Preemptive ReduceTask Scheduling for Fair and Fast Job Completion

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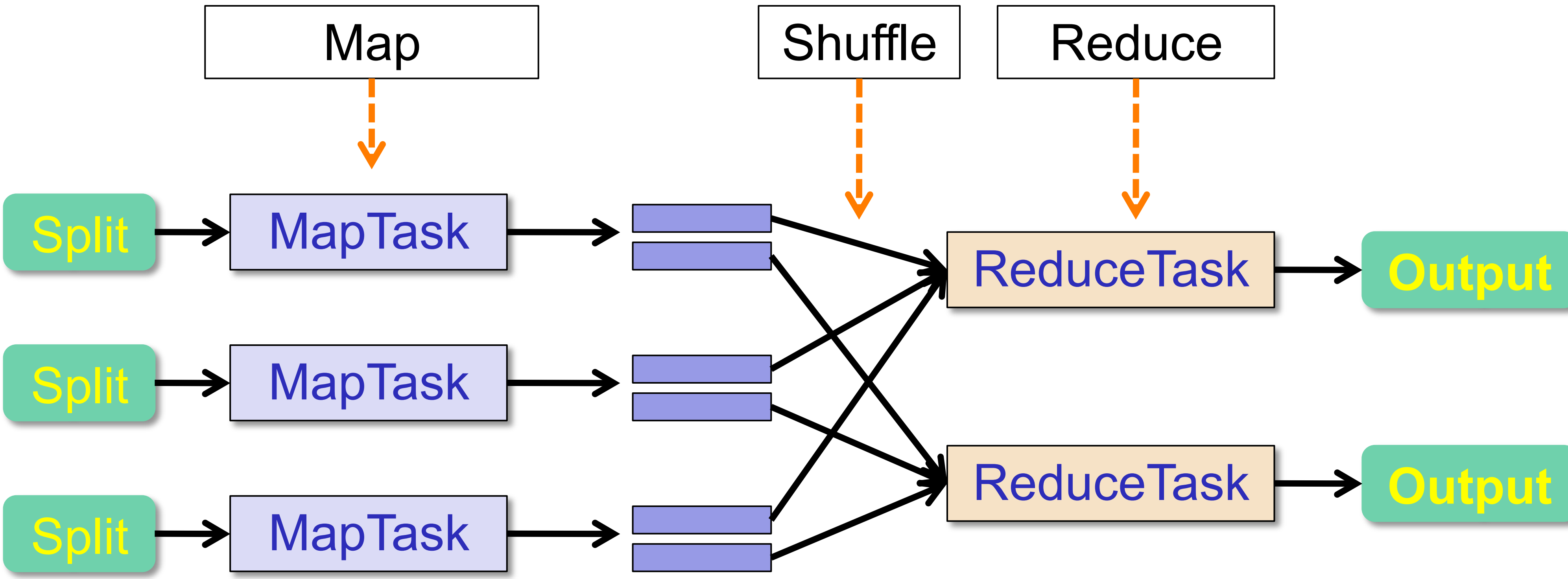
Outline

- Background & Motivation
- Issues in Hadoop Scheduler
- Preemptive ReduceTask
- Fair Completion Scheduler
- Performance Evaluation
- Conclusion and Future Work

Overview

- MapReduce is a programming model for processing massive-scale data.
  - Hadoop: Open-source implementation of MapReduce
- Hadoop has been widely adopted by leading companies.
  - Providing high scalability and strong fault tolerance.
- Data consolidation can be highly beneficial.
  - Co-location of disparate data sets and avoiding data replication cost.
- Mixed workloads of long batch jobs and small interactive queries.
  - Interactive queries are expected to return quickly.
  - Hadoop Fair Scheduler was introduced to allow fair sharing among concurrent jobs.

High-Level Hadoop Overview



- ***Hadoop schedulers strive to overlap the map and shuffle phases to accelerate data processing pipeline.***

Hadoop Fair Scheduler

- A widely used Hadoop scheduler for sharing a Hadoop cluster.
- Providing fairness among concurrently running jobs via max-min fair sharing.
  - Delay scheduling policy are used to provide data locality awareness.
- Tasks occupy slots until successful completion or failure.

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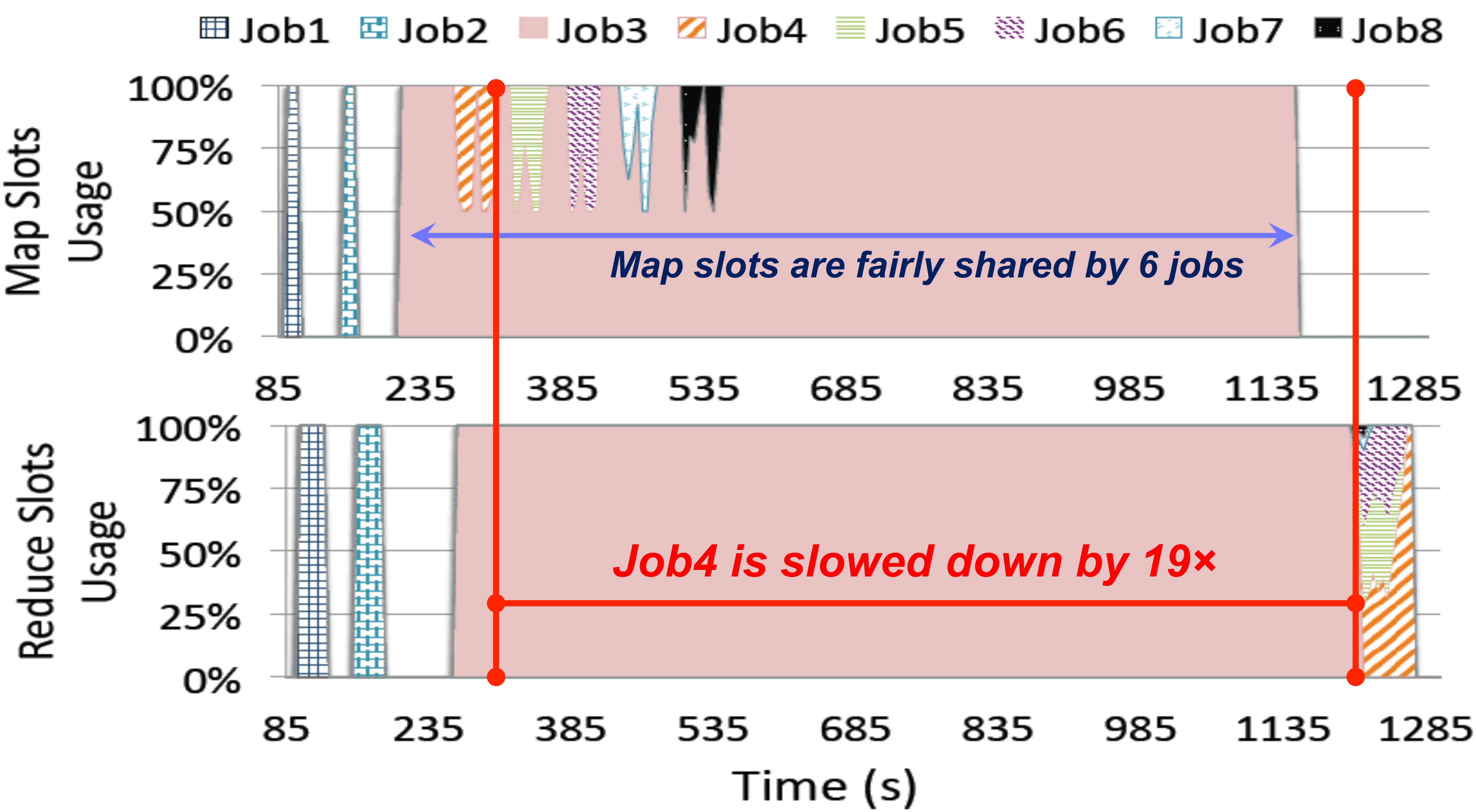
Unfair Reduce Slots Allocation

- Monopolizing behavior of long ReduceTasks from the large job (Job3).
- On average, last 5 small jobs are severely slowed down by 15×.



