University at Buffalo *The State University of New York*

Just-in-Time Data Structures

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What is best in life?

What is best in life?

(for organizing your data)

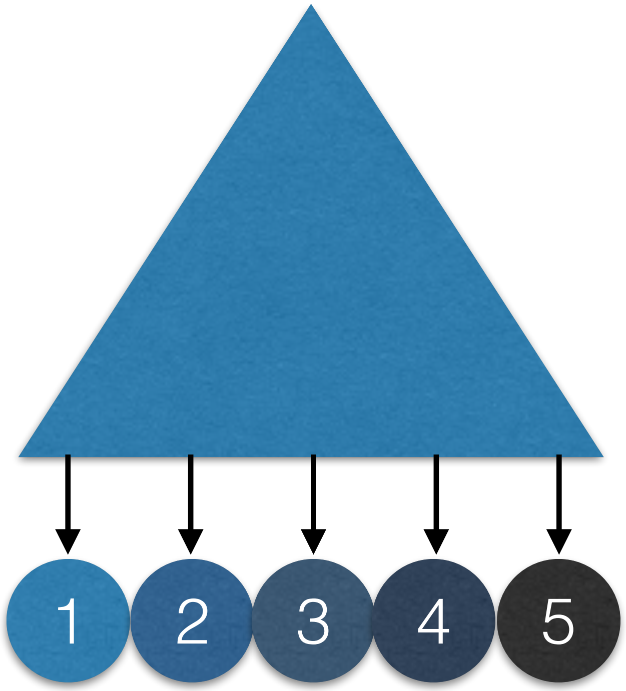
Storing & Organizing Data

API: Insert & Range Scan

Storing & Organizing Data

API: Insert & Range Scan

BTree



Heap

5	1	2	4	3

Sorted Array

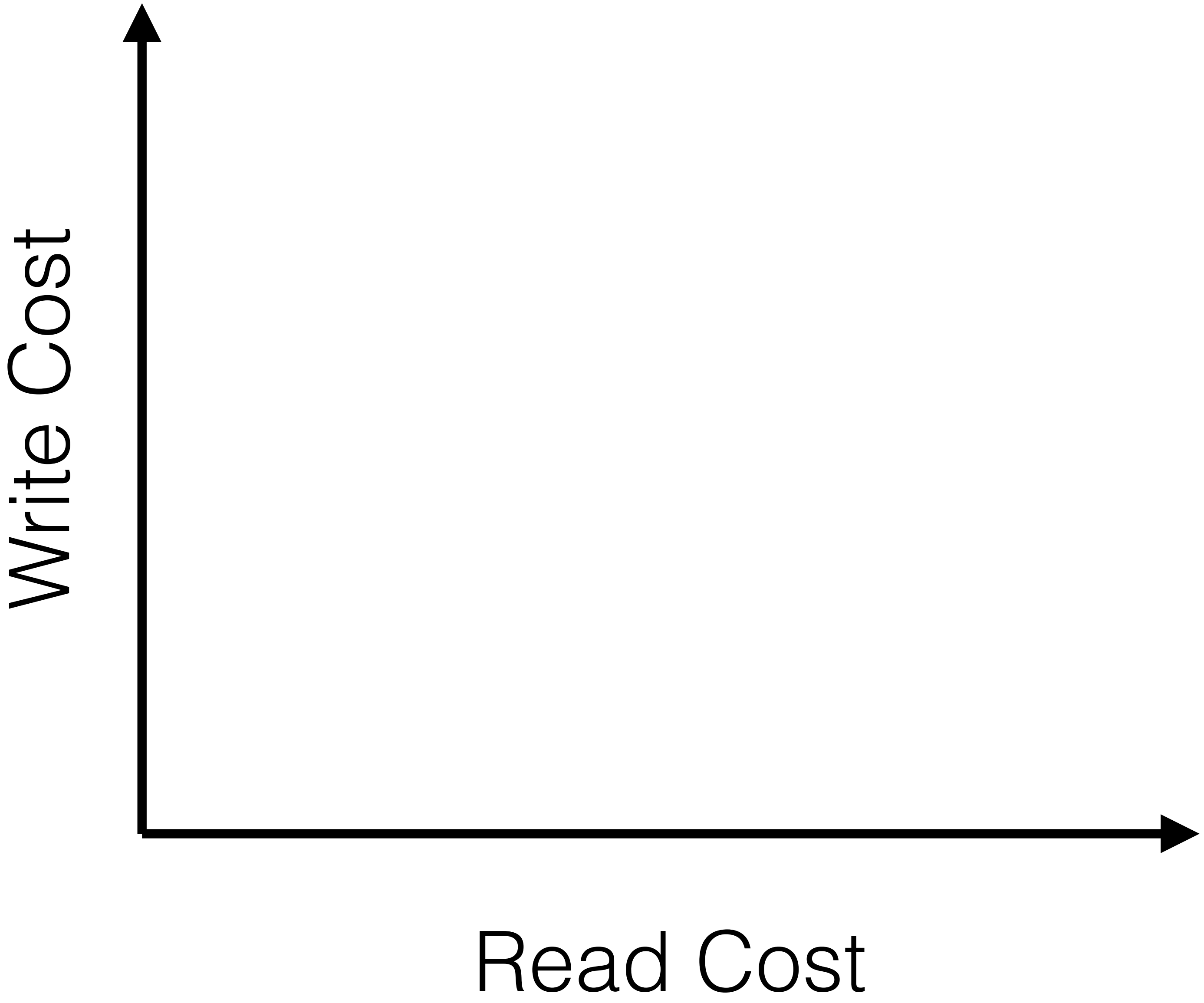
1	2	3	4	5

Which should you use?

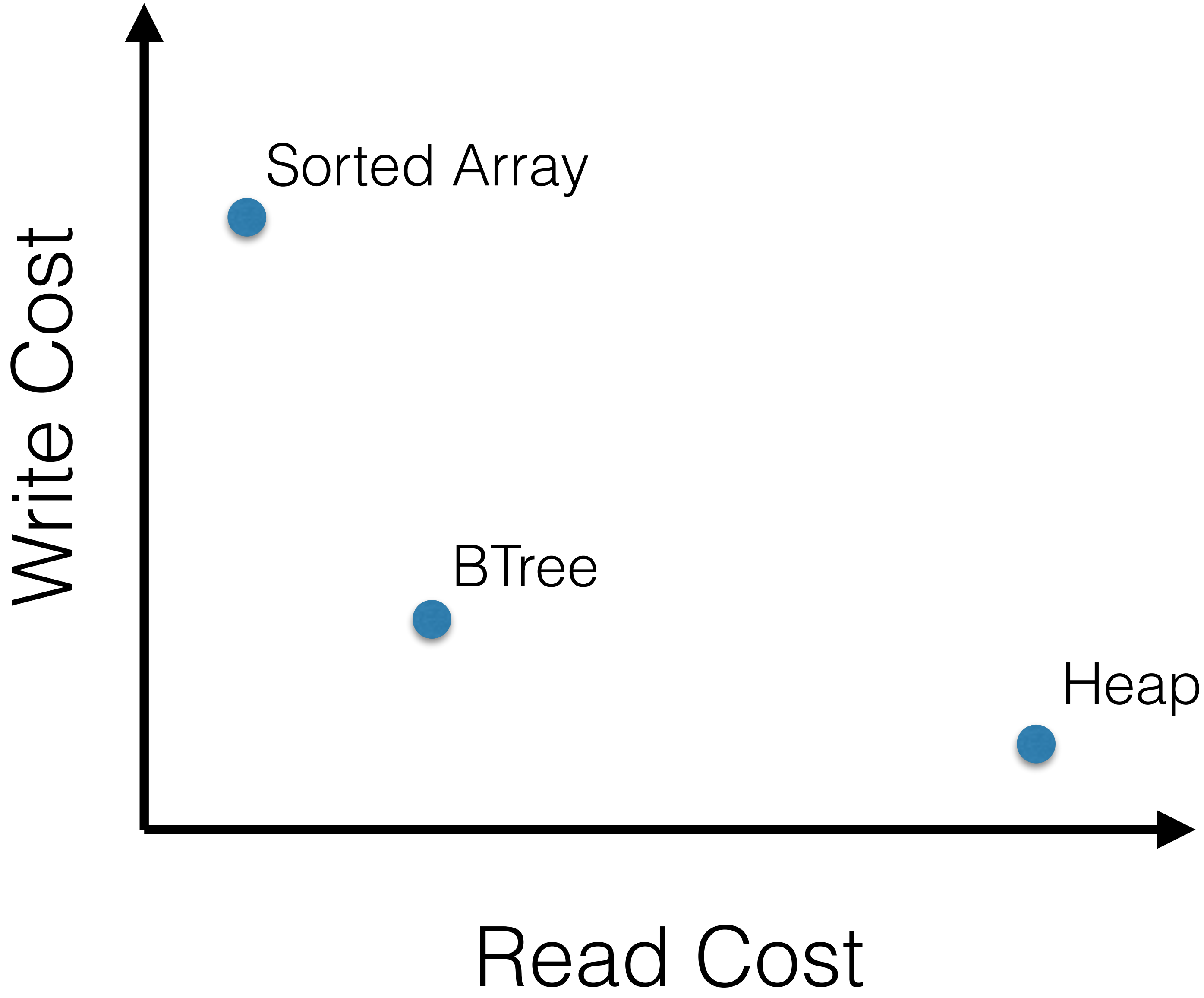
You guessed wrong.

