Scheduling Many-Task Workloads on Supercomputers

Dealing with Trailing Tasks

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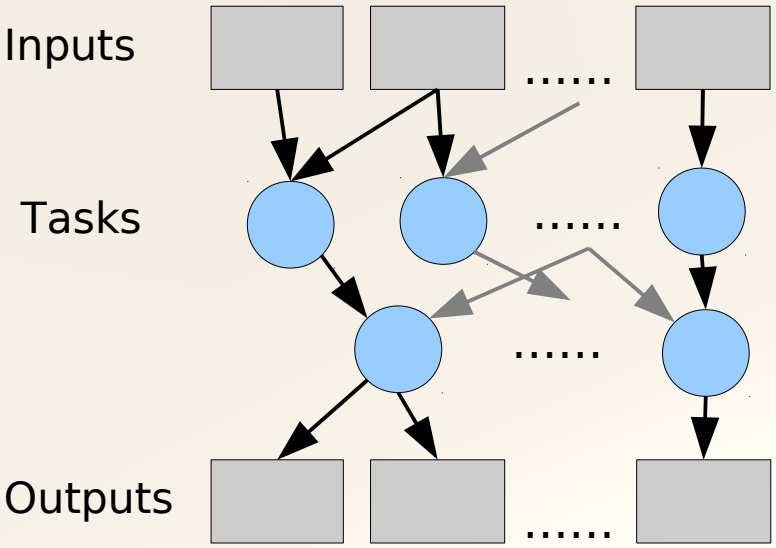
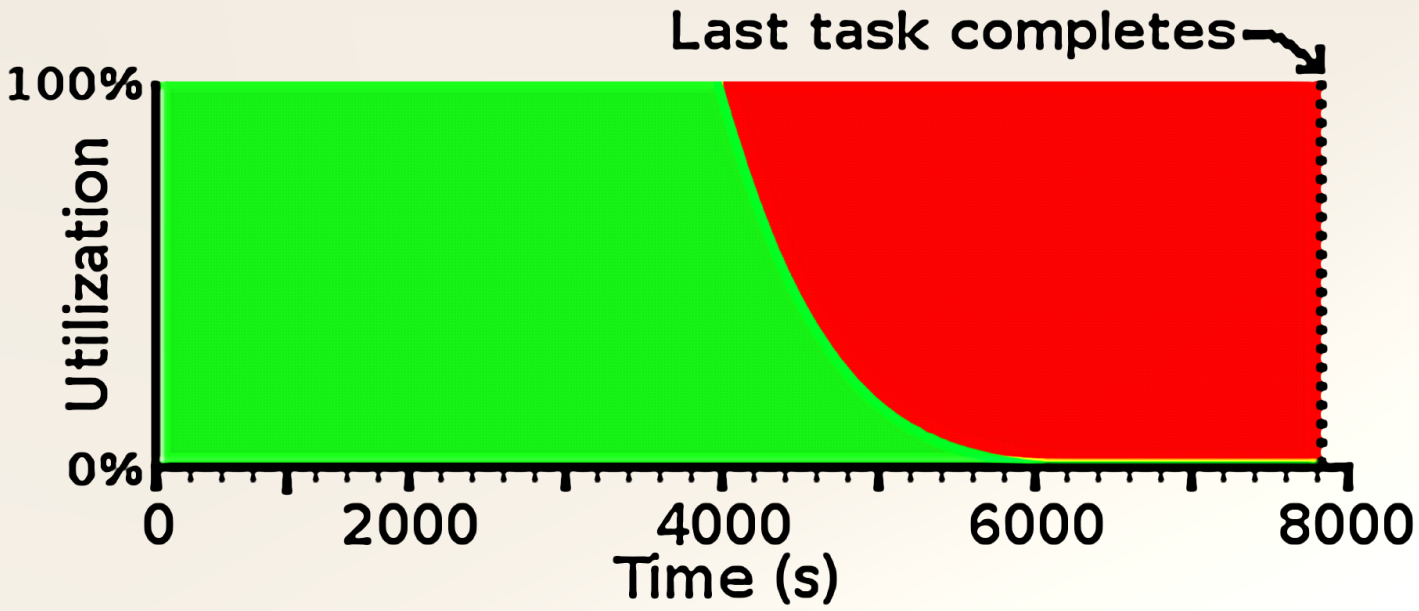
Many-tasks on a Supercomputer