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Distinct Execution Pattern between Map and Reduce Tasks

- Current Hadoop schedulers treat map and reduce tasks similarly.

Distinctions	MapTask	ReduceTask
Execution Time	*Short-lived*	*Long-lived*
Execution Phase	*Single-phase*	*Multi-phase*
Execution Dependency	*None*	*Map phase*

Distinct Execution Pattern between Map and Reduce Tasks

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[illegible]	[illegible]	[illegible]
Execution Phase	Single phase	Multi-phase
Execution Dependency	***None***	***Map phase***

It is critical for Hadoop schedulers to be aware of these different patterns.

Existing Efforts

- Hadoop introduces slow start [1]
  - Mitigating the starvation but at the cost of slowing down the data processing pipeline.
  - Impacting the execution time of small jobs.
- Coupling scheduling policy from IBM[2]
  - Similar to slow start which let monopolization progressively happen
- Copy-Compute Splitting[3]
  - Performance is unknown, no results was reported.

[1]: "mapred.reduce.slowstart.completed.maps" .

[2]: Jian Tan, Xiaoqiao Meng, Li Zhang, "Coupling scheduler for MapReduce/Hadoop", HPDC'12.

[3]: "Job Scheduling for Multi-User MapReduce Cluster", Berkeley, Technical Report *UCB/EECS-2009-55.*

Fundamental Solutions

*How to achieve both high **Efficiency** and **Fairness** ?*

- How to tackle monopolizing behavior of long running ReduceTasks ?
  - Existing schedulers ignore long-lasting ReduceTasks, once they are launched, they occupy resource until completion or failure.
  - Introducing a new mechanism: Preemptive ReduceTask.

- How to coordinate two-phase job scheduling ?
  - MapReduce adopts two-phase scheme (map and reduce) to schedule tasks. However less contemplation has been given to coordinate them.
  - A new scheduler: Fair Completion Scheduler.

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Preemptive ReduceTask

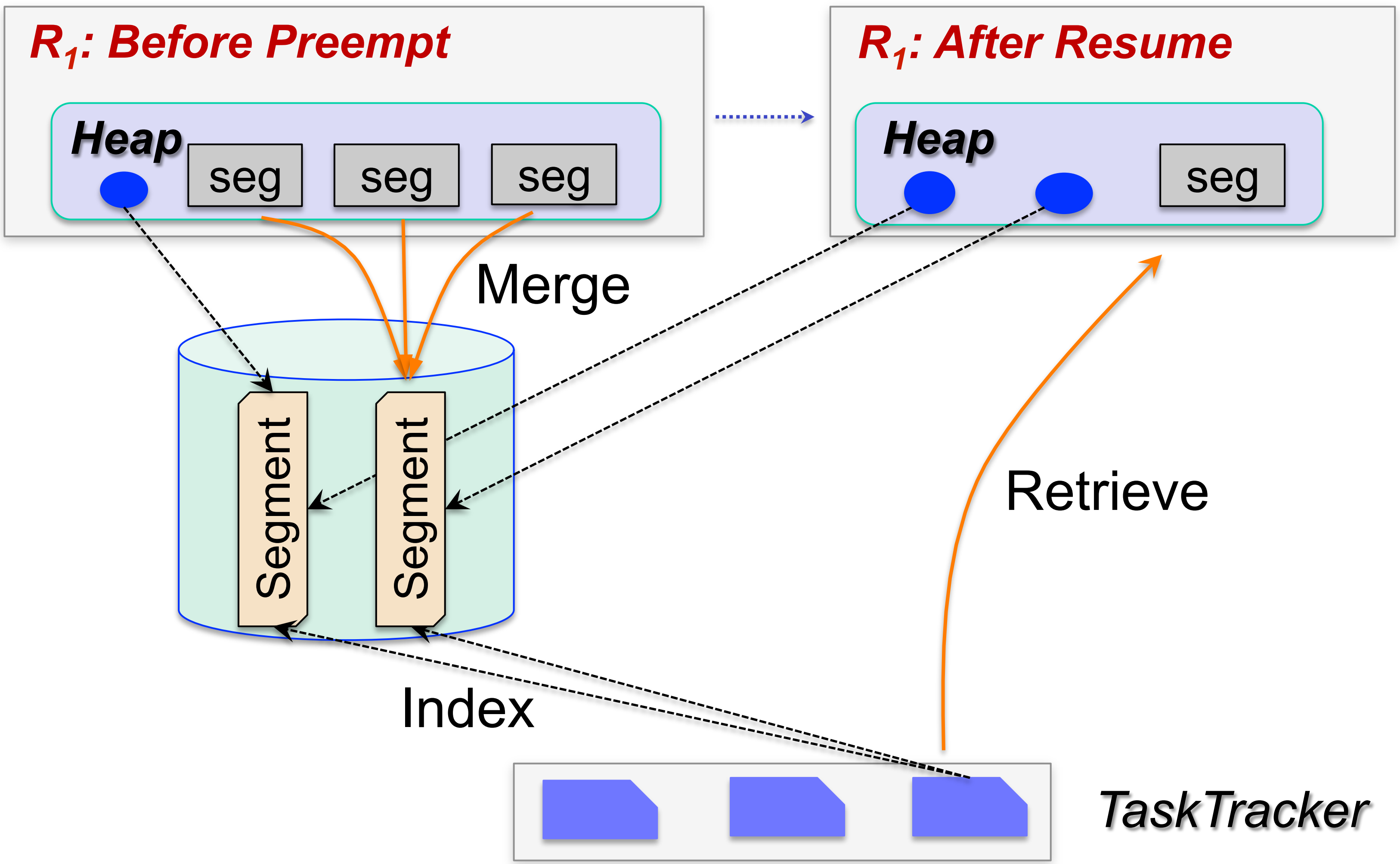
- Lightweight work-conserving preemption mechanism.
  - Preserving previous computation and I/O.
  - Providing lightweight preemption with no noticeable performance impact.

- Different from Linux process suspend commend (“*Kill -STOP $PID*”).
  - Preemptive ReduceTask releases the reduce slot.

- Superior to current killing preemption mechanism.
  - Killing can lead to significant waste of computation and I/O.

