Stratus

Cost-aware container scheduling in the public cloud

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Motivation

- IaaS CSPs provide per-time VM rental of diverse offerings
  - VM types and sizes
  - Contract types (e.g., reliable/on-demand, dynamically-priced/spot,…)
- Can add/remove VMs from virtual cluster (VC) any time
  - VMs paid-for by-the-second while rented
  - Pay for full VM even if only partially used!
- Mgmt complex, **but** sched research has not focused on **both**
  1. Dynamically-sized clusters
  2. Clusters with wide diversity of instance types, sizes, and contracts

Motivation

- IaaS CSPs provide per-time VM rental of diverse offerings
  - VM types and sizes
  - Contract types (e.g., reliable/on-demand, dynamically-priced/spot,…)

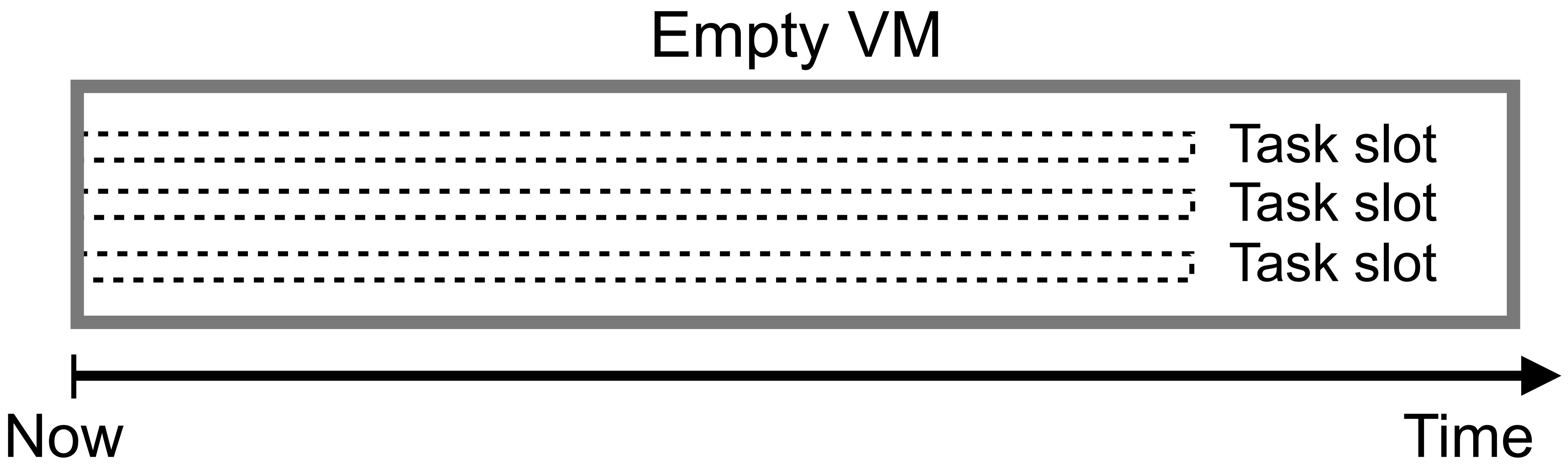
How can we take advantage of diverse offerings and virtual cluster elasticity to lower cost of executing batch workloads?

- Mgmt complex, **but** sched research has not focused on **both**

1. Dynamically-sized clusters
2. Clusters with wide diversity of instance types, sizes, and contracts

Public cloud sched properties

- **Property 1:** Wasted resource-time is wasted money
  - **Money-saving key: Minimize resource-time "bubbles"**
    1. **Resource-cost-awareness**: Pick right-sized, cost-eff VMs
    2. **Efficiently using rental time**: Keep VMs highly utilized when rented, release VMs if no pending tasks



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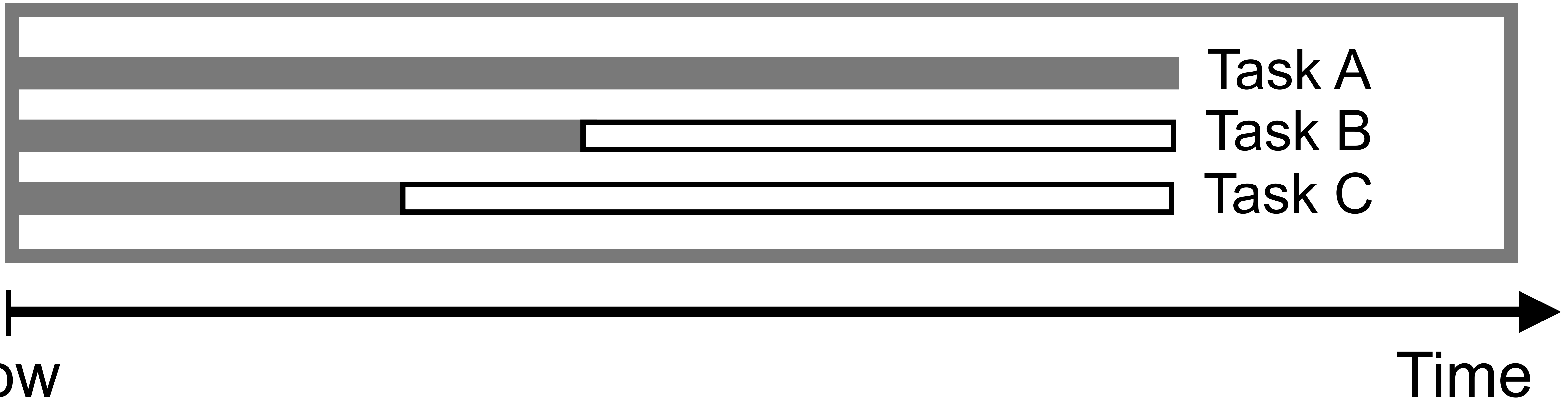

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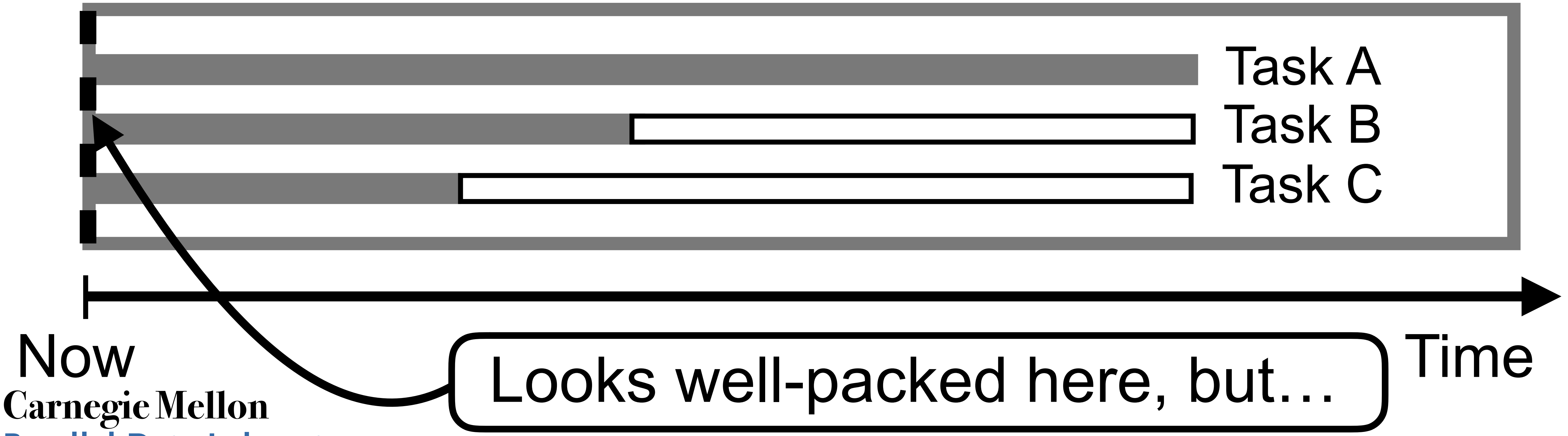

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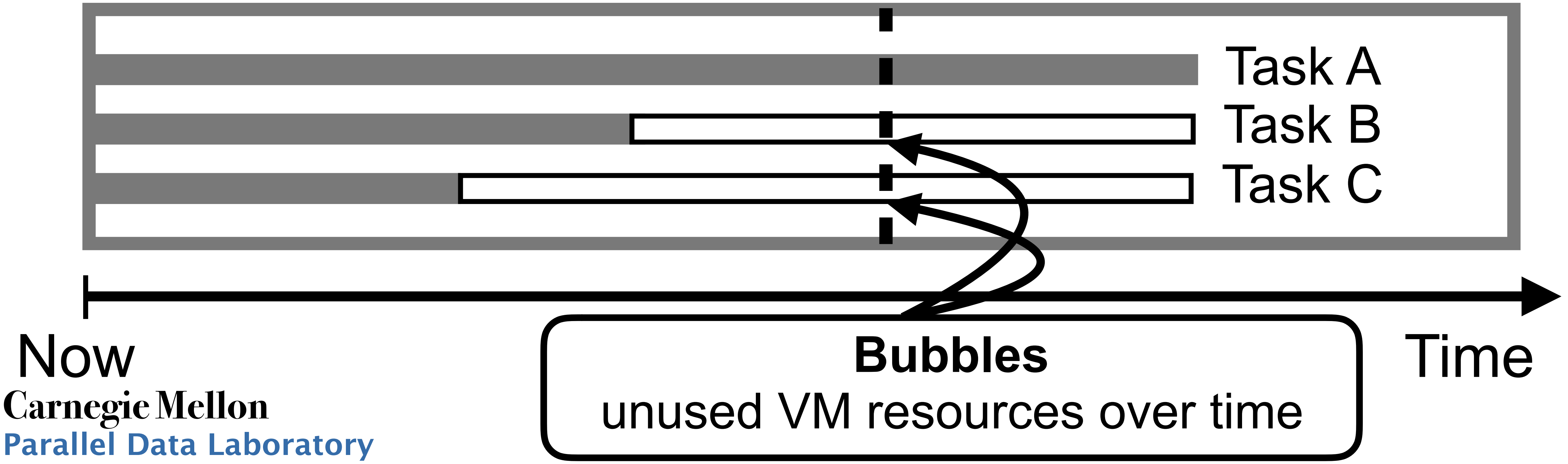

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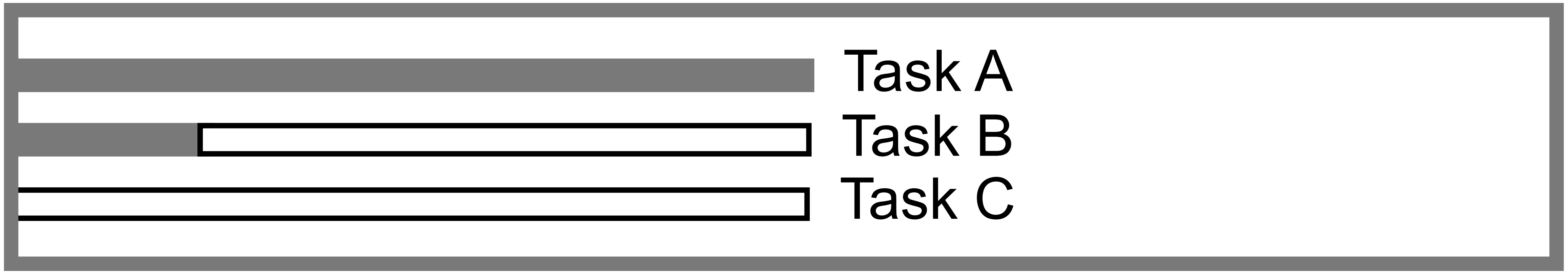