(Unless you asked me what the workload was)

Workloads

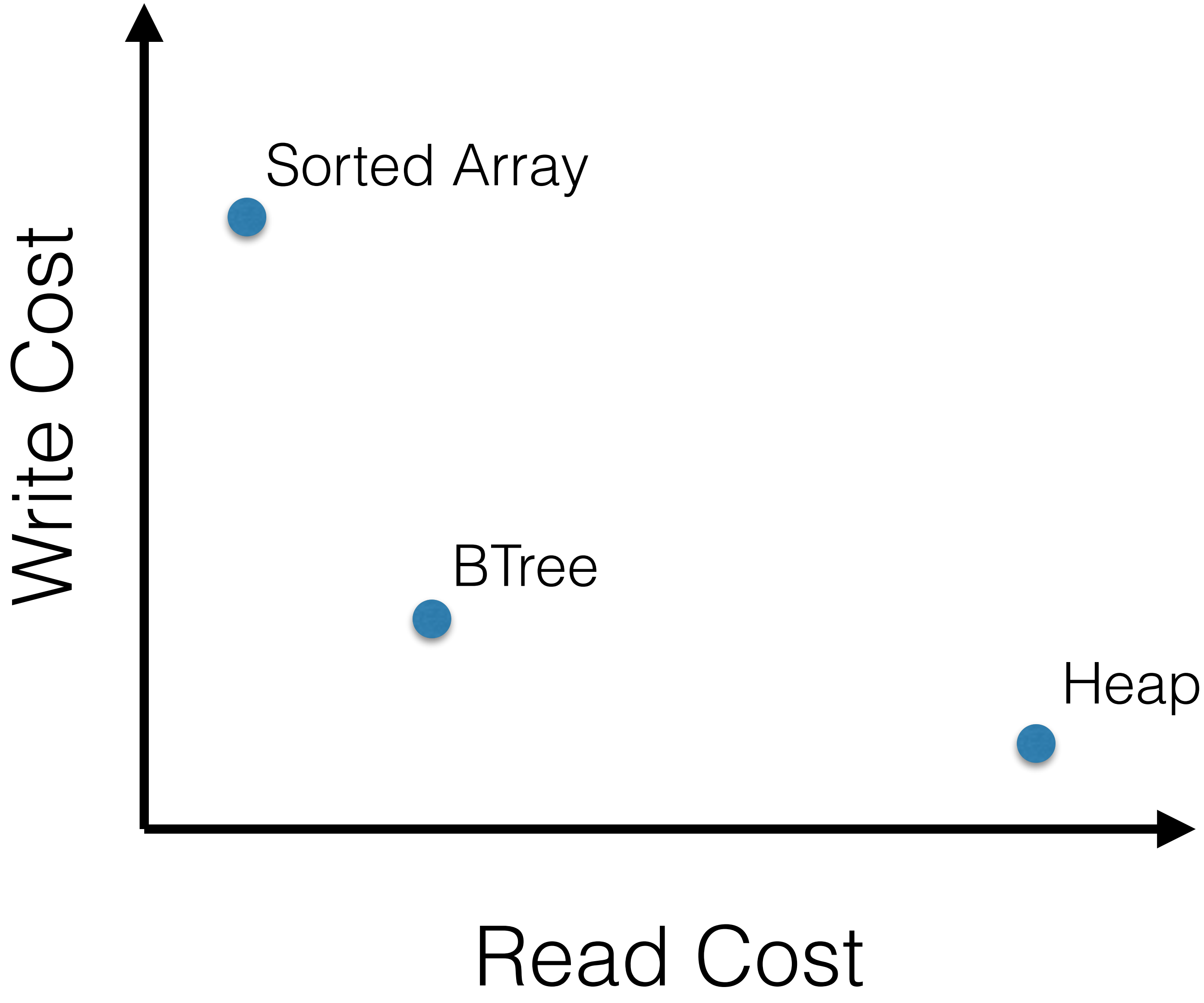


Workloads



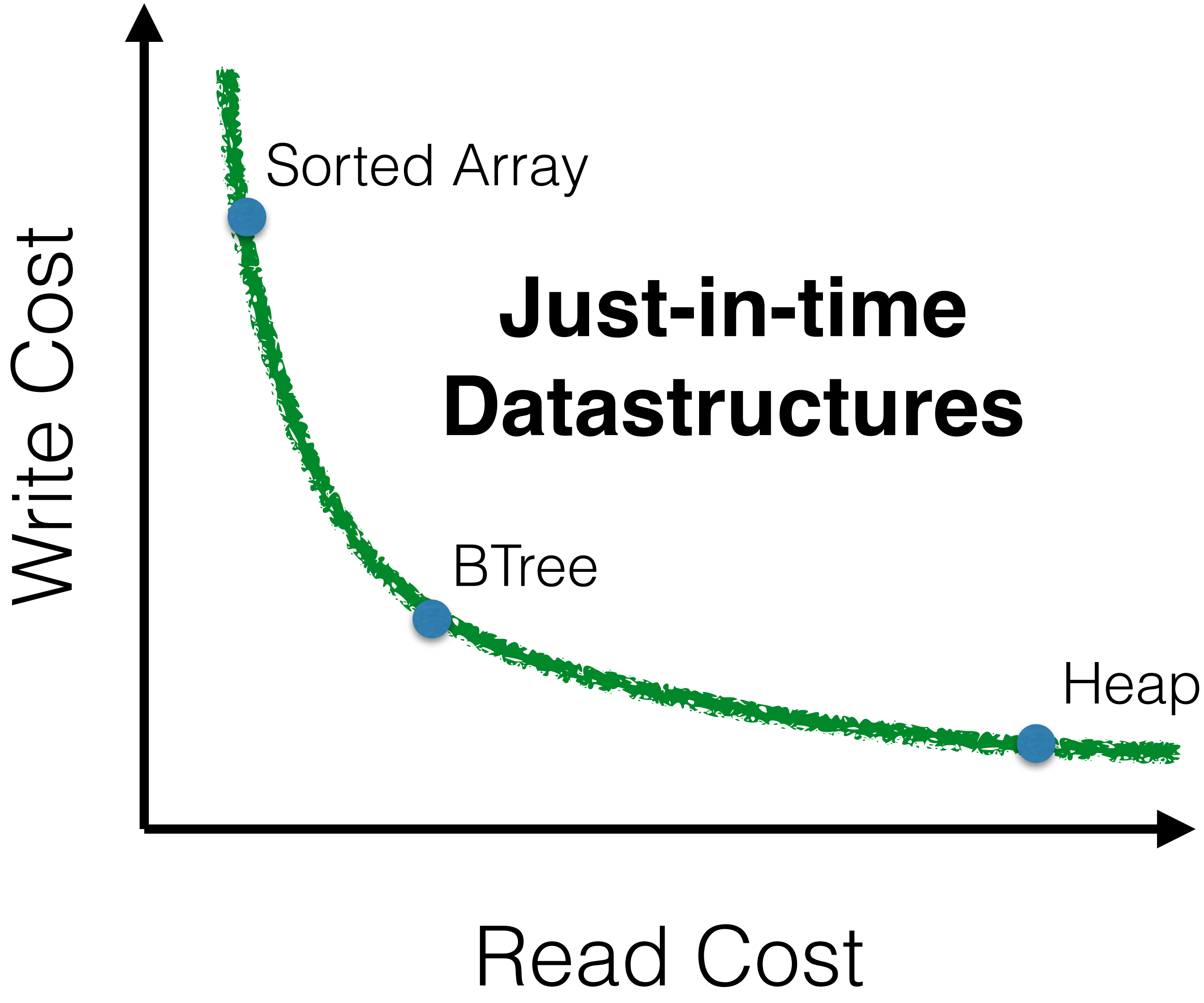
Each data structure makes a fixed set of tradeoffs

Workloads



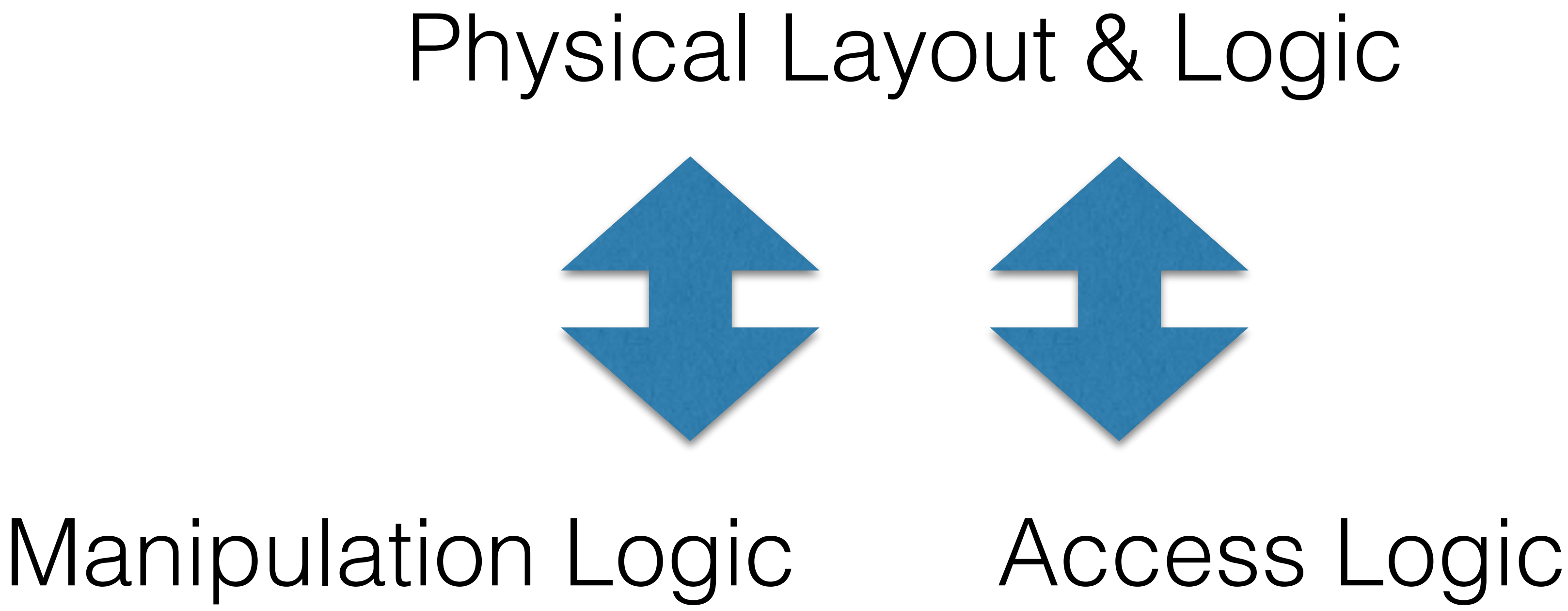
Which structure is best can even change at runtime