- Multi-level scheduling
- Metrics: ***time to solution*** and ***utilization***



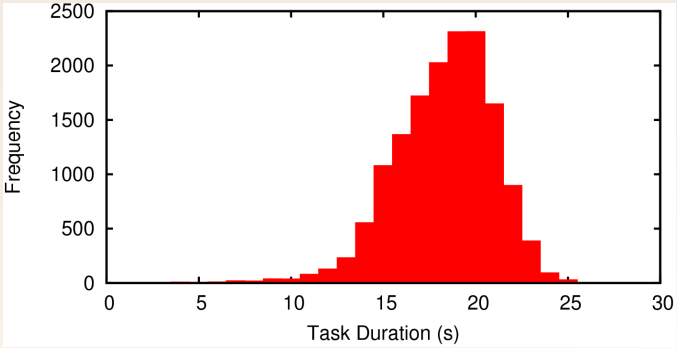
“Trailing Task” Problem



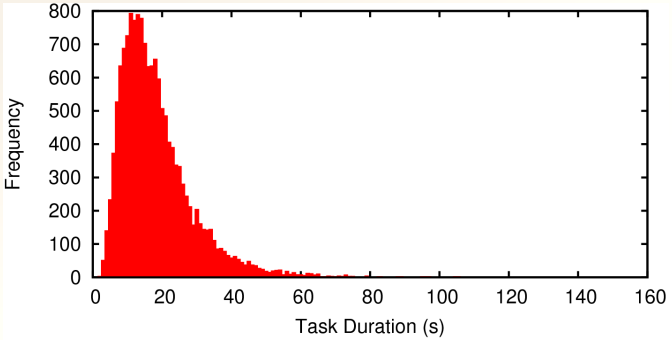
Utilization using 160,000 cores with molecular docking workload of 935,000 independent tasks. Last task completes at 7828 seconds

Runtime Distributions

- Task runtimes can follow various distributions
- Often highly skewed: maybe power law or heavy-tailed distribution
- Many-task computing systems should gracefully handle long-running tasks



Nearly symmetrical distribution of runtimes (another DOCK workload)



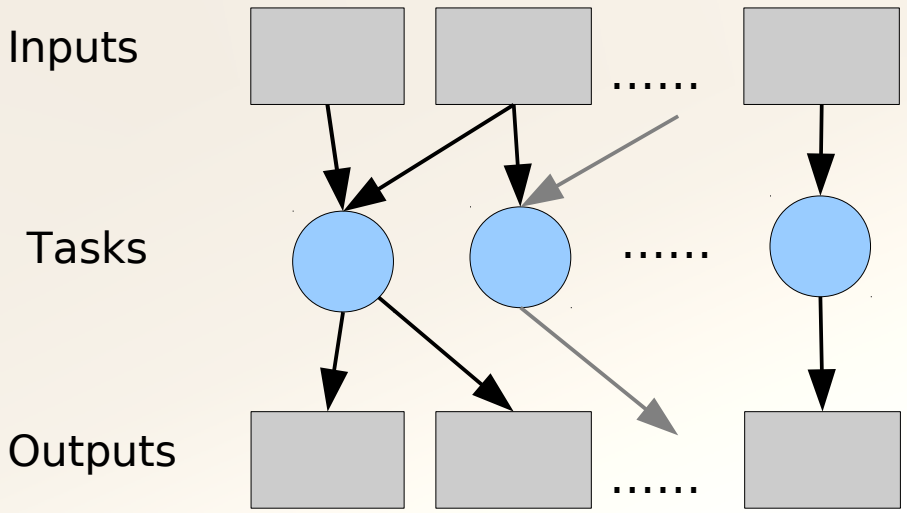
Runtimes with same mean as above but log-normal distribution

Obstacles to Shedding Workers

- Can't always just return unneeded worker CPUs to a pool
- Reasons:
  - Scheduler support
  - Policy restrictions
  - Scheduler not designed for tracking many small allocations
  - Schedule fragmentation
  - Network topology; spatial fragmentation of machine
- Resource provisioning granularity: thousands
- Task scheduling granularity: one

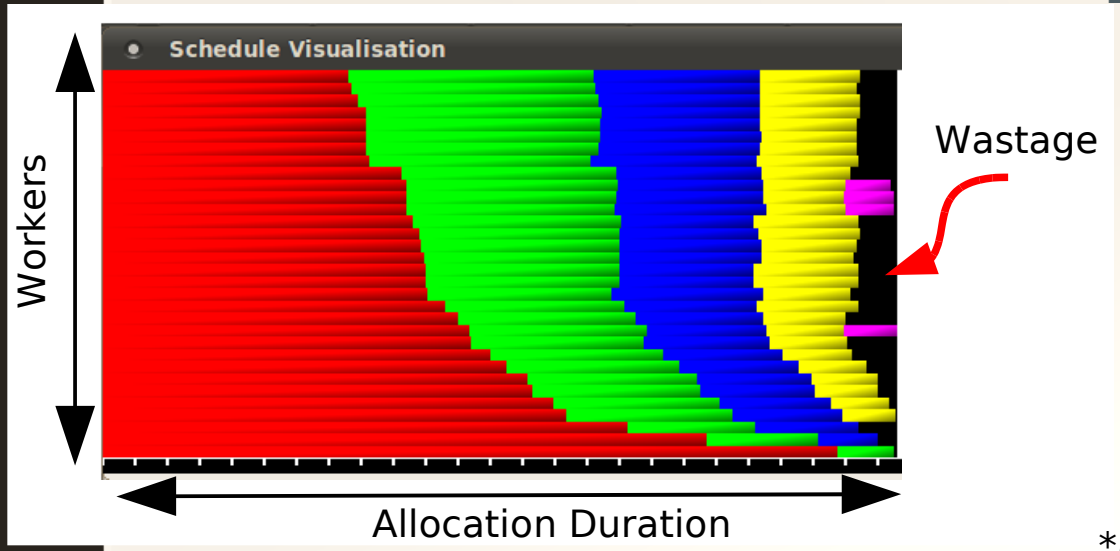
“Bag of Tasks” Workloads

- We only consider workloads with no dependencies: number of “ready” tasks decreases monotonically
  - Most many-task application like this when winding down
  - Similar to a stage of an many-task application with parallel barrier after stage. E.g. *MapReduce* pattern



