RAD Lab
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Improving MapReduce Performance in Heterogeneous Environments

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Motivation

1. MapReduce becoming popular
   - Open-source implementation, Hadoop, used by Yahoo!, Facebook, Last.fm, …
   - Scale: 20 PB/day at Google, O(10,000) nodes at Yahoo, 3000 jobs/day at Facebook

Motivation

2. Utility computing services like Amazon Elastic Compute Cloud (EC2) provide cheap on-demand computing
   – Price: 10 cents / VM / hour
   – Scale: thousands of VMs
   – Caveat: less control over performance

Results

- Main challenge for Hadoop on EC2 was performance heterogeneity, which breaks task scheduler assumptions

- Designed new LATE scheduler that can cut response time in half

Outline

1. MapReduce background

2. The problem of heterogeneity

3. LATE: a heterogeneity-aware scheduler

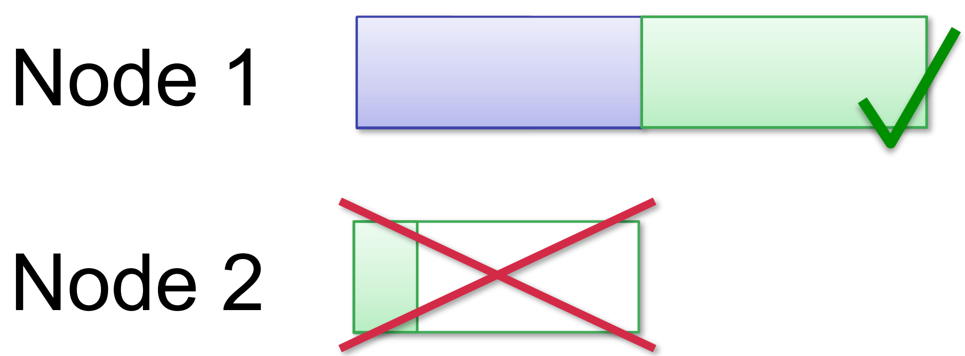
What is MapReduce?

- Programming model to split computations into independent parallel tasks
- Hides the complexity of fault tolerance
  - At 10,000's of nodes, some will fail every day

J. Dean and S. Ghemawat. MapReduce: Simplified Data Processing on Large Clusters. OSDI 2004.

Fault Tolerance in MapReduce

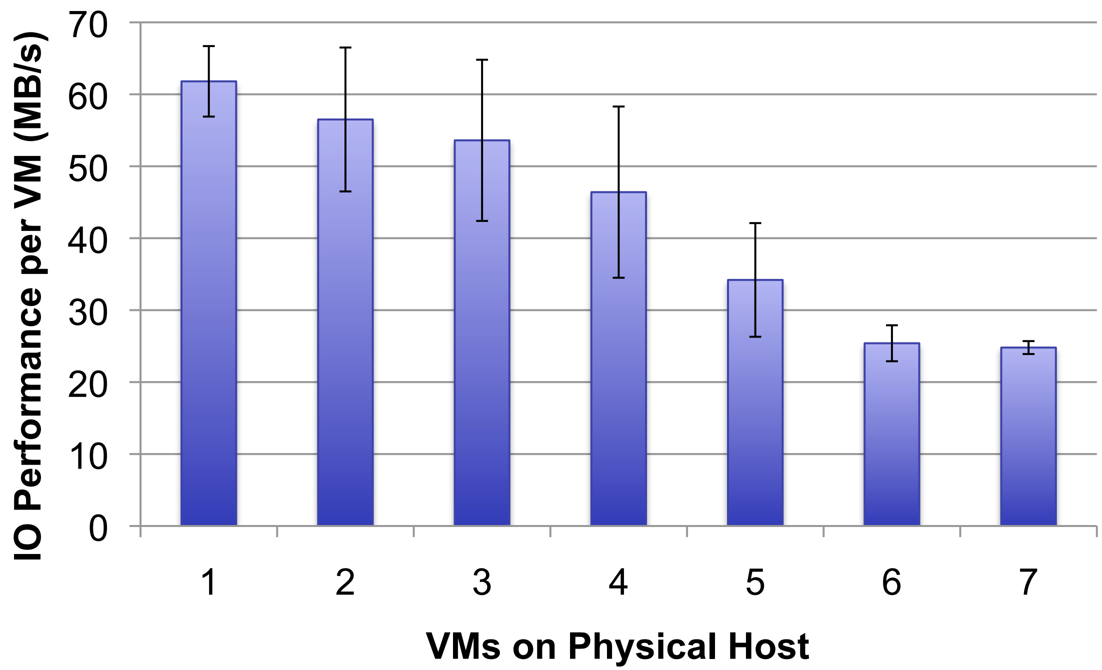
1. Nodes fail → re-run tasks
2. Nodes slow (stragglers) → run backup tasks



How to do this in heterogeneous environment?