Workloads



Which structure is best can even change at runtime

Traditional Data Structures

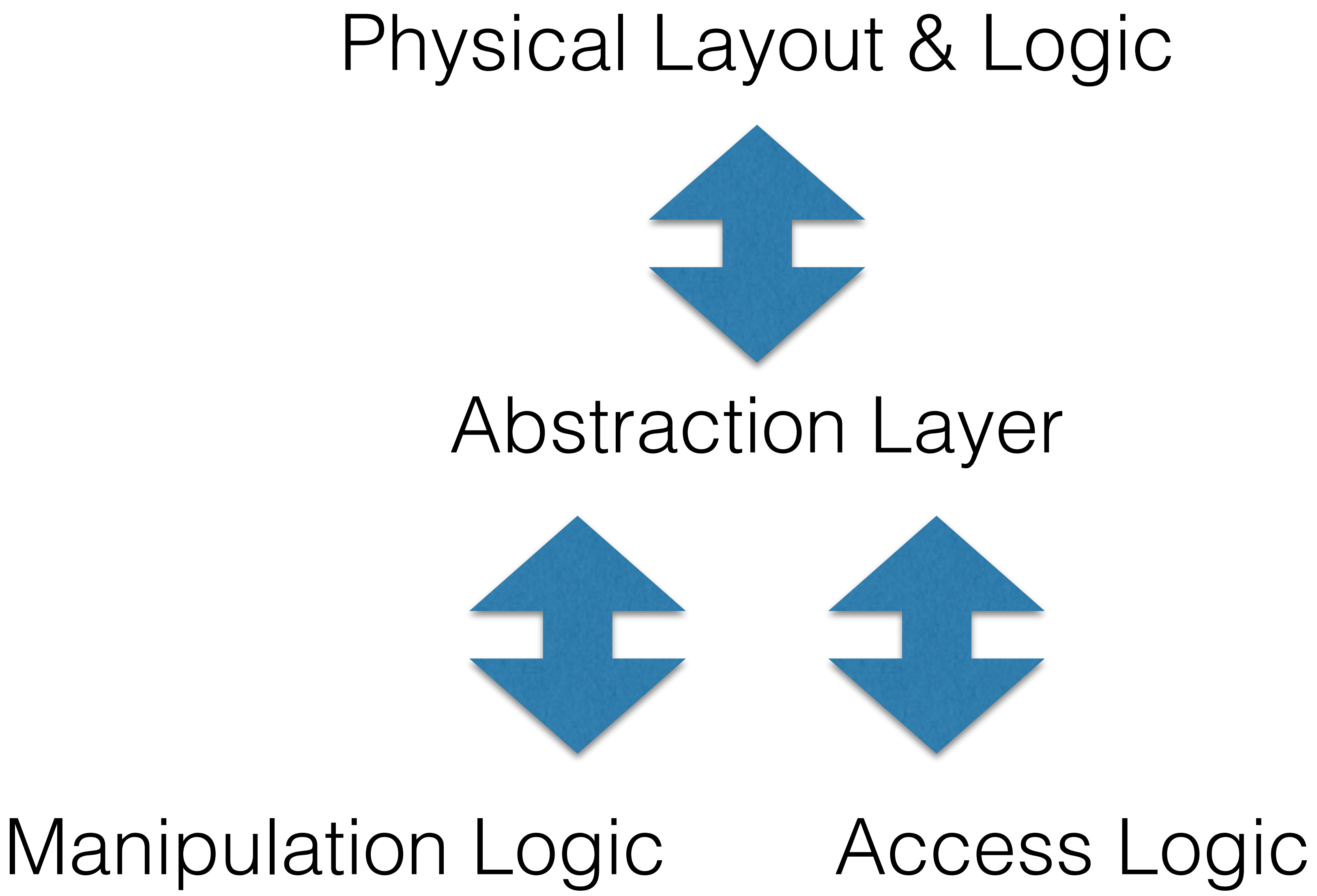


Physical Layout & Logic

Manipulation Logic

Access Logic

Just-in-Time Data Structures



Physical Layout & Logic

Abstraction Layer

Manipulation Logic

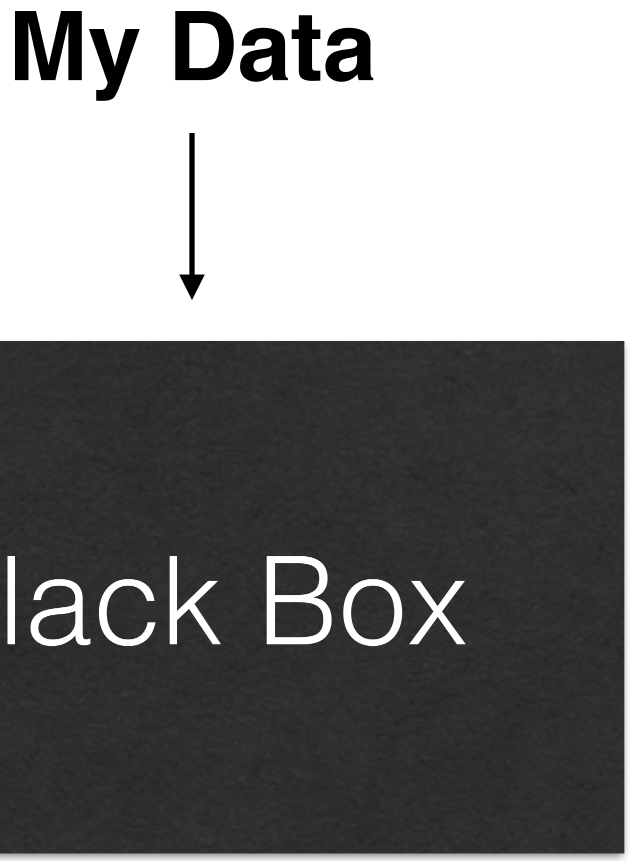
Access Logic

Abstractions

Abstractions

Black Box

Abstractions



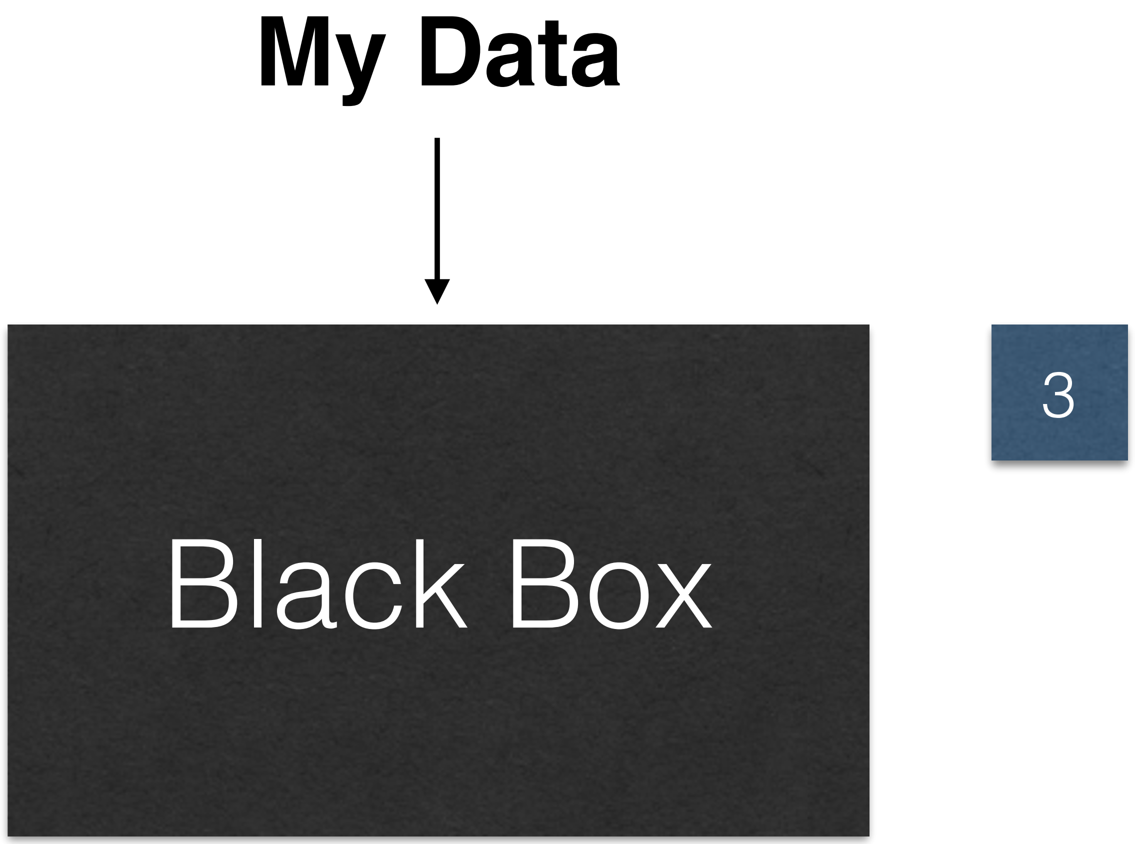
My Data

Black Box

(A set of integer records)
"

Insertions

Let’s say I want to add a 3?



My Data

Black Box

3

Insertions

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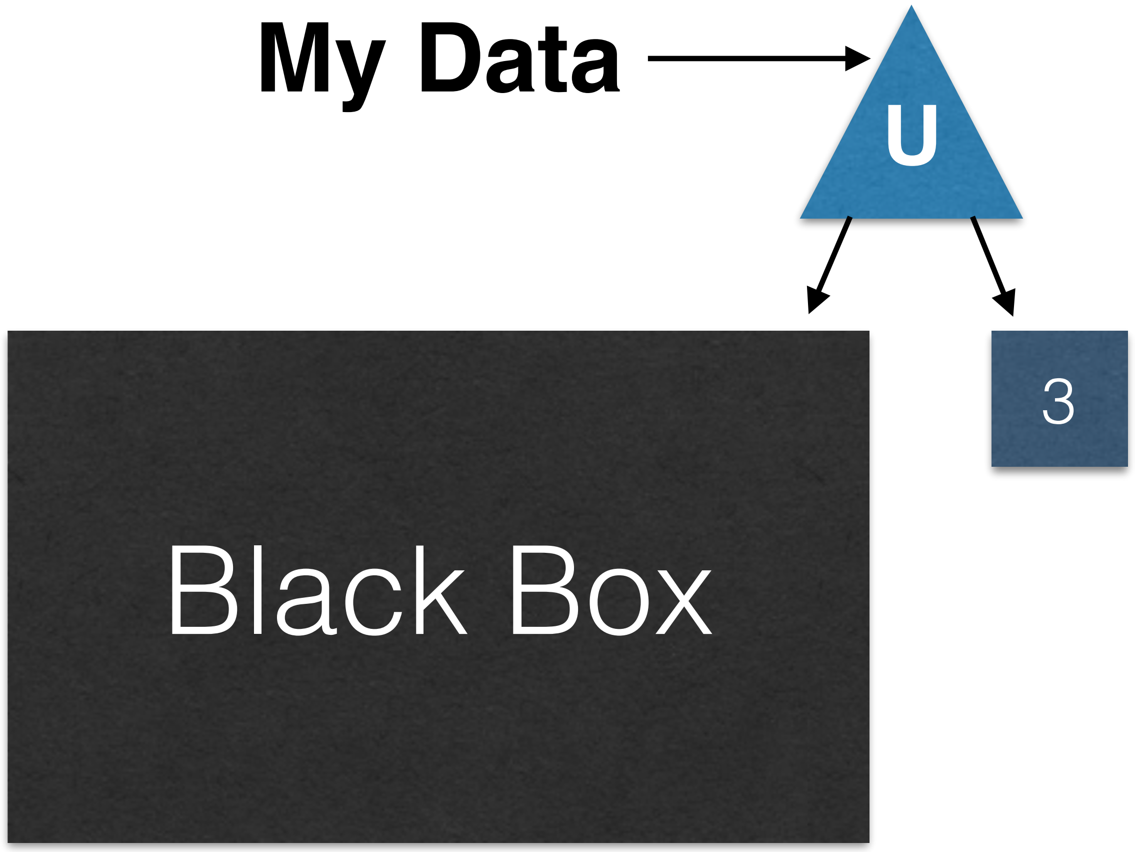