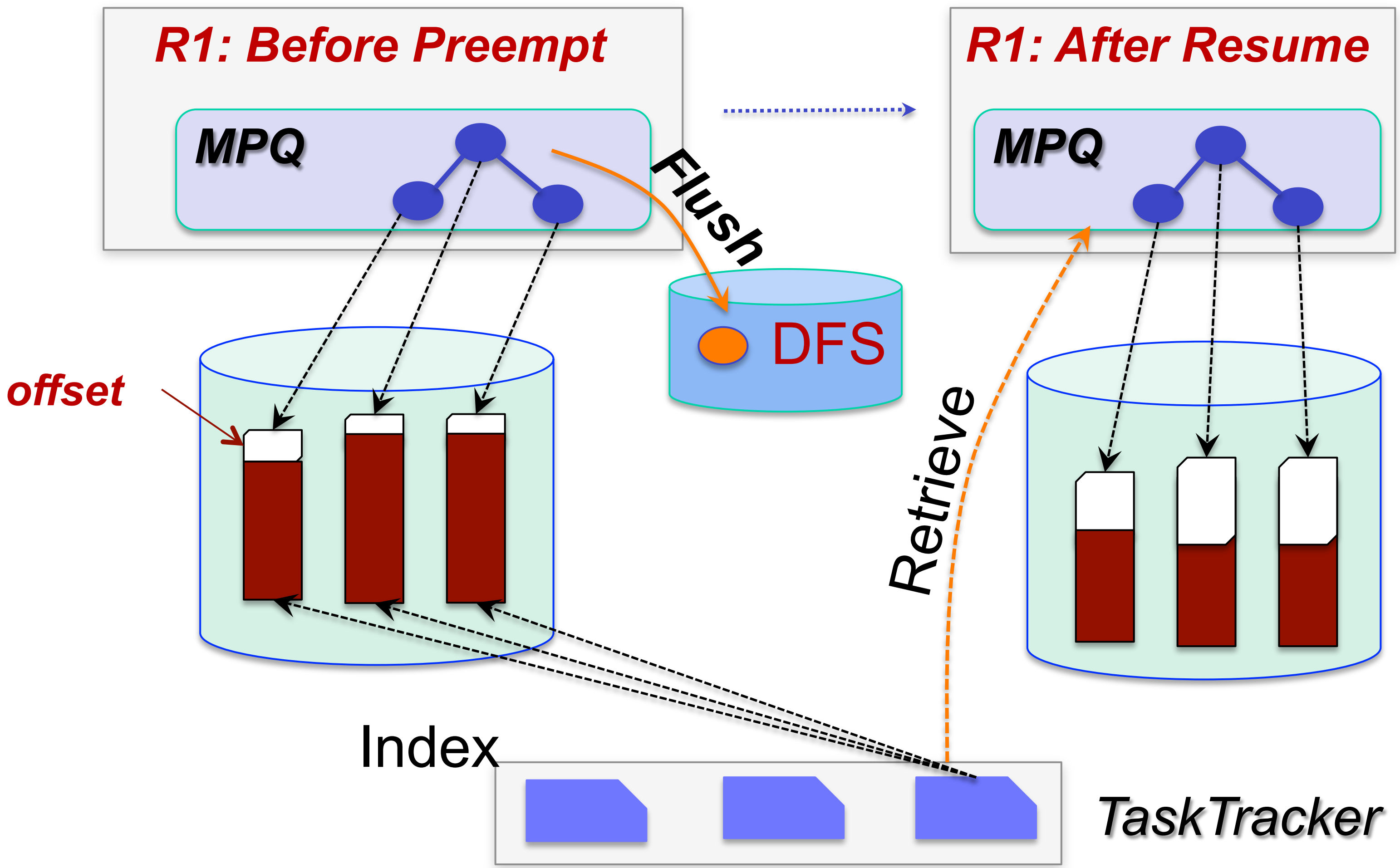
Preemption During Shuffle Phase

- Only merging the in-memory intermediate data, while maintaining on-disk intermediate data untouched.



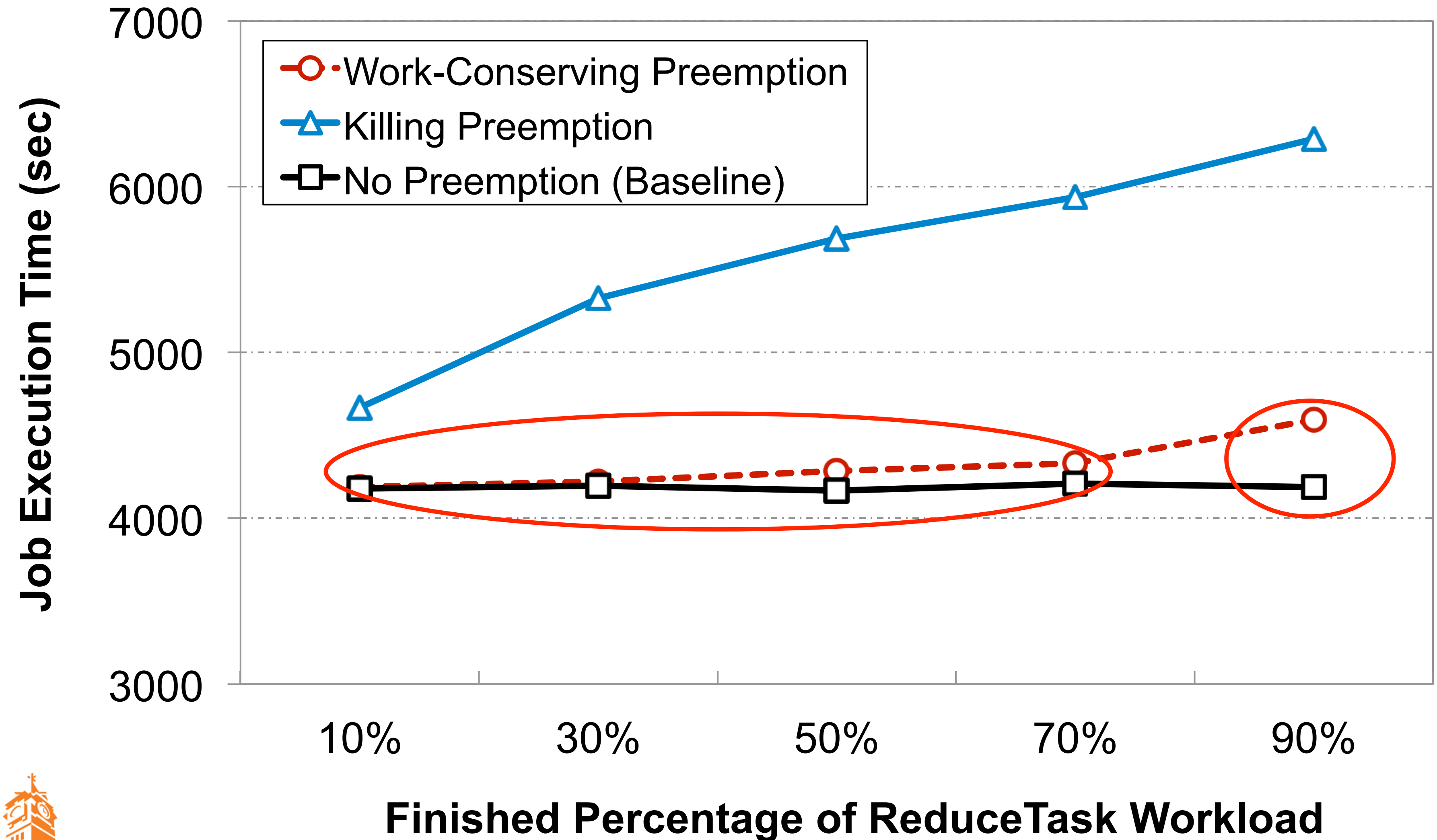
Preemption During Reduce Phase

- Recording the current offset of each segment and minimum priority queue
- Preemption occurs at the boundary of intermediate <key,value> pairs.



Evaluation of Preemptive ReduceTask

- Terasort benchmark with 512GB input data on a cluster of 20 worker nodes.



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Fair Completion Scheduler

- Prioritizing ReduceTasks from jobs with the shortest remaining map phases.
  - Allowing small jobs to preempt long-running ReduceTasks from large jobs.
  - MapTask scheduling follows max-min fair sharing policy.