Heterogeneity in Virtualized Environments

- VM technology isolates CPU and memory, but disk and network are shared
  - Full bandwidth when no contention
  - Equal shares when there is contention
- **2.5x** performance difference



Backup Tasks in Hadoop's Default Scheduler

- Start primary tasks, then look for backups to launch as nodes become free
- Tasks report "progress score" from 0 to 1
- Launch backup if

$$\text{progress} < \text{avgProgress} - 0.2$$

Problems in Heterogeneous Environment

1. *Too many* backups, thrashing shared resources like network bandwidth
2. *Wrong* tasks backed up
3. Backups may be placed on *slow nodes*
4. Breaks when tasks start at different times

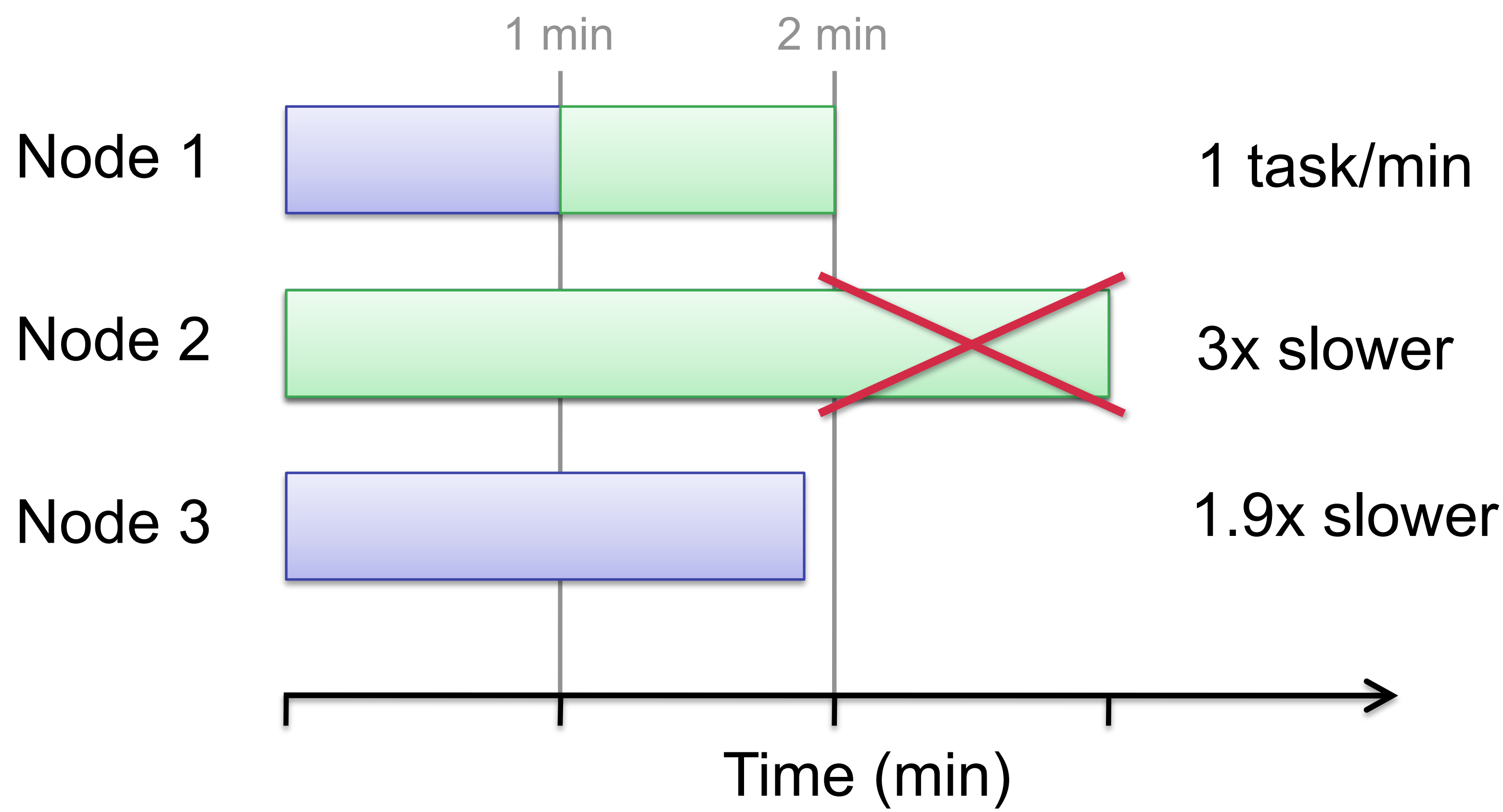
- Example: ~80% of reduces backed up, most losing to originals; network thrashed