Insertions

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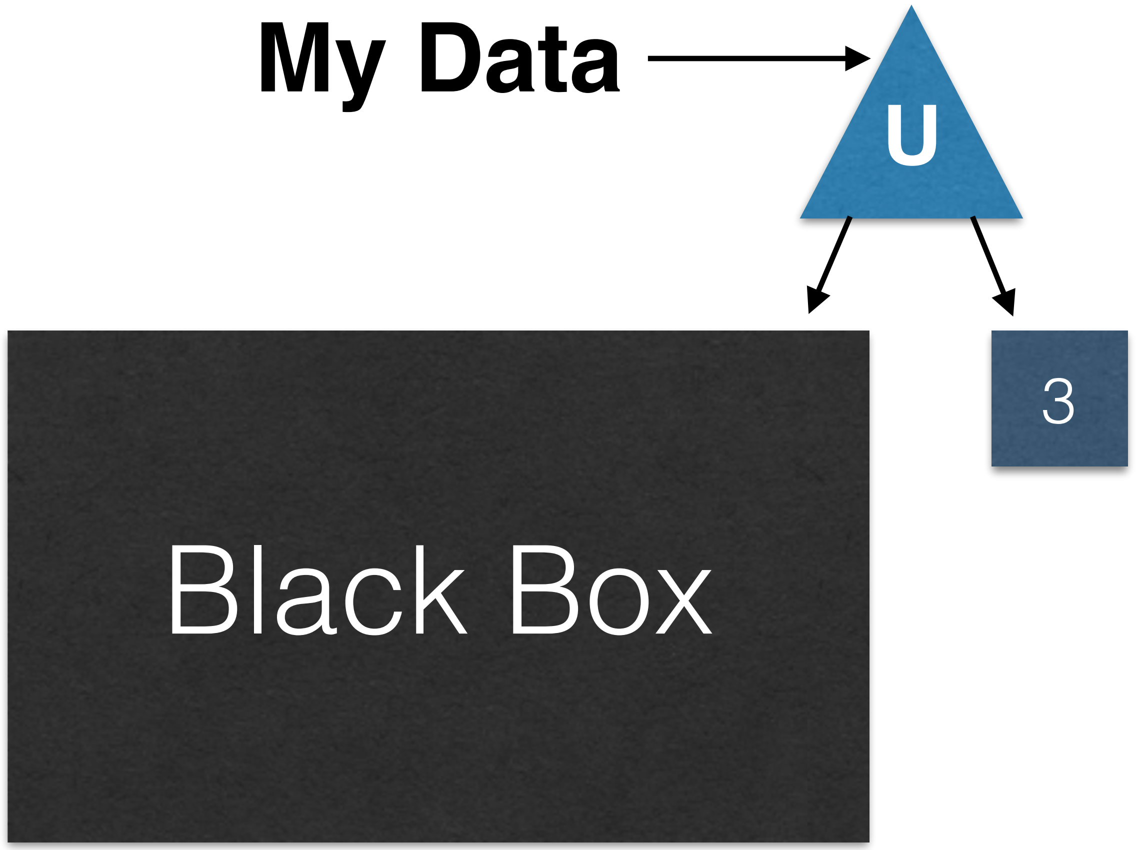
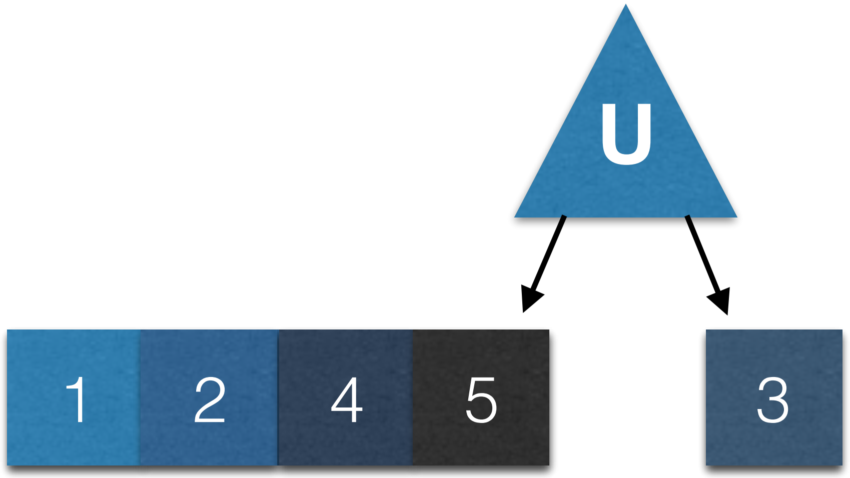


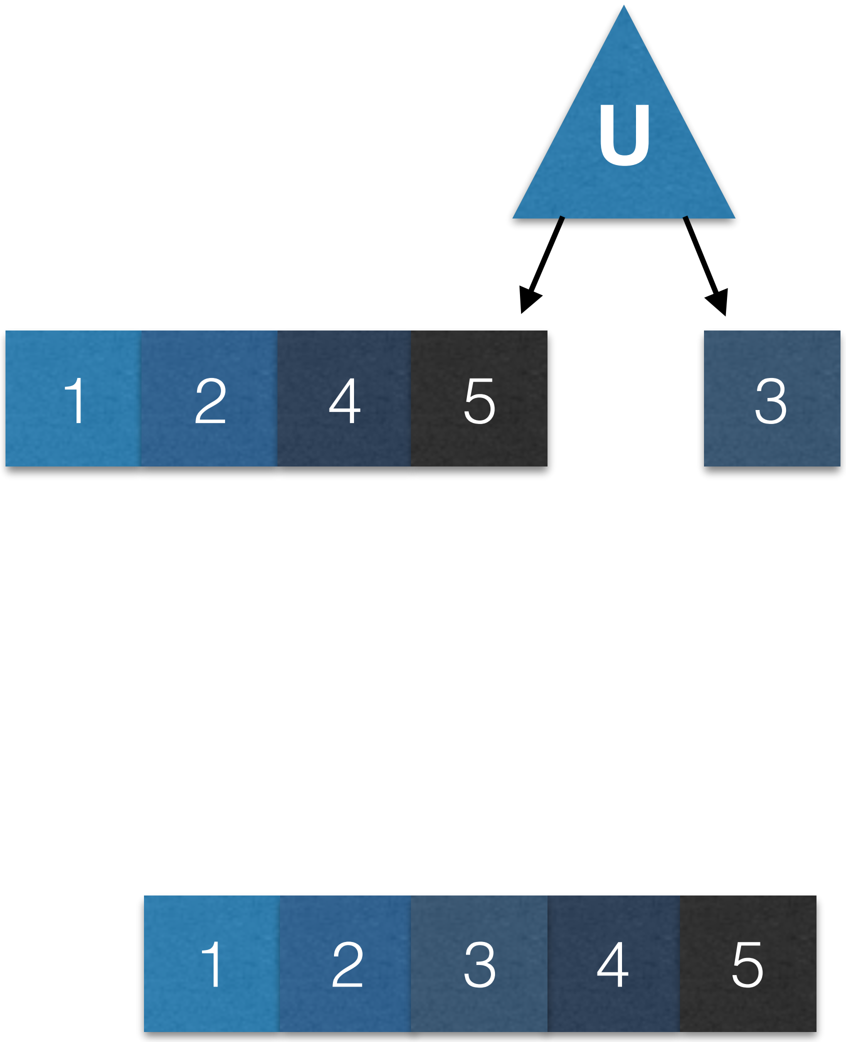
This is **correct**, but probably **not efficient**