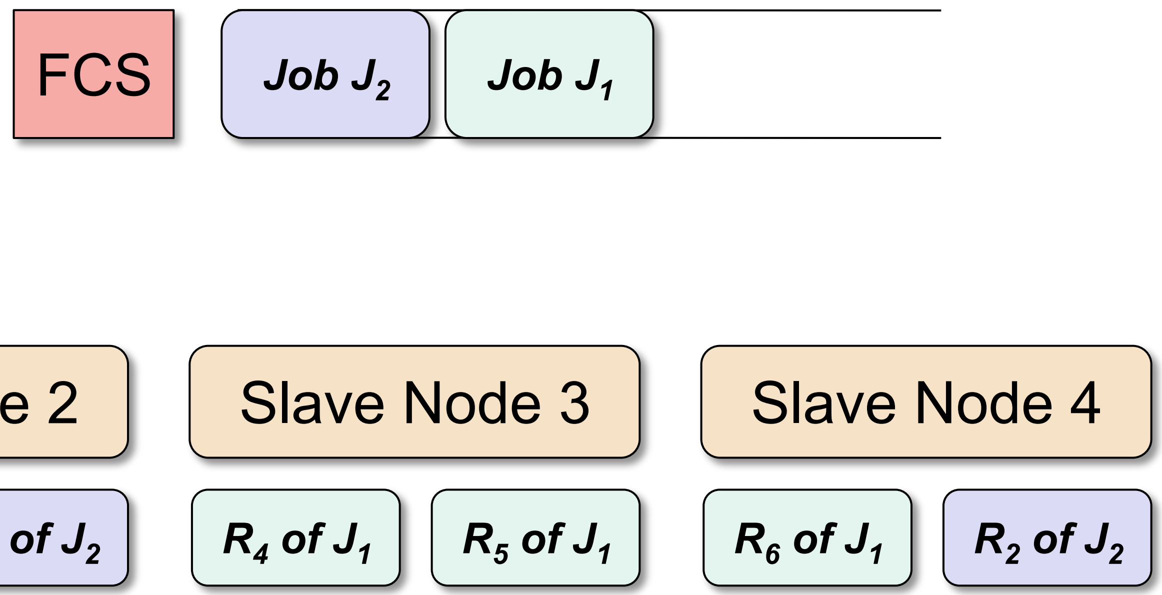
- When remaining map phases are equal, prioritizing ReduceTasks from jobs with least remaining reduce data.

- Detecting the job execution slowdown caused by preemptions.
  - Preventing ReduceTasks of large jobs from being preempted for too long and too many times.

Fair Completion Scheduling Details

	Remaining Map Phase	Remaining Reduce Data	Reduce
J_1	1000 s	100GB	6
J_2	200 s	10GB	2

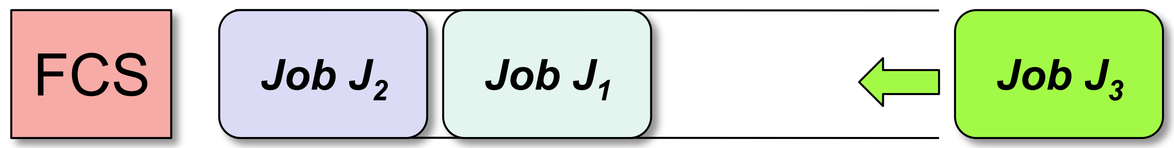
Sort Running Jobs:
(1): According to remaining map time
(2): According to remaining reduce data

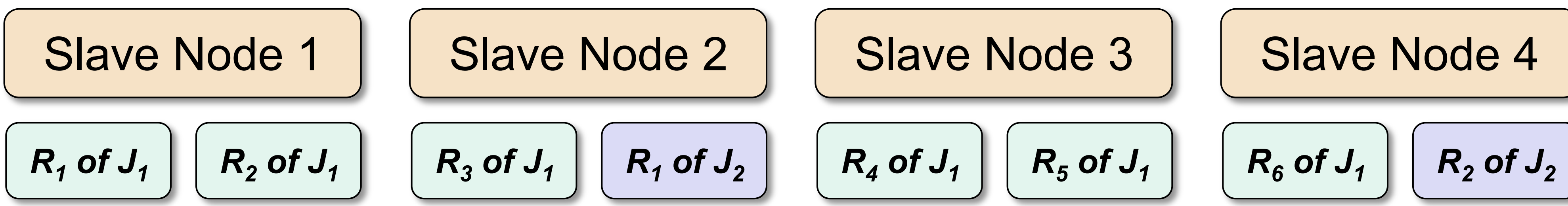


Fair Completion Scheduling Details

	Remaining Map Phase	Remaining Reduce Data	Reduce
J_1	1000 s	100GB	6
J_2	200 s	10GB	2
J_3	80 s	8GB	4

Sort Running Jobs:
(1): According to remaining map time
(2): According to remaining reduce data





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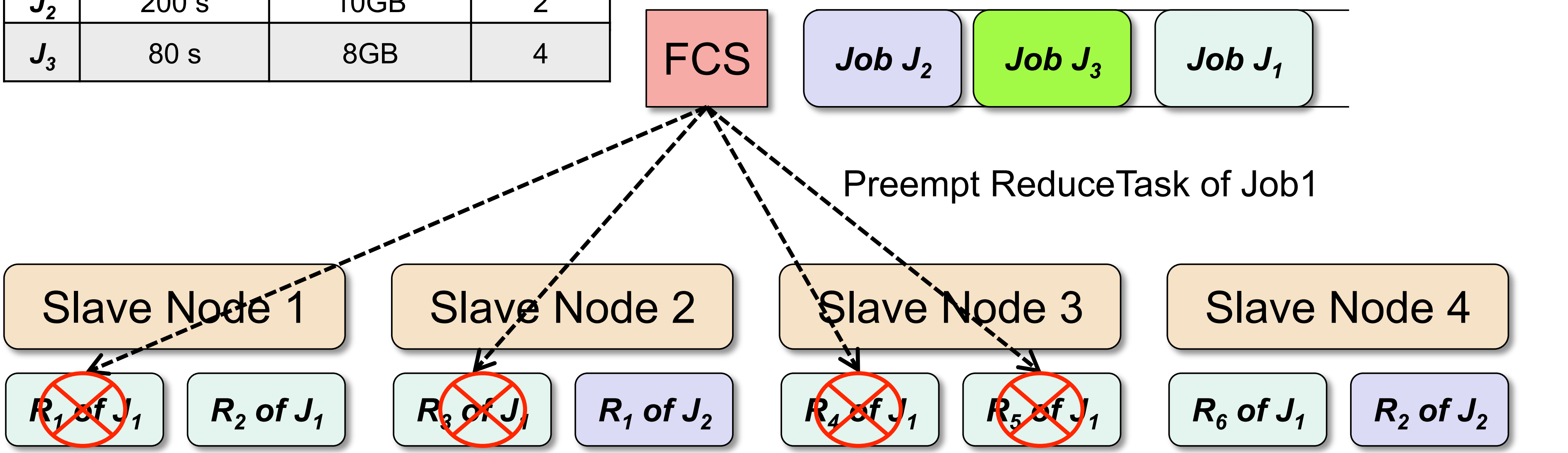

