Speculative Load Balancing

Hassan Eslami
William D. Gropp

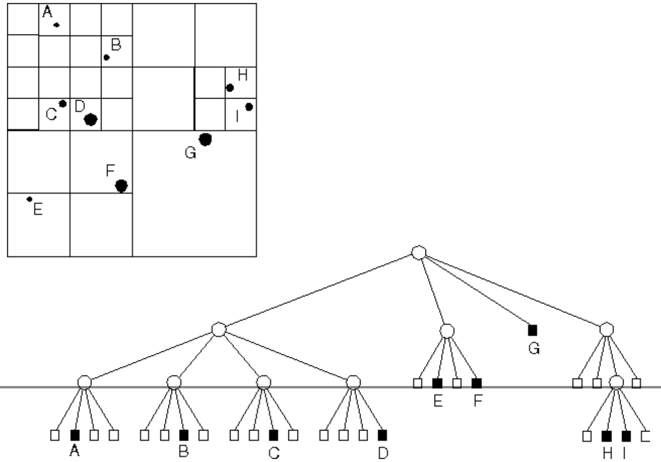
Department of Computer Science
University of Illinois at Urbana Champaign

Continuous Dynamic Load Balancing

- Irregular parallel applications
  - Irregular and unpredictable structure
  - Nested or recursive parallelism
  - Dynamic generation of units of computation
  - Available parallelism heavily depends on input data
  - Require continuous dynamic load balancing

Optimization and search problems

N-Body problems



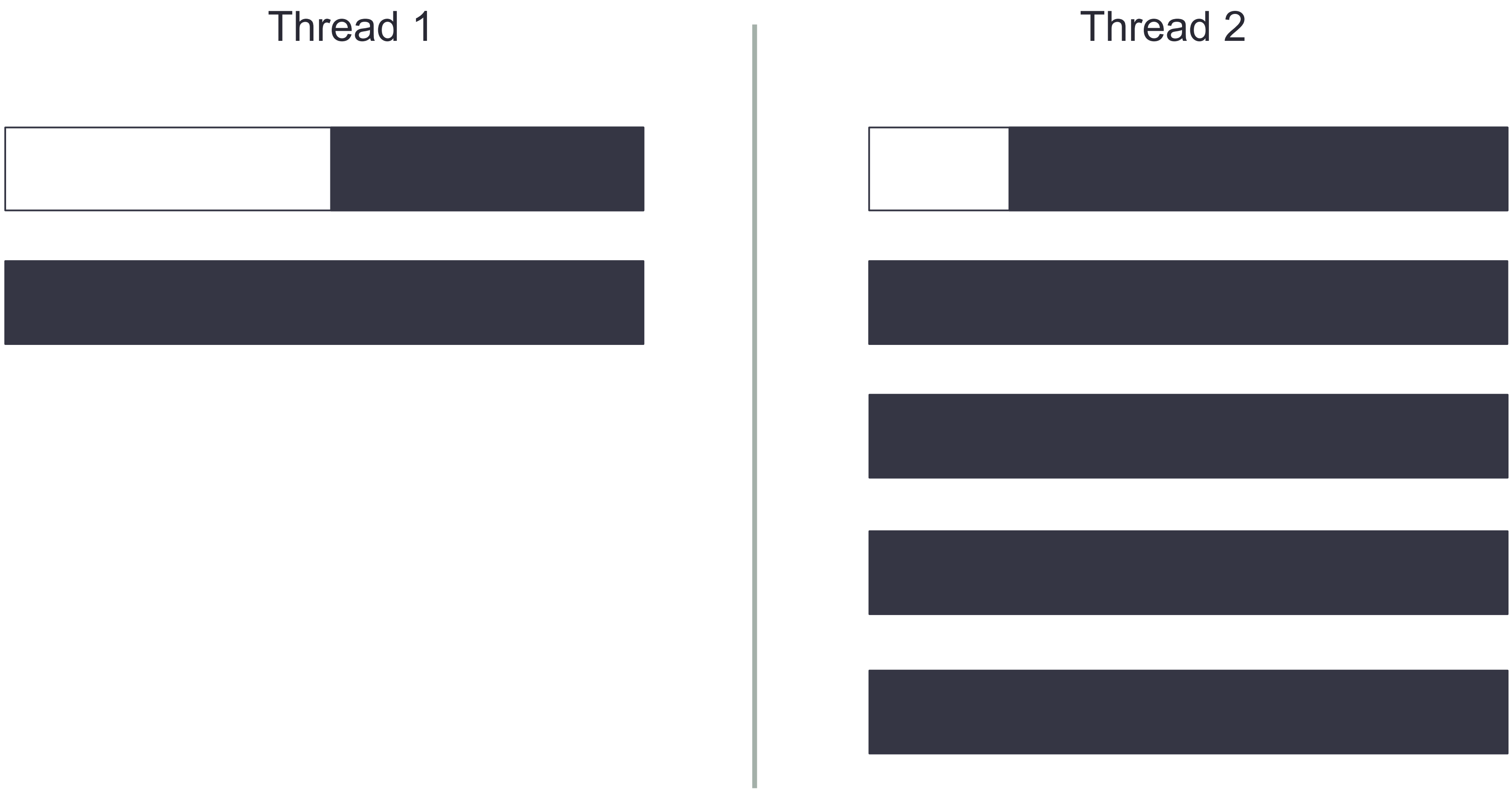
Dynamic Load Balancing Model

```
TaskPool.initialize(initial tasks)
While (t ← TaskPool.get())
      t.execute()
```

In `execute()`, one may call `TaskPool.put()`

Idle time in `TaskPool.get()`

How to Eliminate Idle Time? – Prefetching



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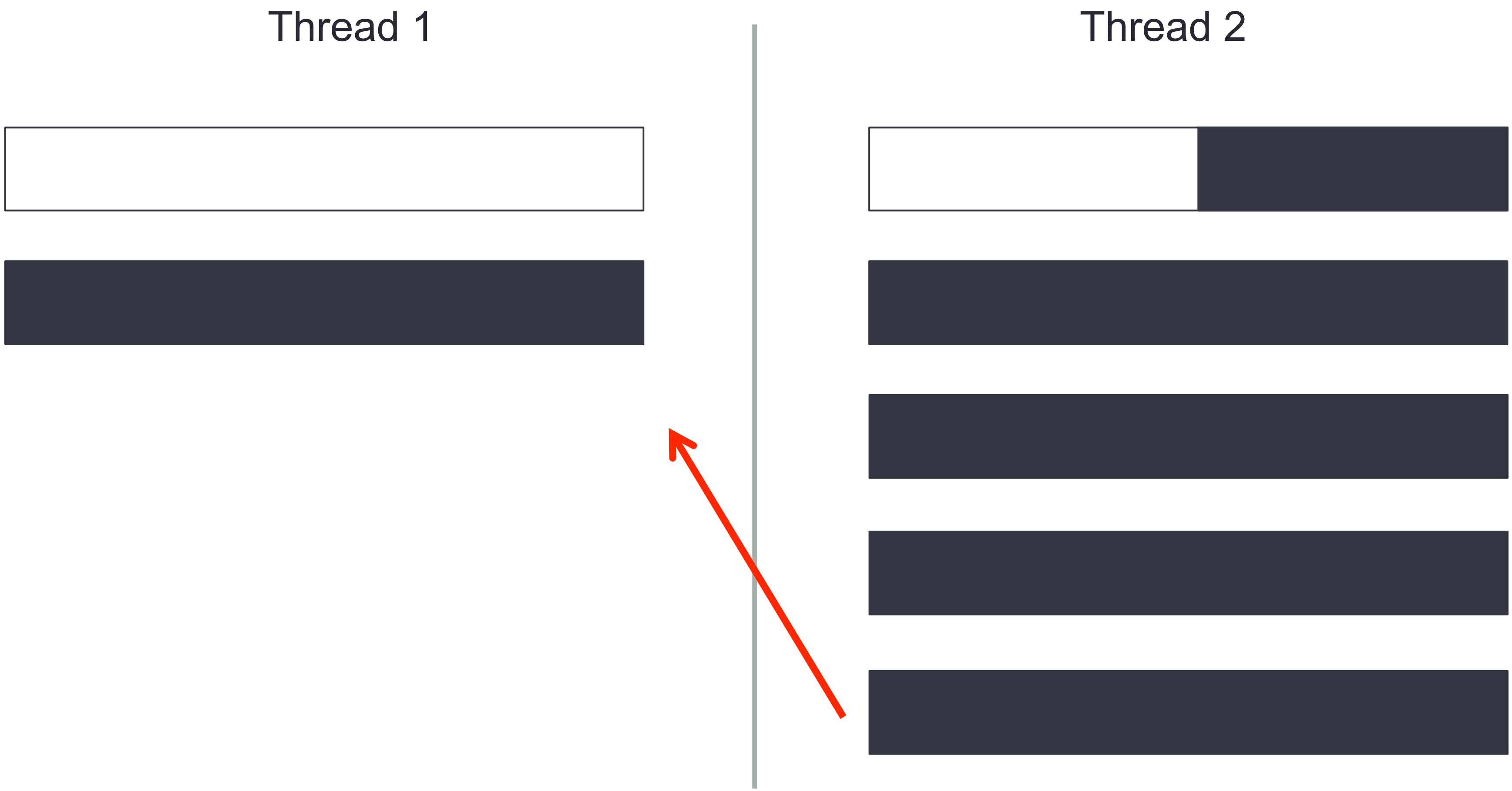

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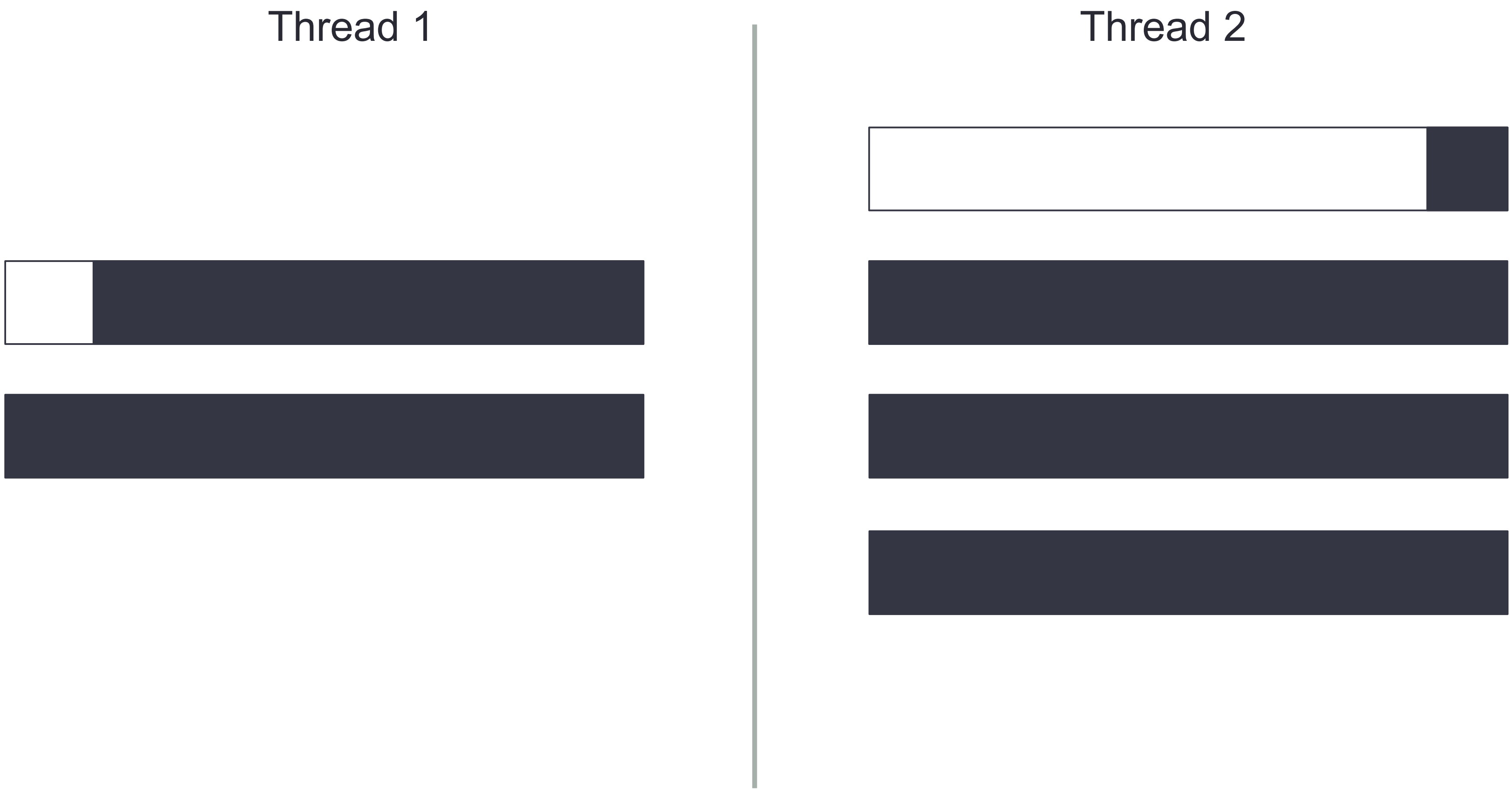

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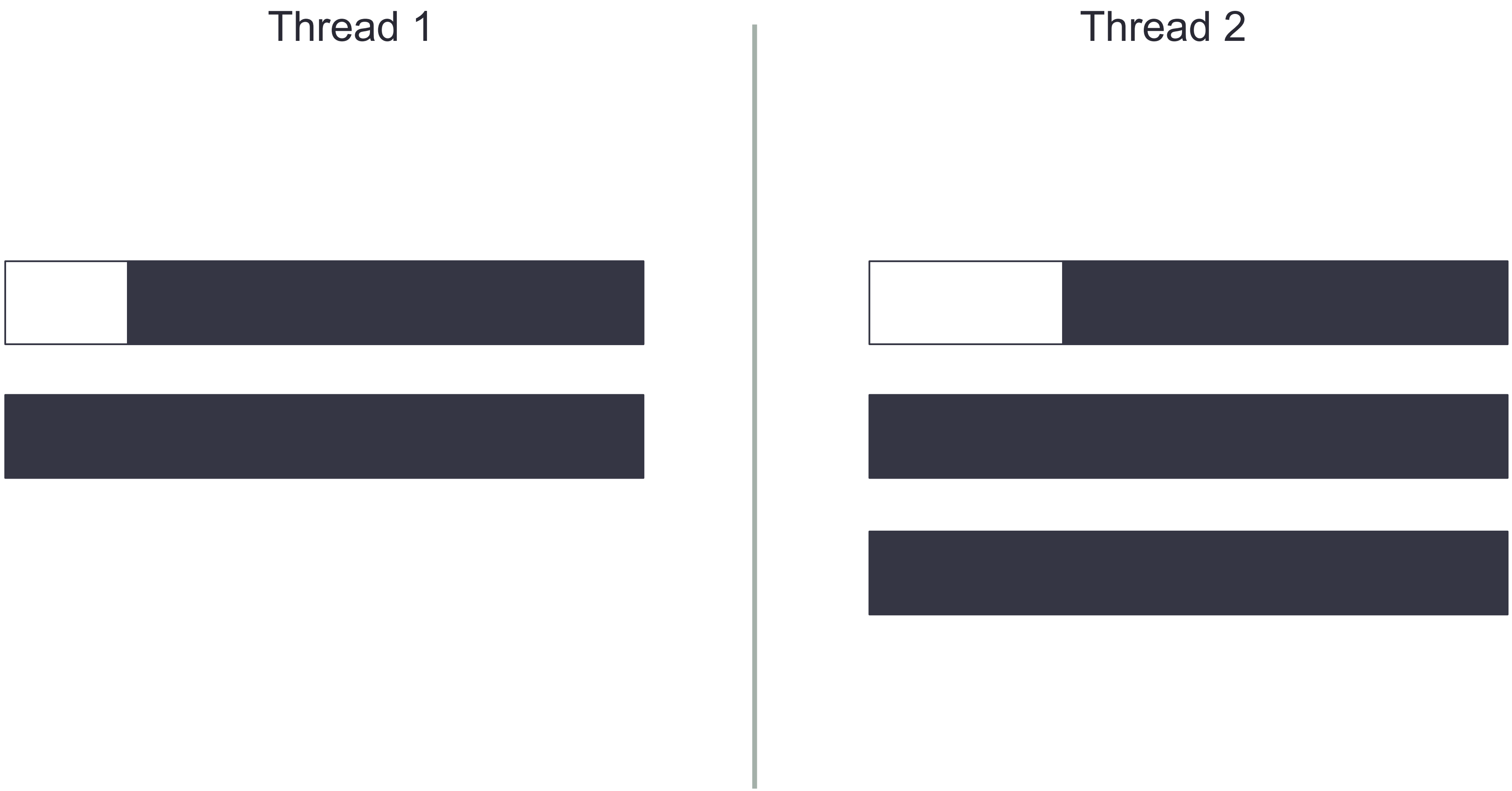