Idea: Progress Rates

- Instead of using progress values, compute progress *rates*, and back up tasks that are “far enough” below the mean

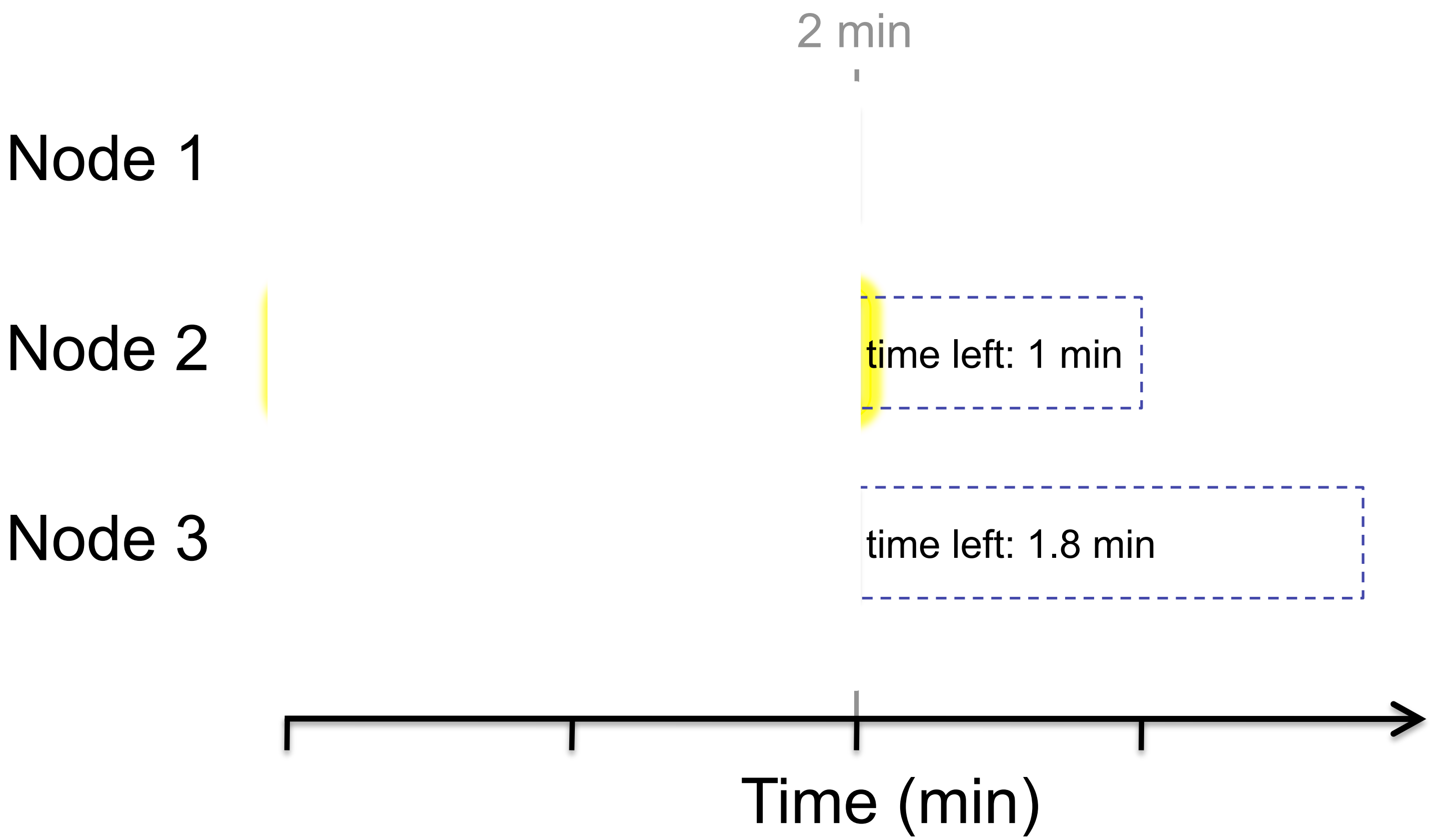
- **Problem:** can still select the wrong tasks