Fixed Worker Count

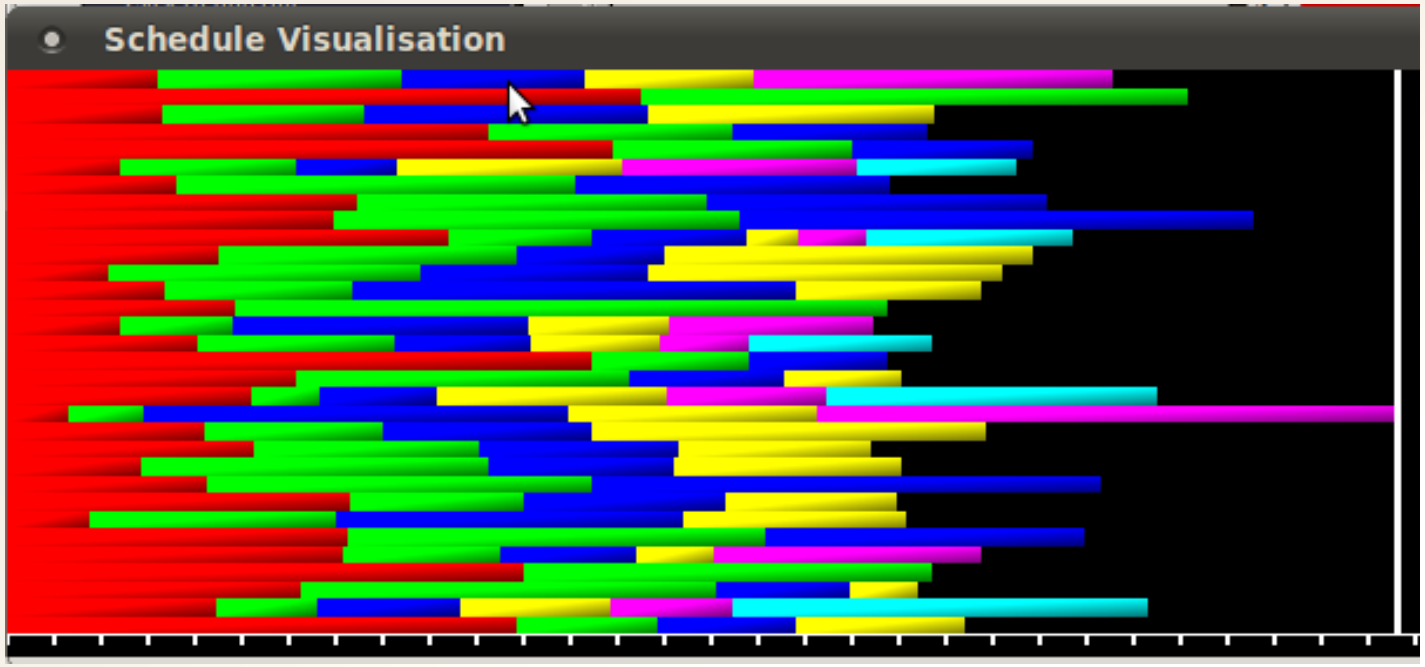
- Minimizing time to sol. leads to maximizing utilization
- NP-Complete optimization problem with heuristics*:
  - Arbitrarily assigning tasks to idle workers *(random)*: 2x opt.
  - Assigning longest running tasks first *(sorted)*: 4/3x opt.
  - Average case behavior for both is better