Insertions

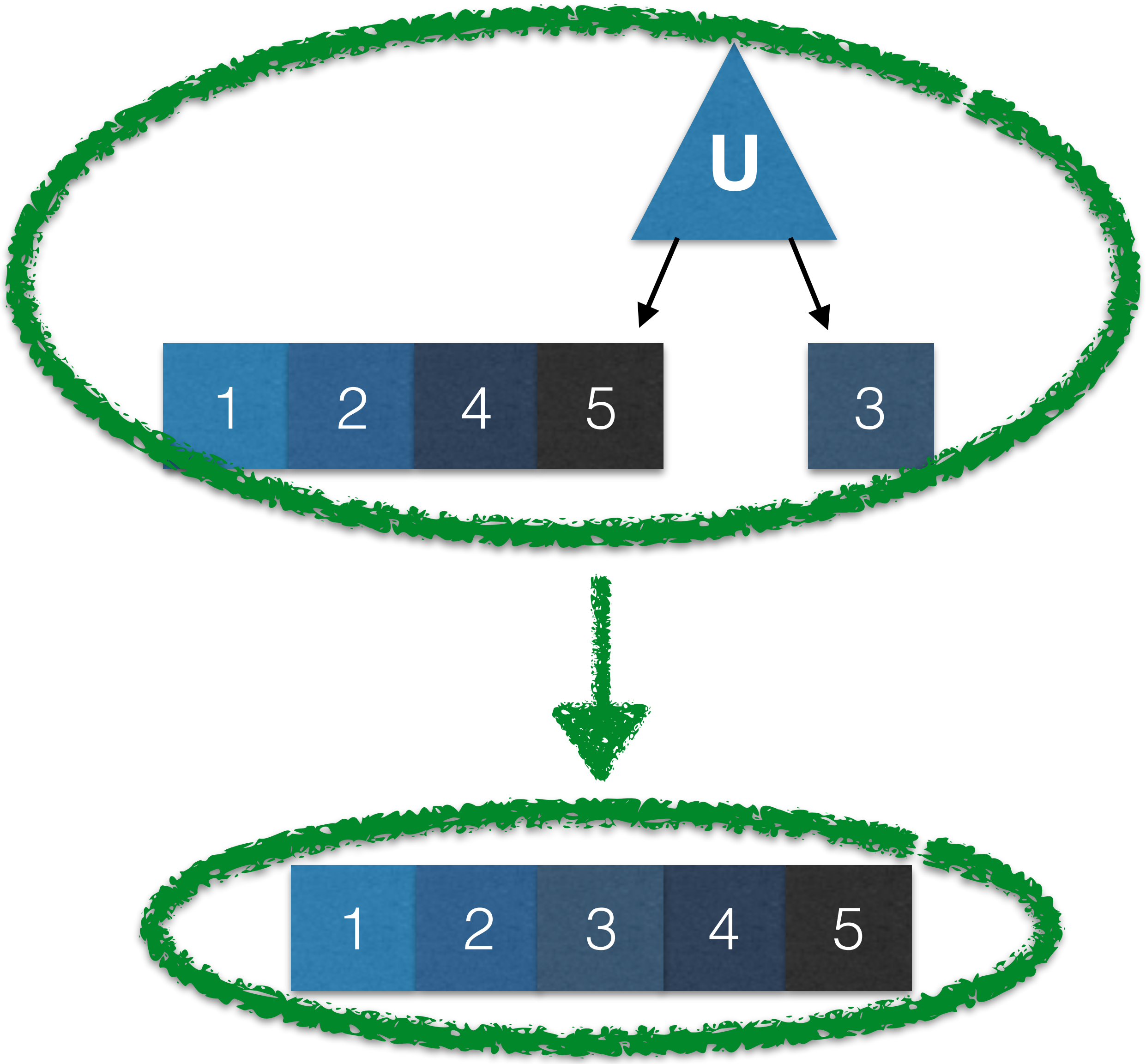


Insertion creates a **temporary** representation…

Insertions



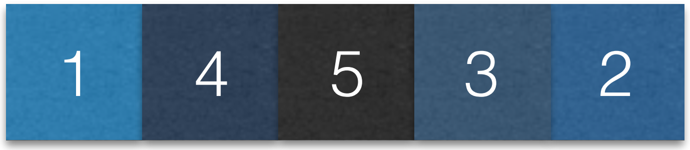
Insertions



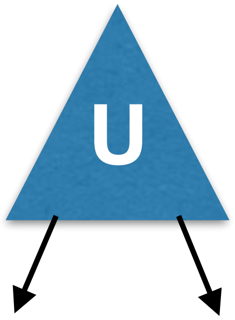
… that we can eventually **rewrite** into a form that is correct and **efficient**

(once we know what ‘efficient’ means)

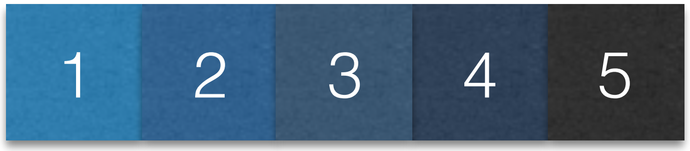
Building Blocks



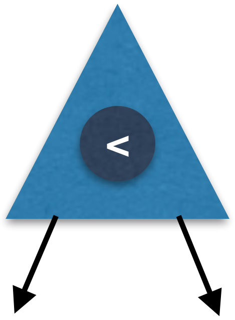
Array (Unsorted)



Concatenate



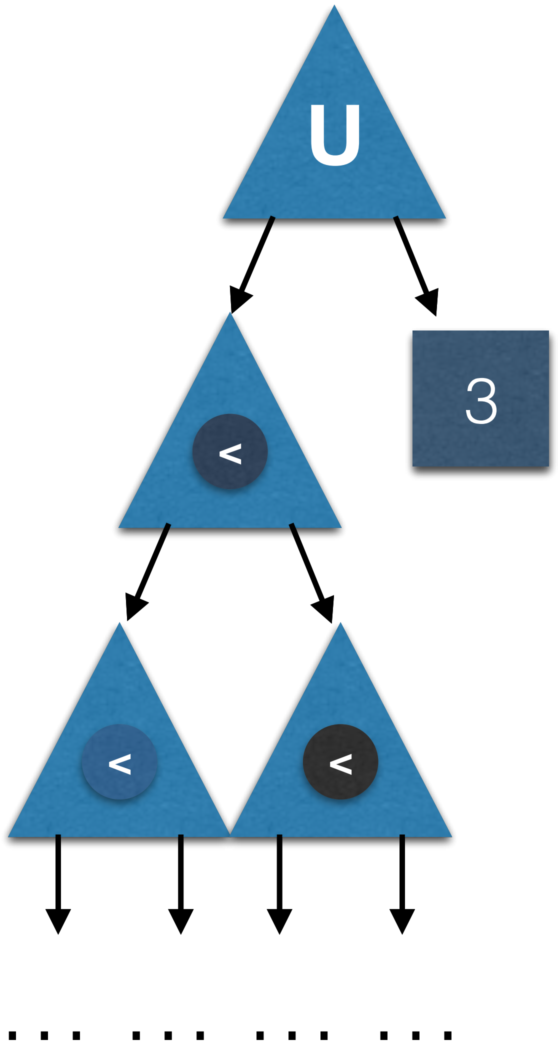
Array (Sorted)