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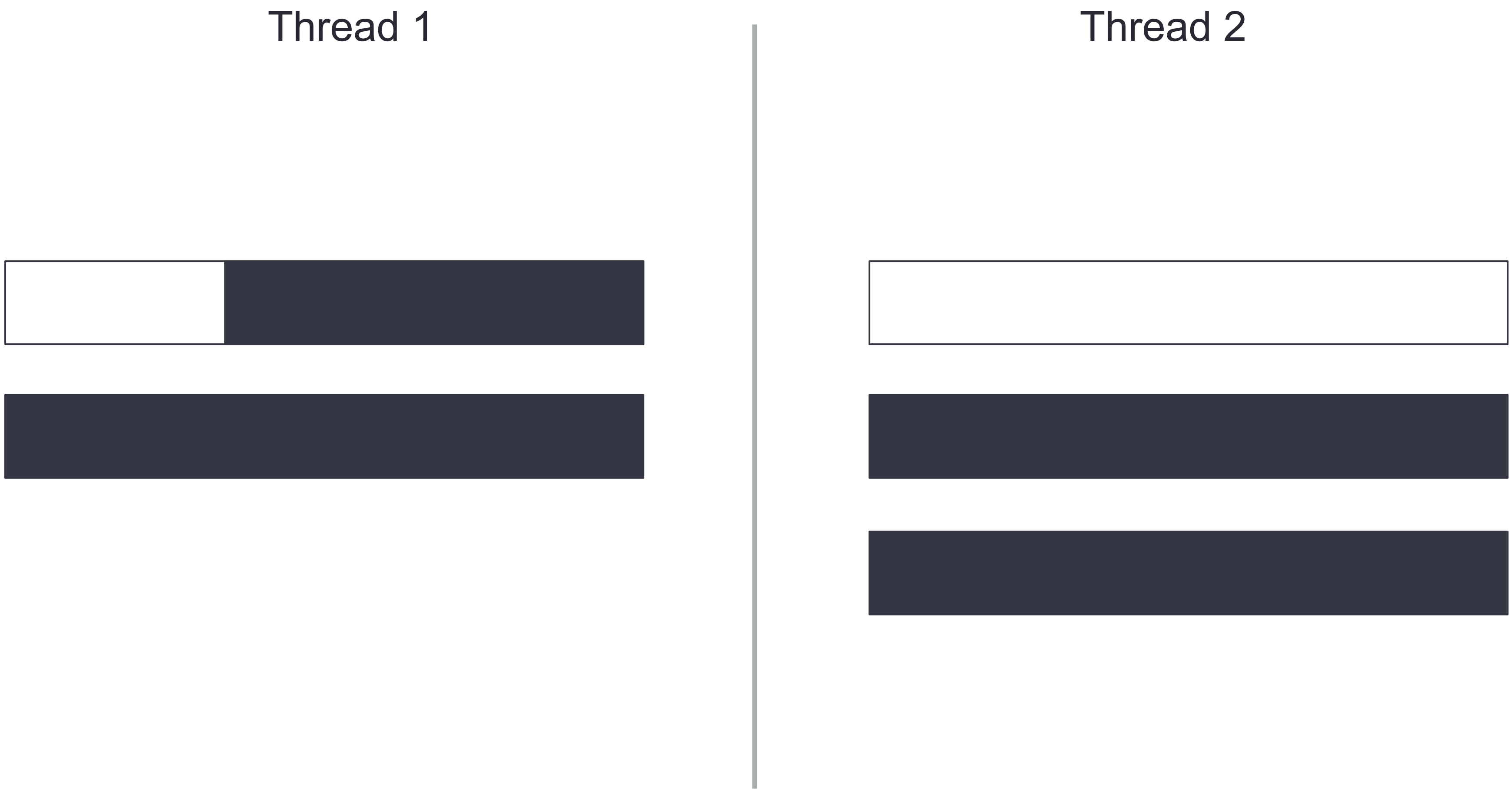

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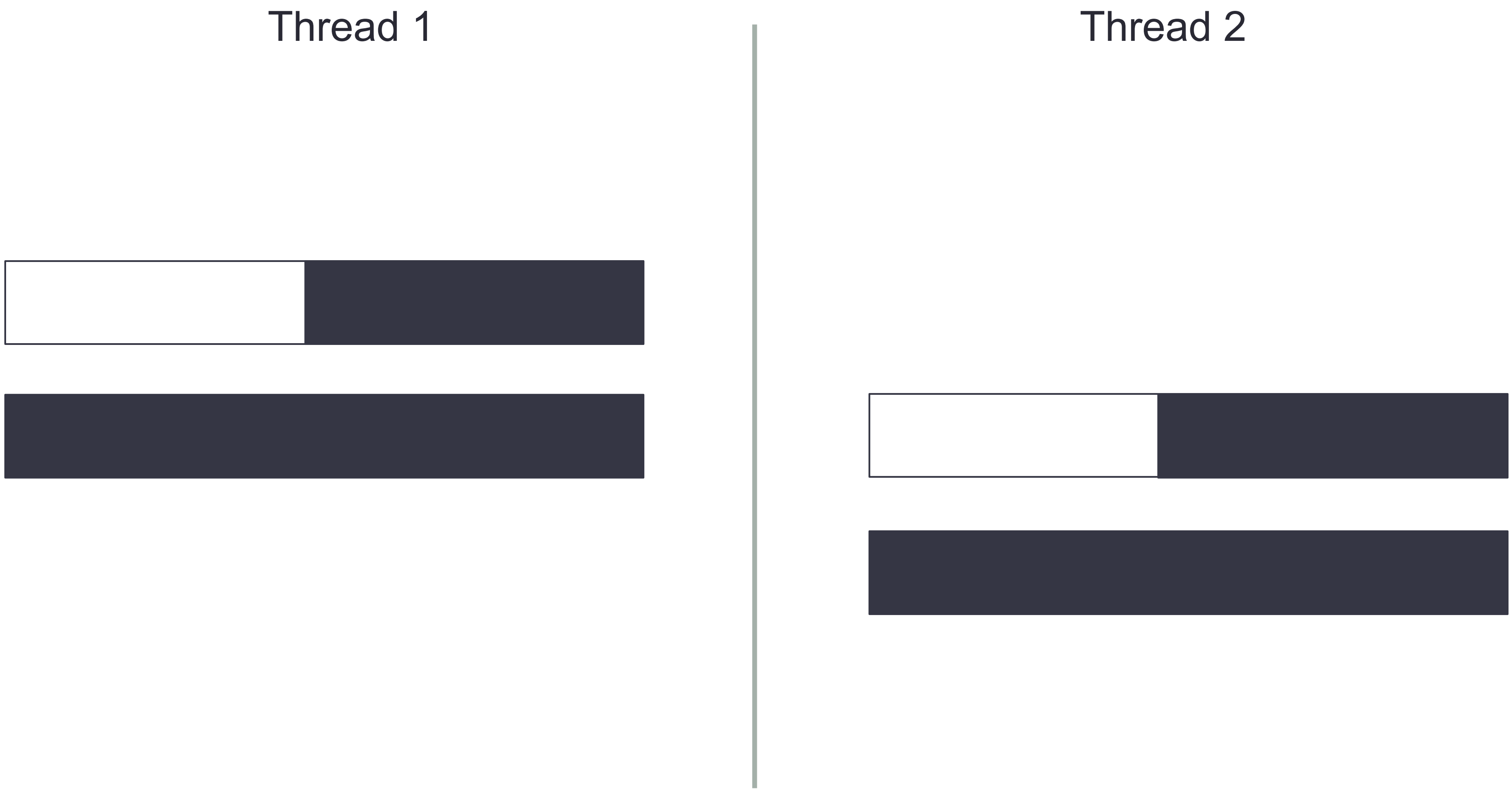

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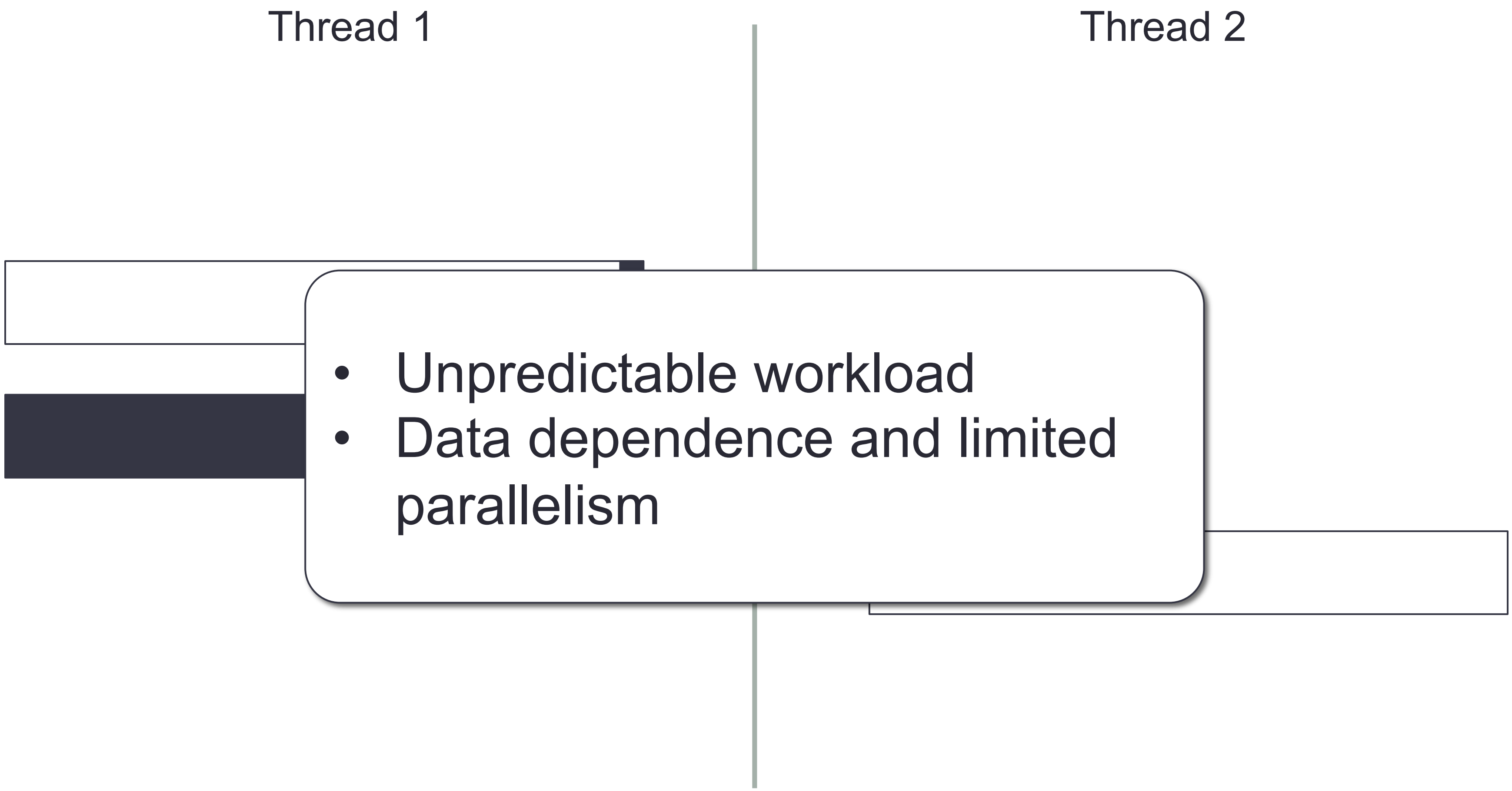
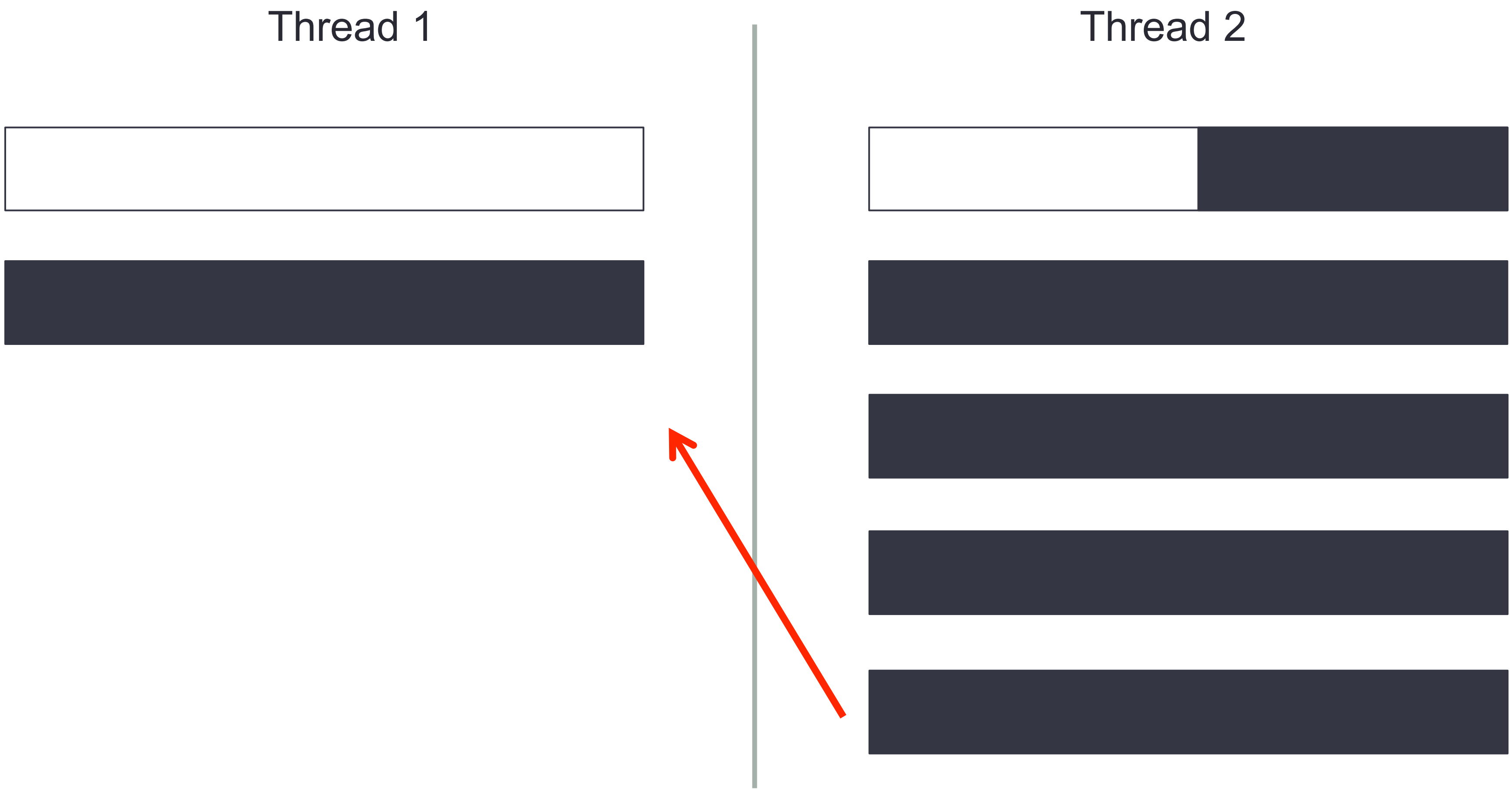