*Many more in scheduling literature

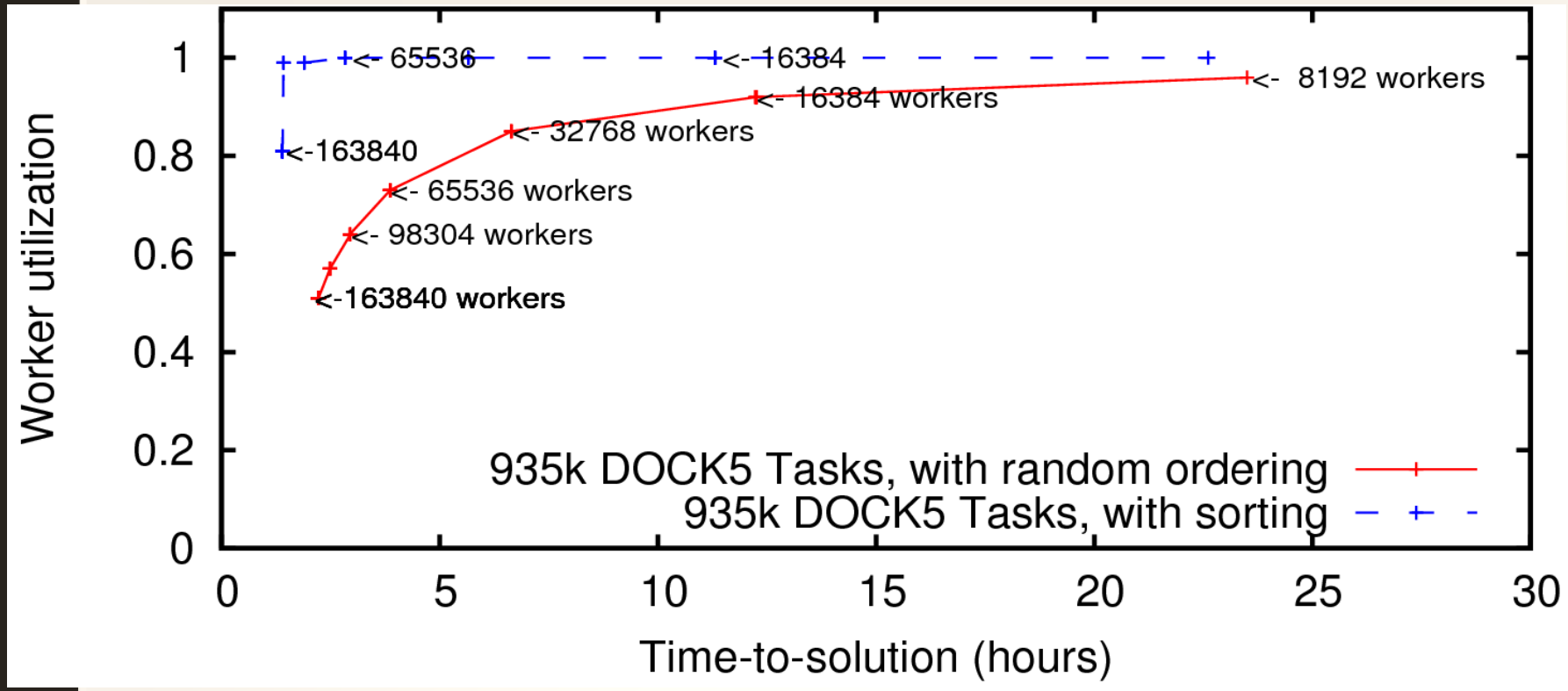
Living with Unknown Runtimes

- In an ideal world we would know the runtime of each task. In practice it is unrealistic assumption
- Random scheduling is what we must live with typically



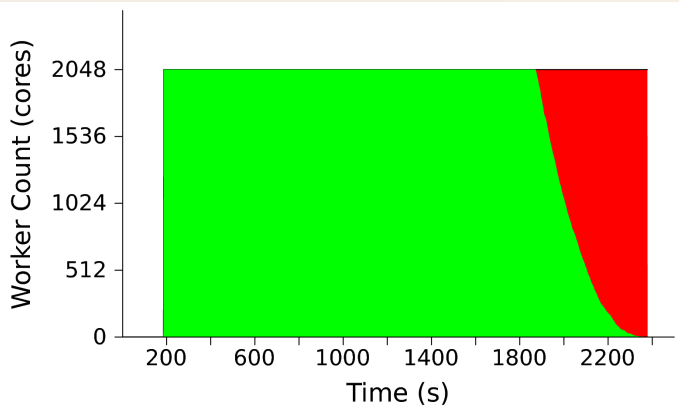
Trade-off with Fixed Worker Count

- With *random,* unavoidable trade-off between utilization and time to solution

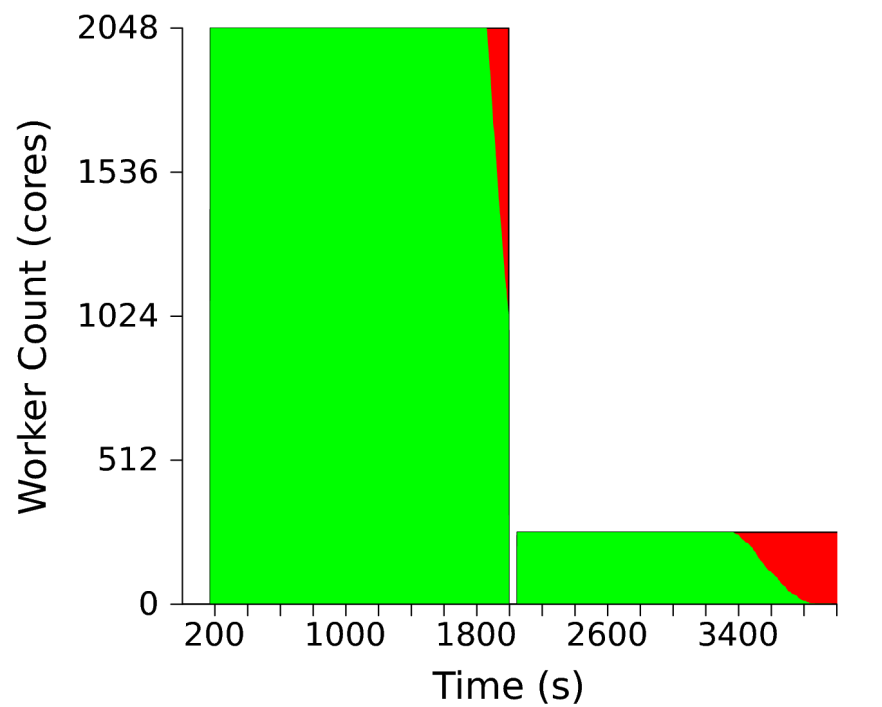


Chopping off the Tail of Tasks

- When utilization gets too low, switch to a smaller allocation
- No special scheduler/system support required