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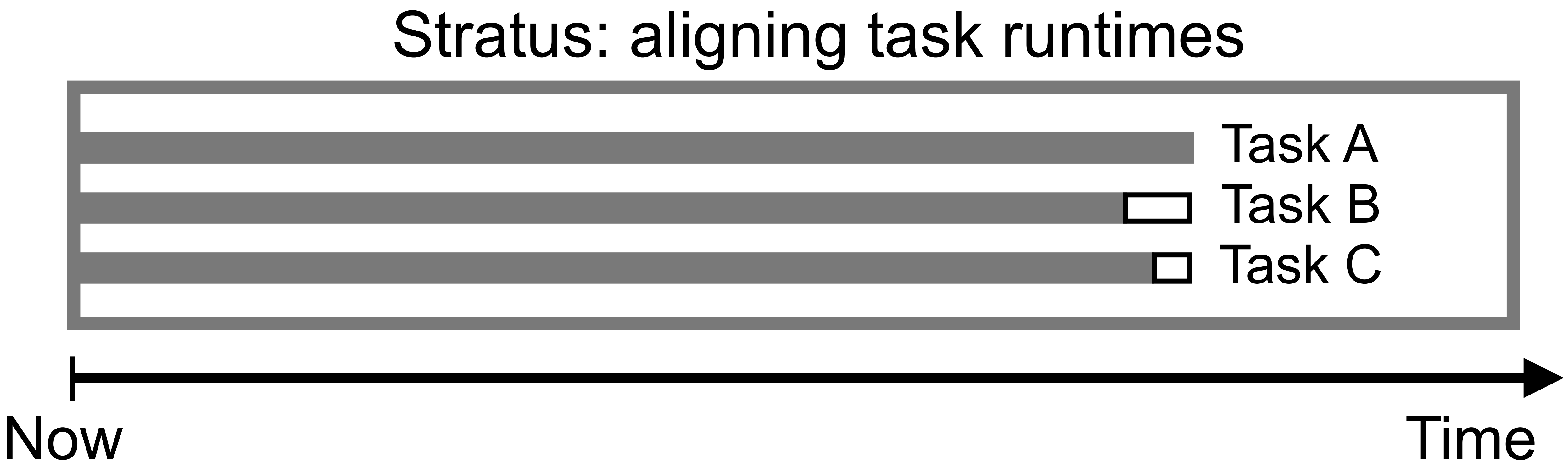
- **Property 2:** Possible to have no task queue time
  - Replaced by VM spin-up time
  - Allows bounded workload latency

Overview and goals

- **Stratus:** VC sched middleware for public clouds
  - Suited for collections of batch jobs
  - How to size VC and where to place tasks
- **Goals**: Lower the cost of executing batch workloads with minimum makespan impact
  - Cost-efficiency by reducing “resource bubbles”
  - Makespan-minimization by sched tasks as they arrive

Efficiently using rental time

- Ideally, all tasks assigned to VM finish at same time
  - 0% utilized (new) → 100% utilized → 0% utilized → released
- Stratus packs tasks on VMs to align task runtimes
  - Does so with a new technique: *runtime binning*



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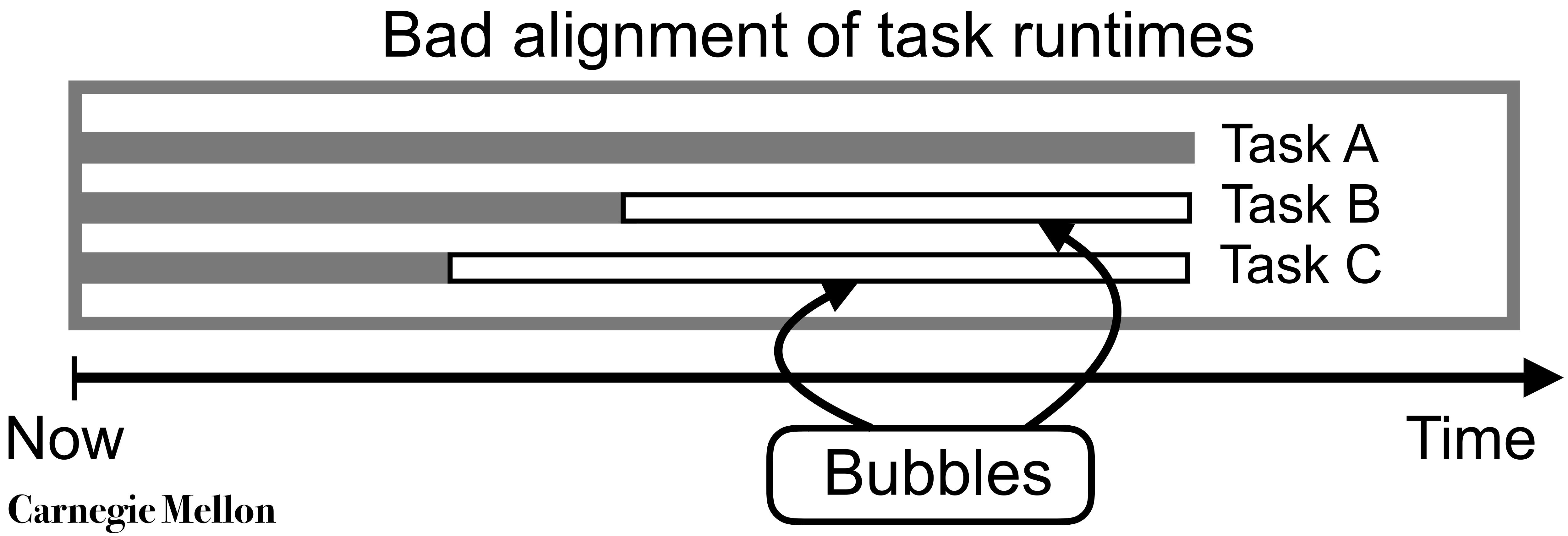
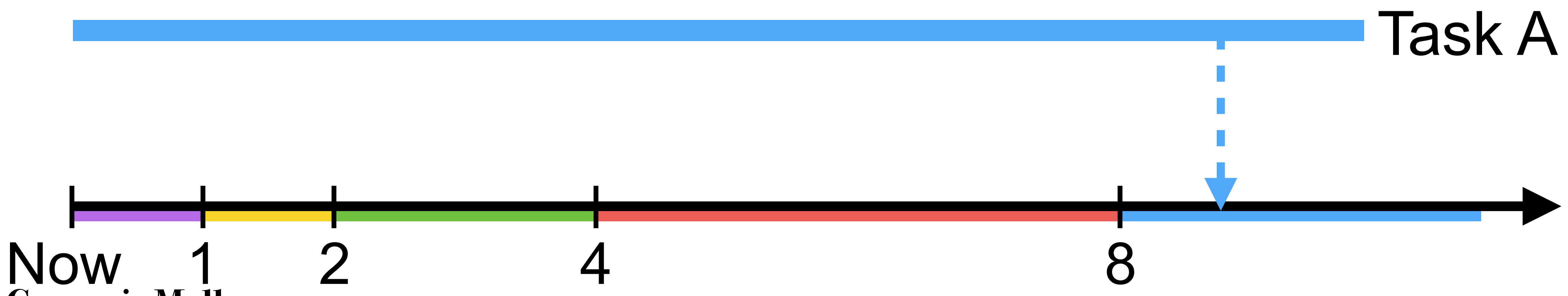


Runtime (RT) binning

- RT bins: logical bins of disjoint time intervals sized exp
  - [now = 0, 1), [1, 2), [2, 4), [4, 8), [8, 16),…, and so on
- Task assigned to bin according to remaining runtime *from now*
  - Ex: Task A, which runs for 11 more time units, in blue bin ([8, 16))



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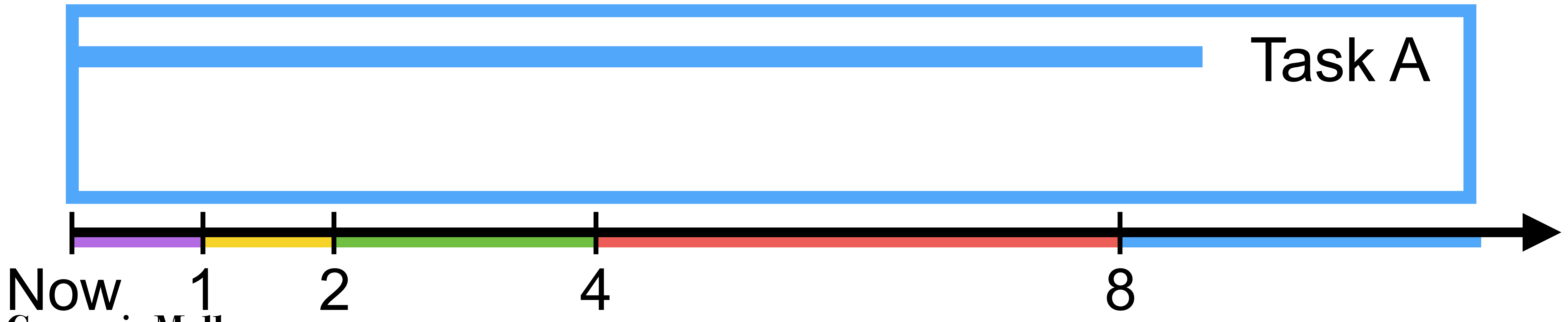

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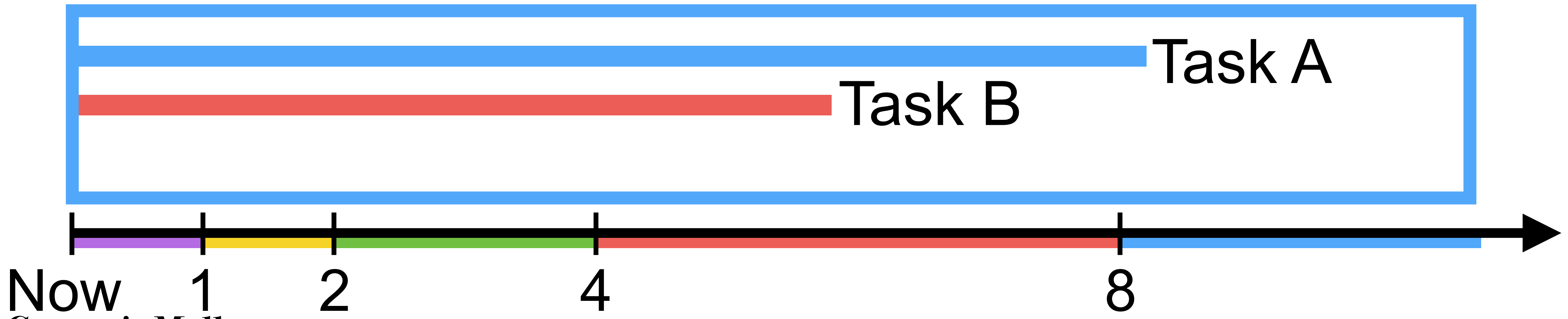

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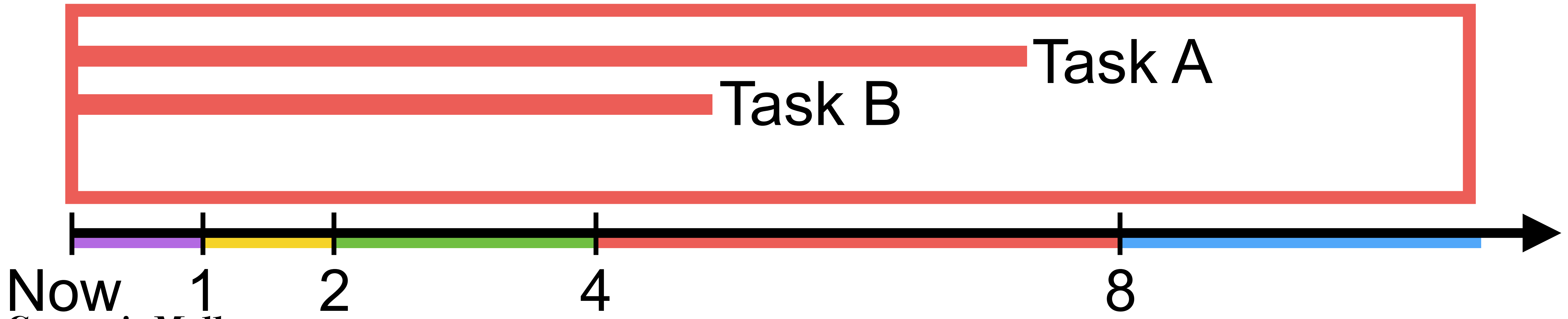

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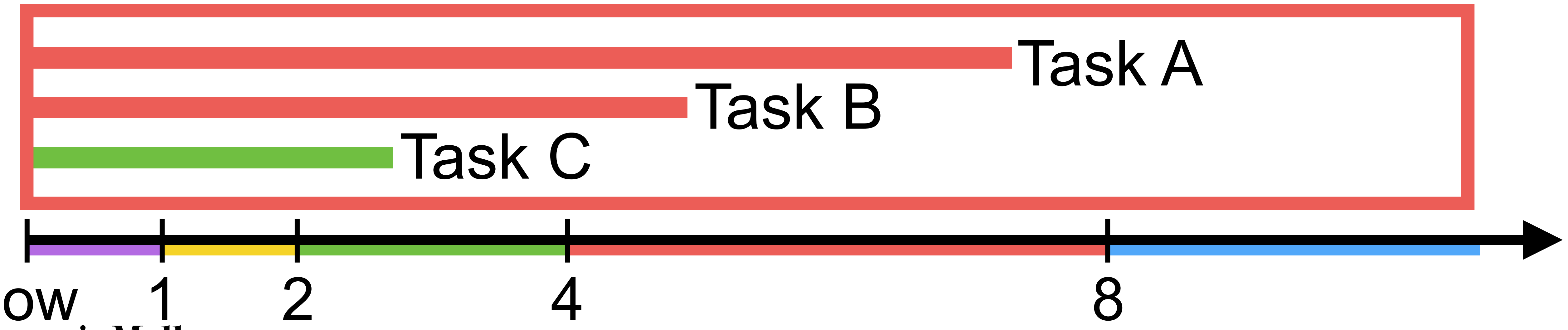