- Unpredictable workload
- Data dependence and limited parallelism

How to Eliminate Idle Time? – Speculation



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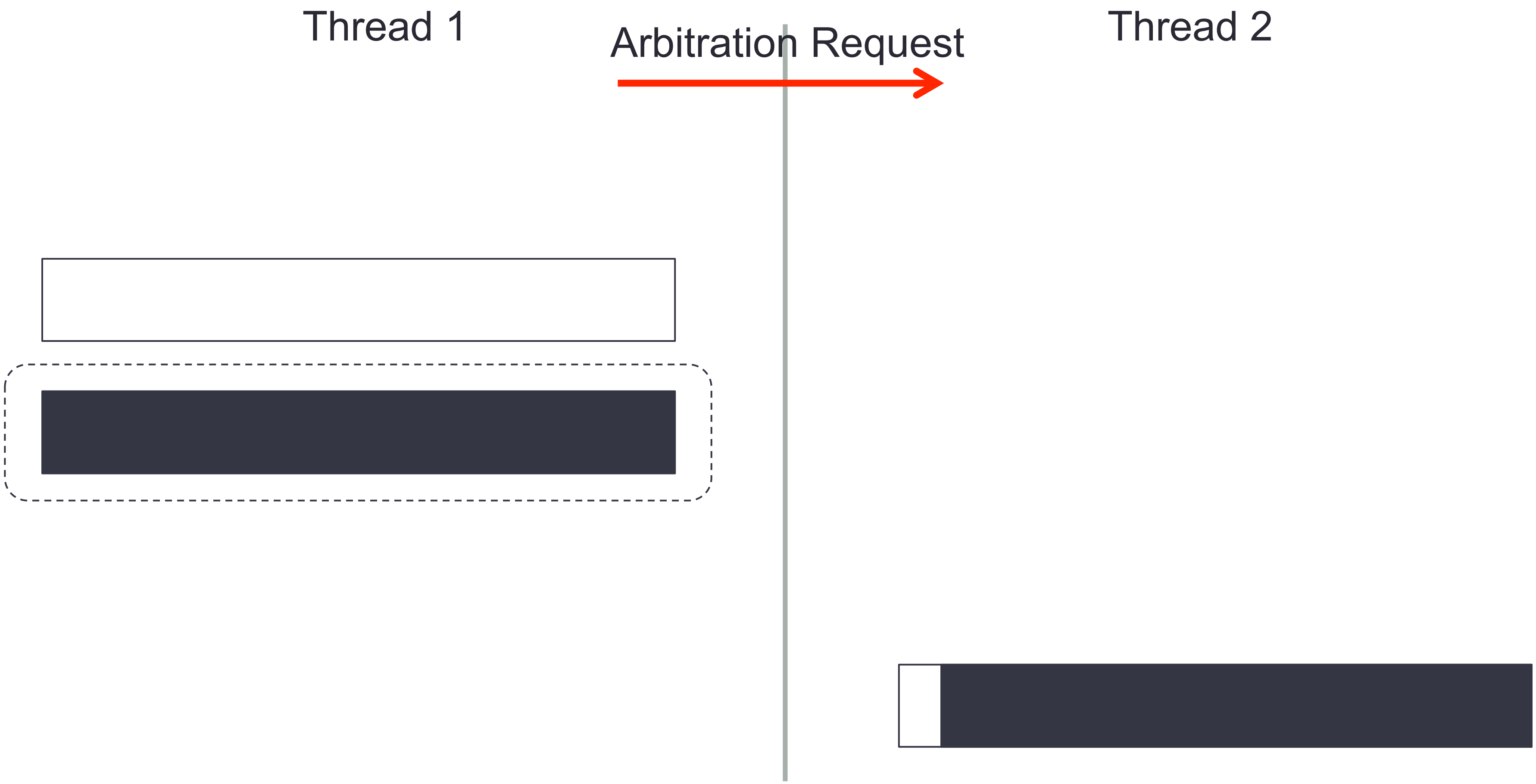

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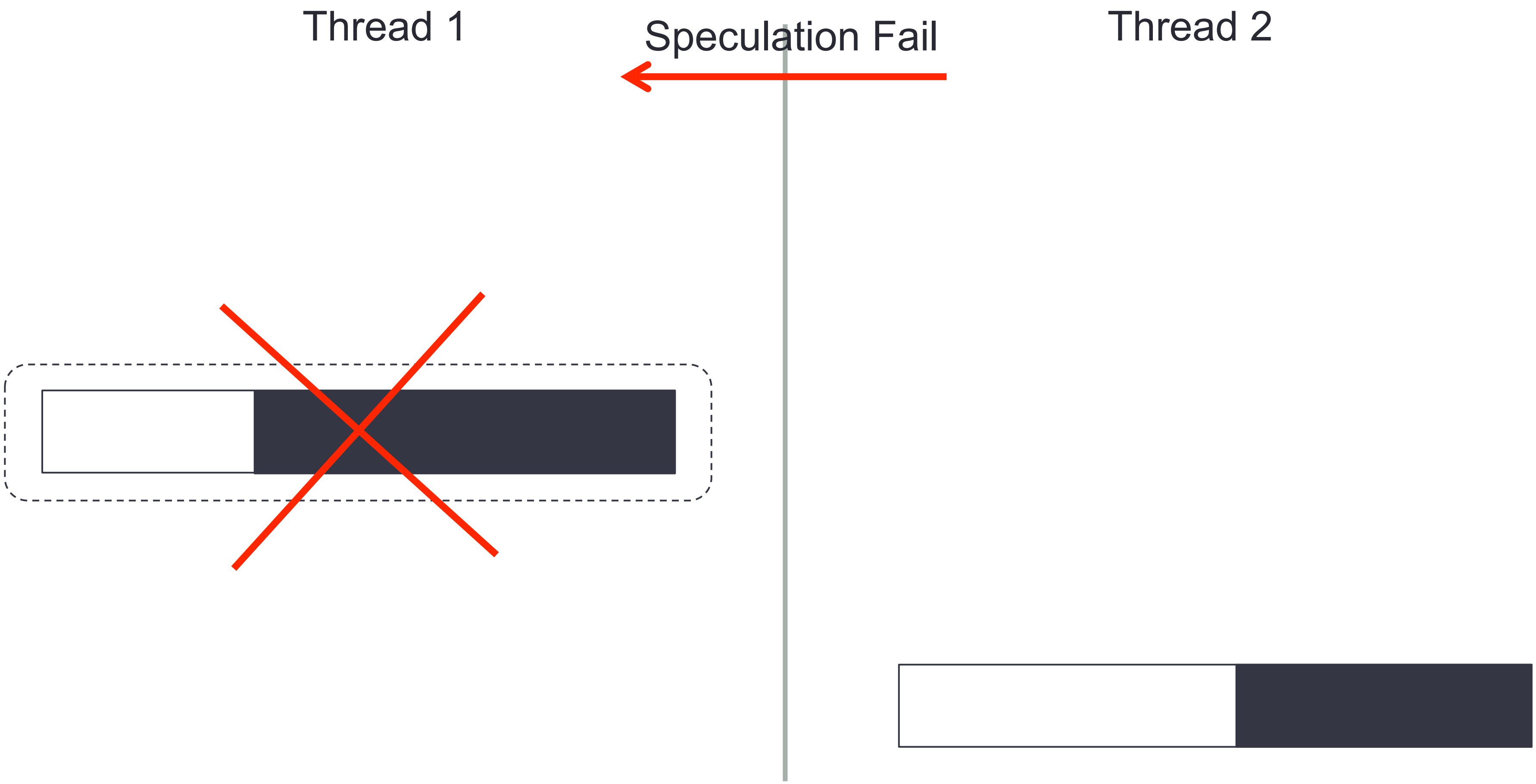
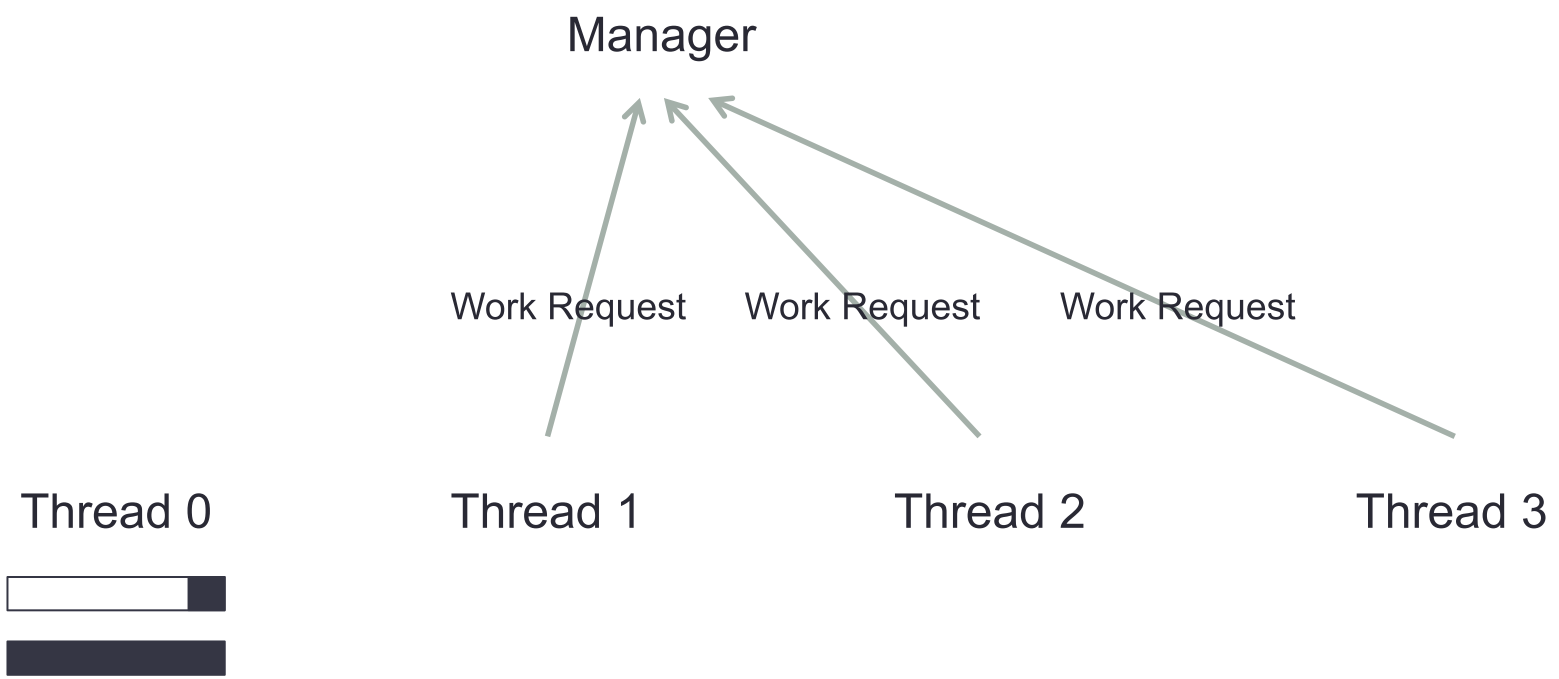


Work Sharing Algorithm



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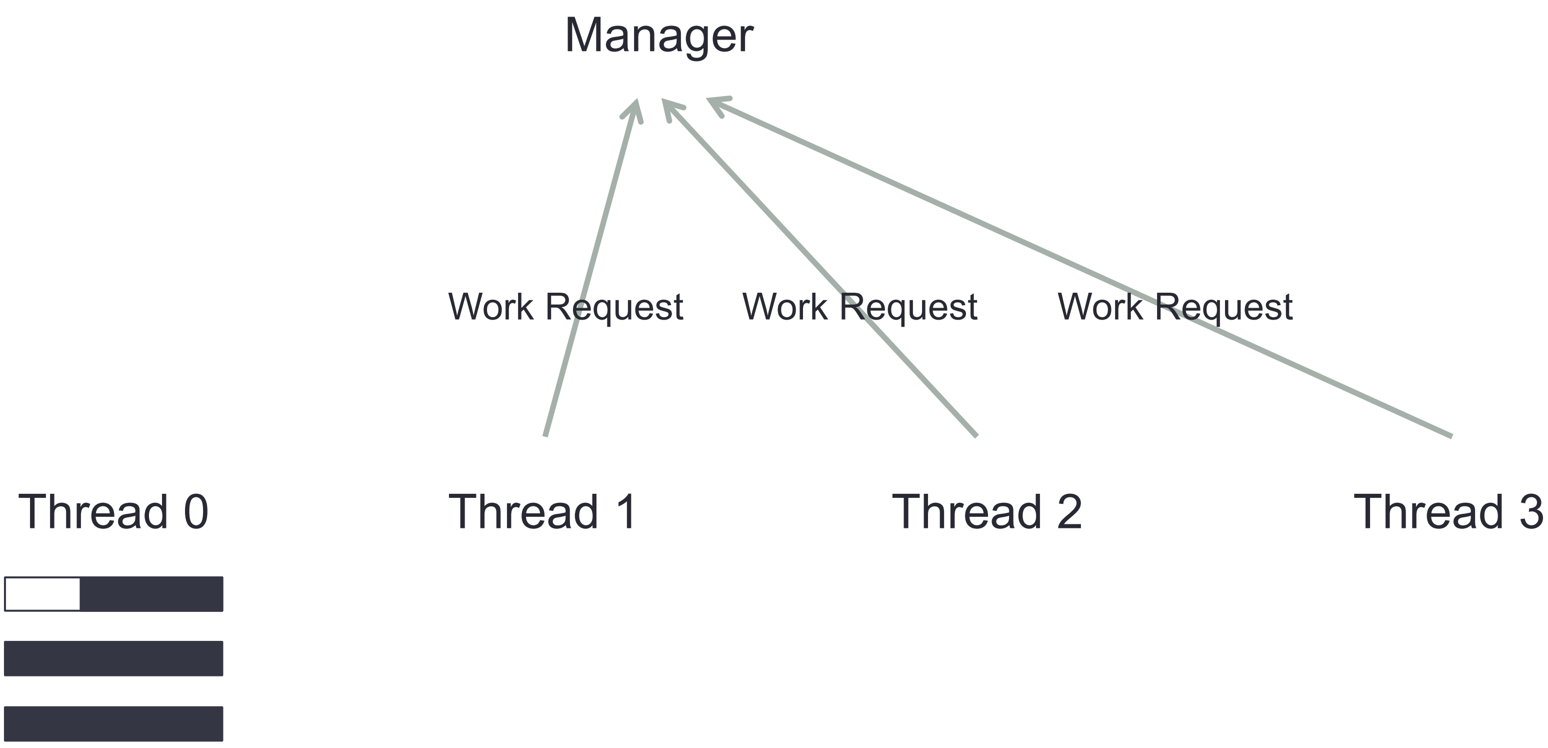