No tail-chopping



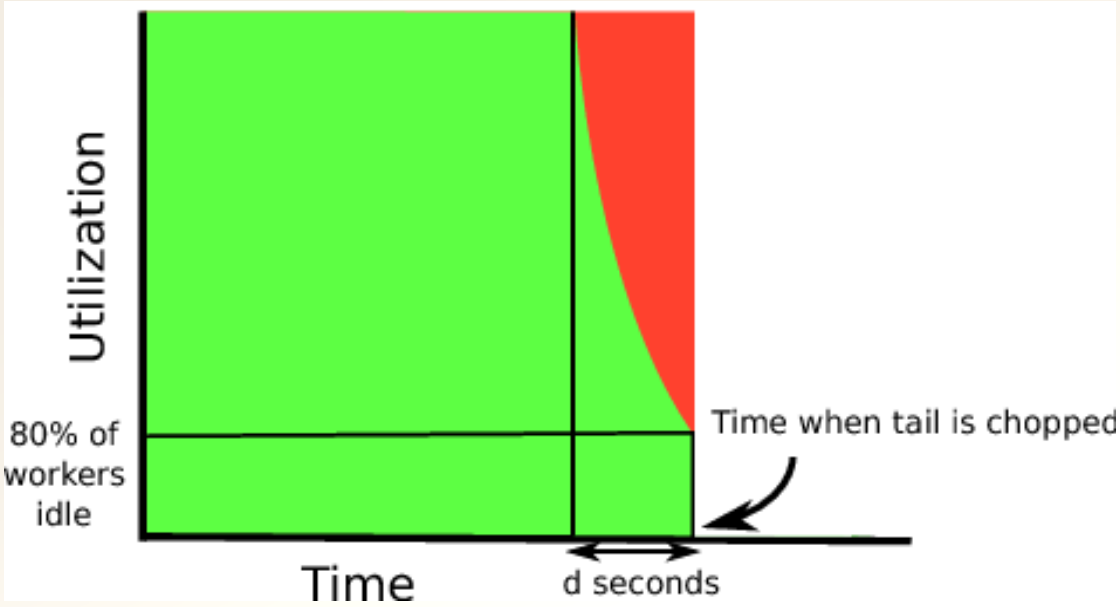
Chopping off the tail

Tail Chopping: Worthwhile?

- Tail-chopping promises to provide:
  - A better trade-off between TTS and Utilization
  - High utilization more robust to changes in worker count
- But has costs:
  - Overhead of migrating to new partition
  - Loss of task progress (unless tasks can be checkpointed)
  - Slower progress on smaller partition
  - Delays in requesting allocation
- Assumptions for study:
  - Tail-chopping means progress of incomplete tasks lost
  - Fixed delay in acquiring new partition

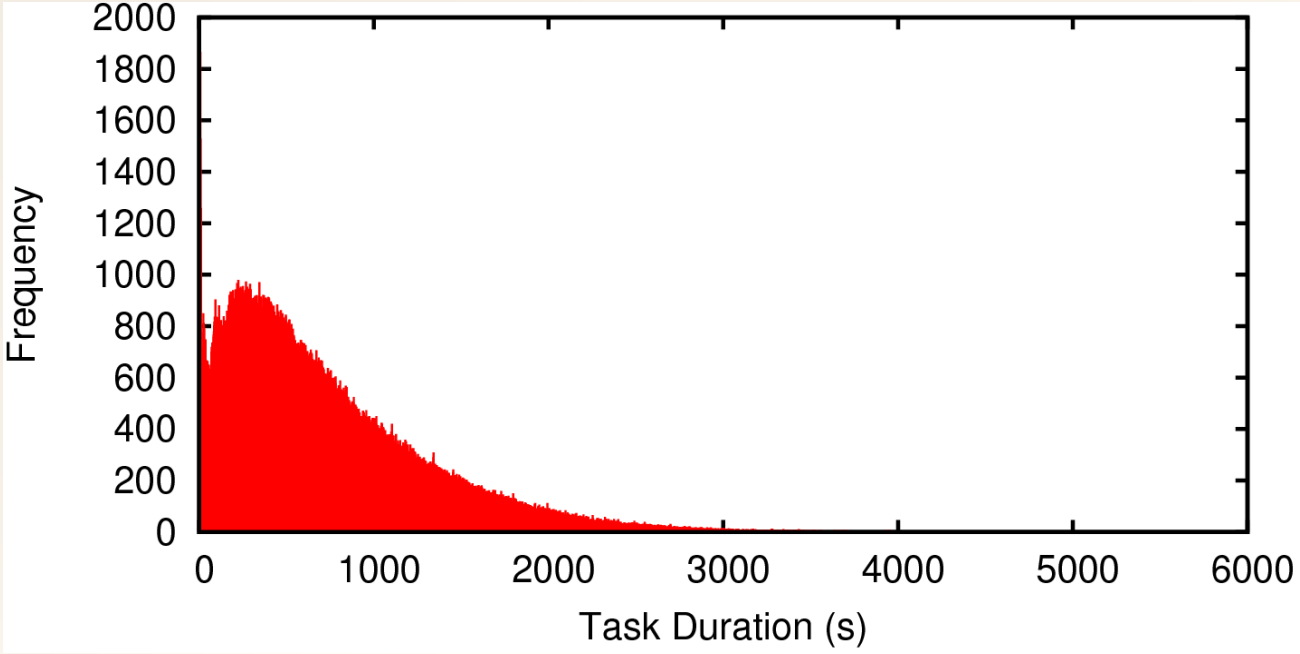
Simulation Design

- Task/worker ratio decides how many workers to request
- Threshold % of idle workers triggers tail-chopping
- Sweep over parameter values to find trade-off curves for different idle thresholds

