL)
  - Task Running Time (TRT)
  - Task Completion Time (TCT)
  - Job Completion Time (JCT)
  - Cluster Resource Utilization (CRU)
- Baselines
  - CS-DP: Capacity Scheduler with resource preemption disabled
  - CS-EP: Capacity Scheduler with resource preemption enabled
  - BIG-C: A container-based preemption solution
- Workloads
  - Latency-sensitive services
    - Spark-SQL is used to generate queries as latency-sensitive services (LSSs)
  - Batch jobs
    - Select batch jobs from HiBench and BigDataBench, such as wordcount, terasort;
  - Batch jobs account for 10% of the mixed workloads.

Performance of LSSs

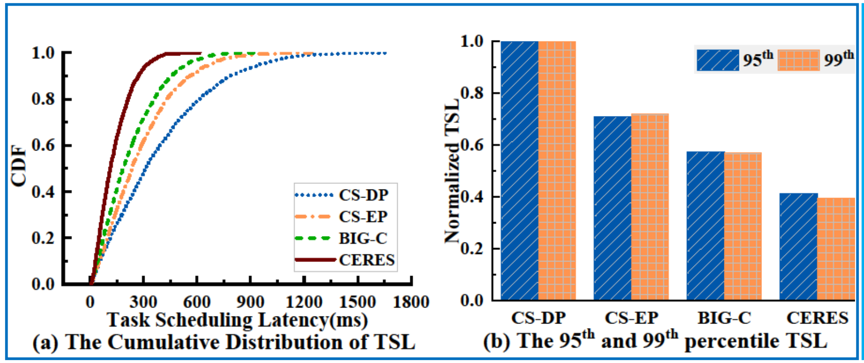


Figure A

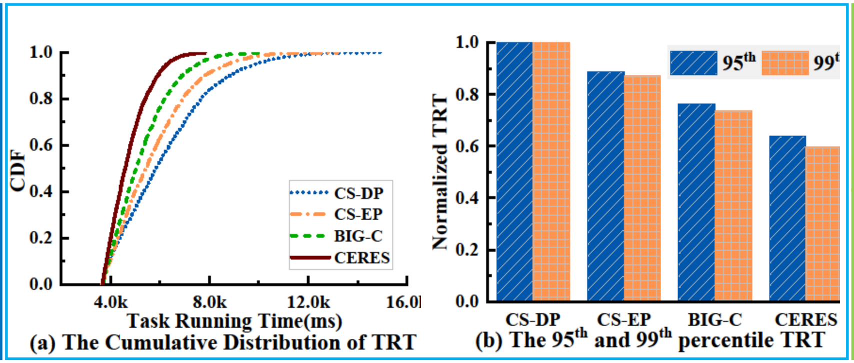


Figure B

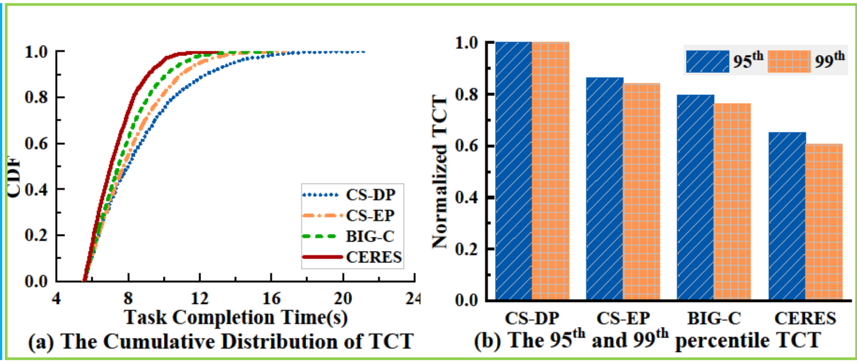