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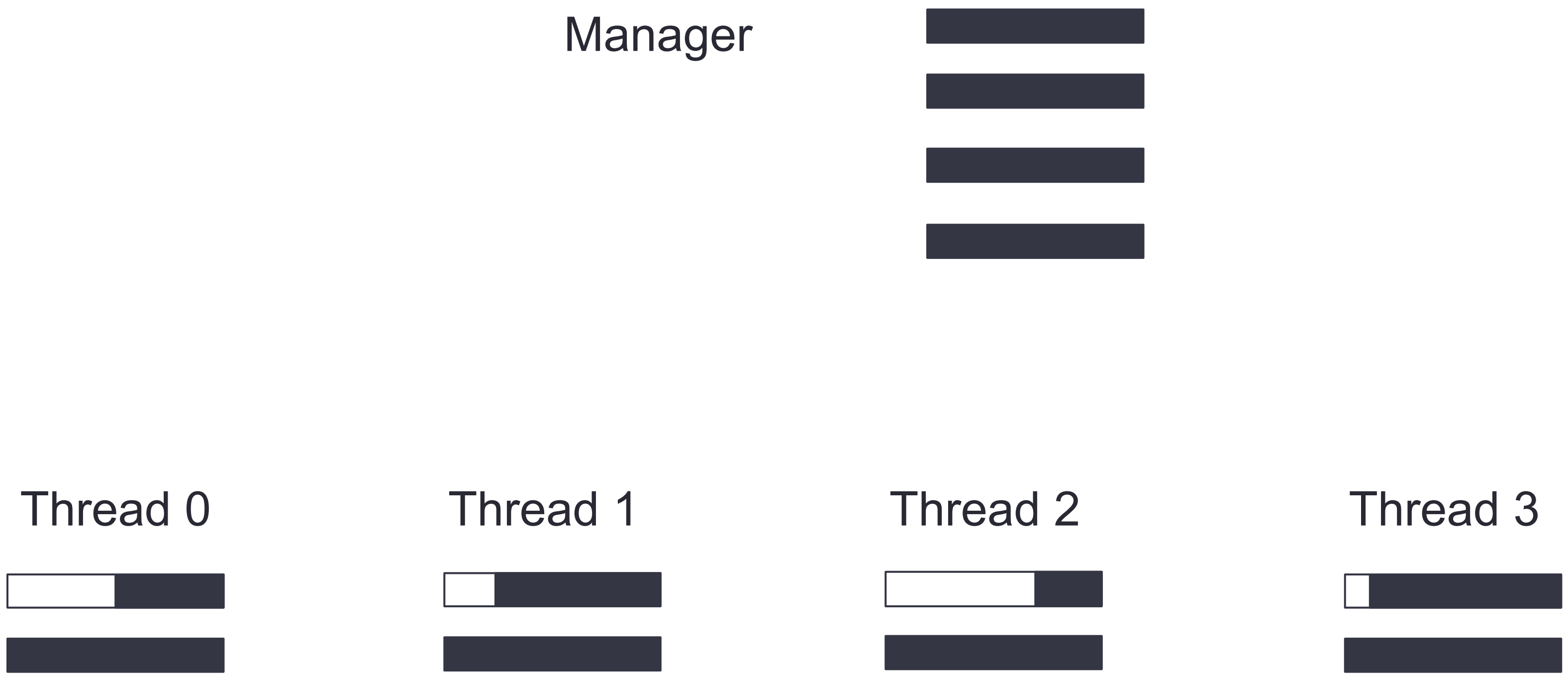
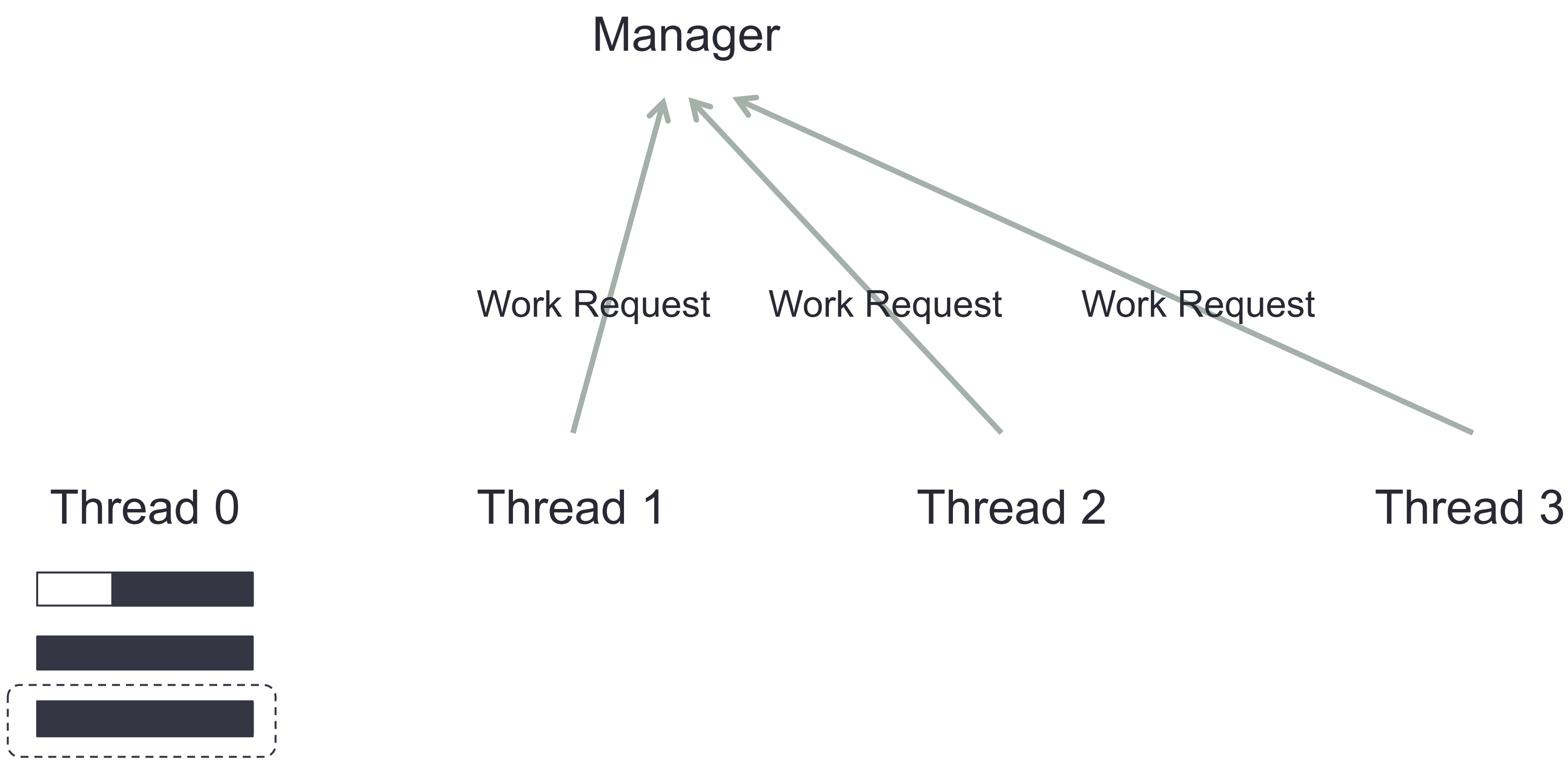


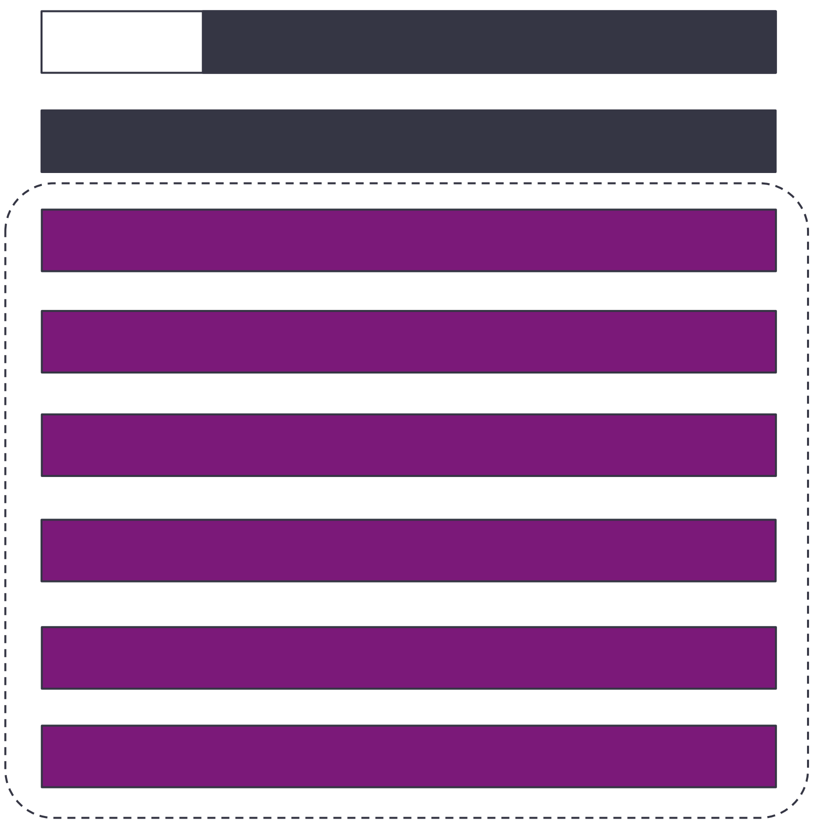
Speculative Work Sharing Algorithm



Speculative Work Sharing Algorithm

Some Worker Thread

Manager Thread



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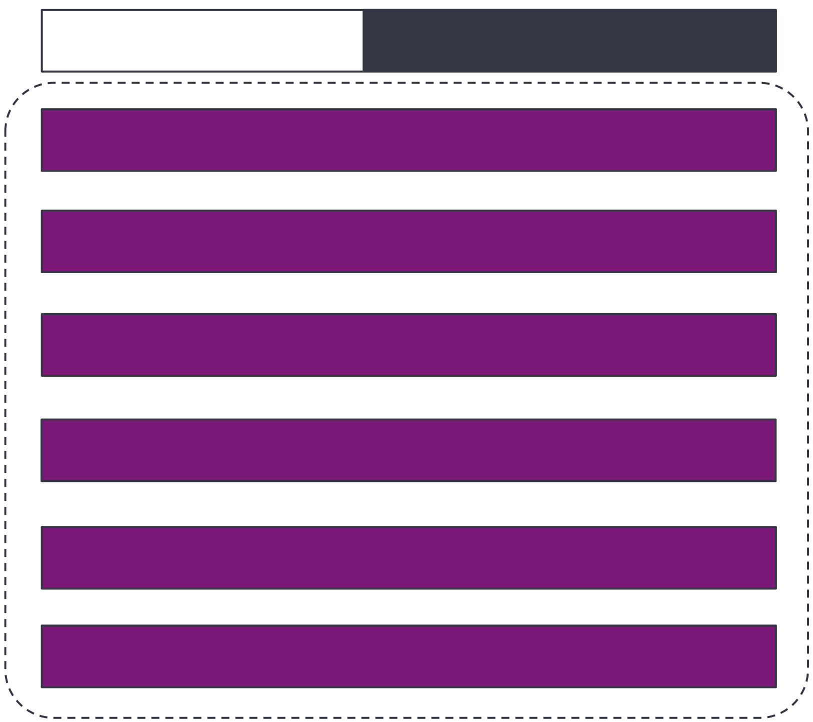

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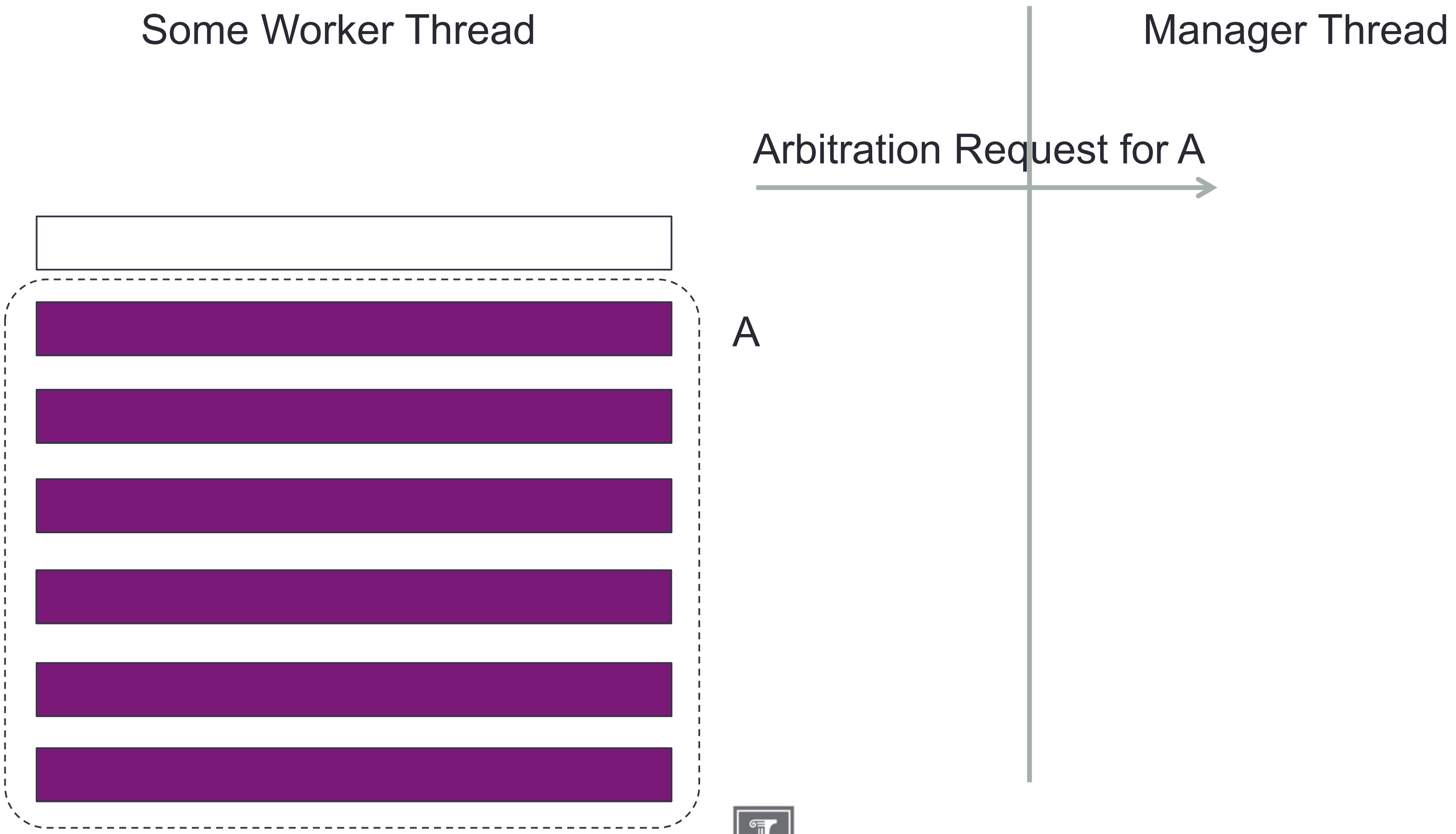