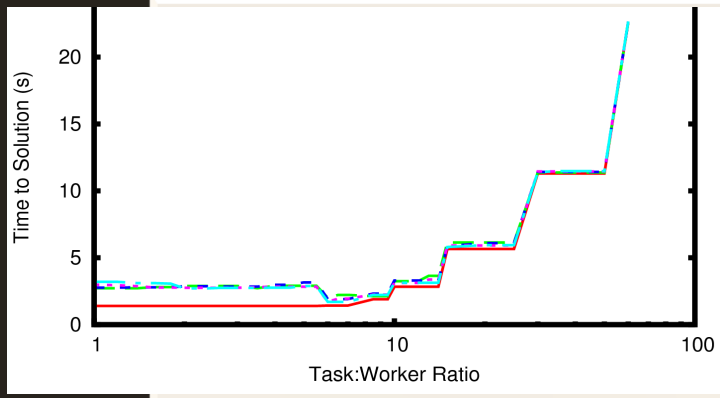


Simulation Data

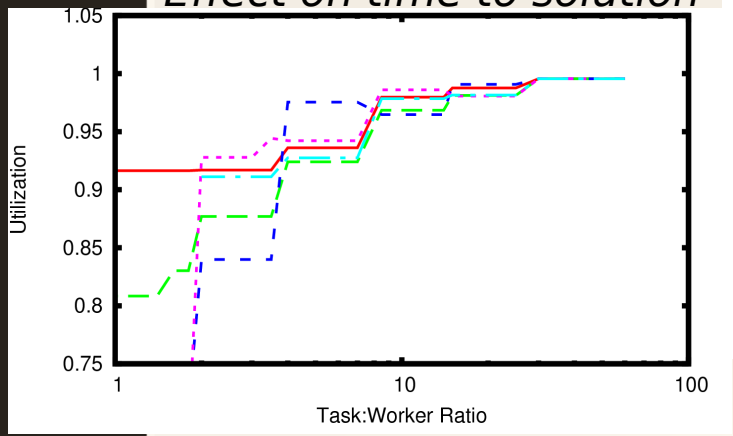
- Runtimes of 935,000 molecular docking tasks
- Skewed distribution of runtimes
- Available allocation sizes those on Blue Gene/P *Intrepid*