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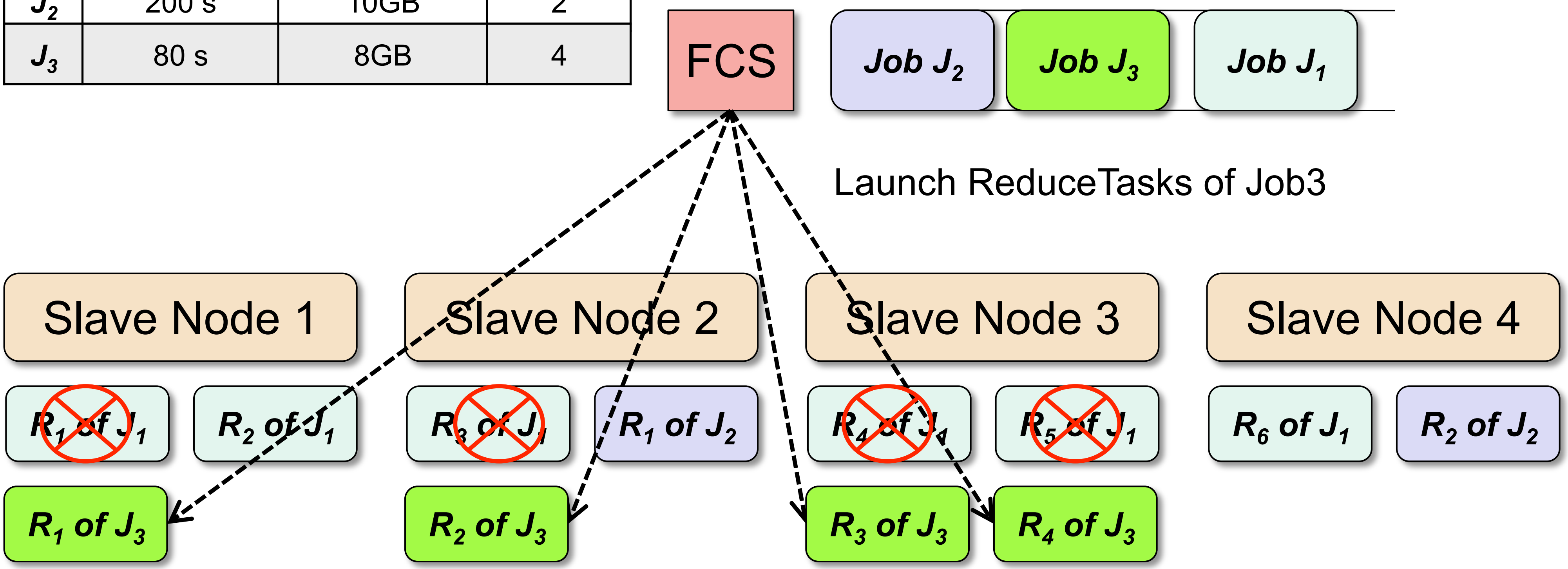
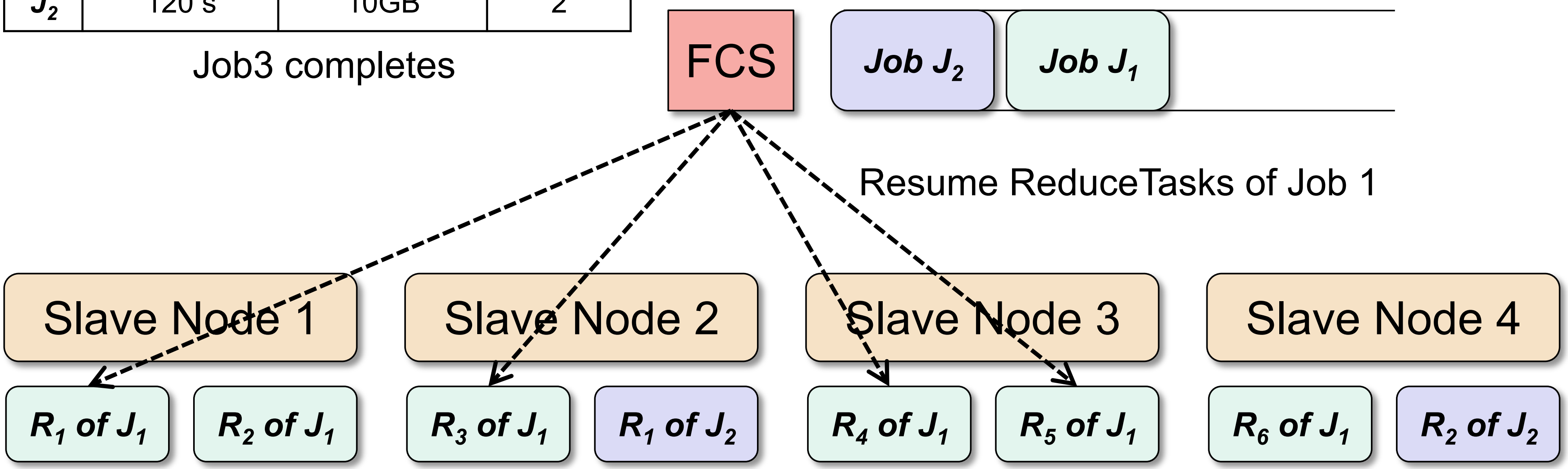


Fair Completion Scheduling Details

	Remaining Map Phase	Remaining Reduce Data	Reduce
J_1	800 s	100GB	6
J_2	120 s	10GB	2

Sort Running Jobs:
(1): According to remaining map time
(2): According to remaining reduce data

Job3 completes



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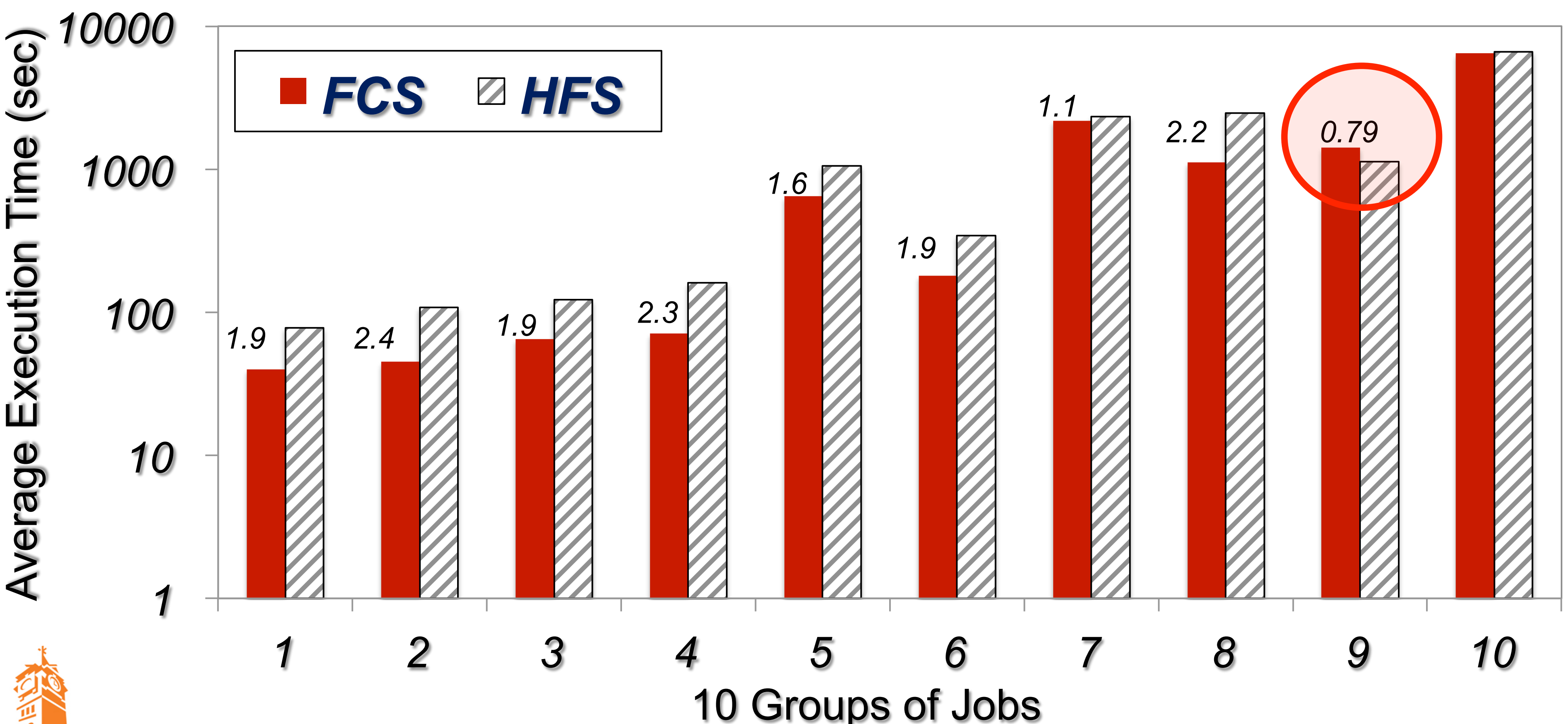
Testbed and Benchmarks/Metrics