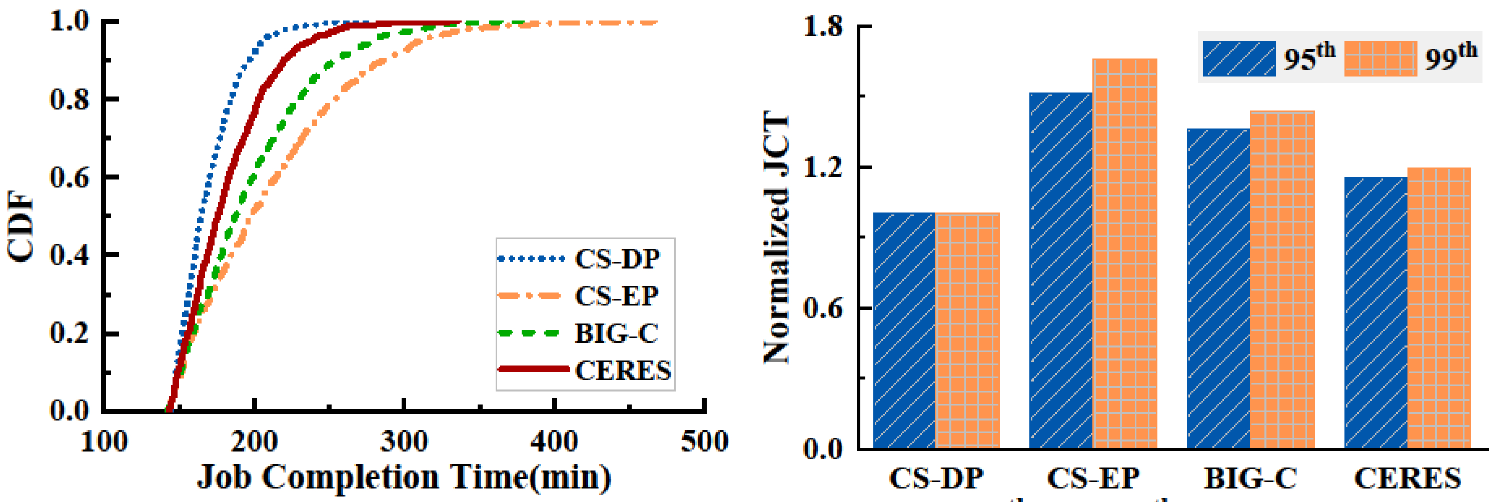
Figure C

- Average task scheduling latency
  - Compared with
    - CS-DP: decreased by 50.87%;
    - CS-EP: decreased by 32.99%;
    - BIG-C: decreased by 16.90%;
- 99^{th} percentile task scheduling latency
  - Compared with
    - BIG-C: decreased by 30.42%;

- 95^{th} percentile task running time
  - Compared with
    - CS-DP: decreased by 36.23%;
    - CS-EP: decreased by 28.04%;
    - BIG-C: decreased by 16.41%;
- 99^{th} percentile task running time
  - Compared with
    - BIG-C: decreased by 18.91%;

- Average task completion time
  - Compared with
    - CS-DP: decreased by 22.42%
    - CS-EP: decreased by 18.00%
    - BIG-C: decreased by 14.07%
- 99^{th} percentile task completion time
  - Compared with
    - BIG-C: decreased by 20.77%