Simulation Results (1) - *Sorted*

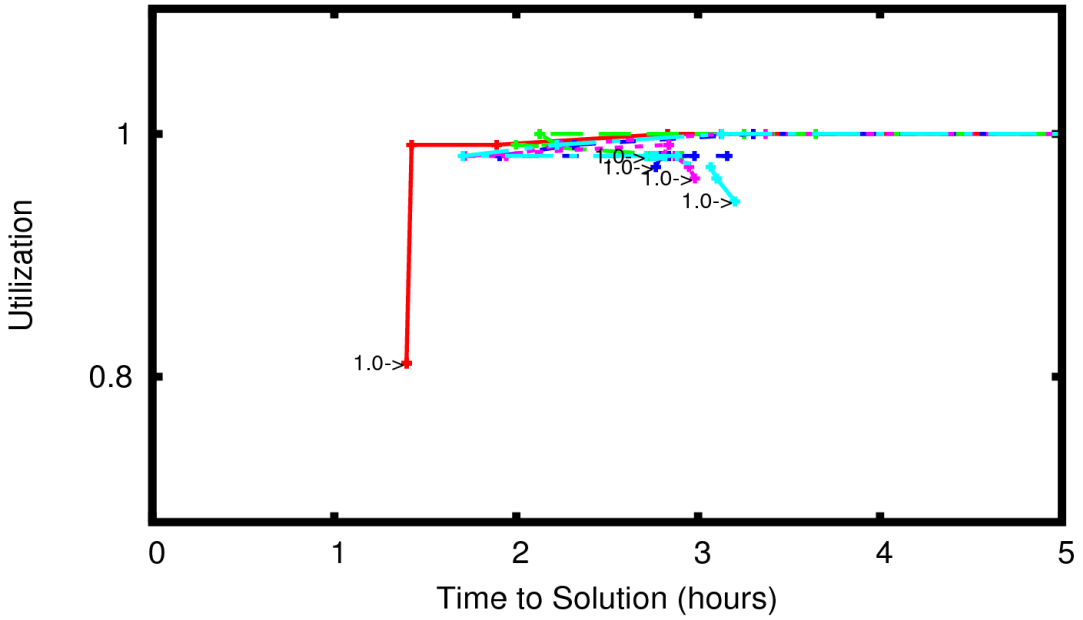


Effect on time to solution



Effect on utilization

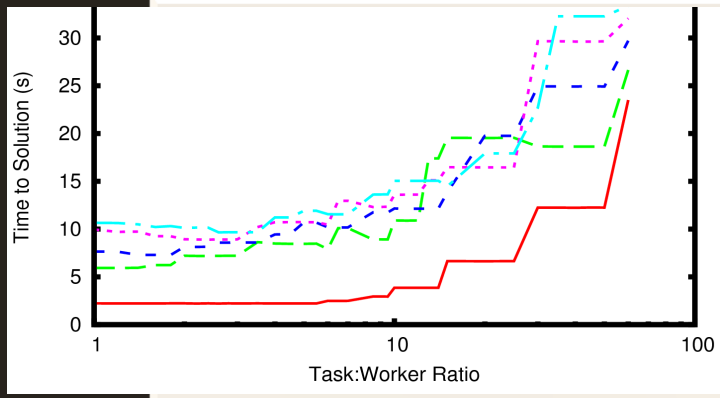
- *Sorted* scheduling



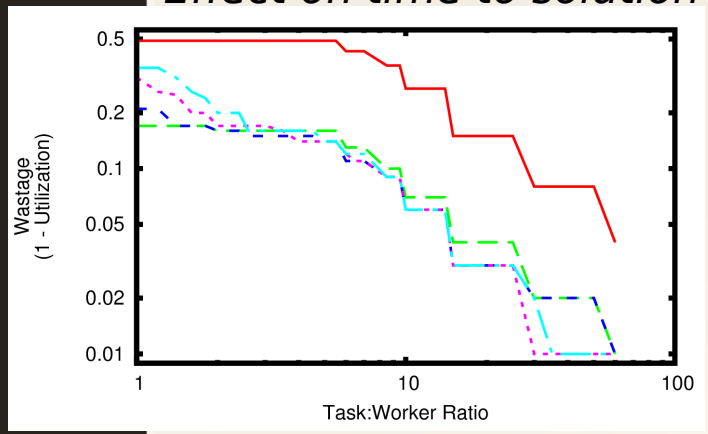
Effect on trade-off

No tail chopping
Max Fraction Idle 0.8
Max Fraction Idle 0.5
Max Fraction Idle 0.2
Max Fraction Idle 0.0