- Hardware configuration
  - A cluster of 46 nodes. 4 2.67GHz hex-core Intel Xeon CPUs, 24GB memory and two hard disks.
- Software configuration:
  - Hadoop 1.0.0 and its Fair Scheduler. 8 map slots and 4 reduce slots on each nodes.
- Gridmix2 and Tarazu benchmarks:
  - Map-heavy workload
  - Reduce-heavy workload
  - Scalability evaluation

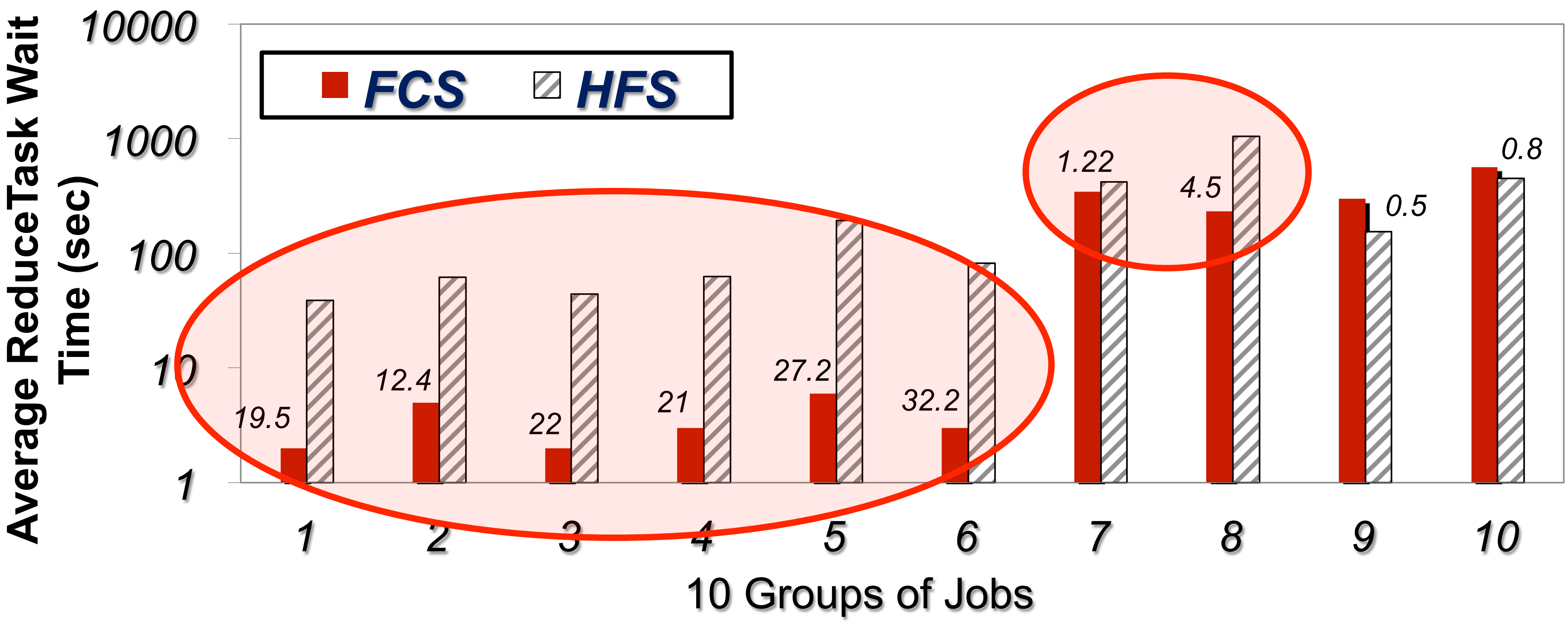
Results for Map-heavy Workload

- FCS reduces average execution time by 31% (171 jobs).
- Significantly speeds up small jobs, slightly slow down large jobs.



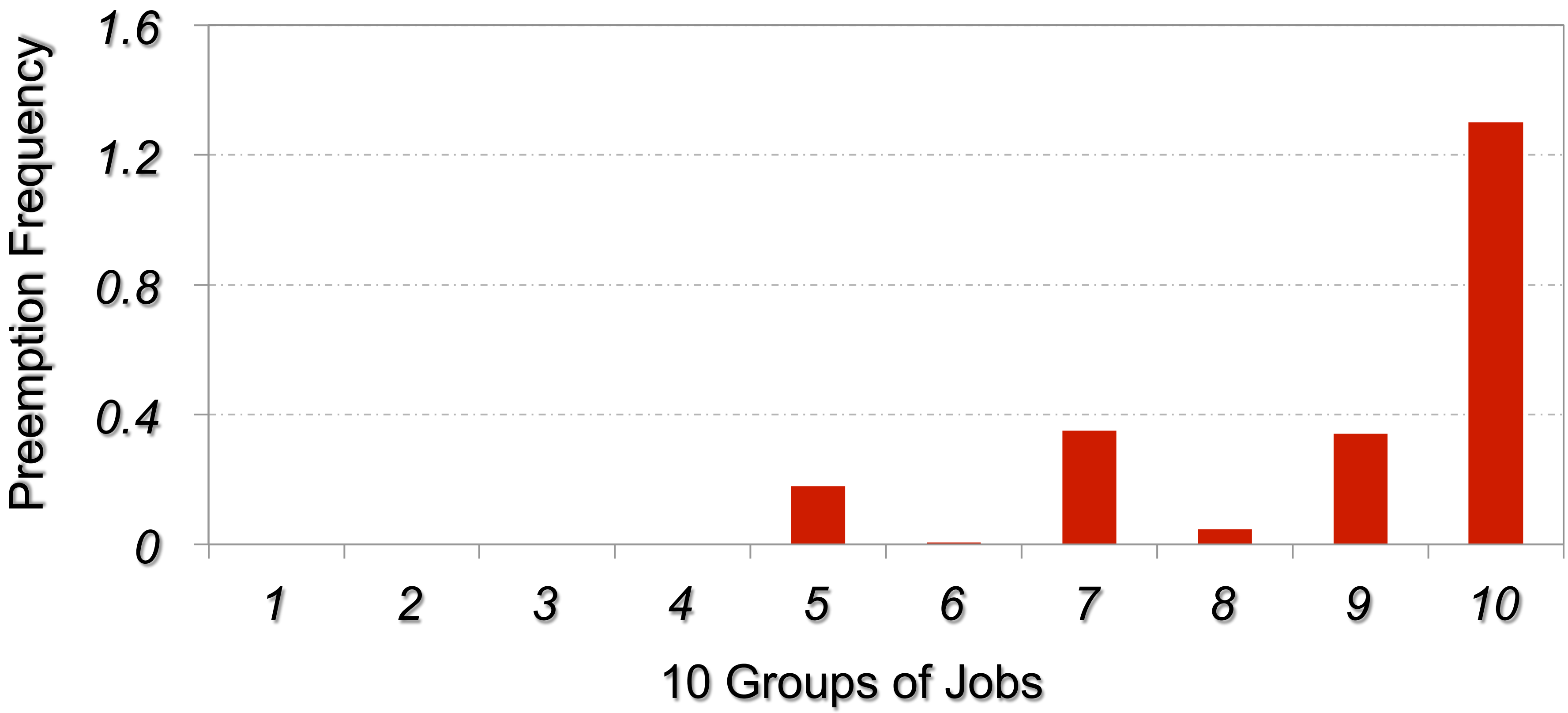
Average ReduceTask Wait Time

- Small jobs are benefited from significantly shortened reduce wait time.
- Waiting time are reduced by 22× for the jobs in the first 6 groups.