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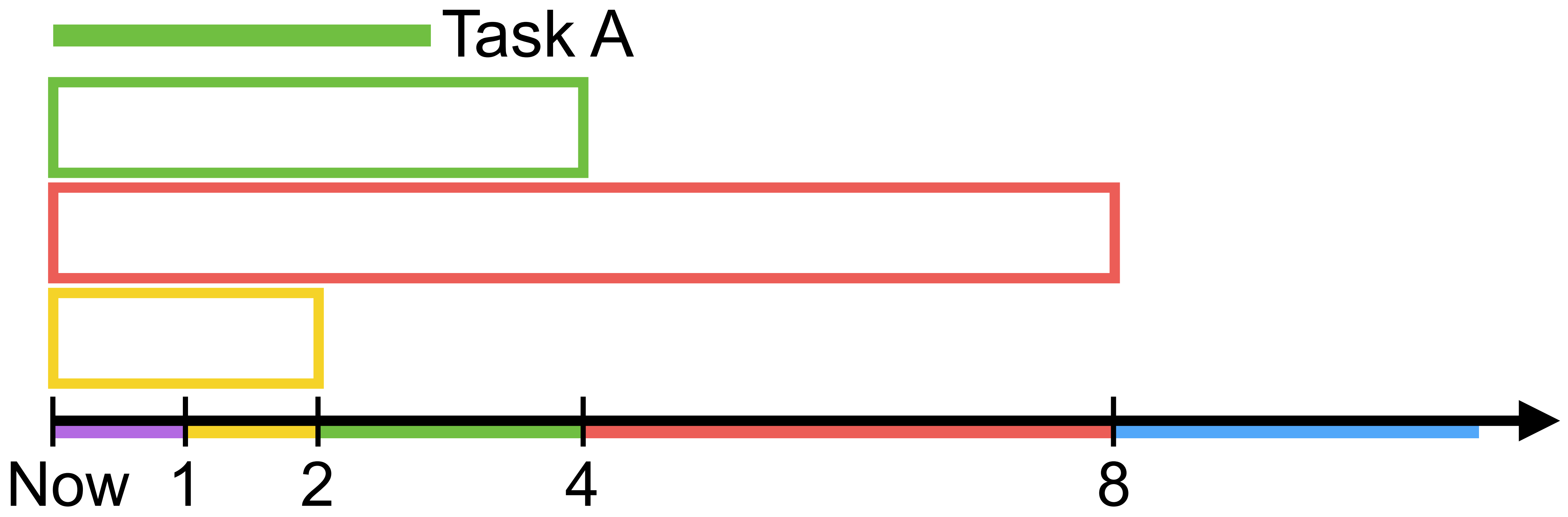
Packing tasks to VMs

- Packing preference for task in runtime bin β
  - VM in β > VM in greater RT bins > VM in lesser RT bins
  - Least impact to extend VM time-to-release



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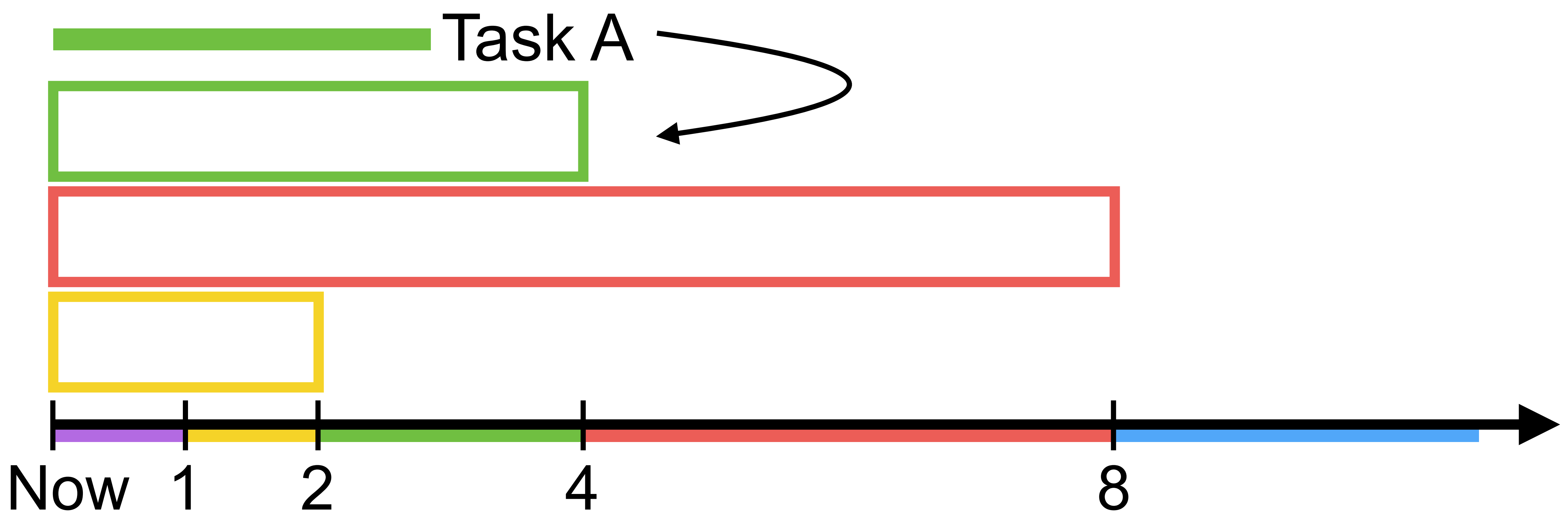

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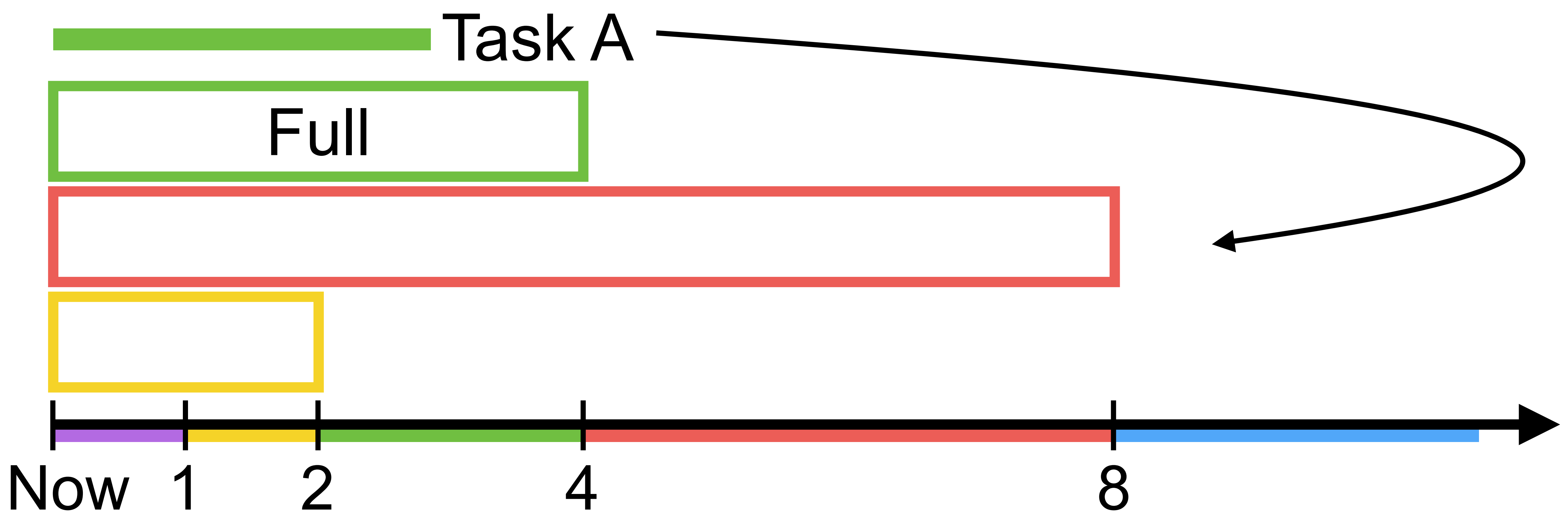

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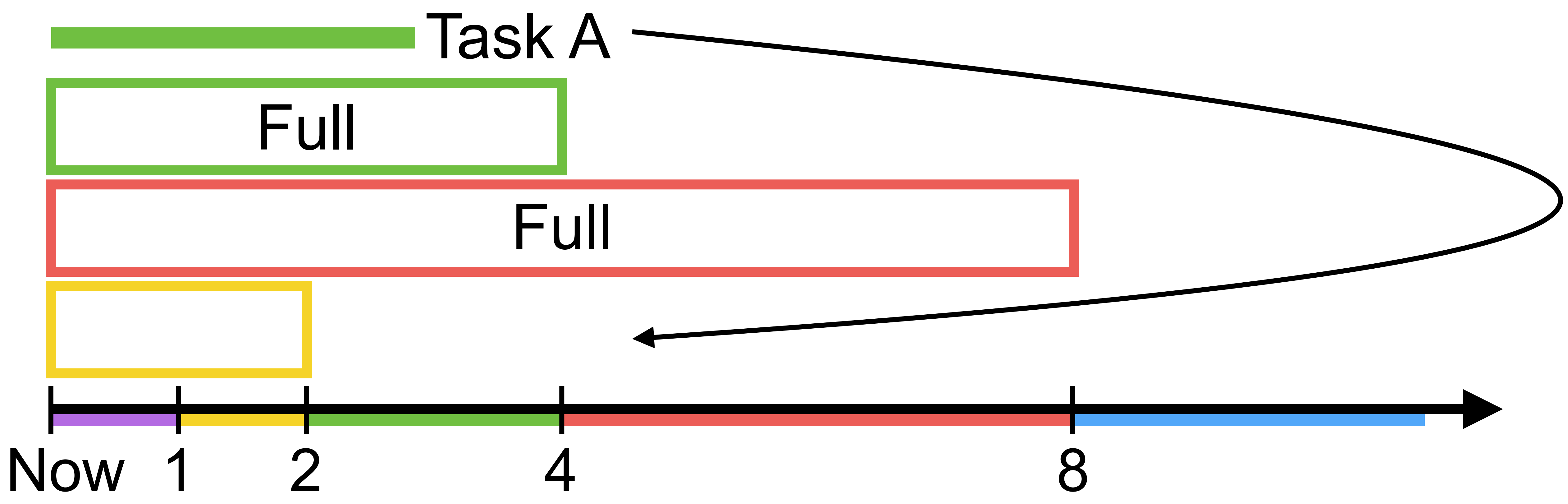

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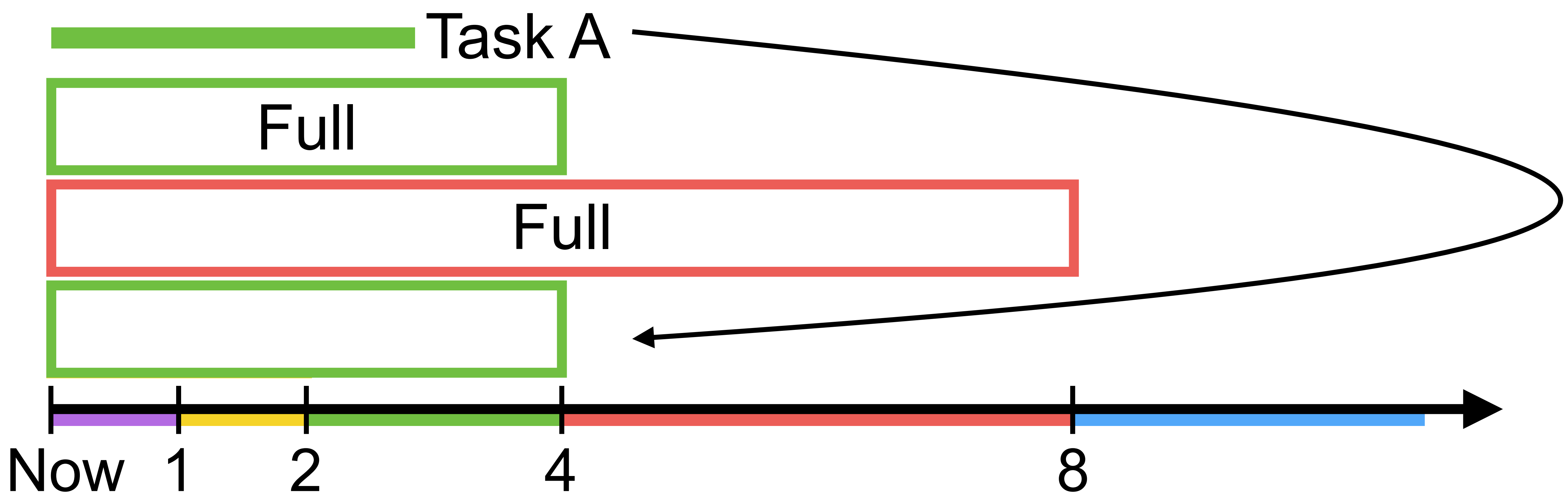