Progress Rate Example



Progress Rate Example

What if the job had 5 tasks?



Node 2 is slowest, but should back up Node 3's task!

Our Scheduler: LATE

- Insight: back up the task with the largest *estimated finish time*
  - "Longest Approximate Time to End"
  - Look forward instead of looking backward
- Sanity thresholds:
  - *Cap* number of backup tasks
  - Launch backups on *fast nodes*
  - Only back up tasks that are *sufficiently slow*

LATE Details

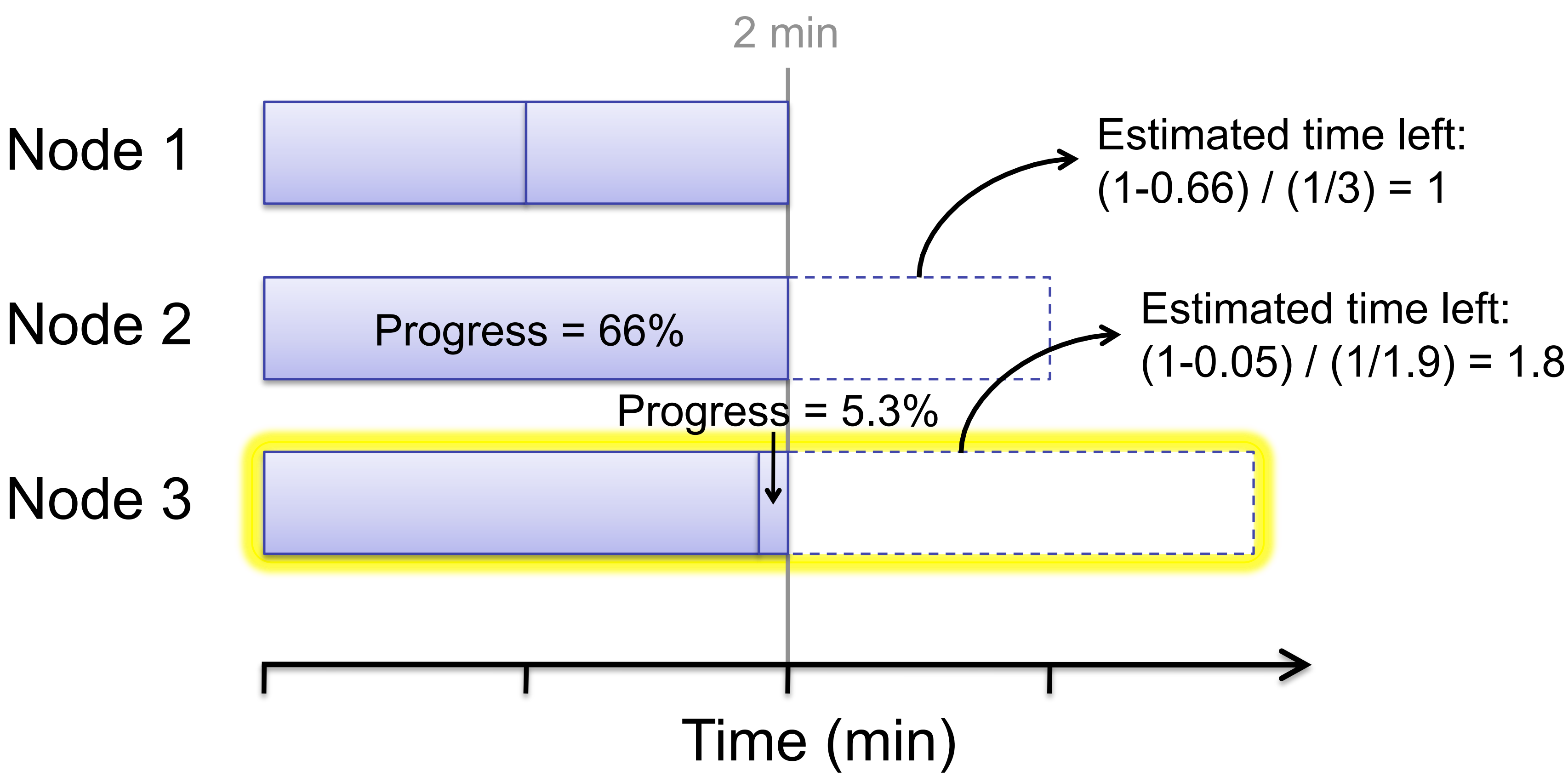
- Estimating finish times:

$$\textit{progress rate} = \frac{\text{progress score}}{\text{execution time}}$$

$$\textit{estimated time left} = \frac{1 - \text{progress score}}{\text{progress rate}}$$

- Threshold values:
  - 10% cap on backups, 25th percentiles for slow node/task
  - Validated by sensitivity analysis

LATE Example

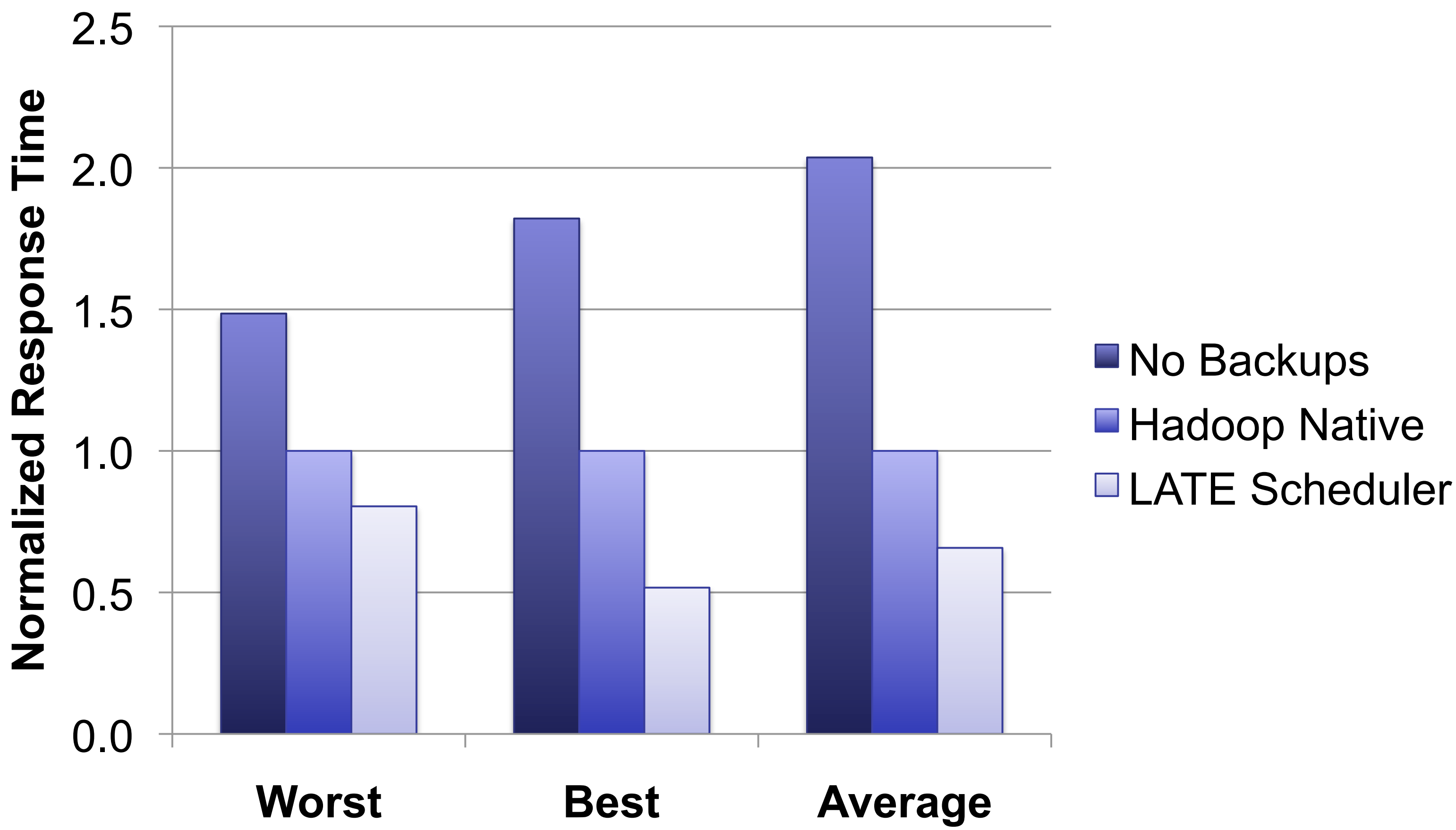


LATE correctly picks Node 3

Evaluation

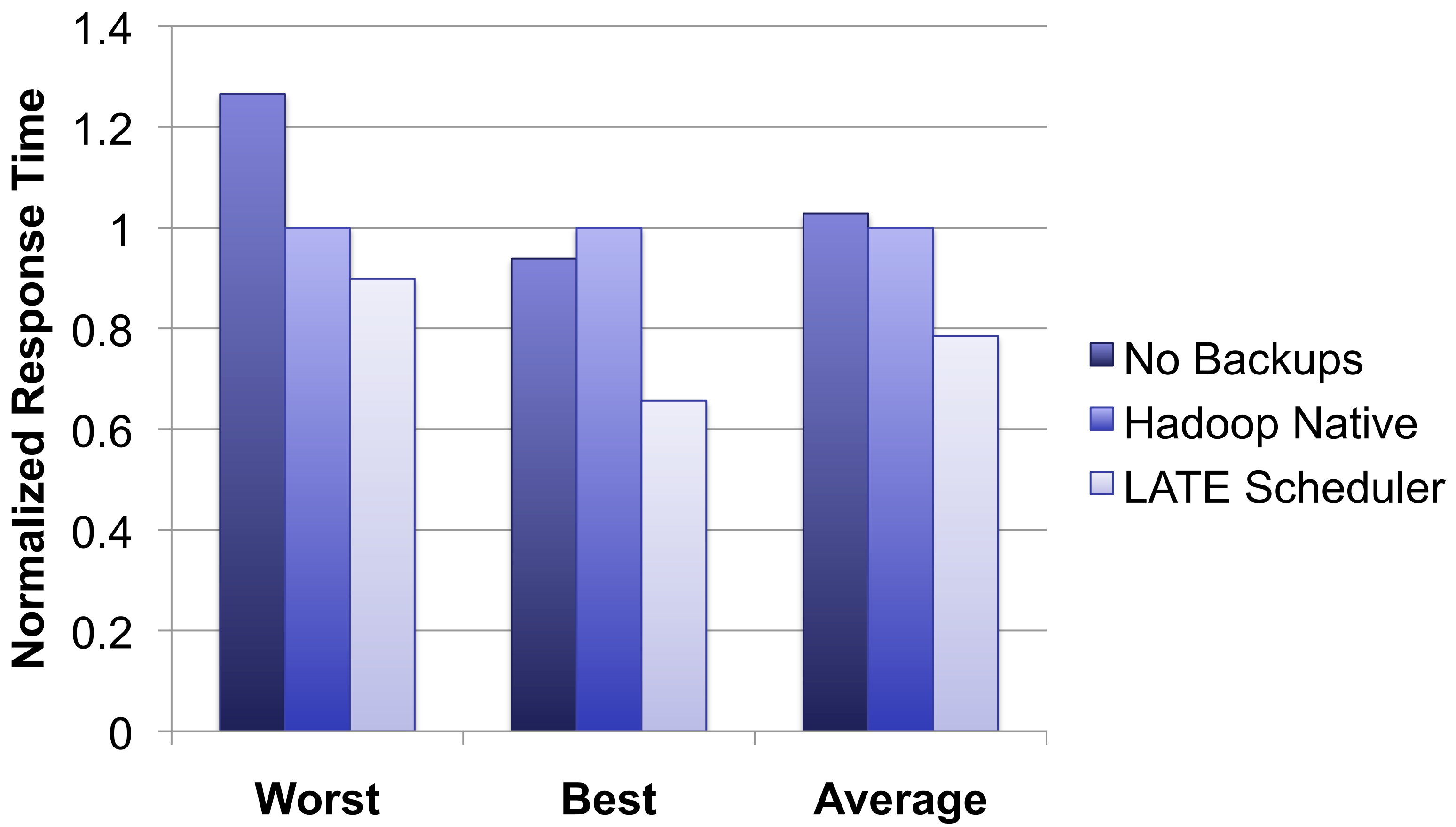
- Environments:
  - EC2 (3 job types, 200-250 nodes)
  - Small local testbed
- Self-contention through VM placement
- Stragglers through background processes