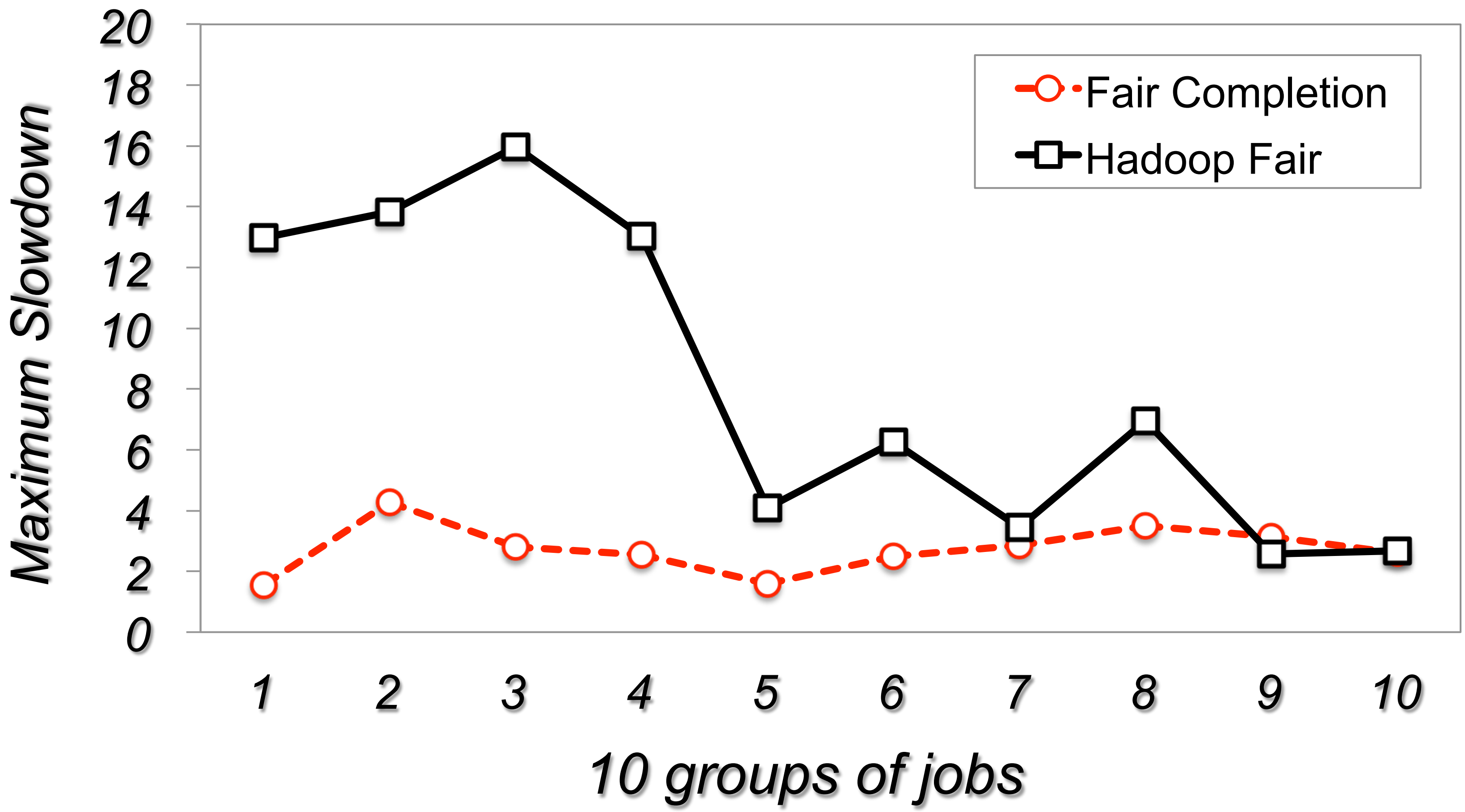
Preemption Frequency

- FCS controls the preemption frequency to avoid excessive preemptions.



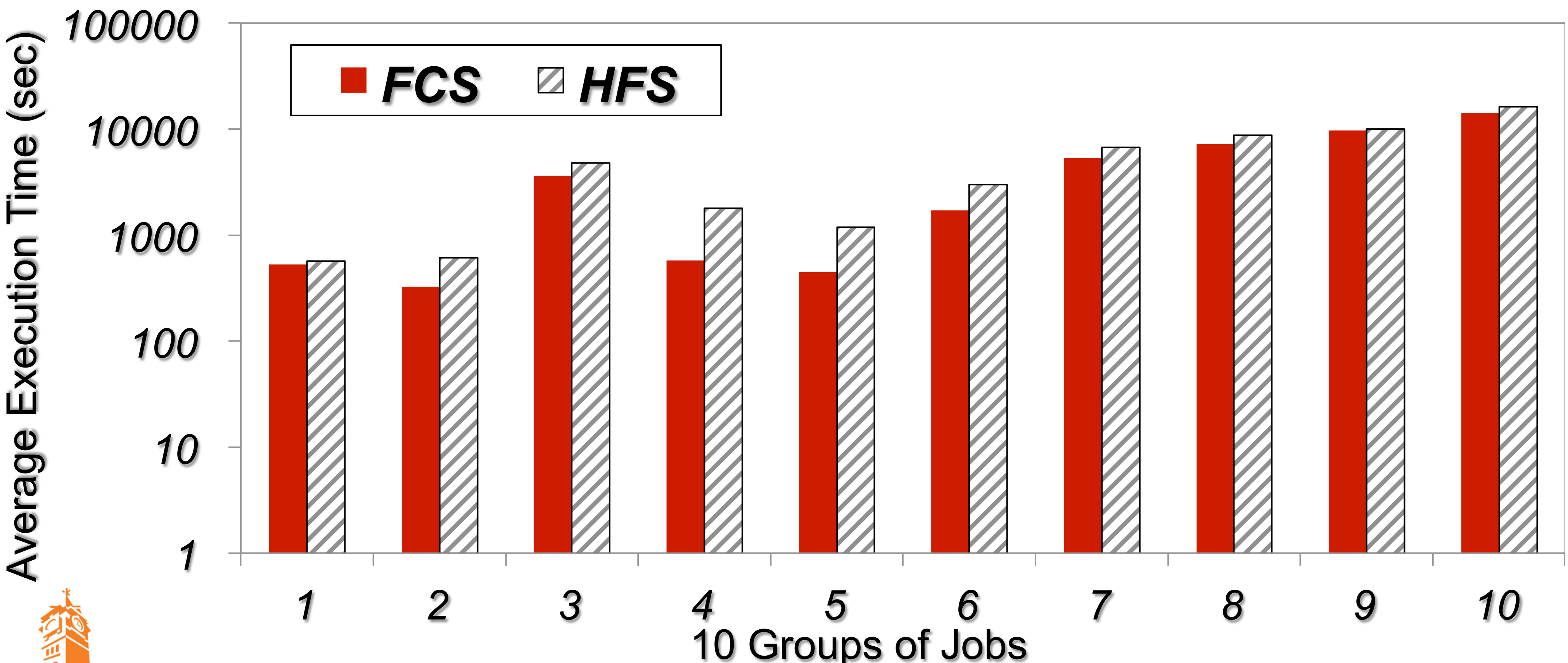
Fairness Evaluation: Maximum Slowdown

- FCS improves the fairness by 66.7% on average.
- Achieving nearly uniform maximum slowdown for all groups of jobs.