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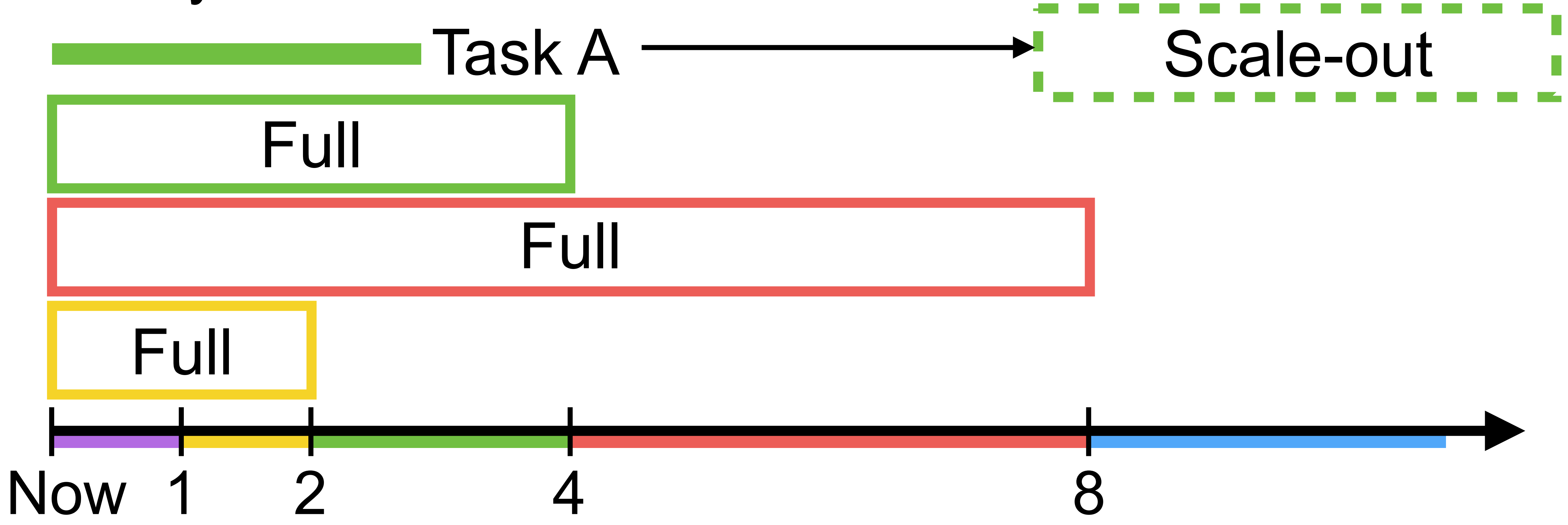
Packing tasks to VMs

- Packing preference for task in runtime bin β
  - VM in β > VM in greater RT bins > VM in lesser RT bins
  - Least impact to extend VM time-to-release
- Only scale-out as last resort



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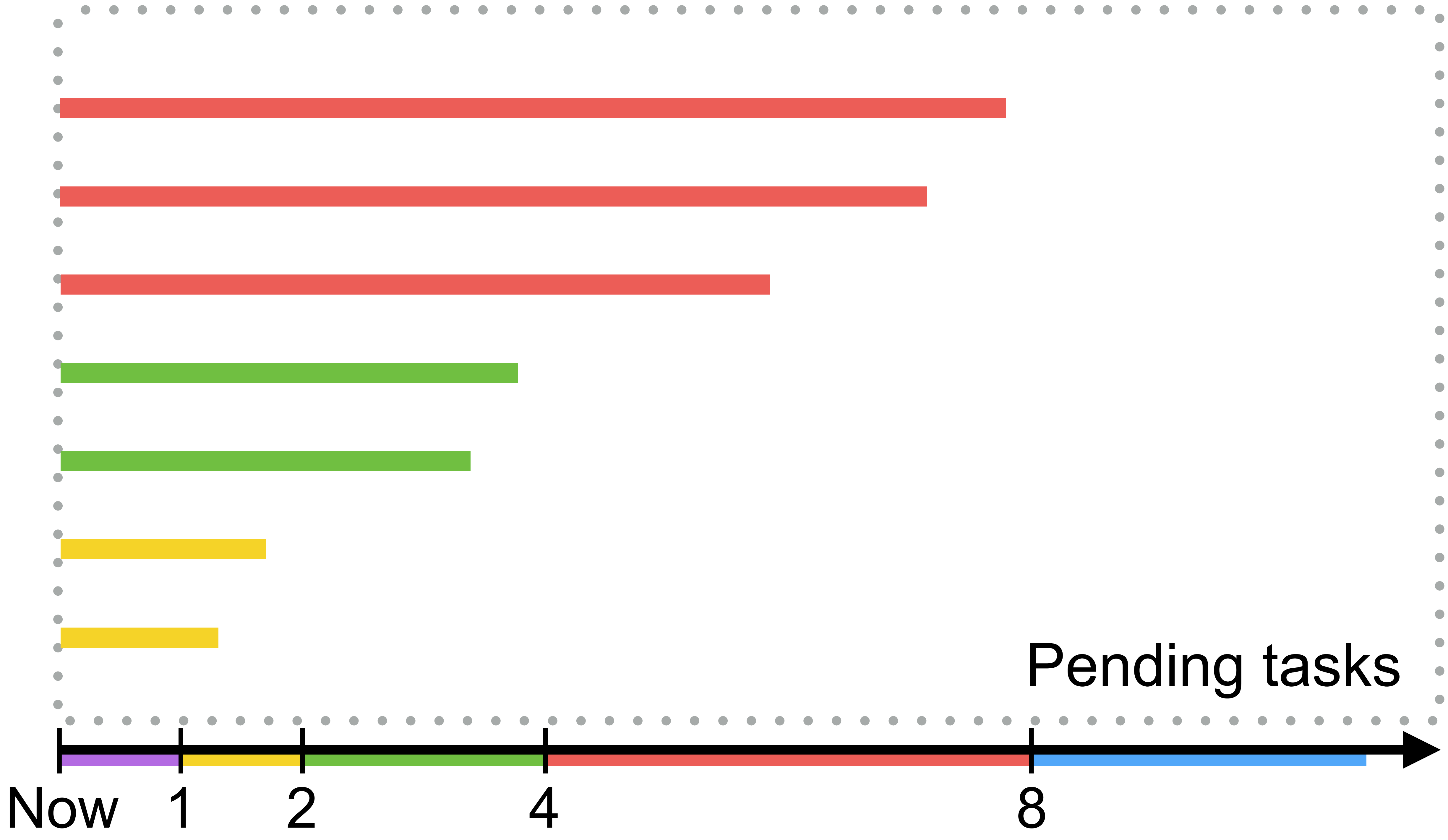
Resource-cost-awareness

- Stratus performs dynamic selection of VC composition
  - Acquire new VMs only if tasks don't fit on any VMs
  - Release VMs as soon as they become empty
- Recall: diverse offerings and dynamic pricing of VMs
- **Key**: Resource-cost-aware scale-out that considers *both* packing of pending tasks & dynamic rental costs
  - Eval packing of combinations of tasks in <u>same runtime bin</u> on to candidate VMs based on cost-per-resource-<u>utilized</u>
  - Packing/scaling in isolation with another increases cost

Acquiring new VMS



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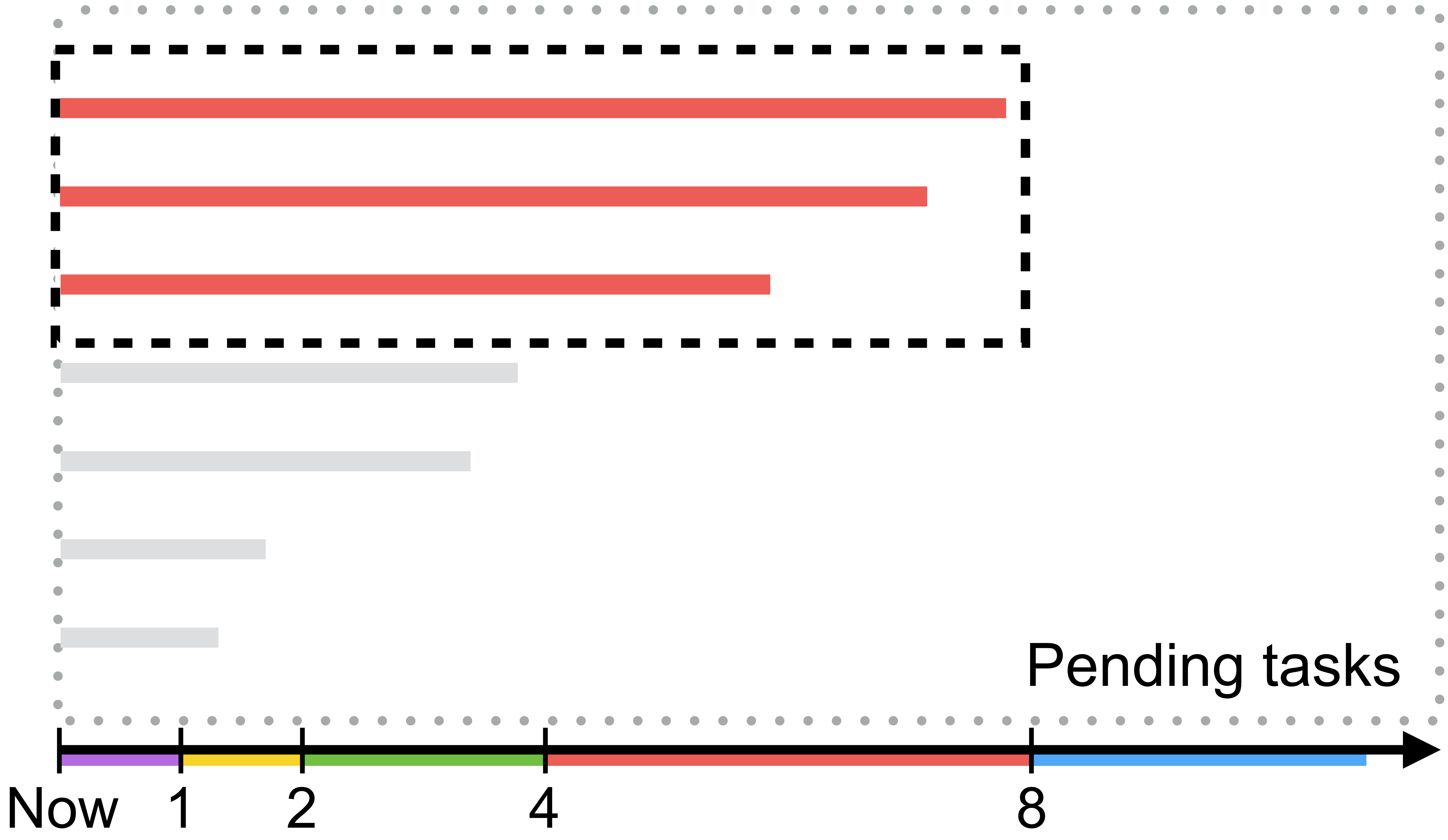