EC2 Sort with Stragglers



- Average **58%** speedup over native, **220%** over no backups
- **93%** max speedup over native

EC2 Sort without Stragglers



- Average **27%** speedup over native, **31%** over no backups

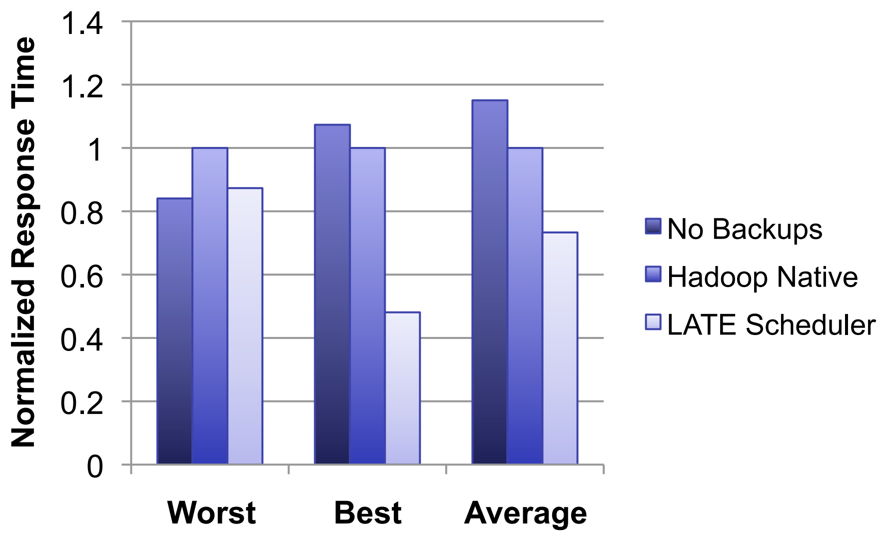
Conclusion

- Heterogeneity is a challenge for parallel apps, and is growing more important
- Lessons:
  - Back up tasks which hurt response time most
  - Mind shared resources
- 2x improvement using simple algorithm

Questions?

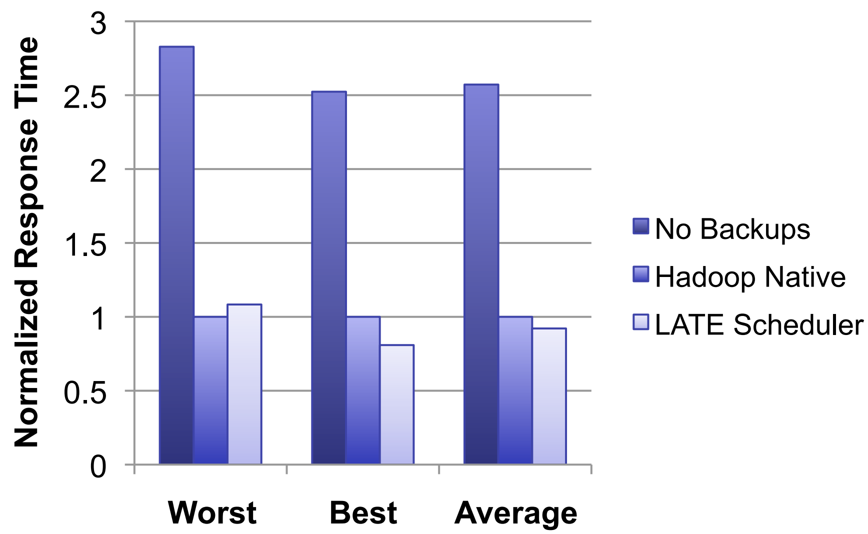
EC2 Grep and Wordcount

Grep



- 36% gain over native
- 57% gain over no backups

WordCount



- 8.5% gain over native
- 179% gain over no backups