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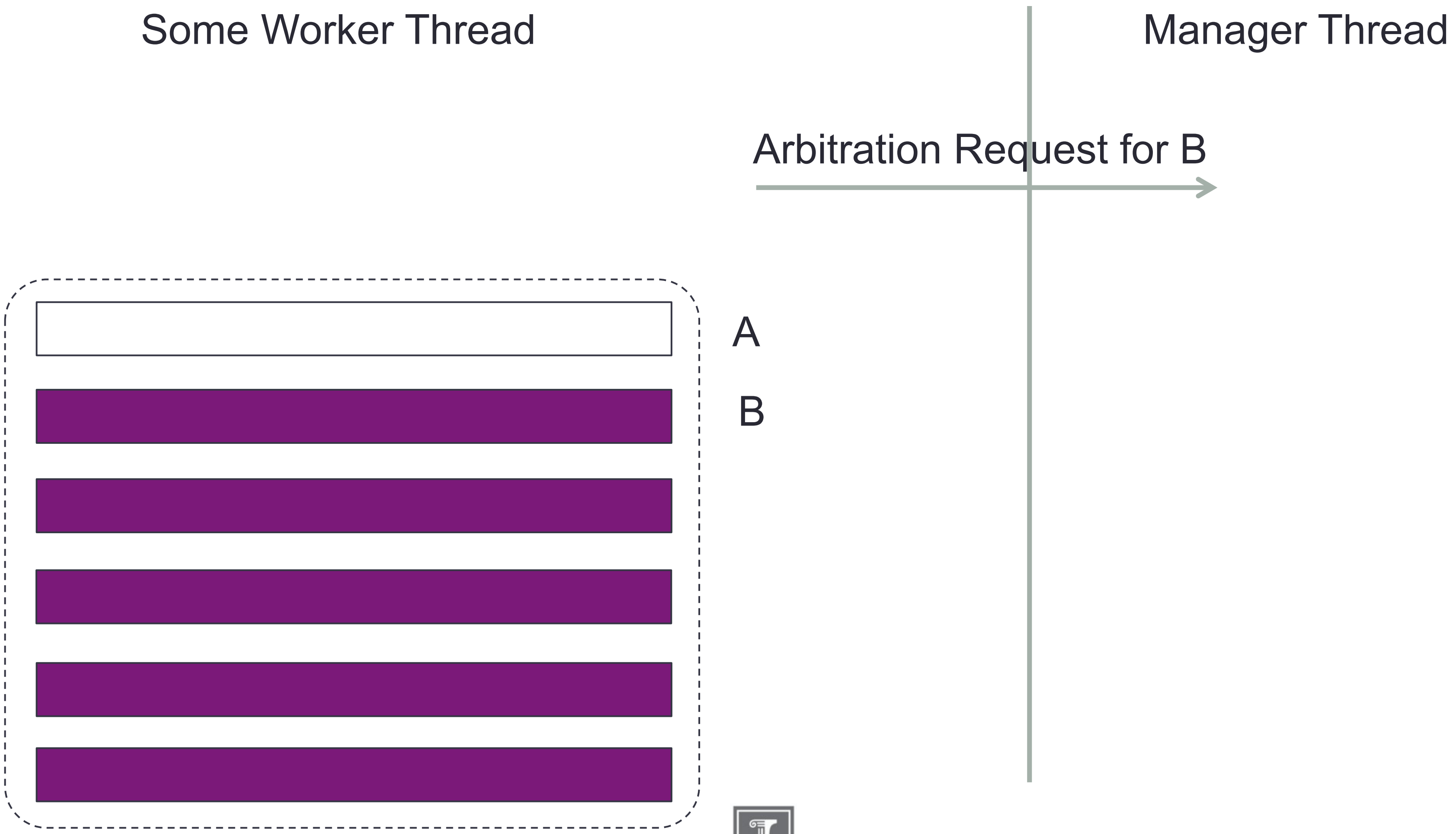

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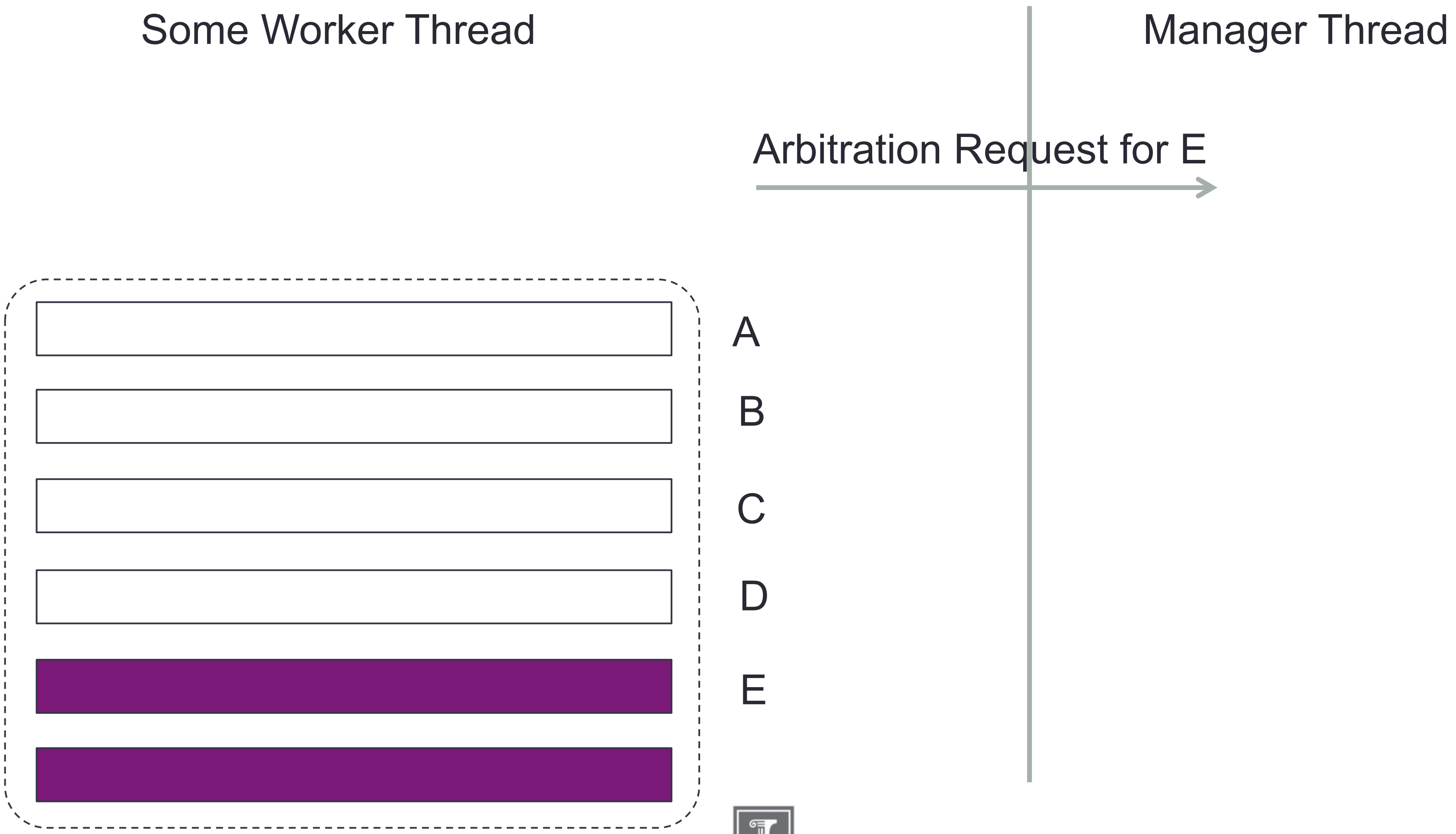

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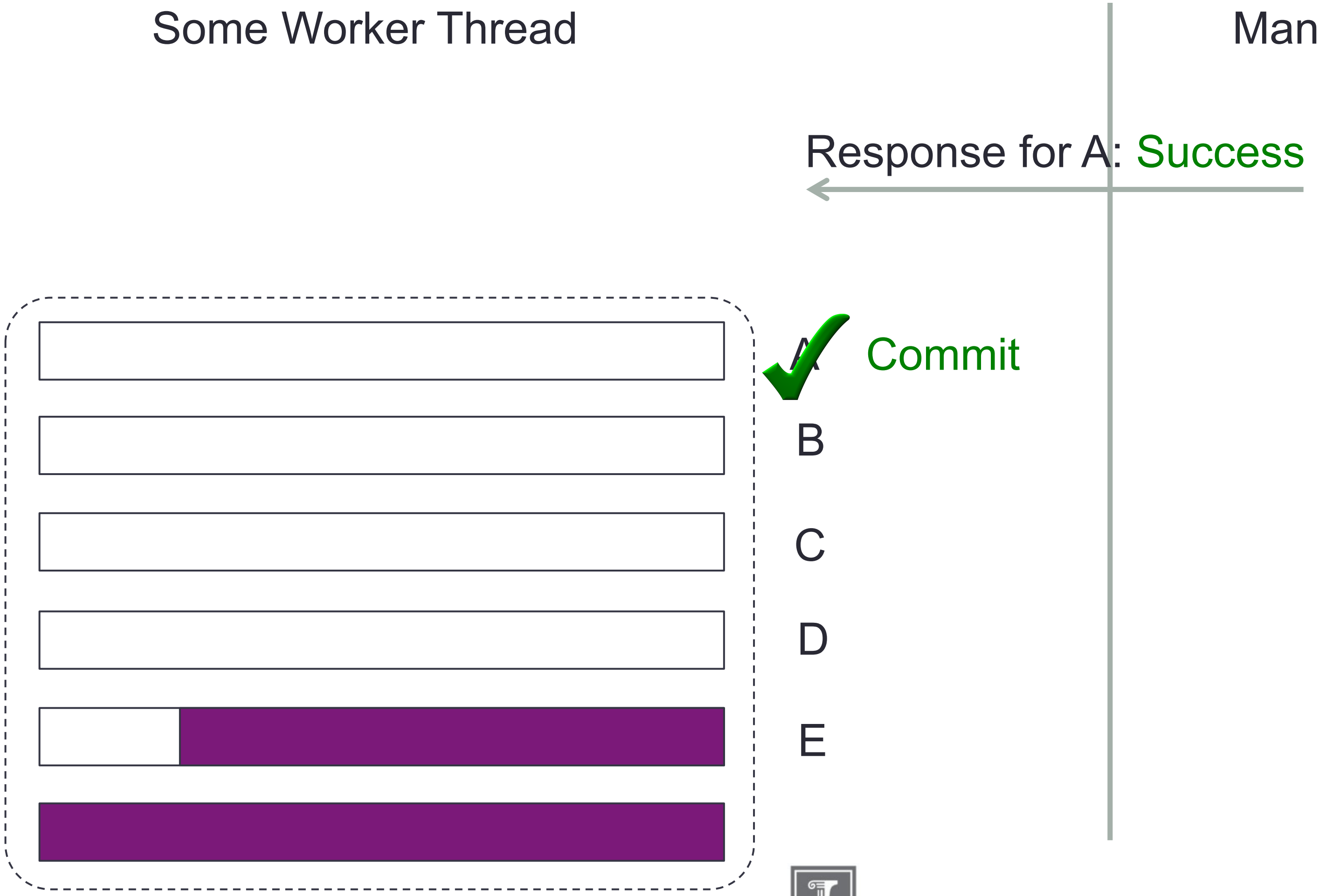

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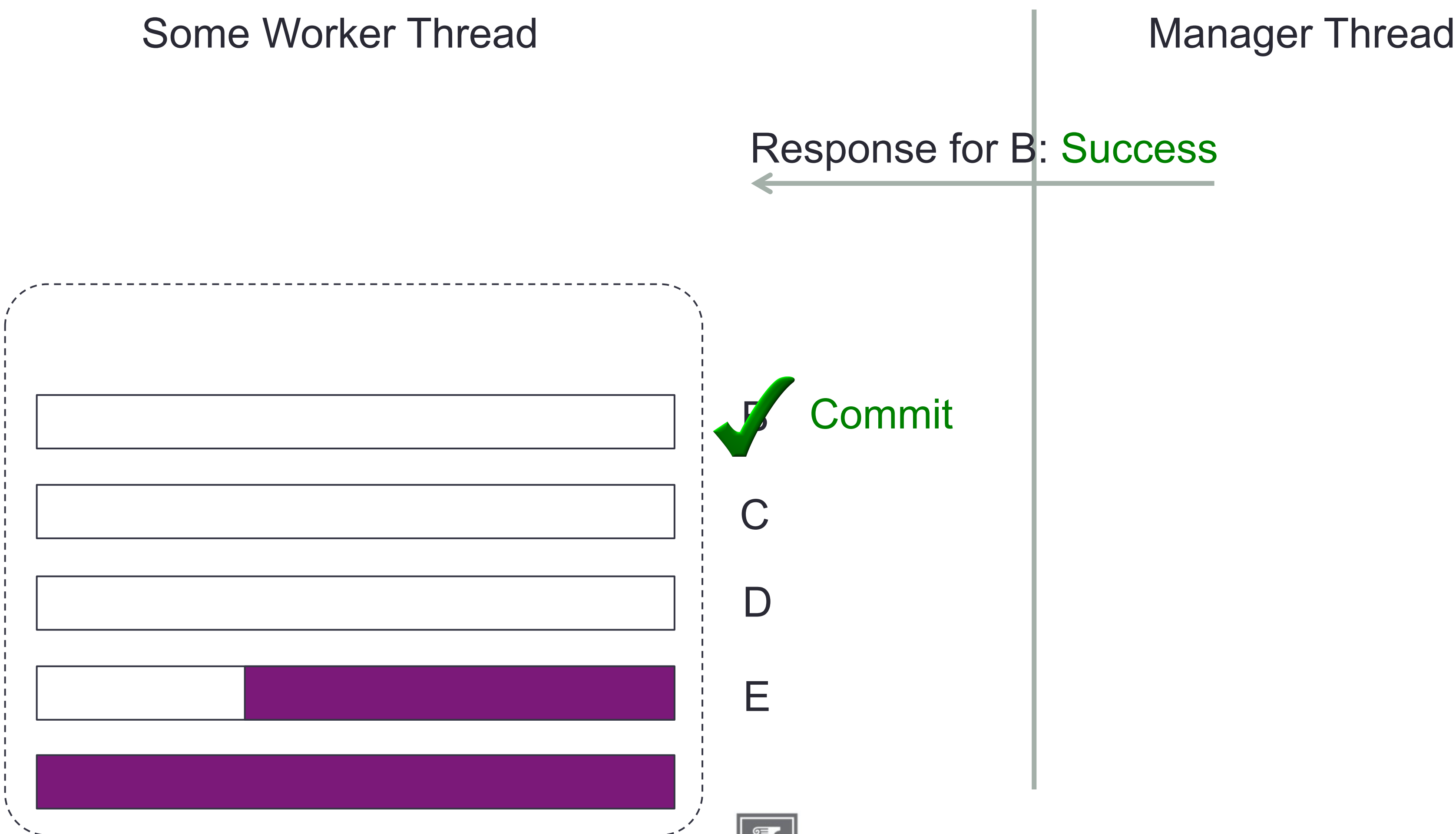

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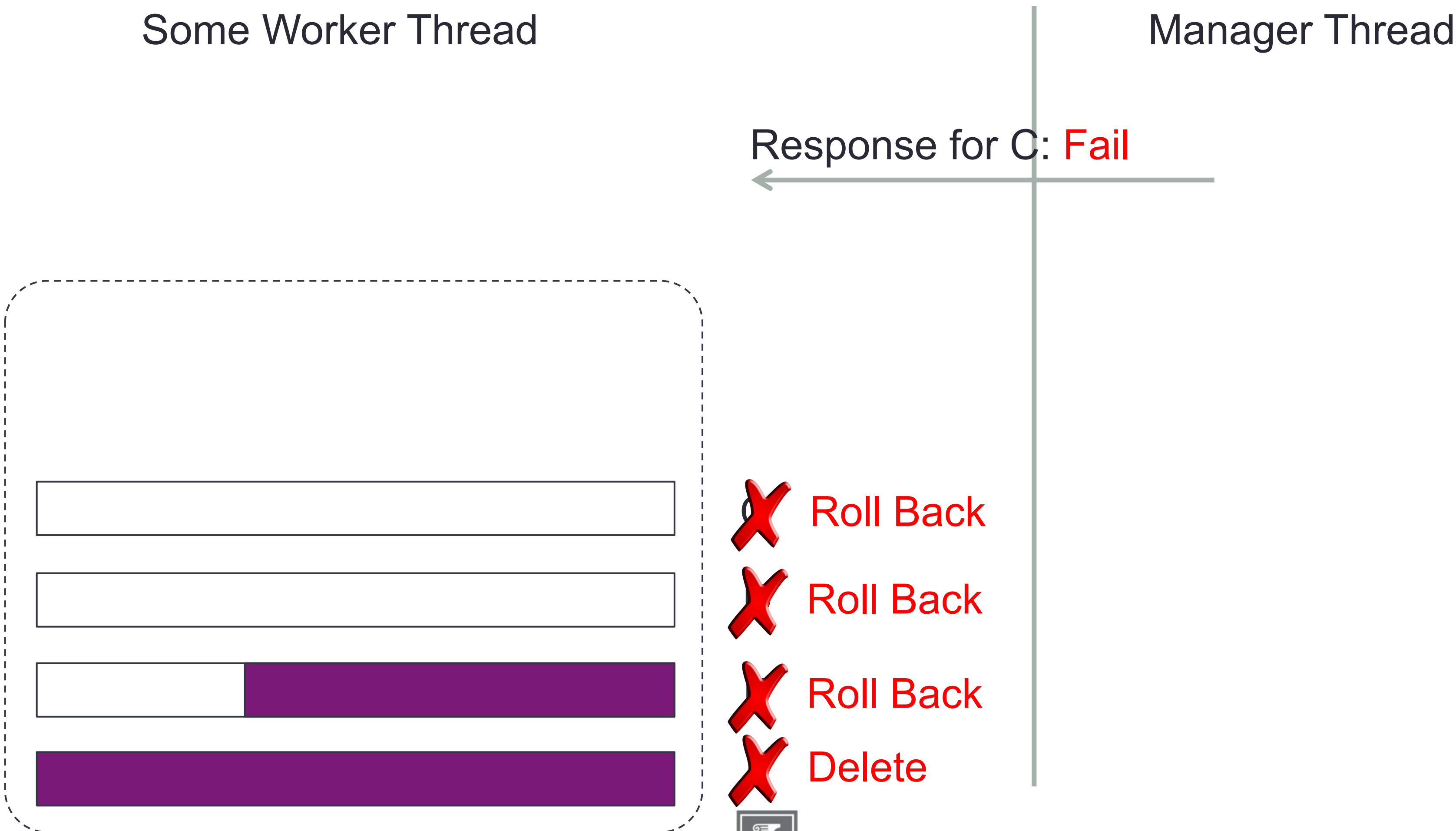