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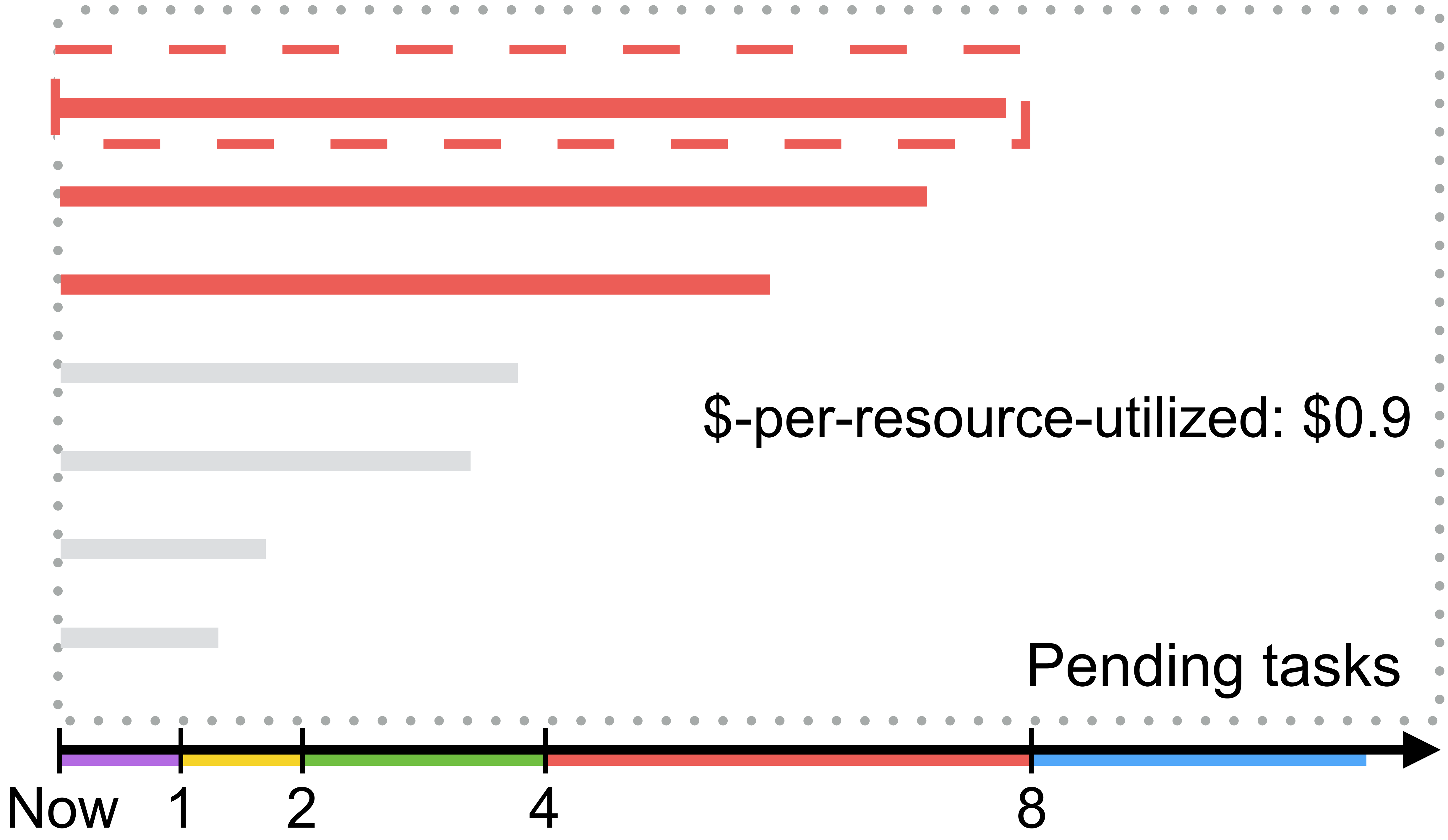

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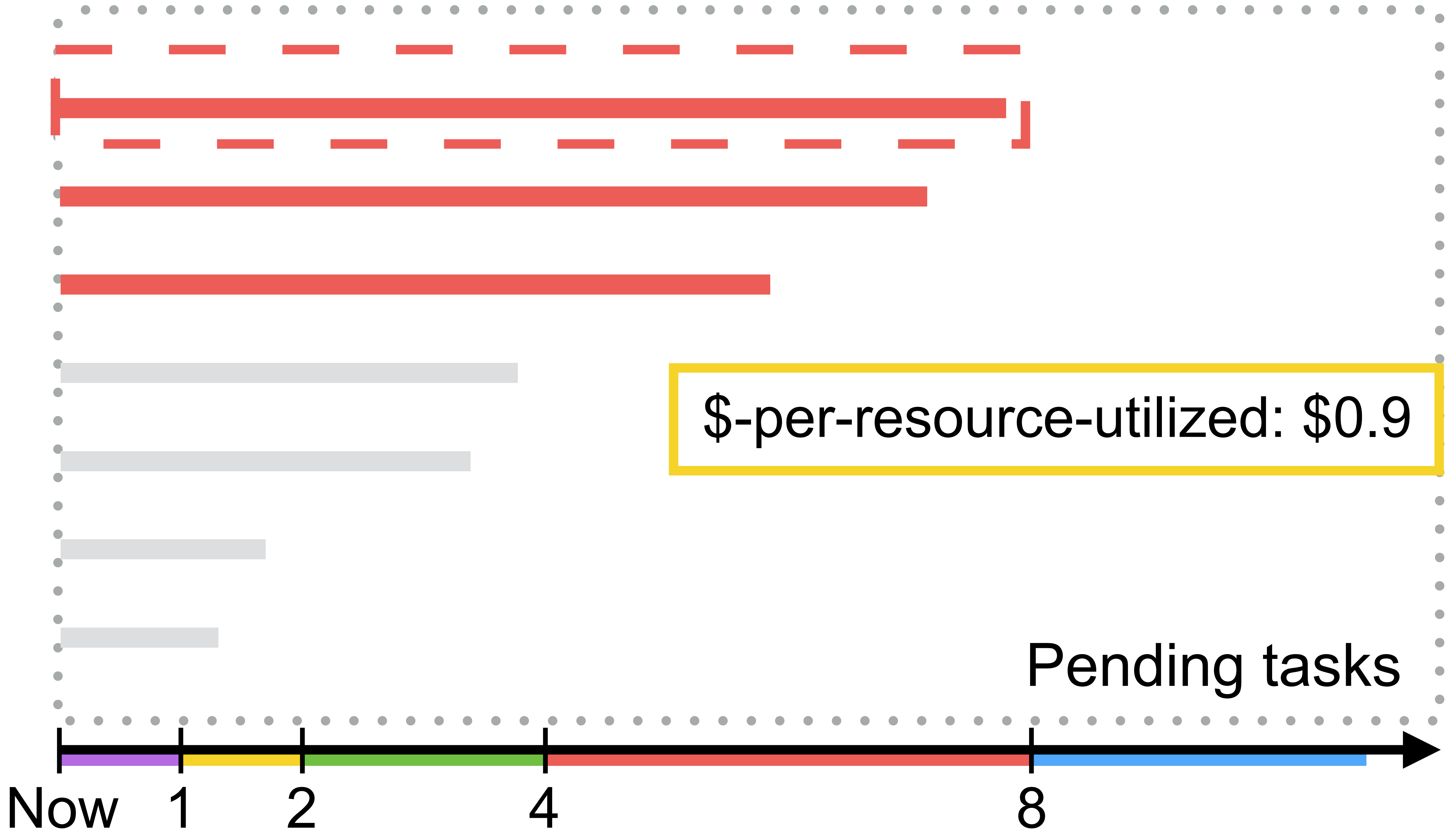

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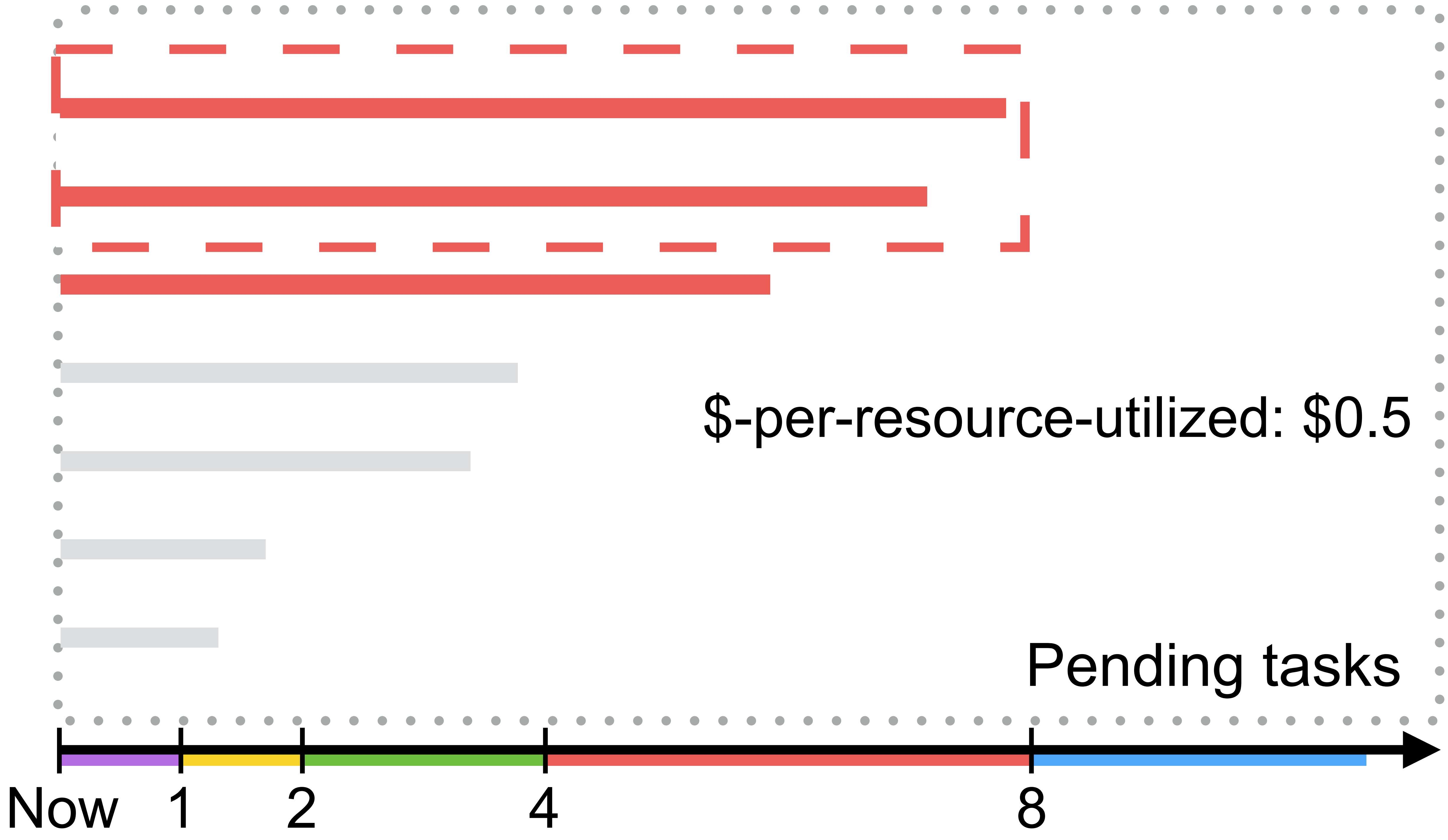

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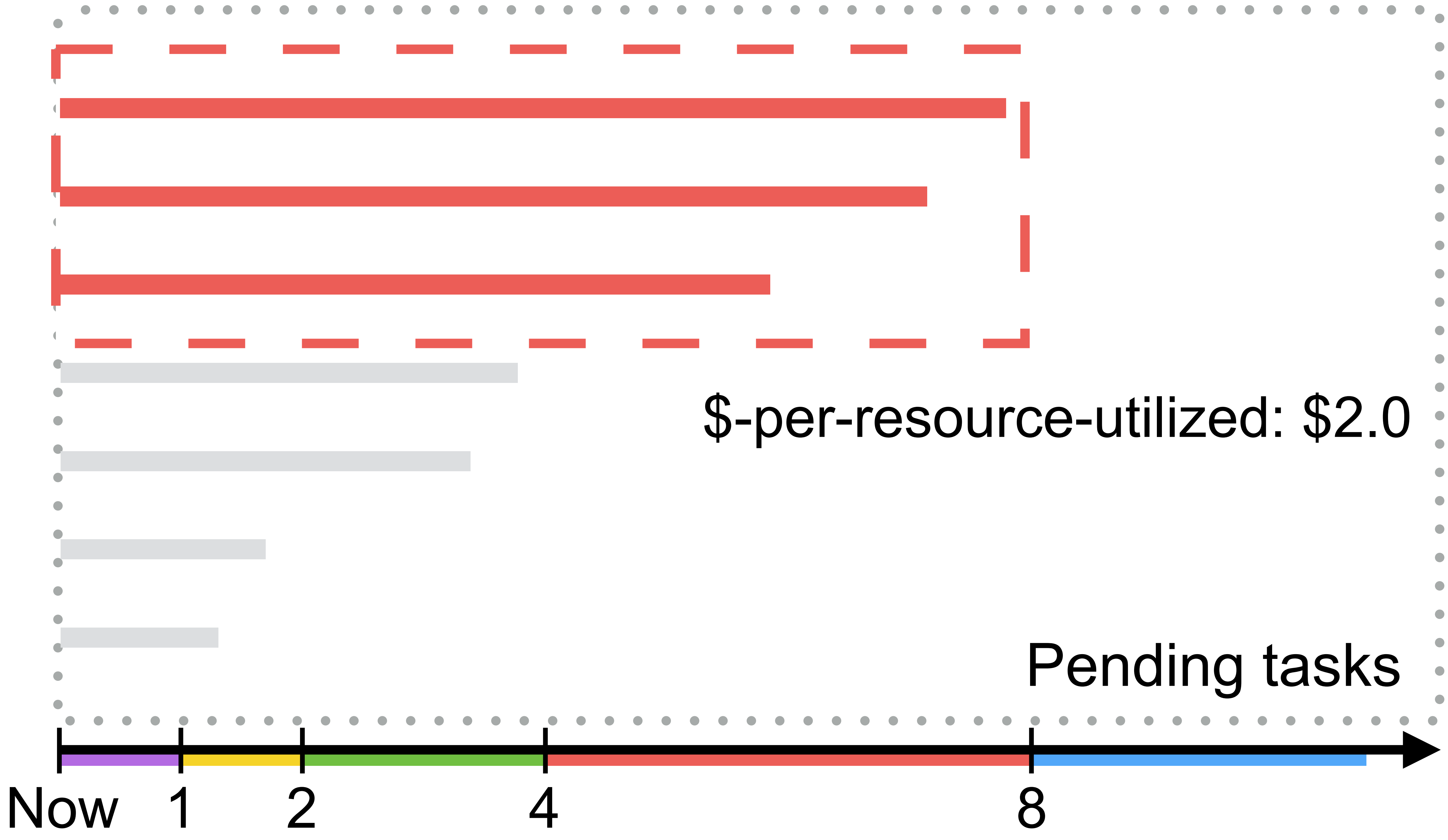