Completion Time of Batch Jobs

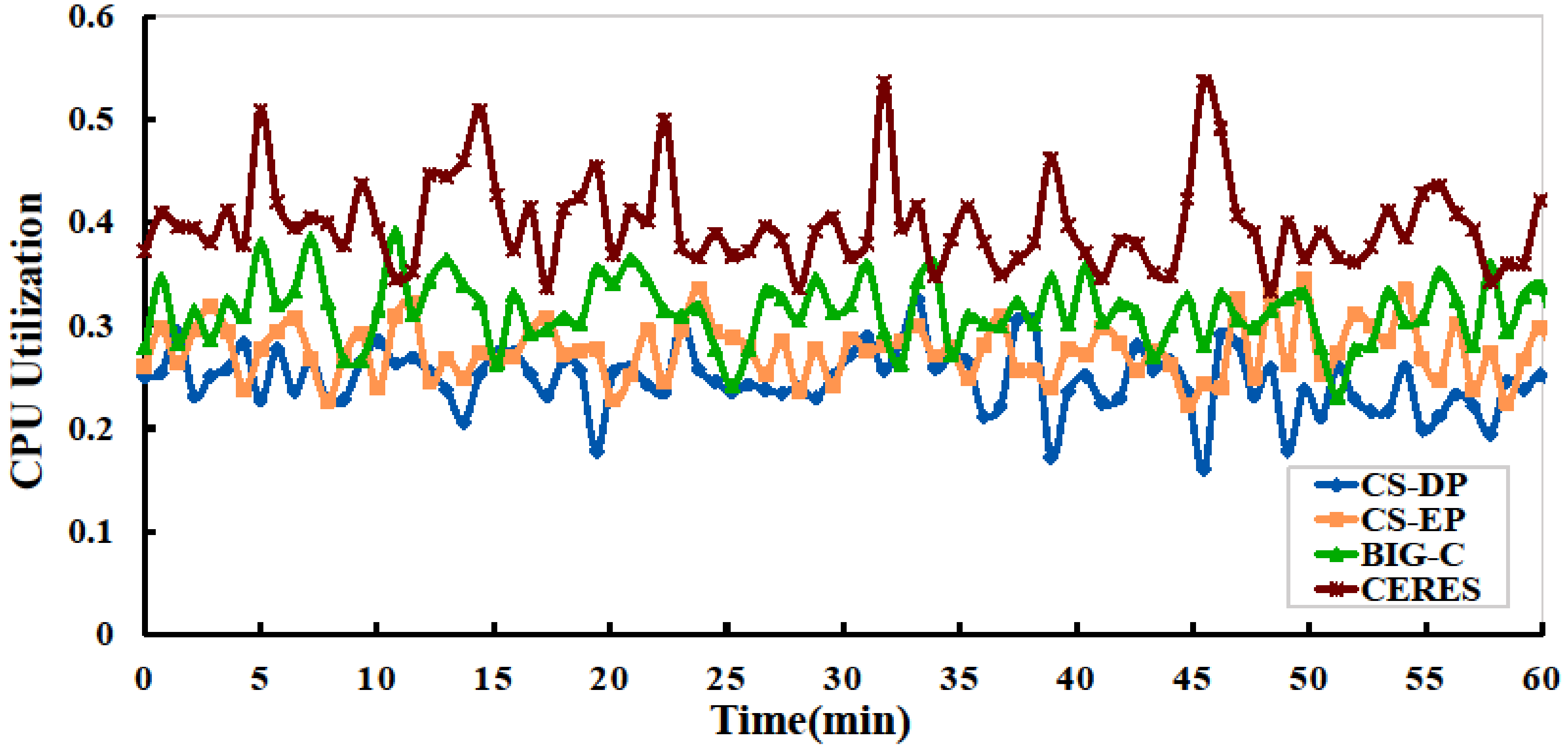


(a) The Cumulative Distribution of JCT

(b) The 95^{th} and 99^{th} percentile JCT

- Compared with
  - CS-DP: at most increased by 15.46%
  - CS-EP: at most reduced by 26.06%
  - BIG-C: at most reduced by 17.7%

Resource Utilization of the Cluster



- Cluster resource utilization reached 53.73%;
- Average resource utilization
  - Compared with BIG-C, promoted by 27.06%;

Conclusion

- Problems of MWD
  - Resource contentions and inter-task Interferences lead to severe QoS losses to LSSs
  - Existing solutions guarantee the QoS of LSSs by preempting resources from batch tasks
    - Performance loss to batch jobs
  - Tasks do not fully utilize the allocated resources
- We propose CERES to guarantee the QoS with surplus resources
  - Accurate task filters
  - Adaptive resource adjustment policies
- CERES can guarantee the QoS of LSSs and reduce the performance penalty for batch jobs.

Thanks! Q&A

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