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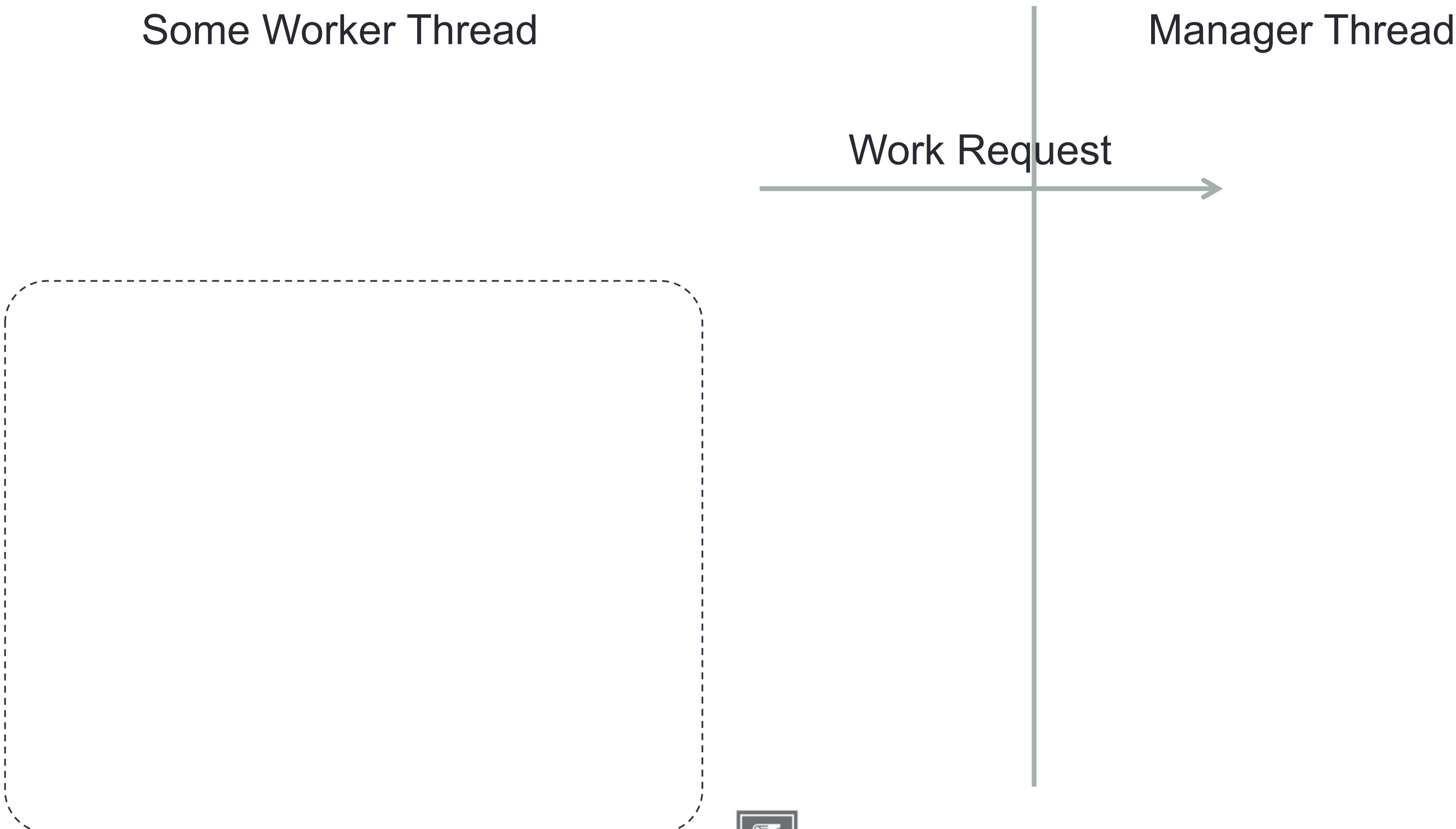


Unbalanced Tree Search (UTS)

- Counting nodes in randomly generated tree
- Tree generation is based on separable cryptographic random number generator

```
childCount = f(nodeId)
childId = SHA1(nodeId, childIndex)
```

- Different types of trees
  - Binomial (probability q, # of child m)
  - Geometric (depth limit d, branching factor is geometric distribution with mean b)

Work Sharing in UTS

- A *node* in tree is a unit of work
- A *chunk* is a set of nodes, and minimum transferrable unit
- *Release interval* is the frequency with which a worker releases a *chunk* to the manager

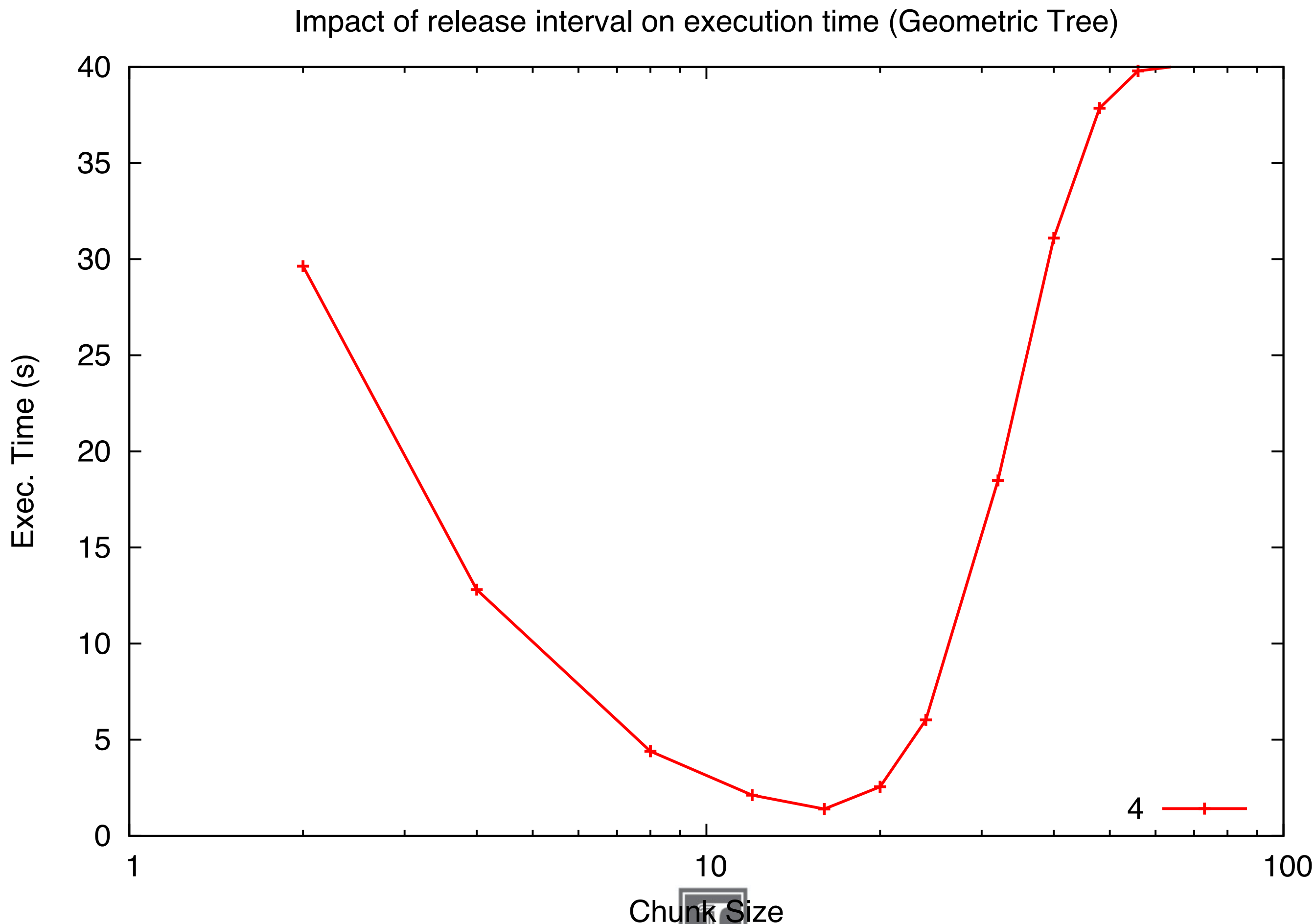
```
If (HasSurplusWork() and
    NodesProcessed % release_inerval == 0)
{
     ReleaseWork()
}
```

Experimental Setup and Inputs

- Illinois Campus Cluster
  - Cluster of HP ProLiant Servers
  - 2 Intel X5650 2.66Ghz 6Core Processors per Node
  - High Speed Infiniband Cluster Interconnect

	Binomial (10^9 Nodes)	Geometry (10^9 Nodes)
Small	0.111	0.102
Medium	2.79	1.64
Large	10.6	4.23

Tuning of Original Algorithm – Small Input (on 4 nodes, 12 cores each)



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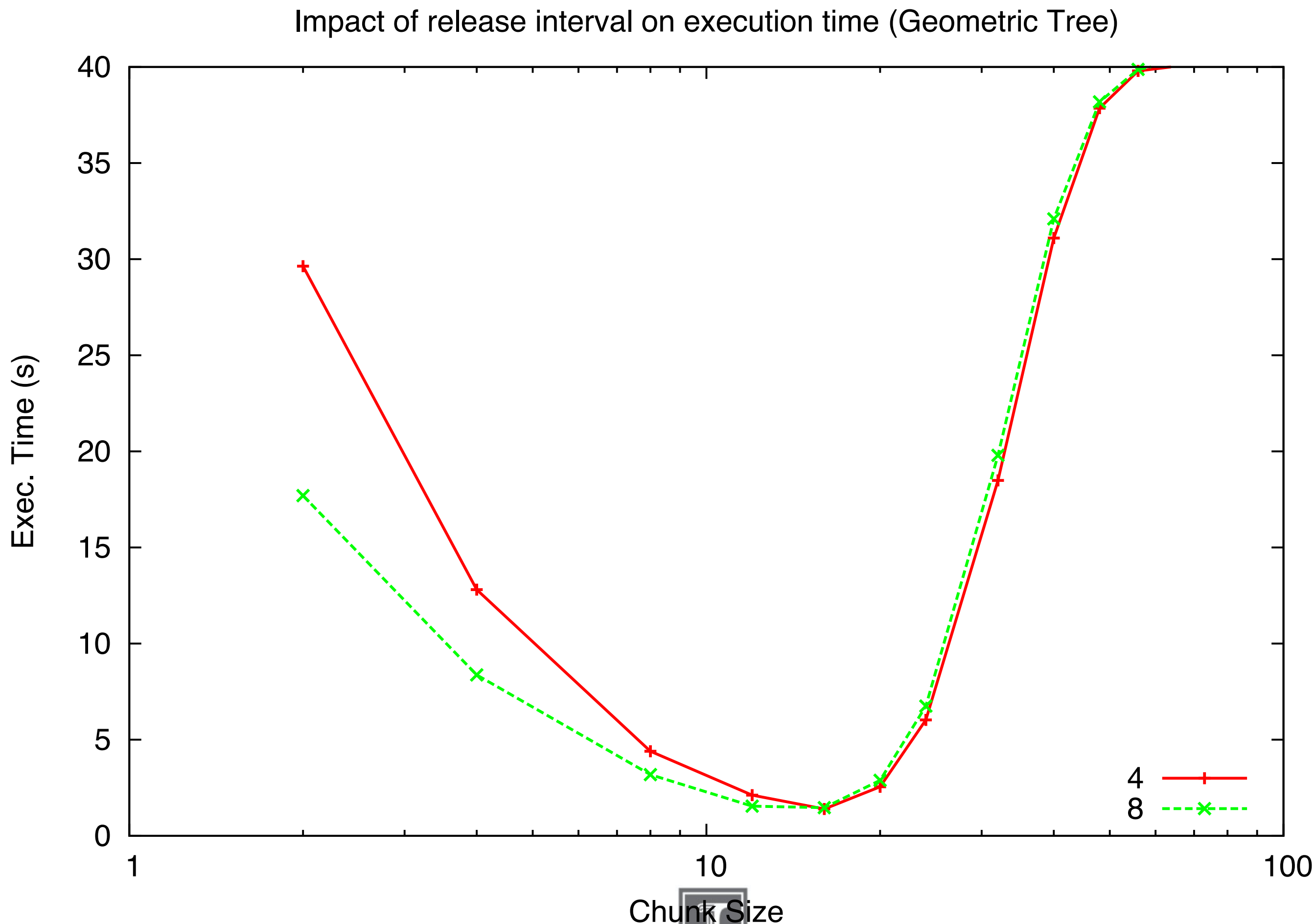

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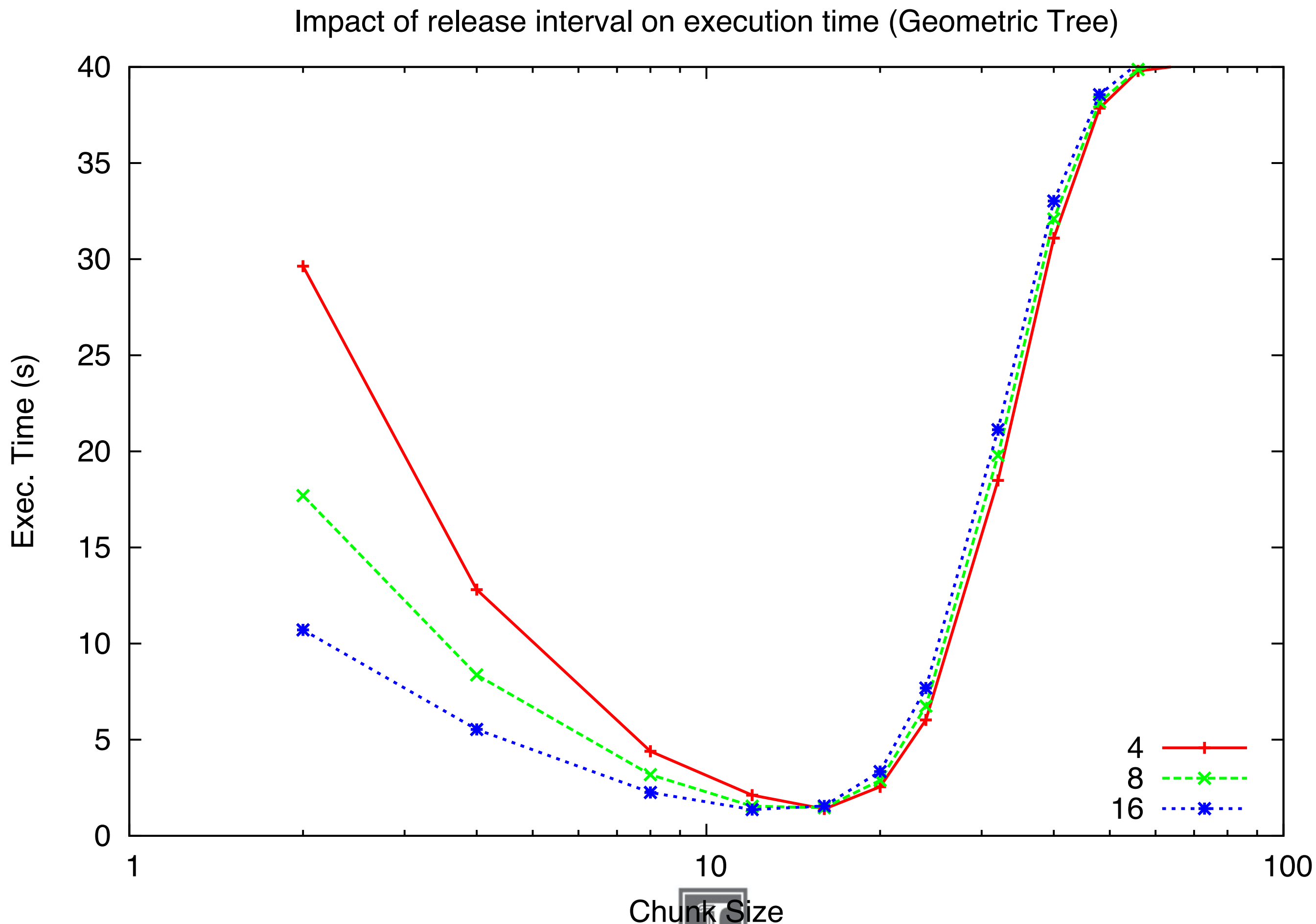