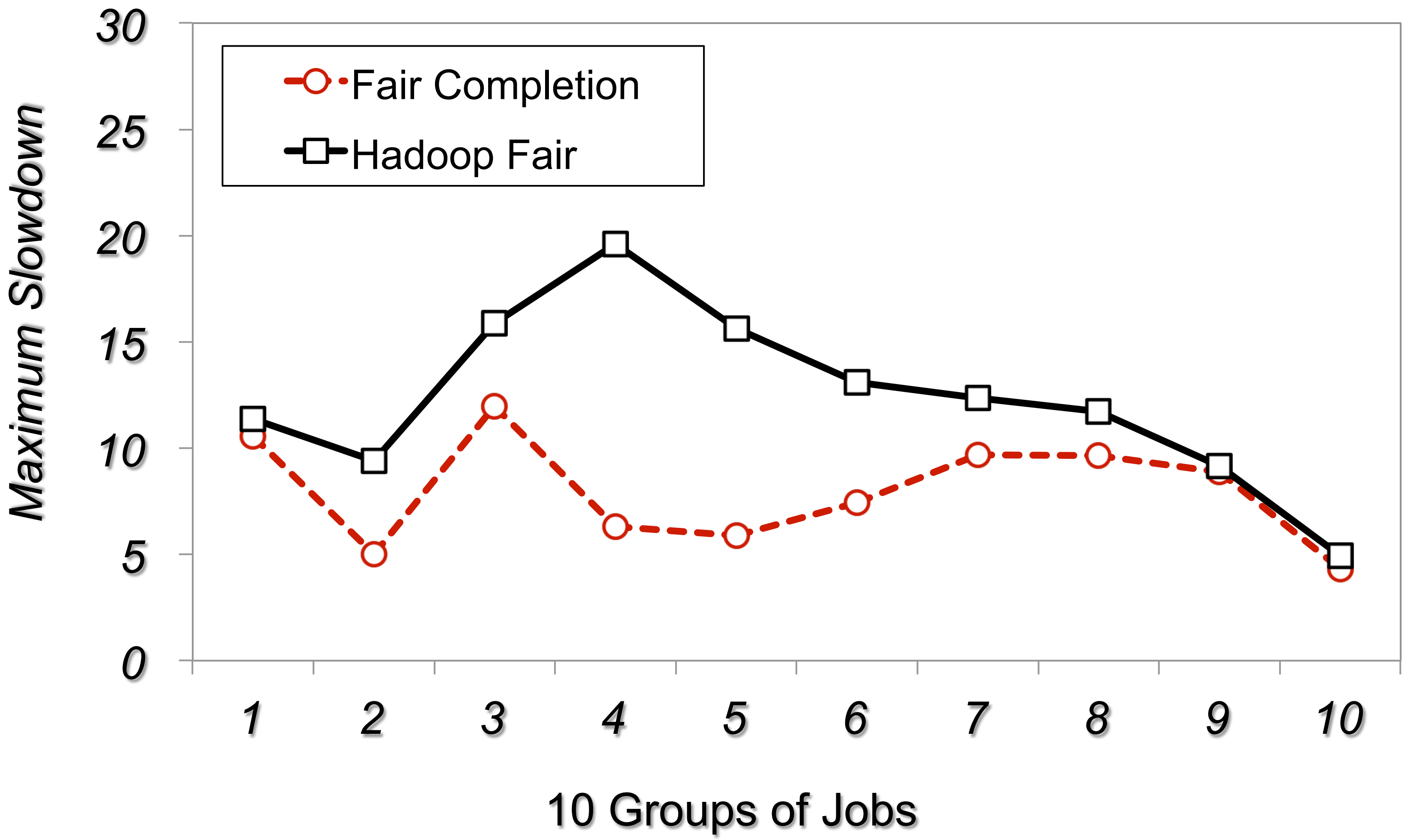
Results for Reduce-heavy Workload

- FCS reduces average execution time by 28% (171 jobs).
- FCS accelerates all types of jobs in the reduce-heavy workload.
  - Impact of preemption on large job is not heavy due to they are still in map phases.



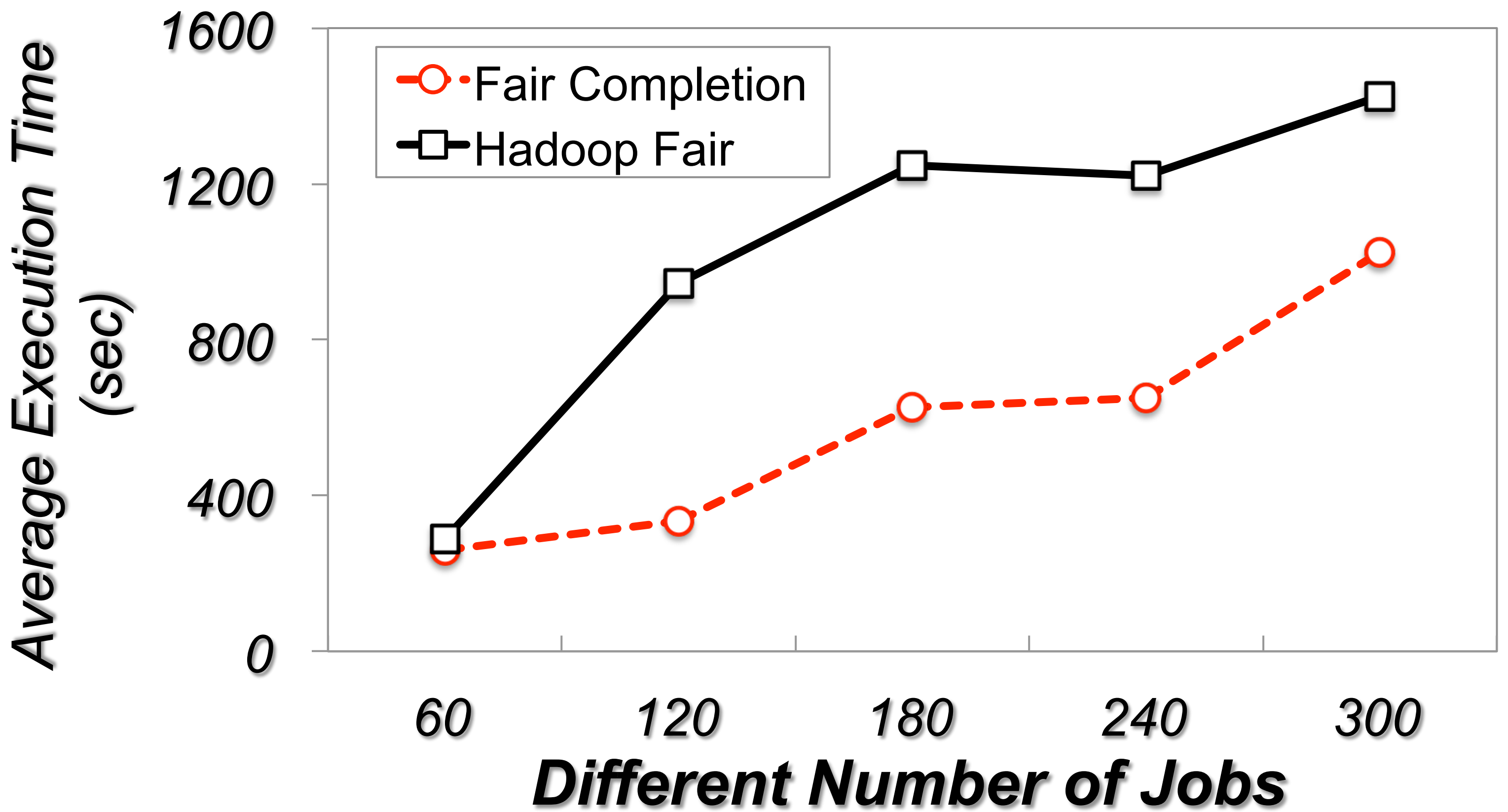
Fairness of Reduce-heavy Workload

- FCS improves the fairness by 35.2% on average.



Scalability Evaluation with GridMix-2

- FCS reduces the average execution time by 39.7%.
- Small improvement at 60 due to dominant number of small jobs.



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Conclusion and Future Work

- Identify the inefficiencies in existing Hadoop schedulers.
- Preemptive ReduceTask provides an efficient preemption approach.
- Fair Completion Scheduler is introduced to improve the efficiency and fairness of the concurrently running jobs.
- Preemptive ReduceTask provides opportunities to improve the fault tolerance mechanism.
- More preemptive scheduling policy can be implemented based on Preemptive ReduceTask.

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Thank You and Questions ?