BTree Node

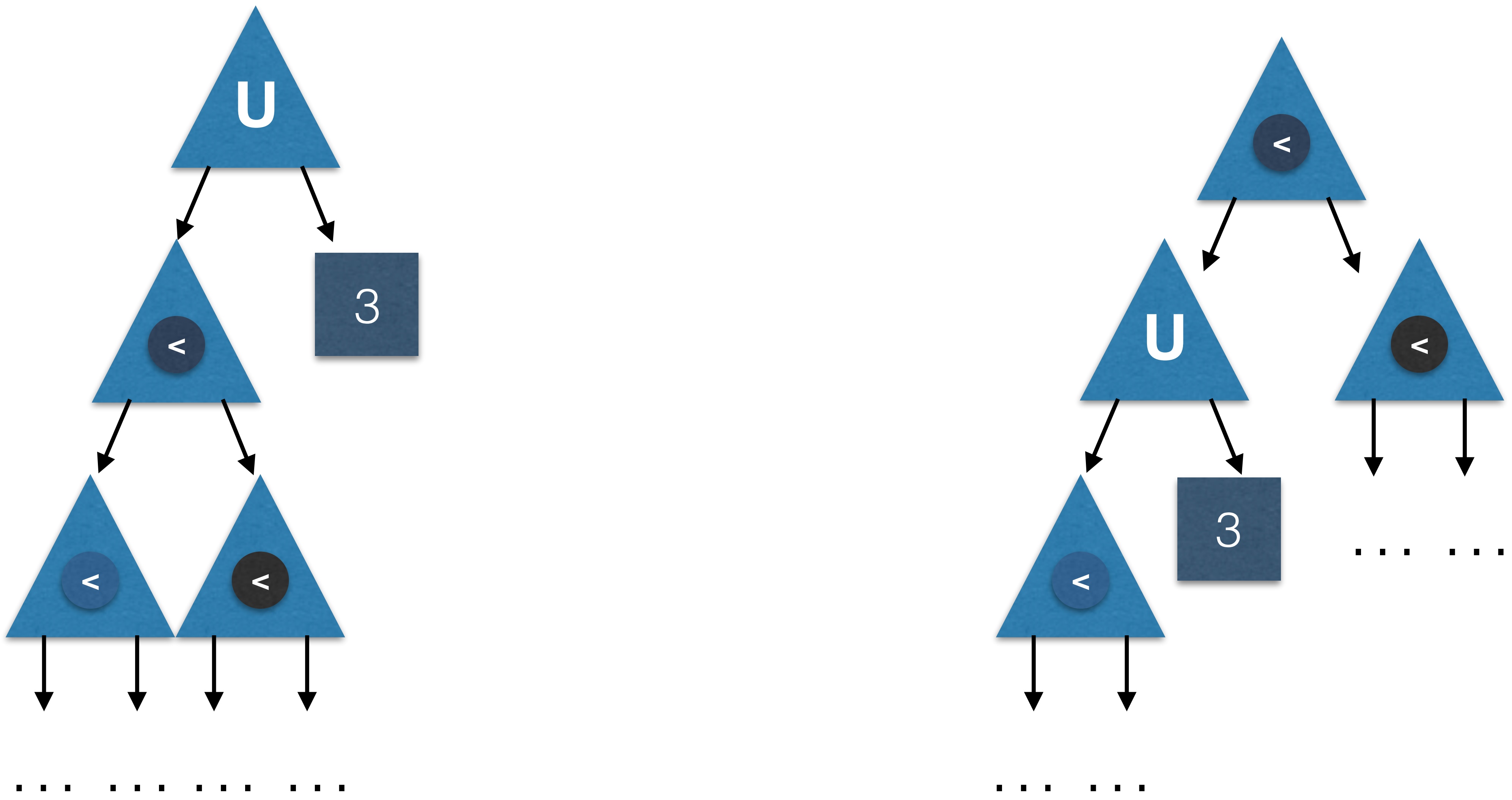
BTree Insertions

Let's try something more complex: A BTree



BTree Insertions

A rewrite pushes the inserted object down into the tree



BTree Insertions

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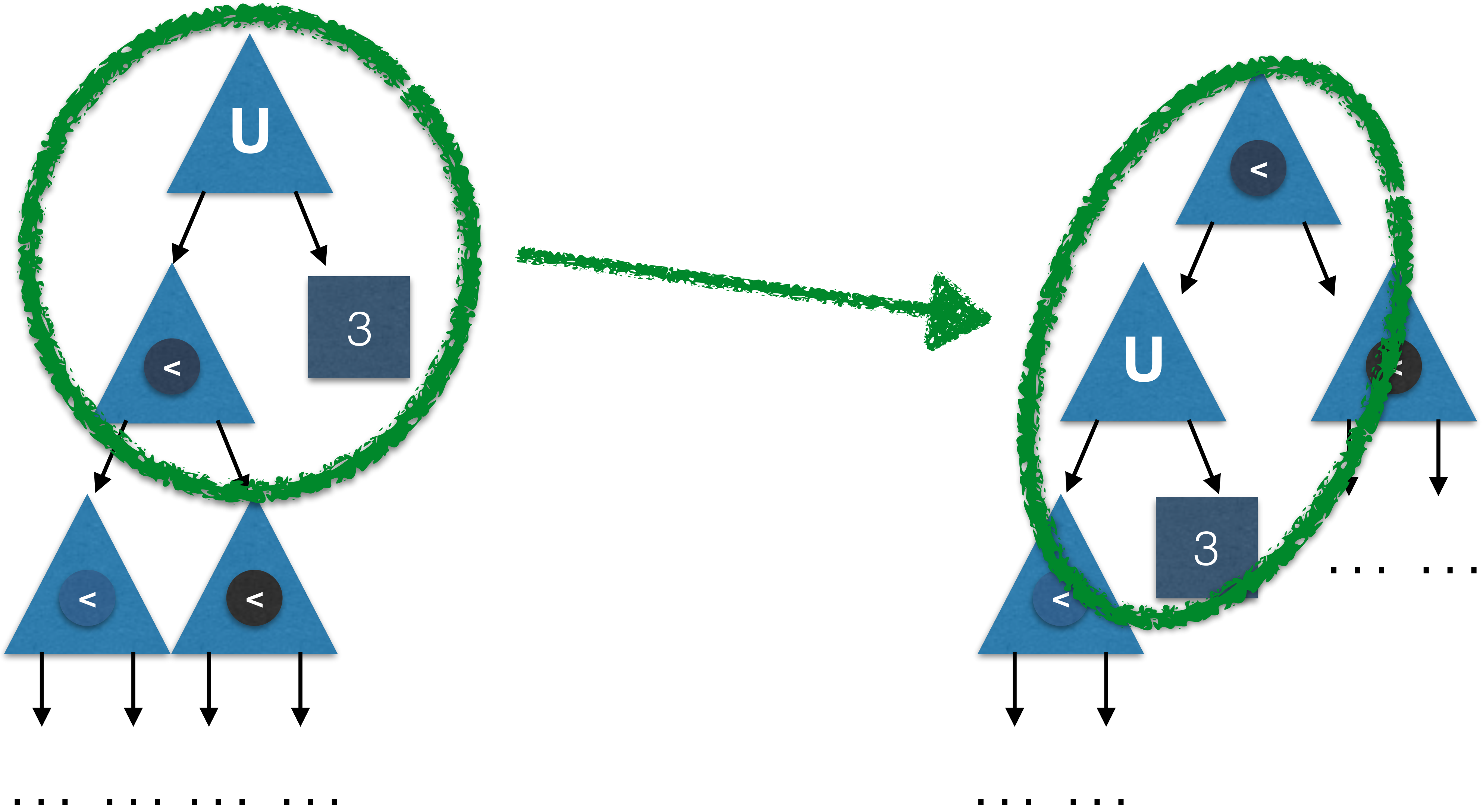
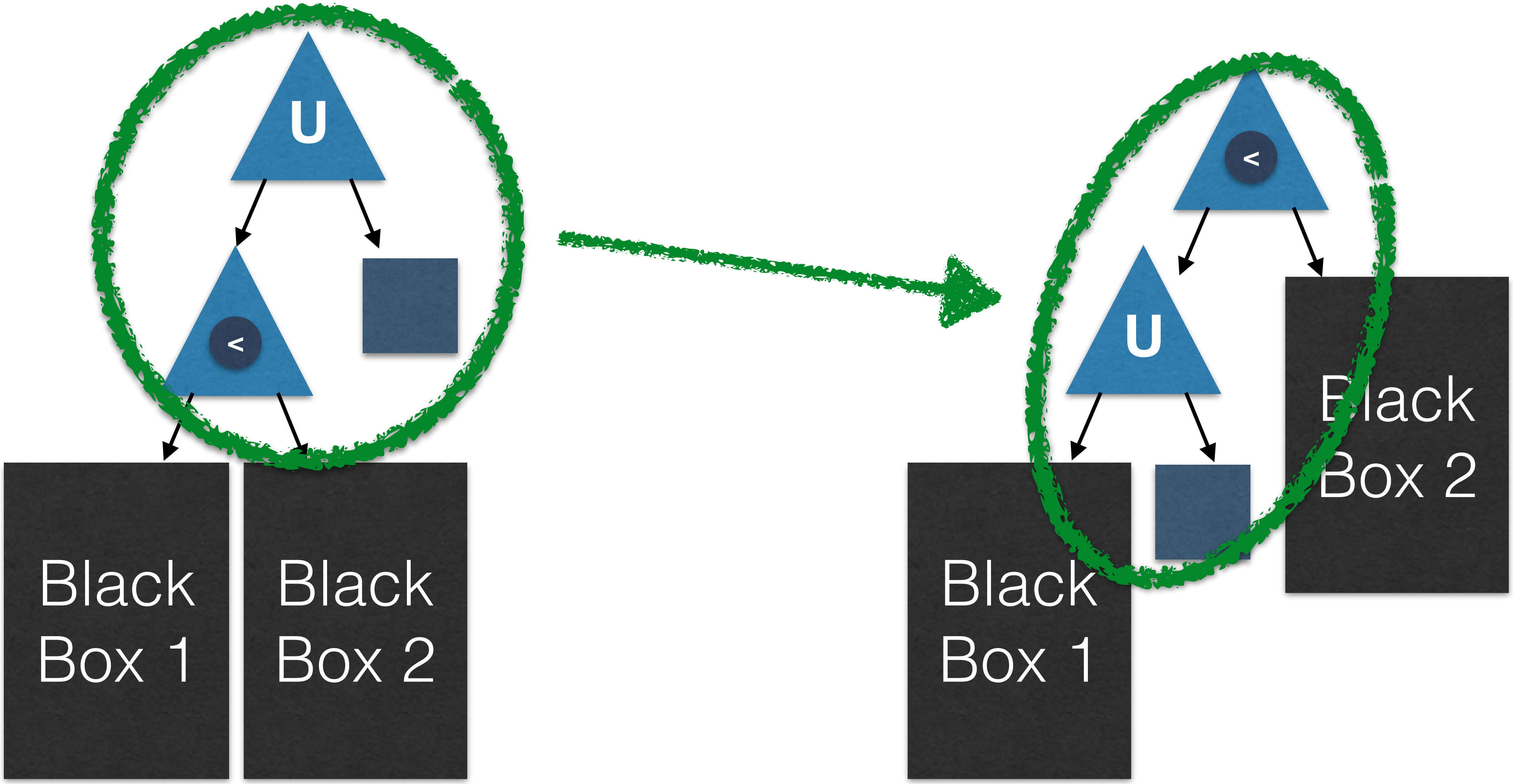
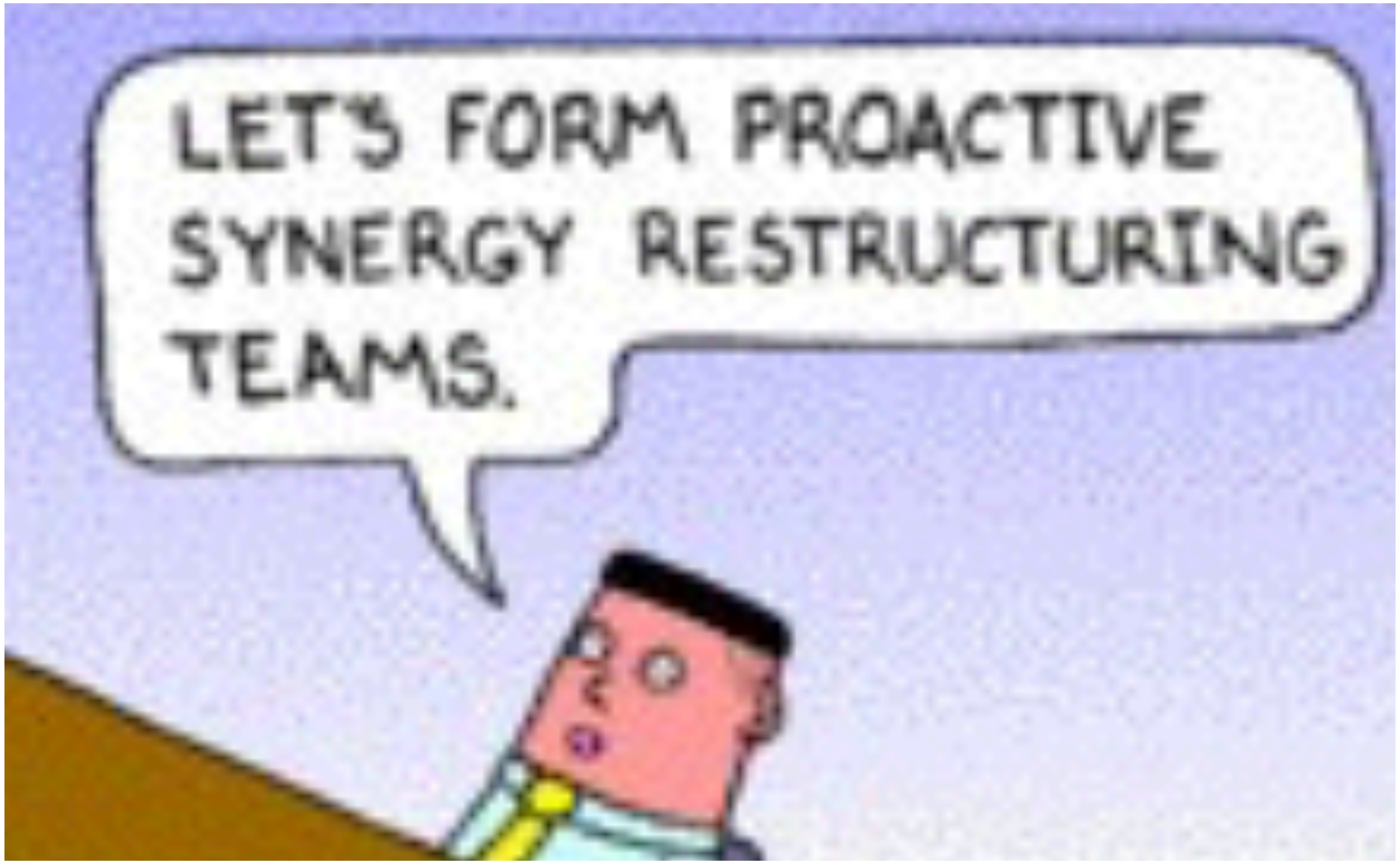


BTree Insertions

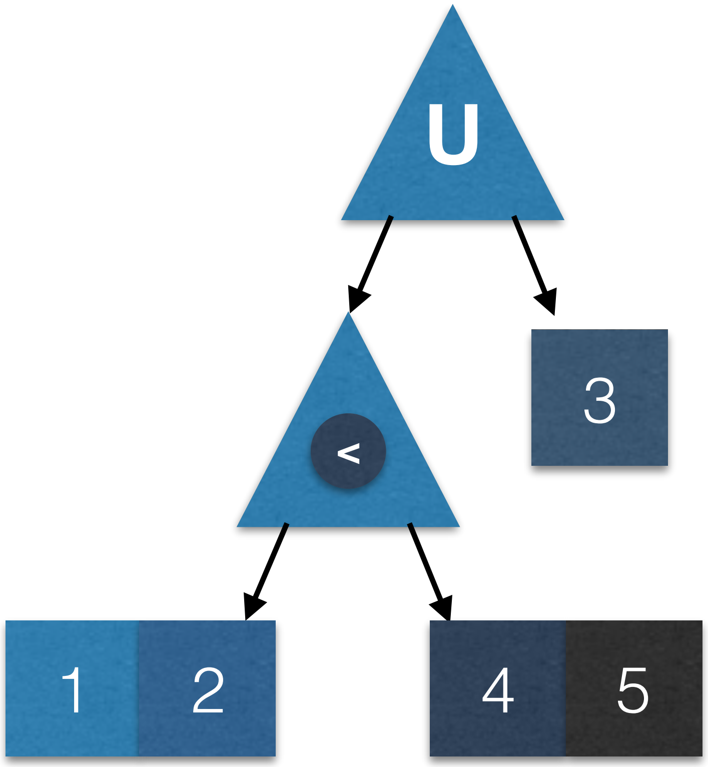
The rewrites are **local**.
The rest of the data structure doesn't matter!