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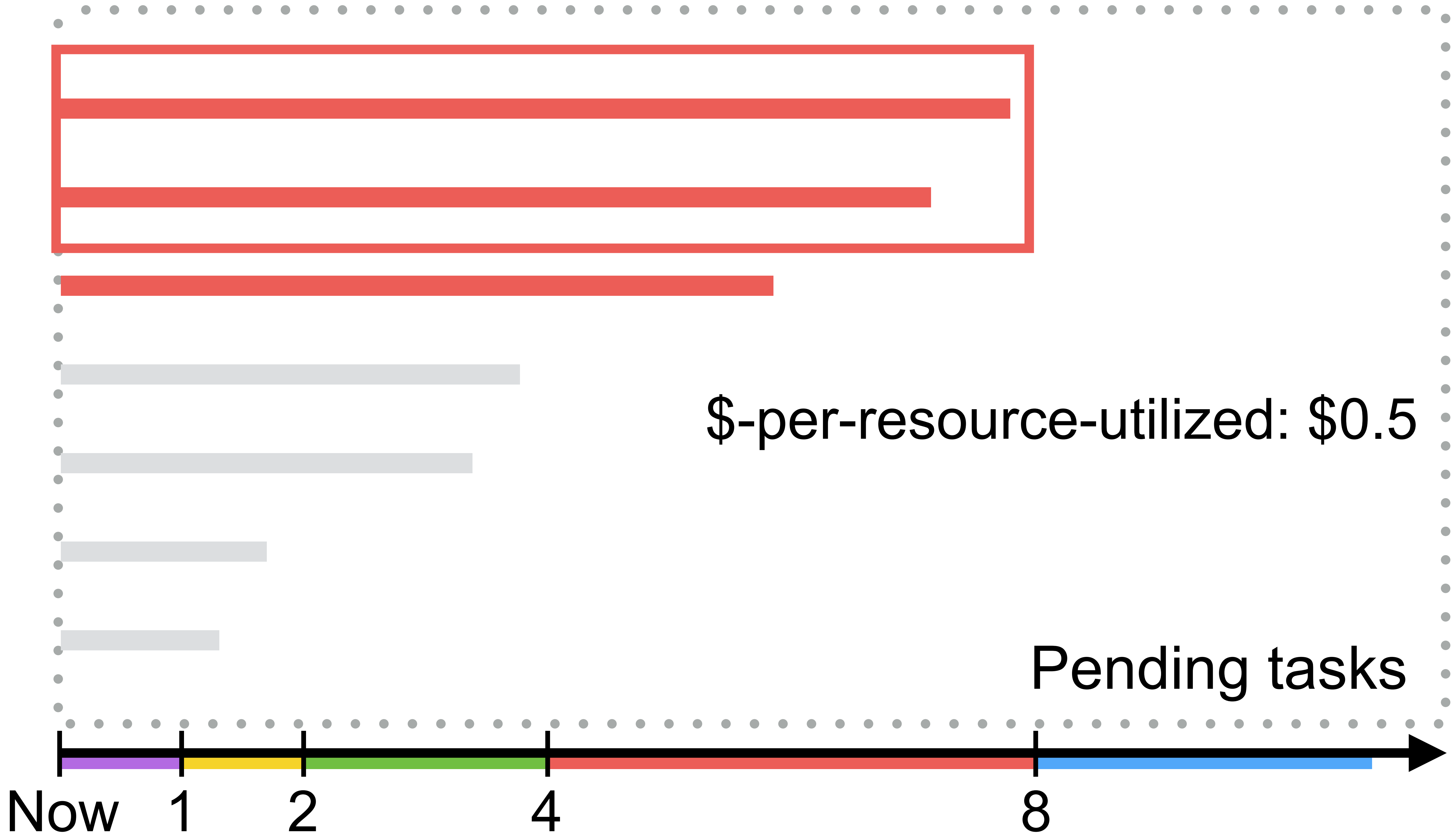

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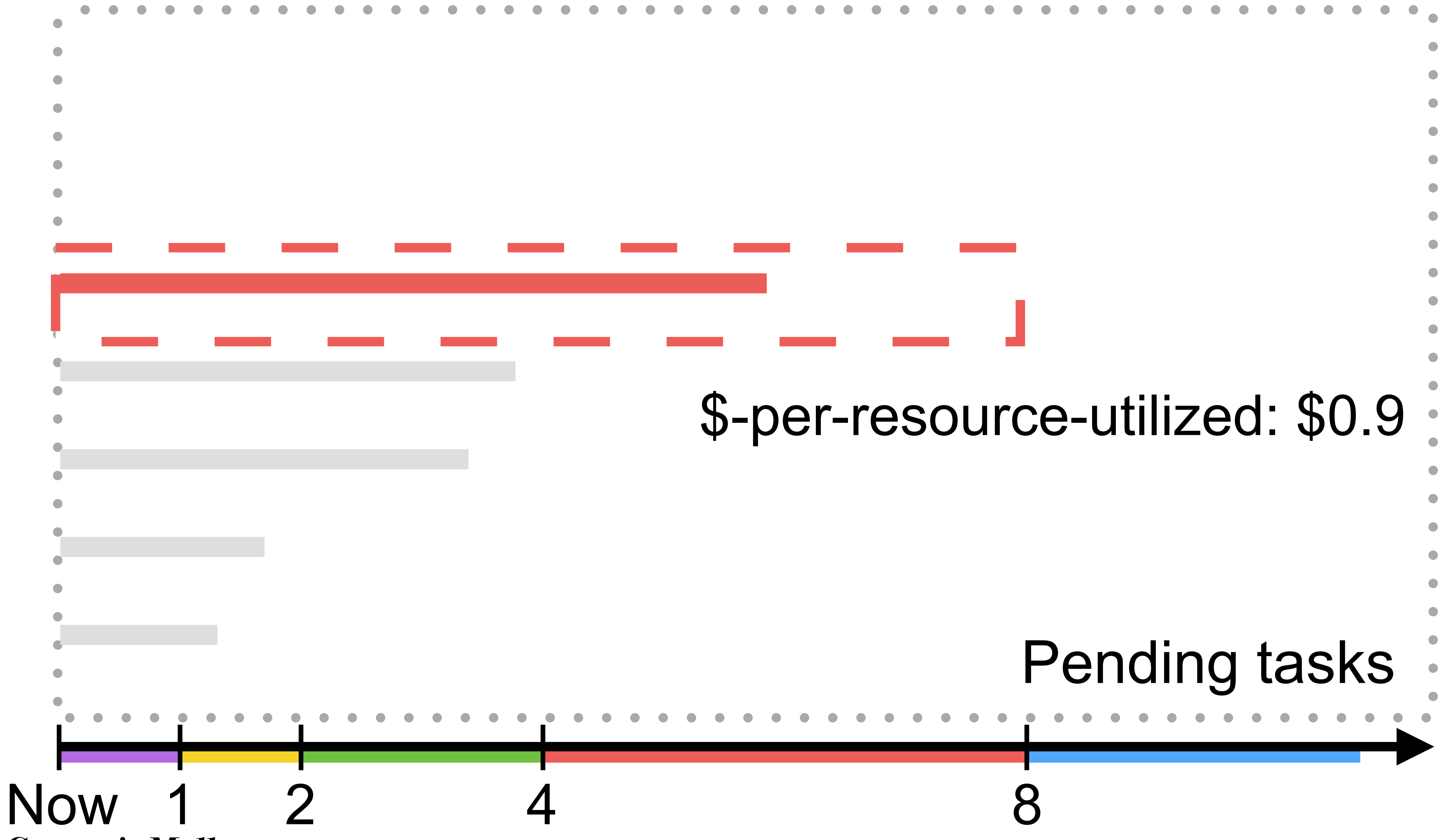

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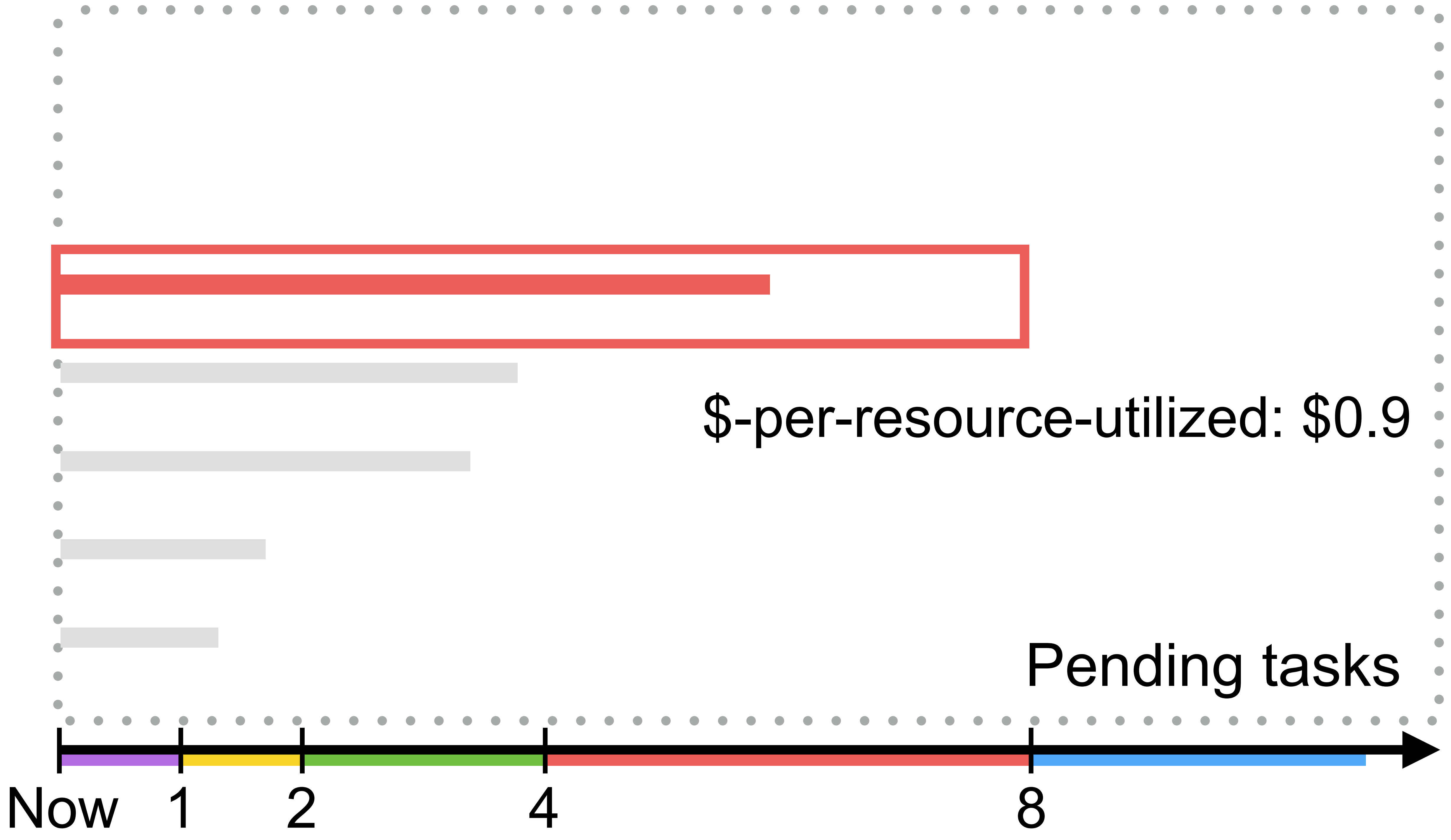