Simulation Results (2) - *Random*

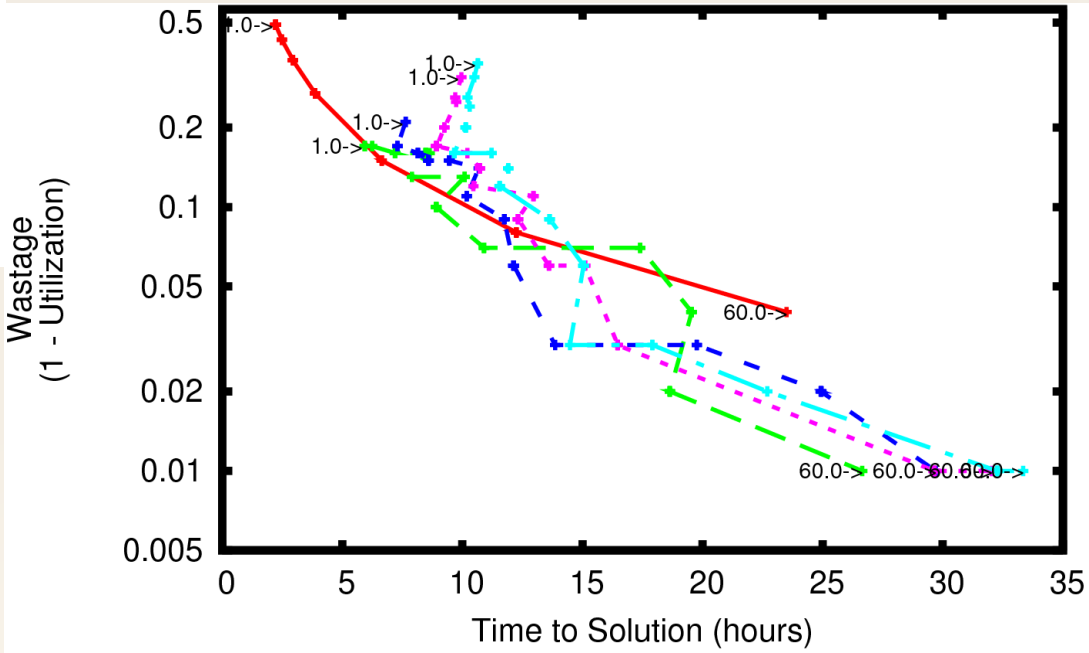


Effect on time to solution



Effect on wastage

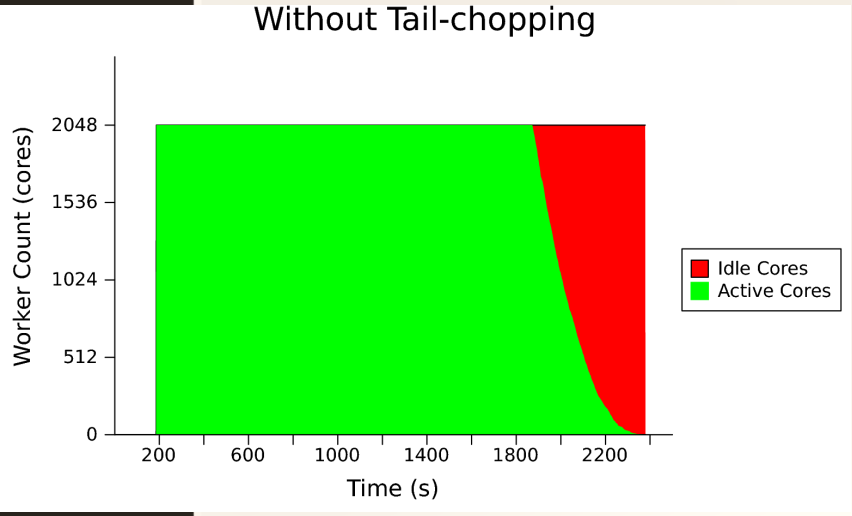
- *Random* scheduling

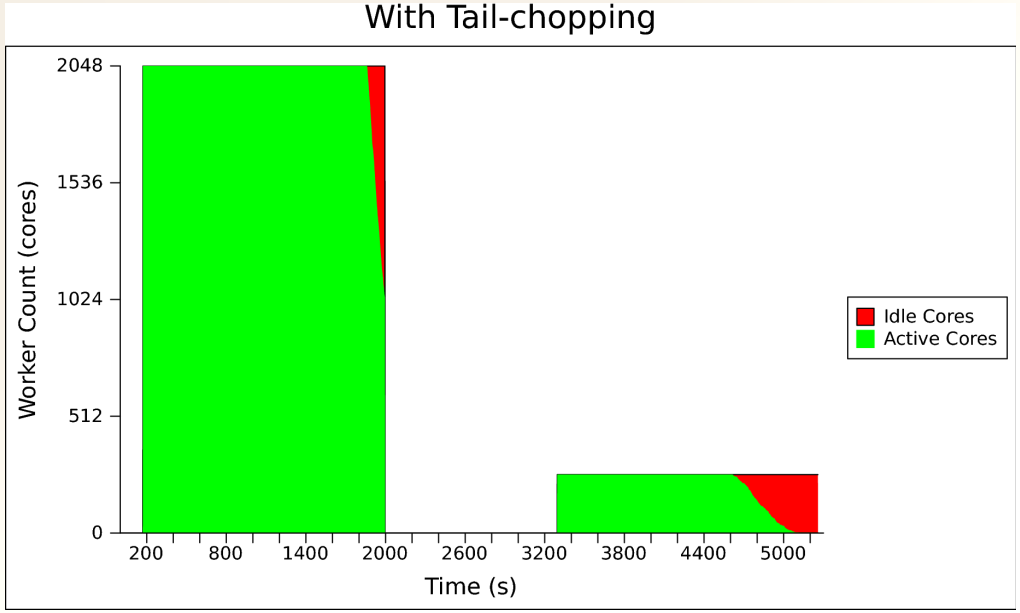


Effect on trade-off

Experiment on Blue Gene/P

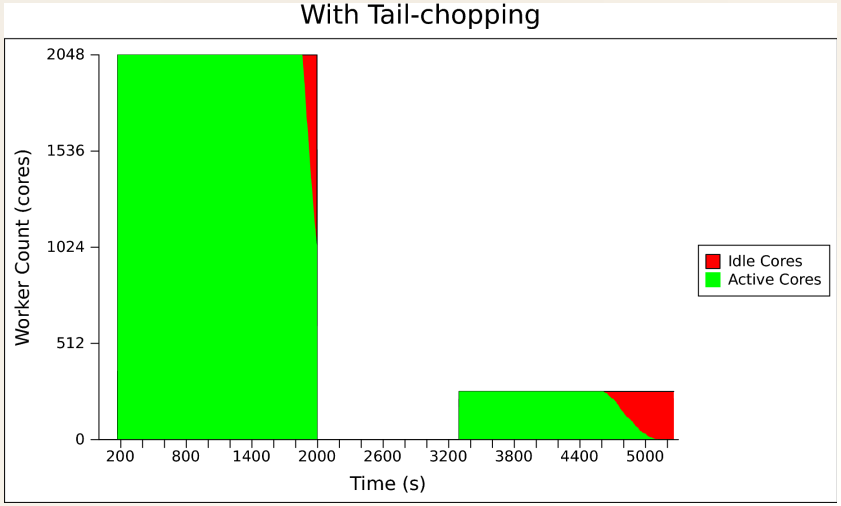
- Proof of concept on Blue Gene/P Intrepid at Argonne National Laboratory using Falkon task dispatcher
- Provisions machine partitions using task/worker ratio.
- Chops off tail when idle workers above 50% threshold





Possible Improvements

- “Warm up” partition before canceling old one
- Scheduler support for shedding workers
- Task migration
- Better heuristic for when to chop tail: use available information about task runtimes



Conclusions

- Need to consider scheduling when running many-task application on a supercomputer, especially if runtimes of tasks are highly variable
- Favorable utilization/time to solution trade-off not always possible with fixed worker count
- Tail-chopping can give better results for time to solution and utilization
- Tail-chopping delivers robustly high utilization

Questions?

The “Straggler” Problem

- Described in MapReduce literature; related but different
- “Straggler”: a task that is running slowly due to poor hardware/software performance
- Standard solution: replicate the task on other machines
  - Only works if the long-running tasks don't intrinsically involve more computation