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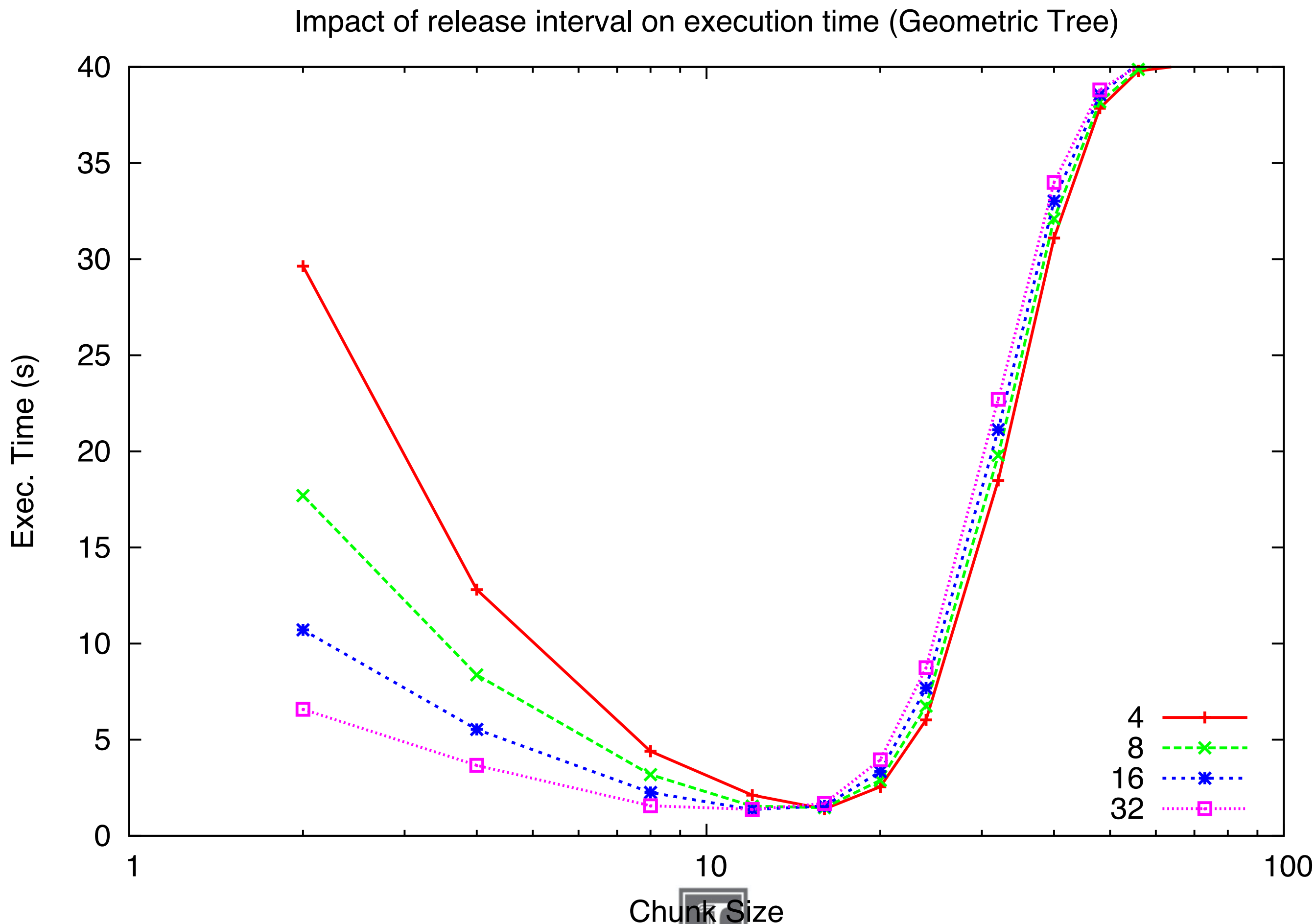

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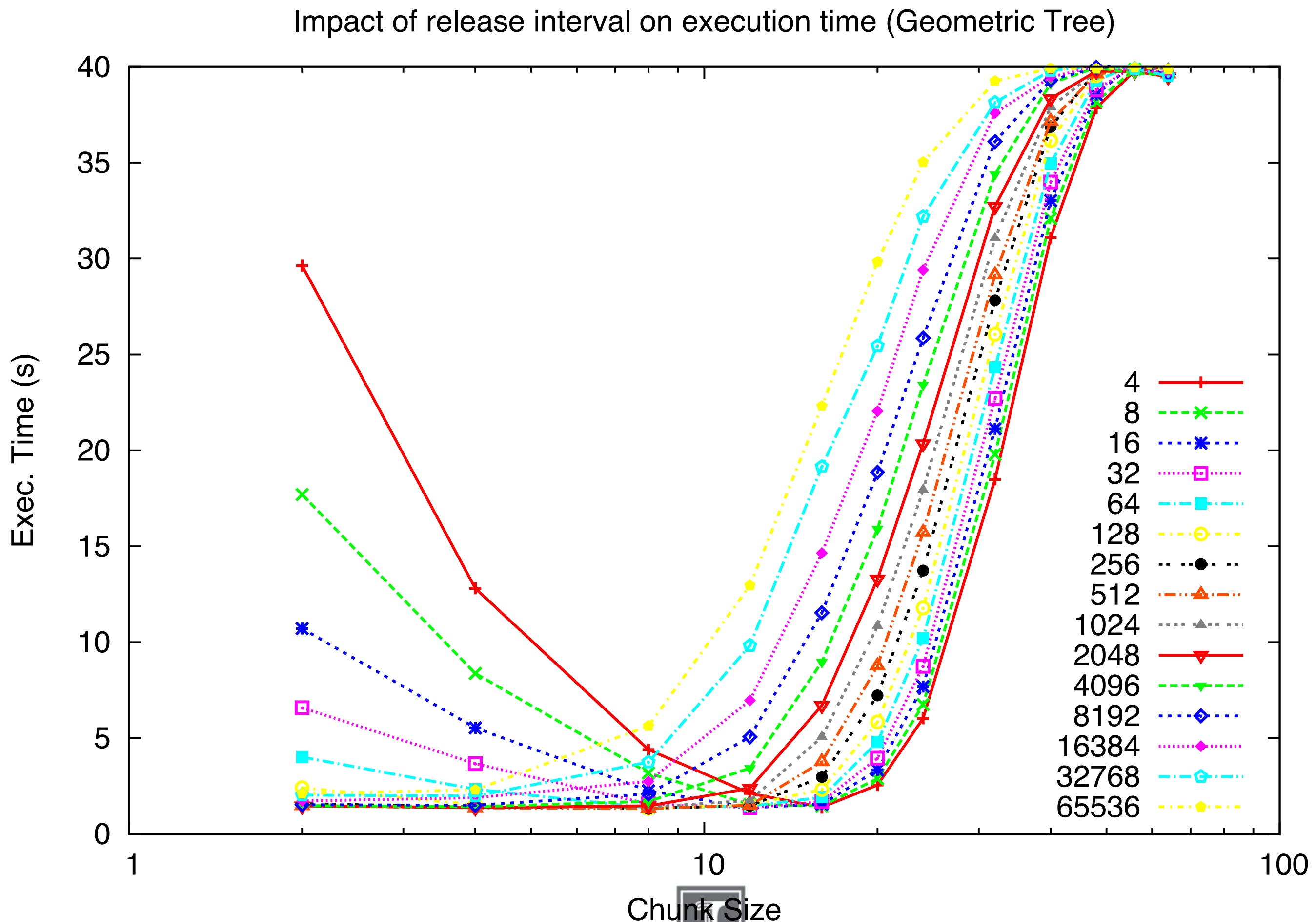
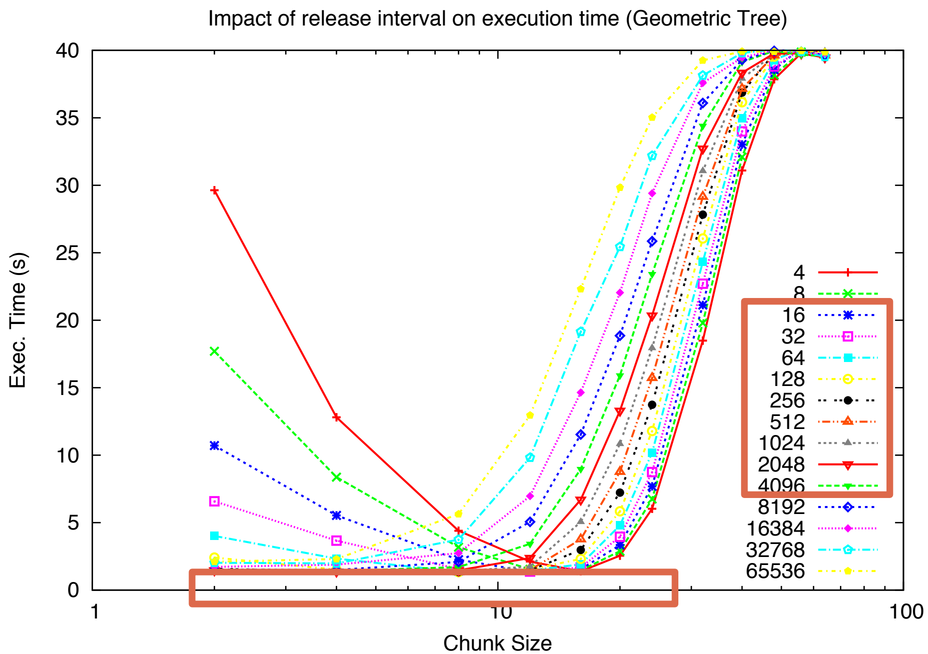
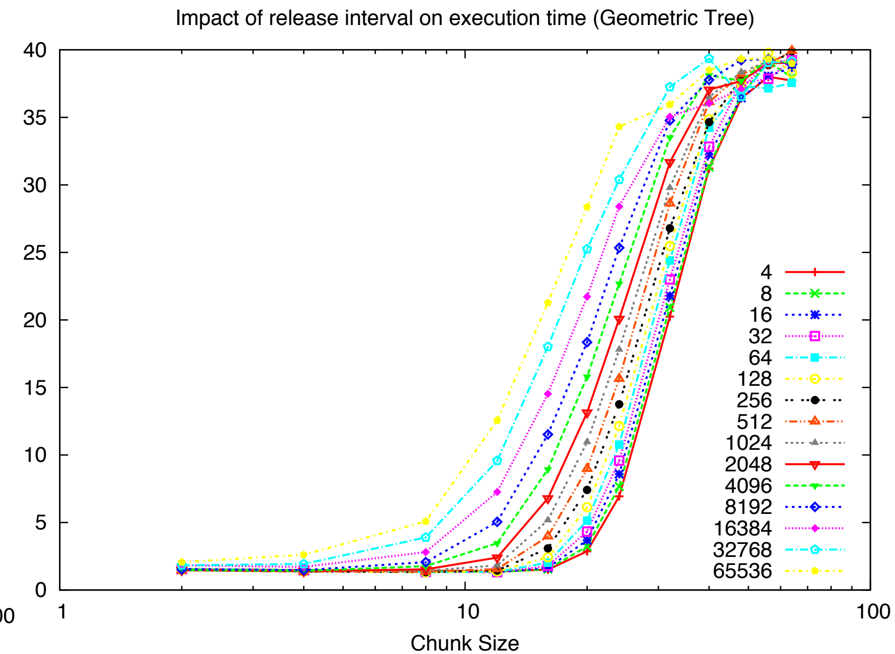


Original vs. Speculative Algorithm – Small Input (on 4 nodes, 12 cores each)