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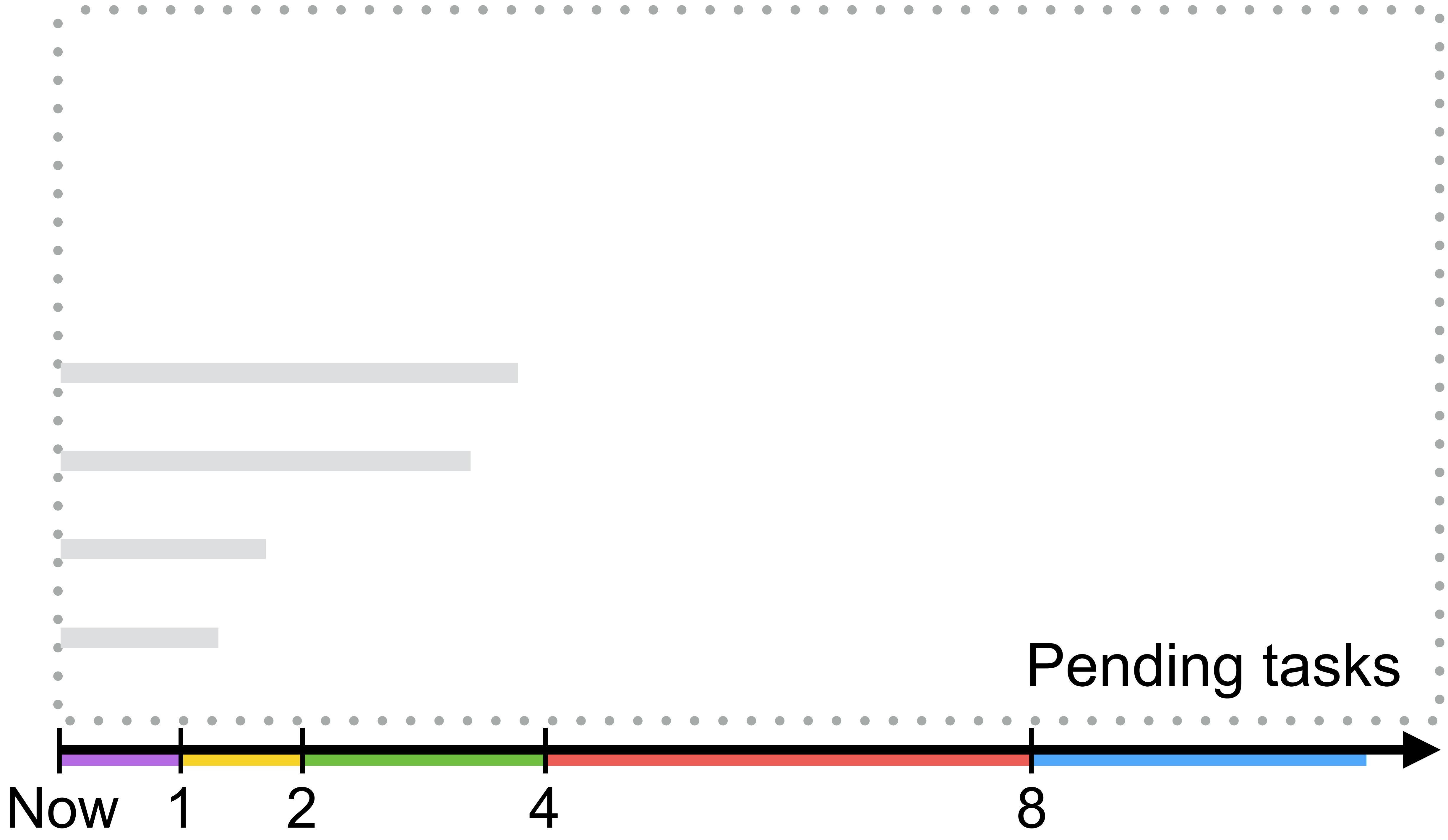

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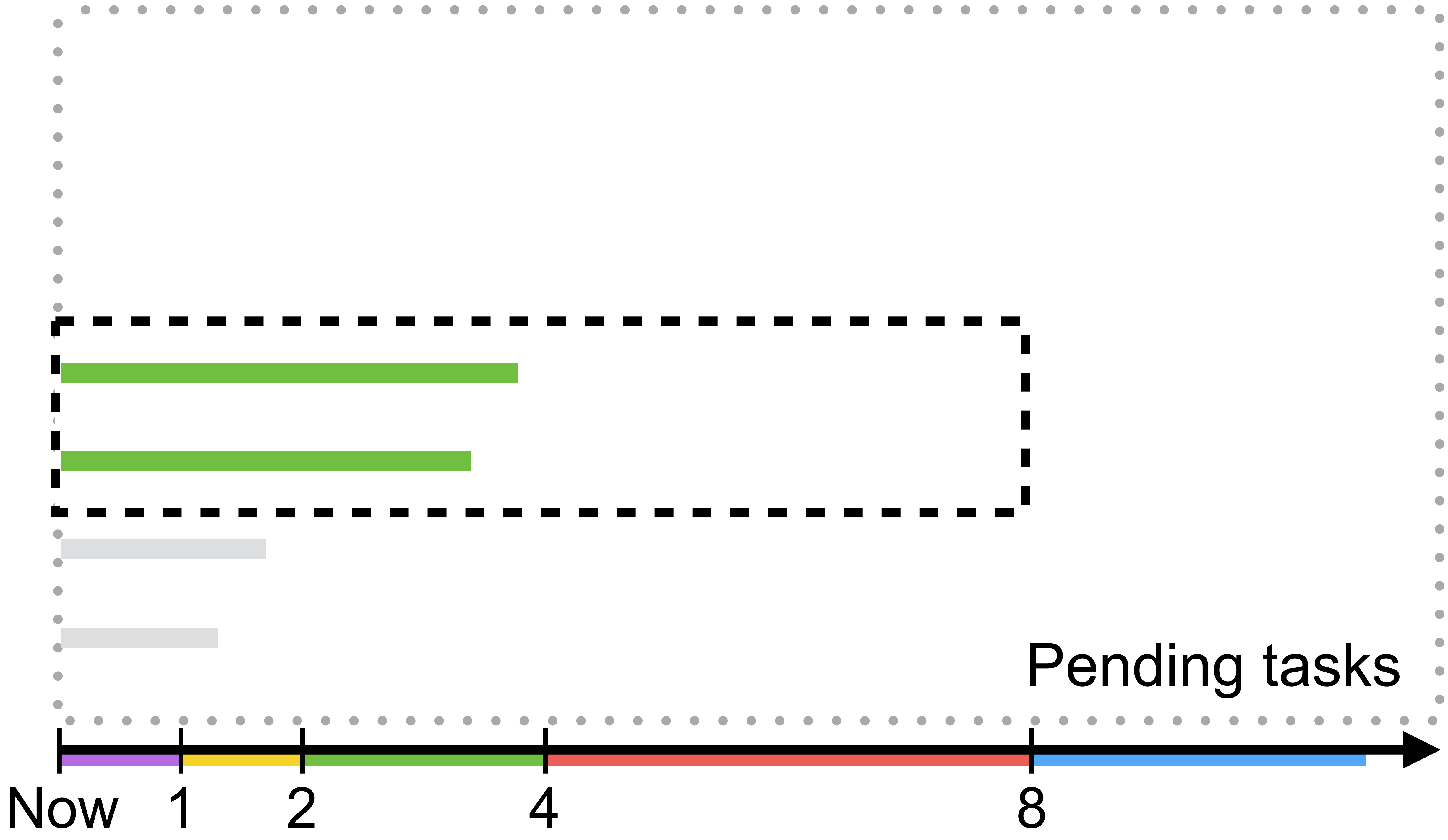
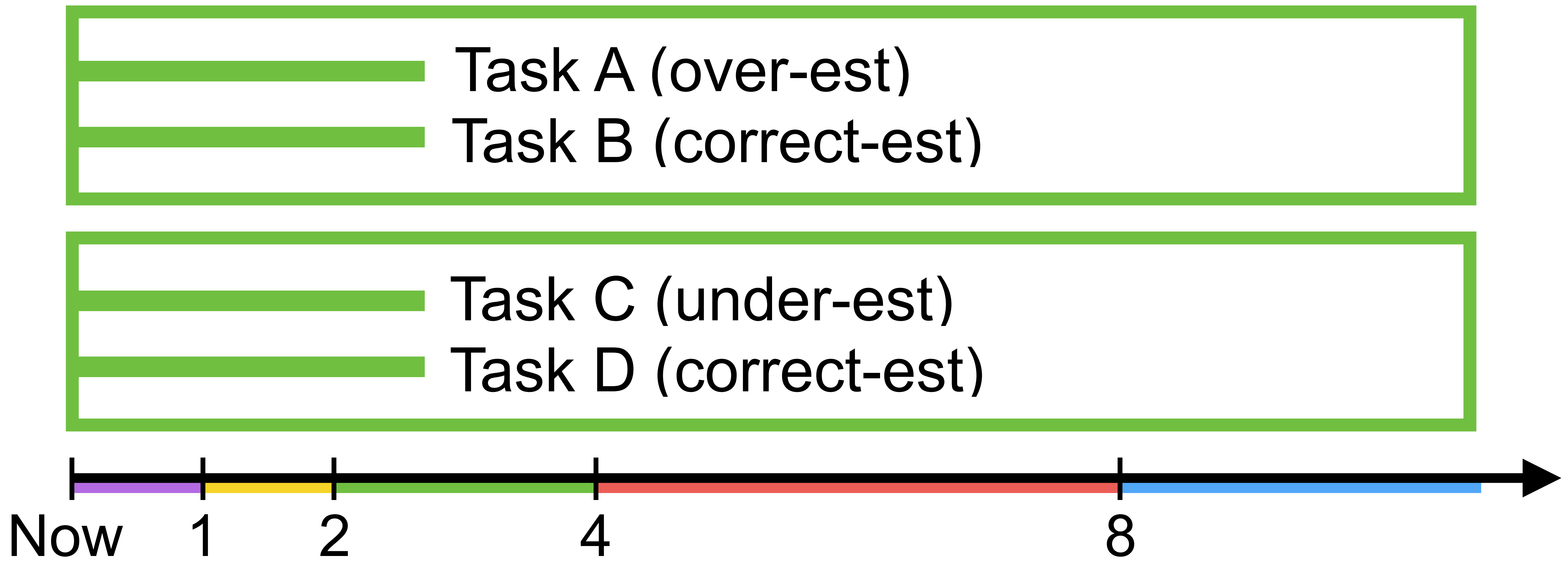


Runtime mis-estimates

- Mis-estimates can lead to low resource utilization

Example: 4 tasks on 2 instances



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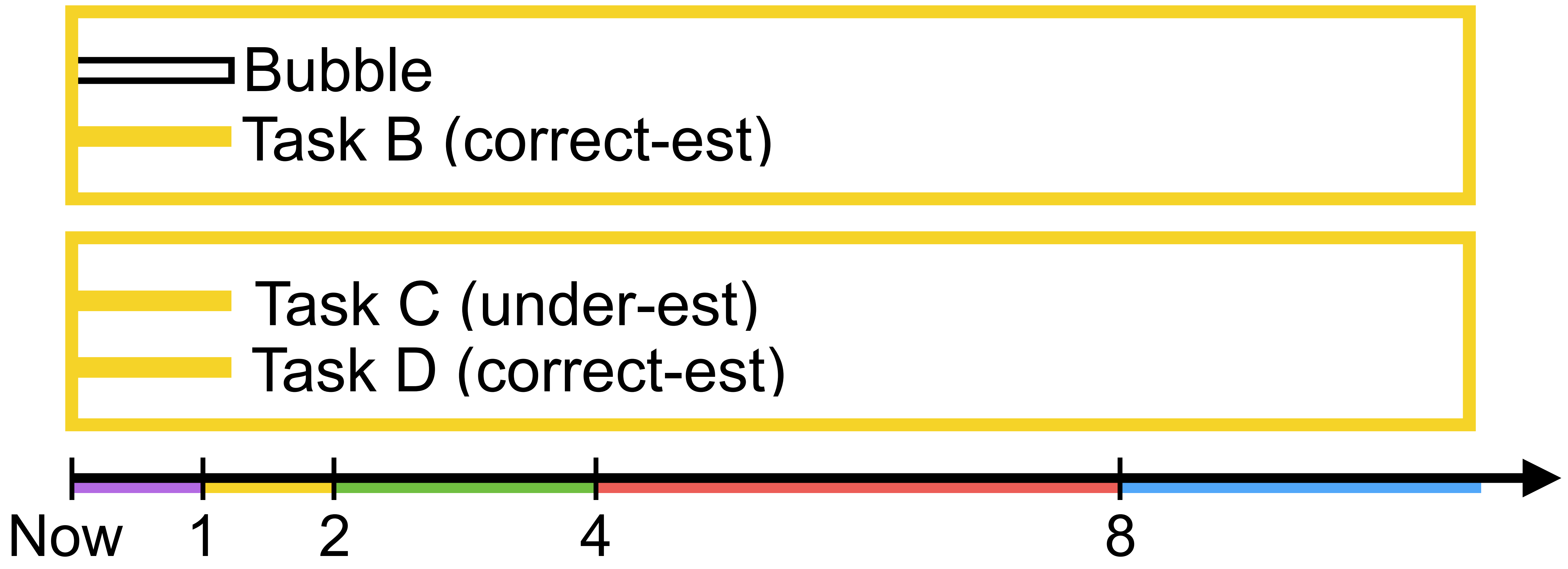