Synergy

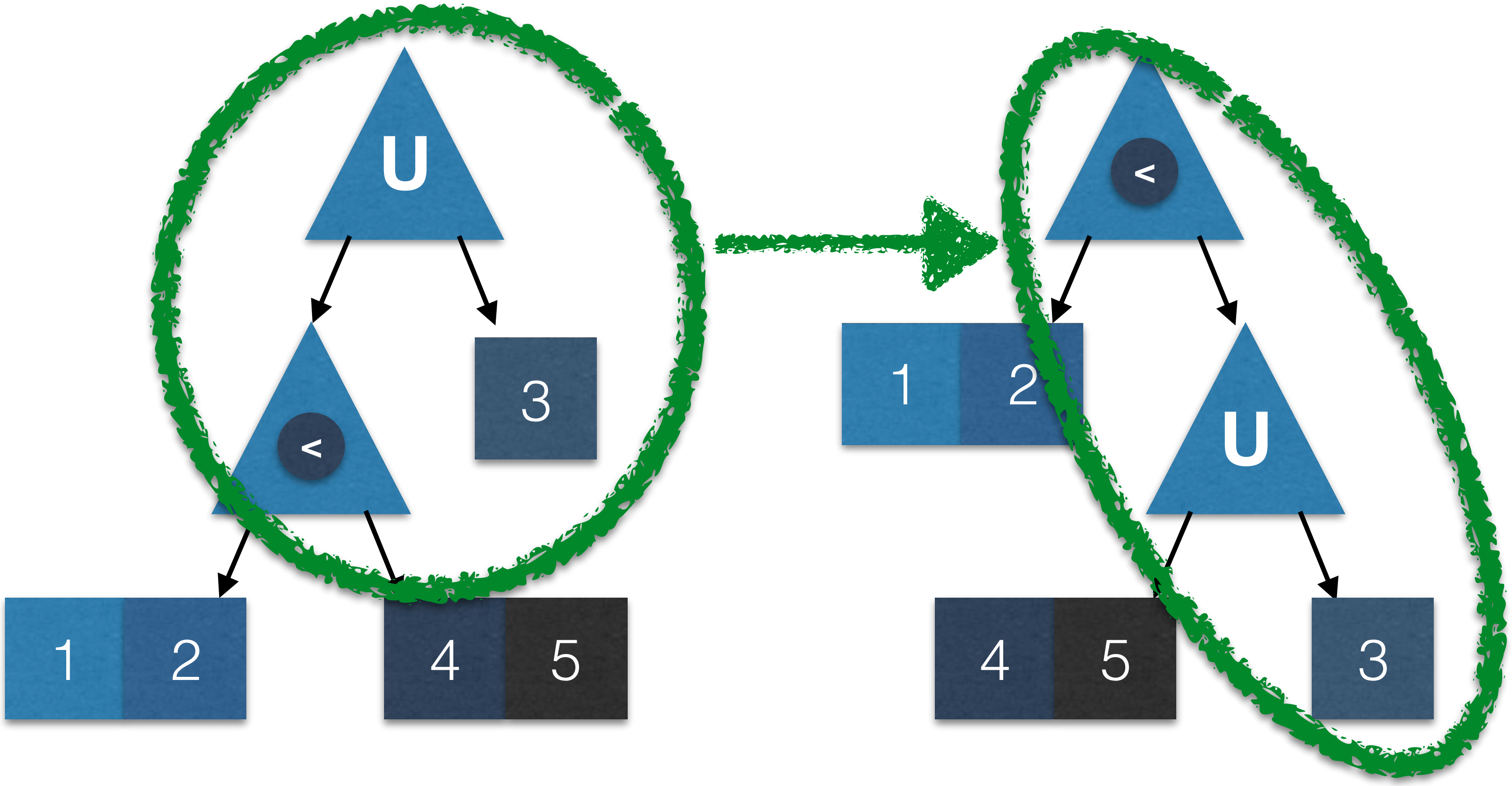


Hybrid Insertions



Hybrid Insertions

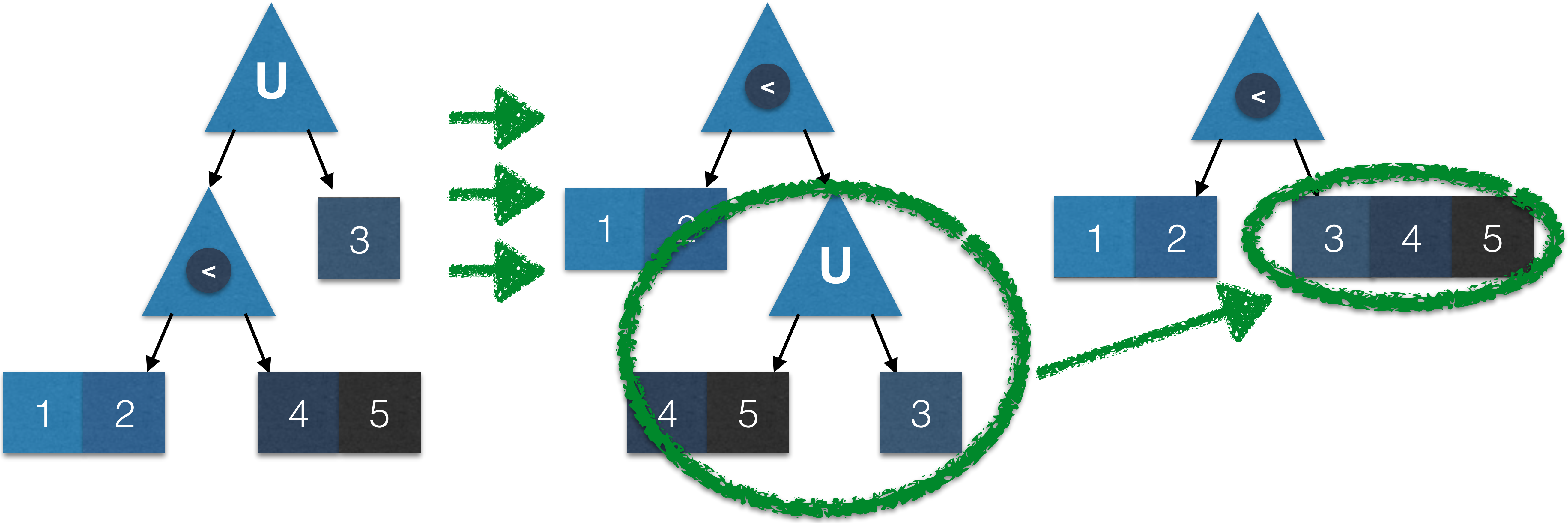
BTree
Rewrite



Hybrid Insertions

BTree Rewrite

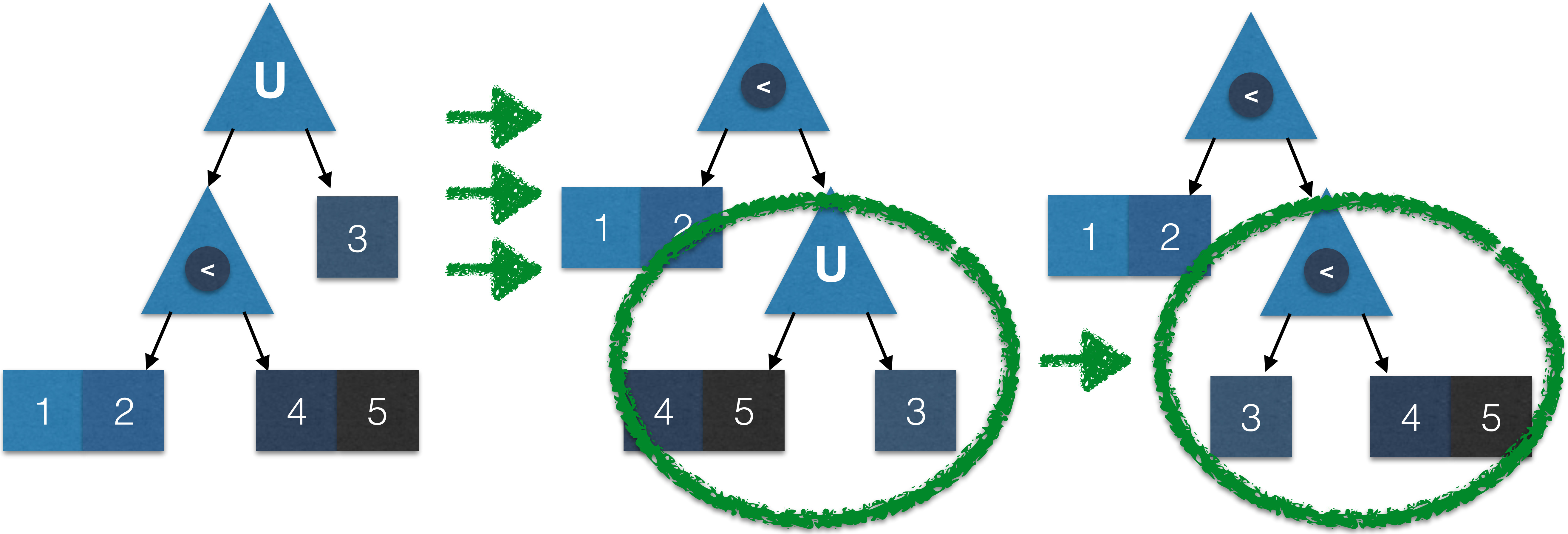
SArray Rewrite



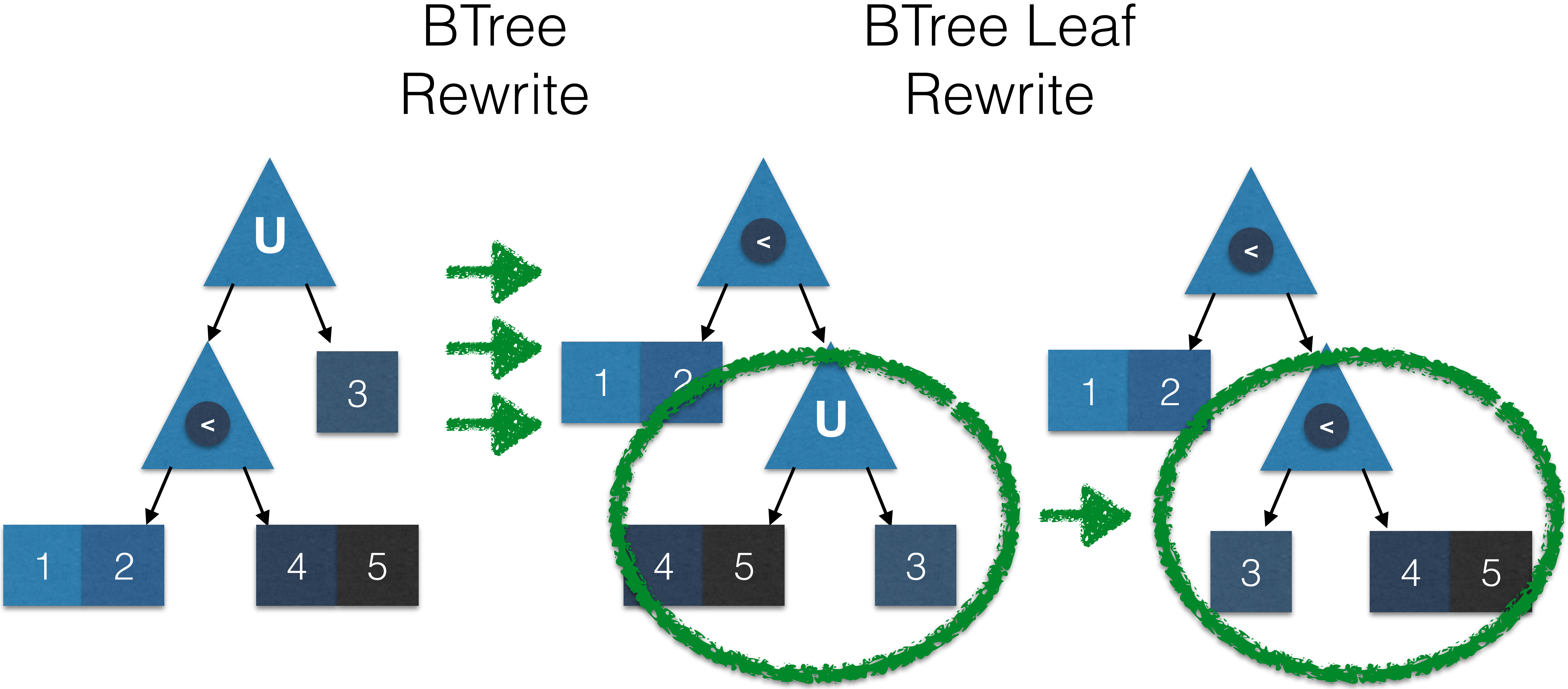
Synergy

BTree Rewrite

BTree Leaf Rewrite



Synergy



Which rewrite gets used depends on workload-specific policies.

Experiments

Cracker Index

vs

Adaptive Merge Tree

vs

JITDs

<u>API</u>

- RangeScan(low, high)