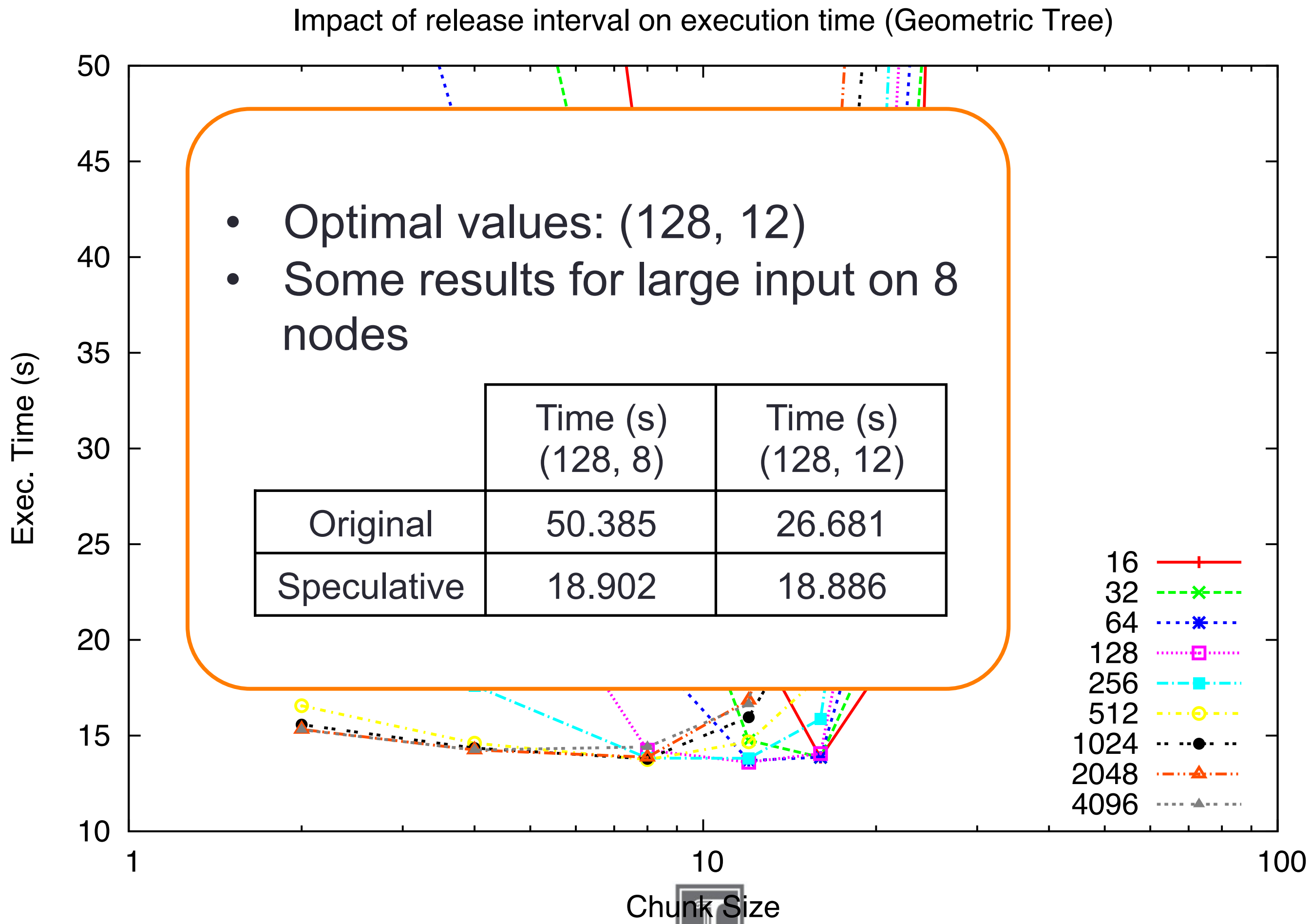
Original



Speculative



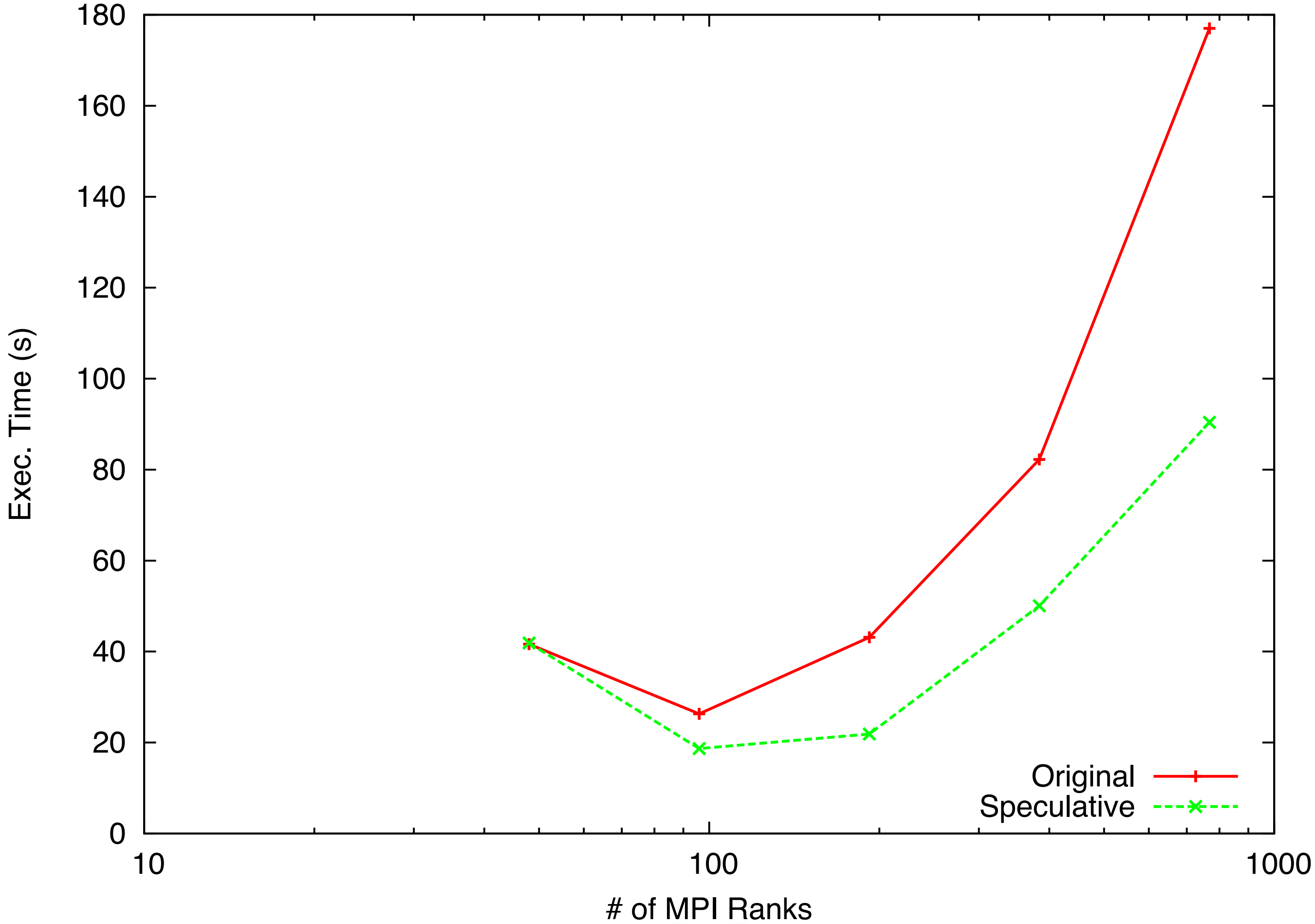
Tuning of Original Algorithm – Medium Input (on 4 nodes, 12 cores each)



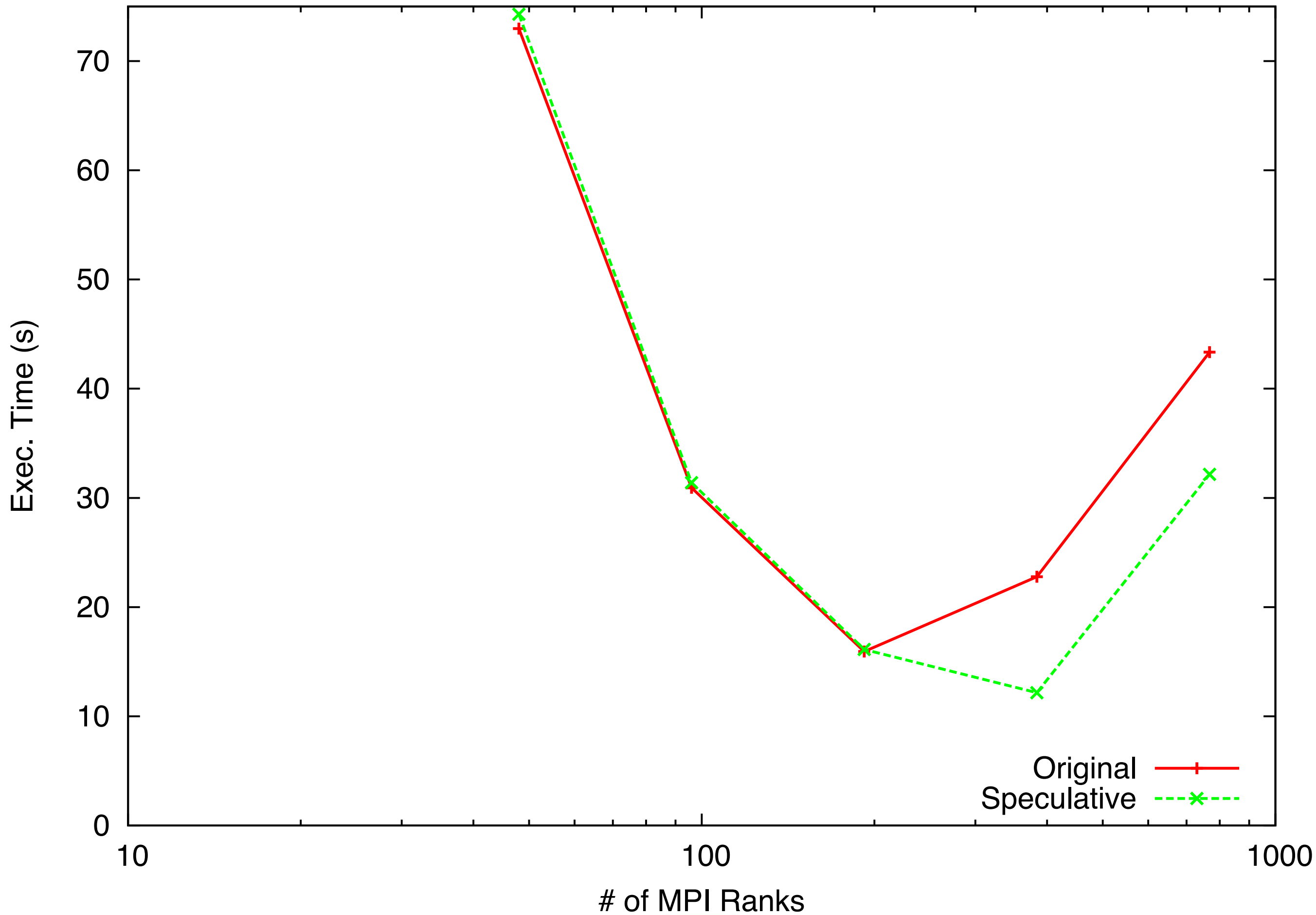
- Optimal values: (128, 12)
- Some results for large input on 8 nodes

	Time (s) (128, 8)	Time (s) (128, 12)
Original	50.385	26.681
Speculative	18.902	18.886

Scalability Study – Geometric Tree



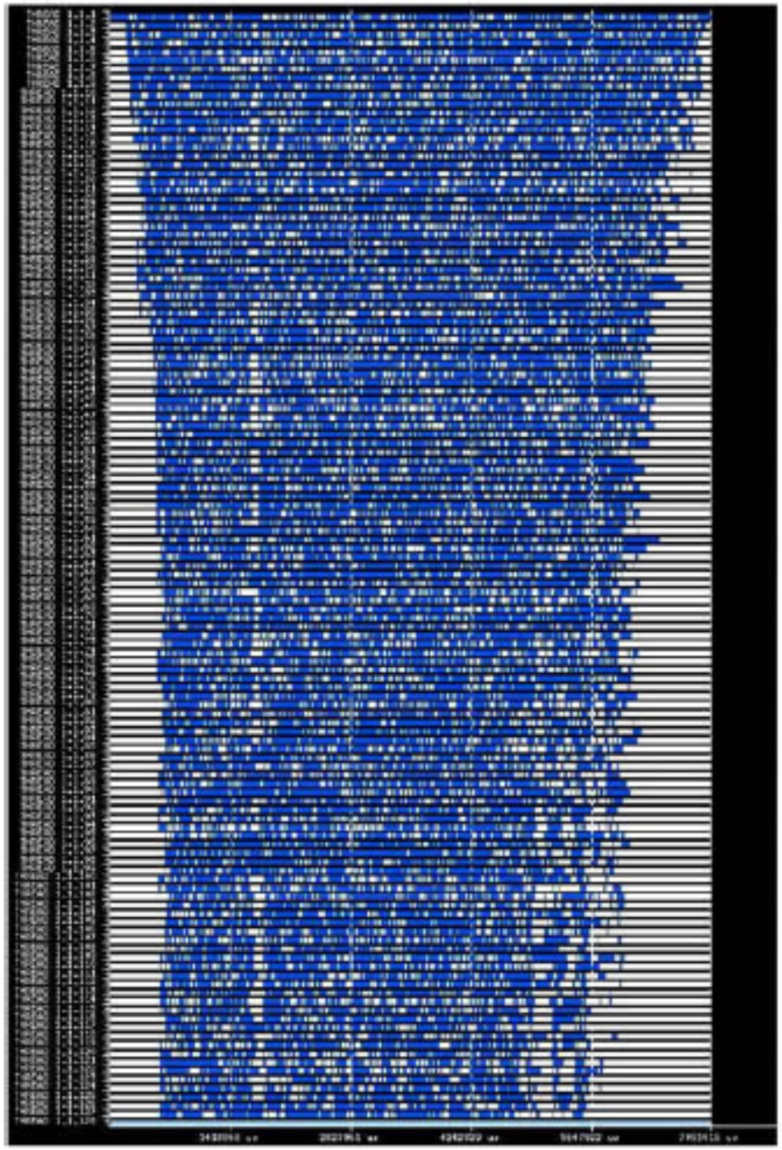
Scalability Study – Binomial Tree

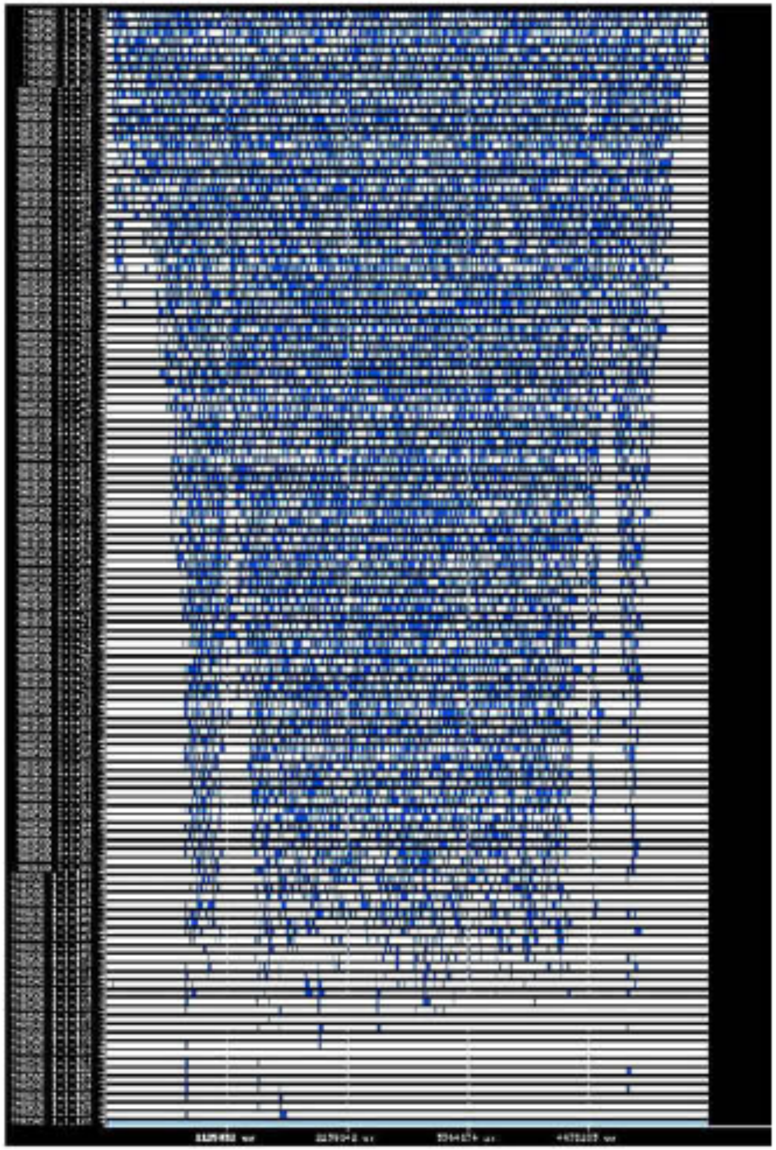


Conclusion

- Speculation
  - Is a **light-weight technique** in load-balancing algorithms
  - Is a potential solution to **eliminate idle time**
  - **Reduces sensitivity** of a load-balancing algorithm to parameters
  - Helps to **reduce tuning efforts**
  - Exhibits a **higher scalability**

Back Up Slides





Design Guidelines

- The time it takes to process a speculative task is far less than the time it takes to get response of an arbitration
  - A worker may need multiple speculative tasks at a time
- Low overhead algorithm to get speculative task
  - Minimal speculative task transfer (i.e. minimizing speculative task destroy)
- Quality of an speculative task decreases over time
  - Move actual task a worker has, less speculative task it should carry
- Quality of an speculative task increases as it goes deeper in its owner’s actual queue

Does Speculation Help Work Stealing?

- Base-line algorithm + speculative algorithm guidelines = speculative work stealing (Algorithm A)
- Speculative work stealing + replacing speculative messages with prefetching = optimized prefetch-based work stealing (Algorithm B)
- “A” has a slight performance benefit over “B” (less than 5 percent overall)
  - Reason: Even the base-line does not have too much idle time in UTS
- … But, speculative work stealing is helpful in problems where there is a limited parallelism due to data dependence
  - Example: Depth-first traversal of a graph