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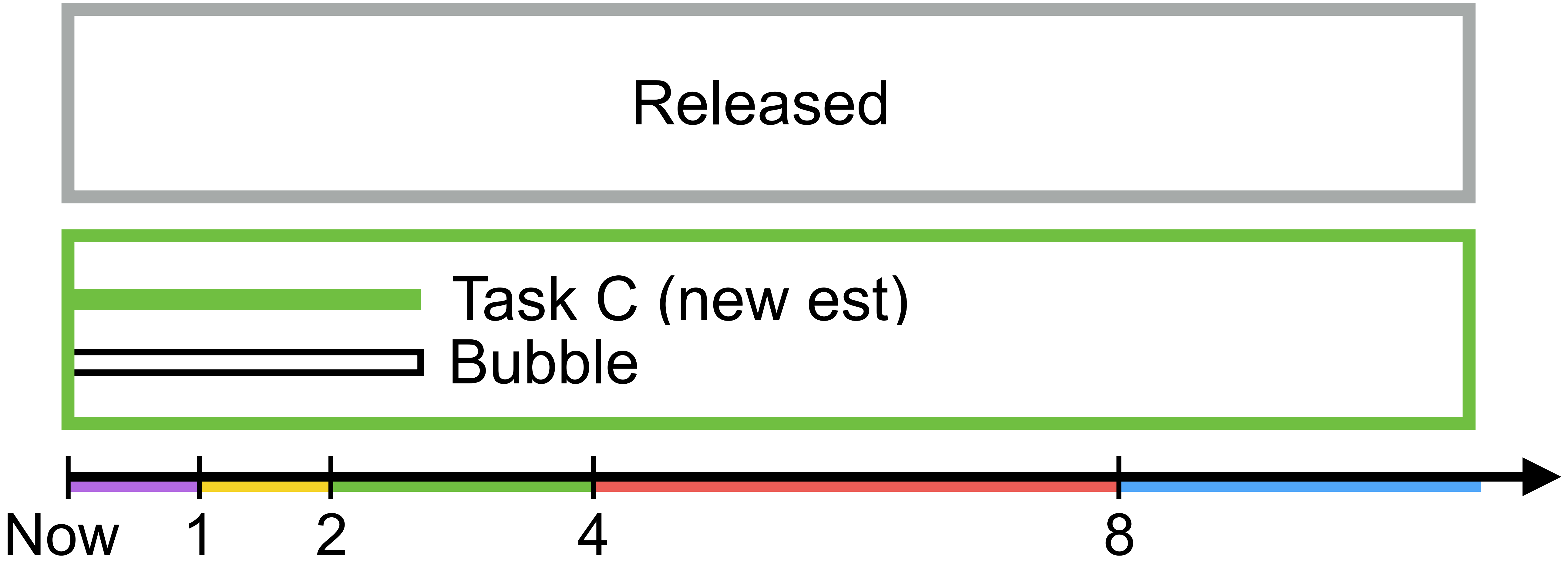


Runtime mis-estimates

- Mis-estimates can lead to low resource utilization
- RT binning mitigates mis-estimates to some degree
- Adjusting mis-estimates
    - Over-estimates: No adjustment necessary (task done)
    - Under-estimates: Assume task has run for half of its runtime
- Instance-clearing: If VM experiences low utilization for extended period of time, migrate tasks and re-distribute

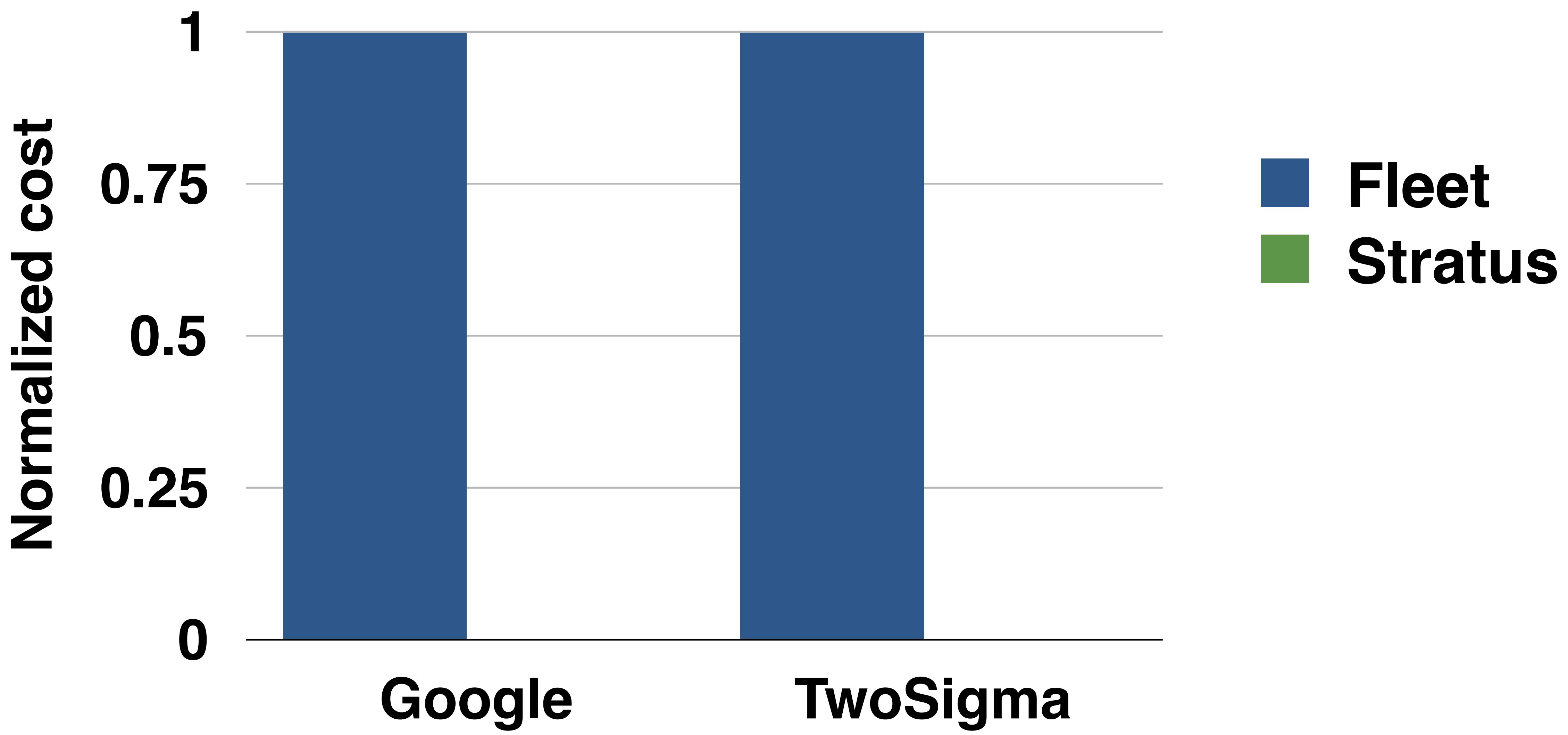
Experimental setup

- Simulation-based experiments
  - Workloads: Google and TwoSigma cluster traces
- Focus on batch jobs
  - Filter out jobs running > 1 day
- EC2 spot market for dynamically-priced markets
  - Same family VMs for comparable perf

Evaluation: Normalized cost

Fleet (Spot Fleet + ECS, Amazon offerings)

- LowestPrice + BinPack policy

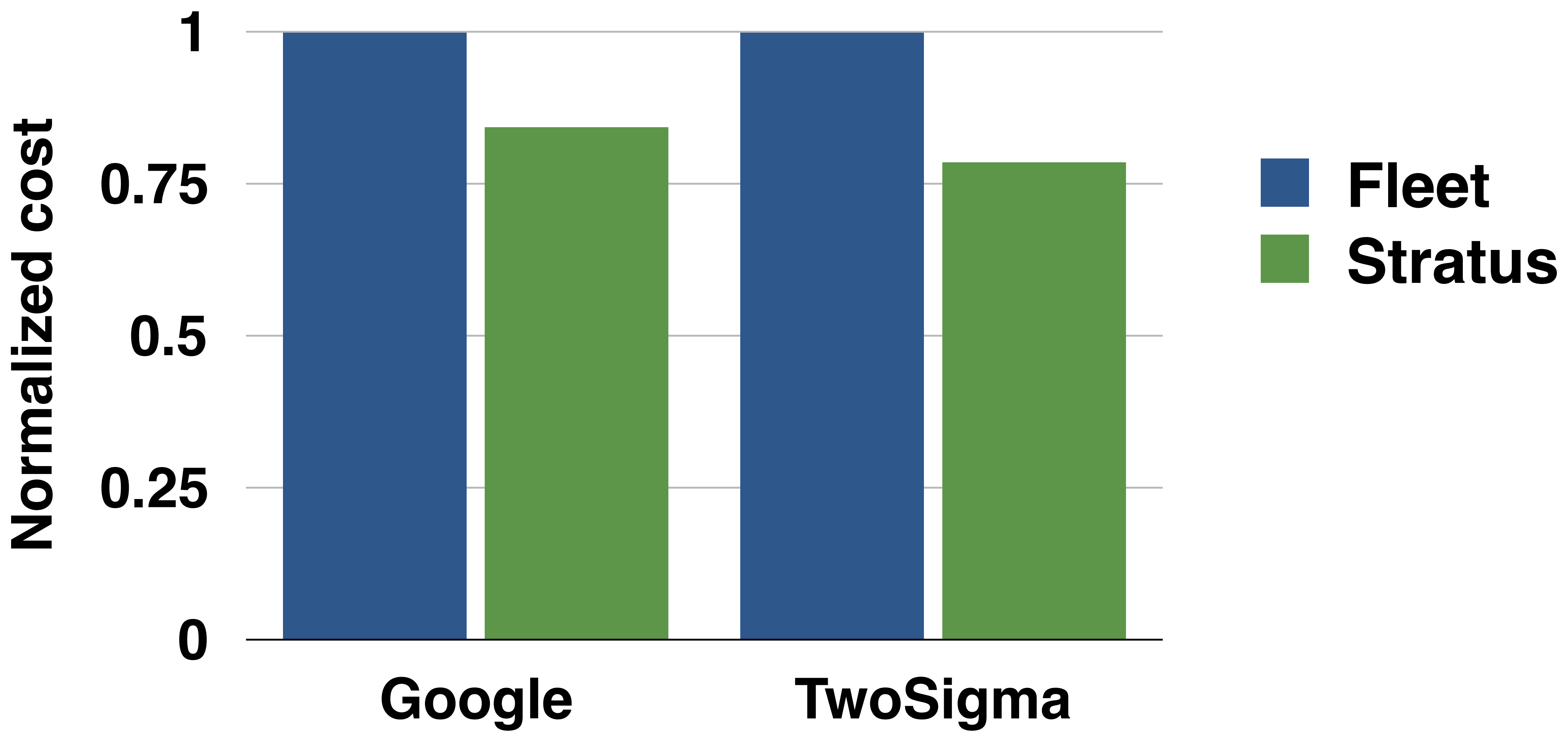


Note: Comparisons vs other state-of-the-art-schedulers left out for brevity
Stratus lowers cost vs each compared scheduler by at least 17%

Evaluation: Normalized cost

Stratus

- 17% (Google) and 22% cost reduction (TwoSigma)



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Summary

- Packing/scaling heuristics based on runtime binning
  - Allows for high utilization of resources during rental period
- Scale VC by simultaneous consideration of possible packings and available instance types and prices
  - Indep consideration of packing/scaling leads to higher cost
- ~17% cost reduction on Google and TwoSigma traces compared to next-best evaluated scheduler
  - Attains high resource utilization