- Insert(Array)

<u>Gimmick</u>

- Insert is Free.
- RangeScan uses work done to answer the query to also organize the data.

Experiments

Cracker Index ← **Less** organization per-read

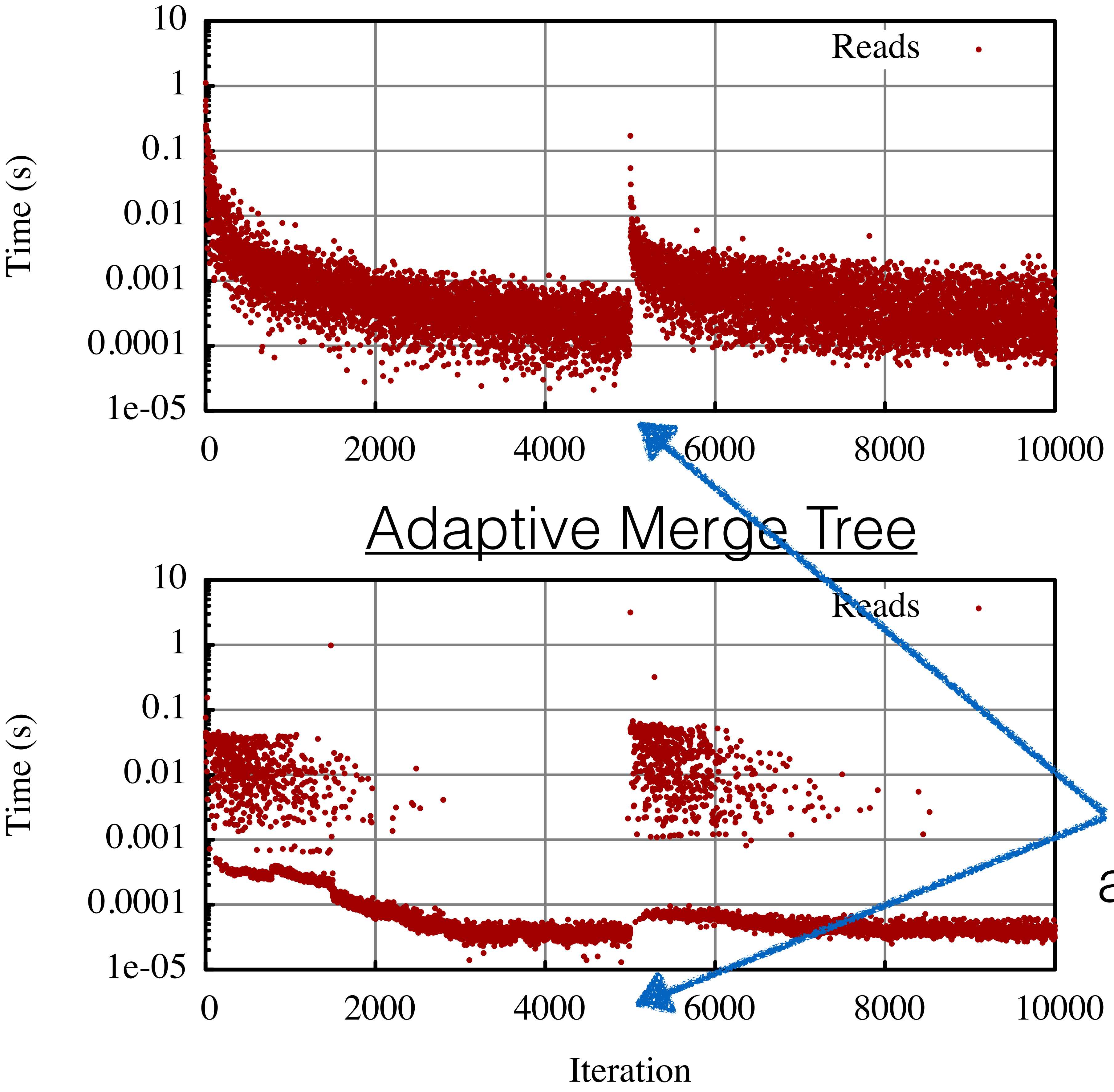
vs

Adaptive Merge Tree ← **More** organization per-read

vs

JITDs

Cracker Index



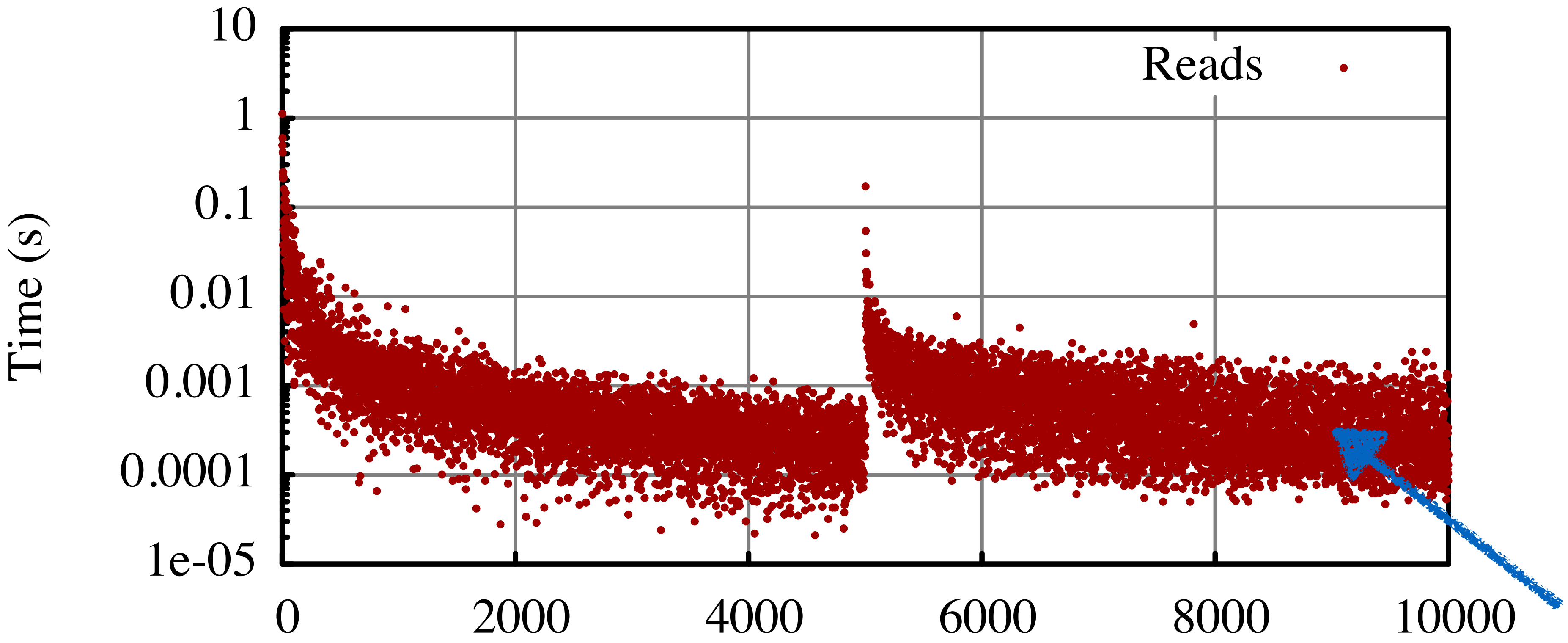
Adaptive Merge Tree

100 M records
(1.6 GB)

10,000 reads for
2-3 k records
each

10M additional
records written
after 5,000 reads

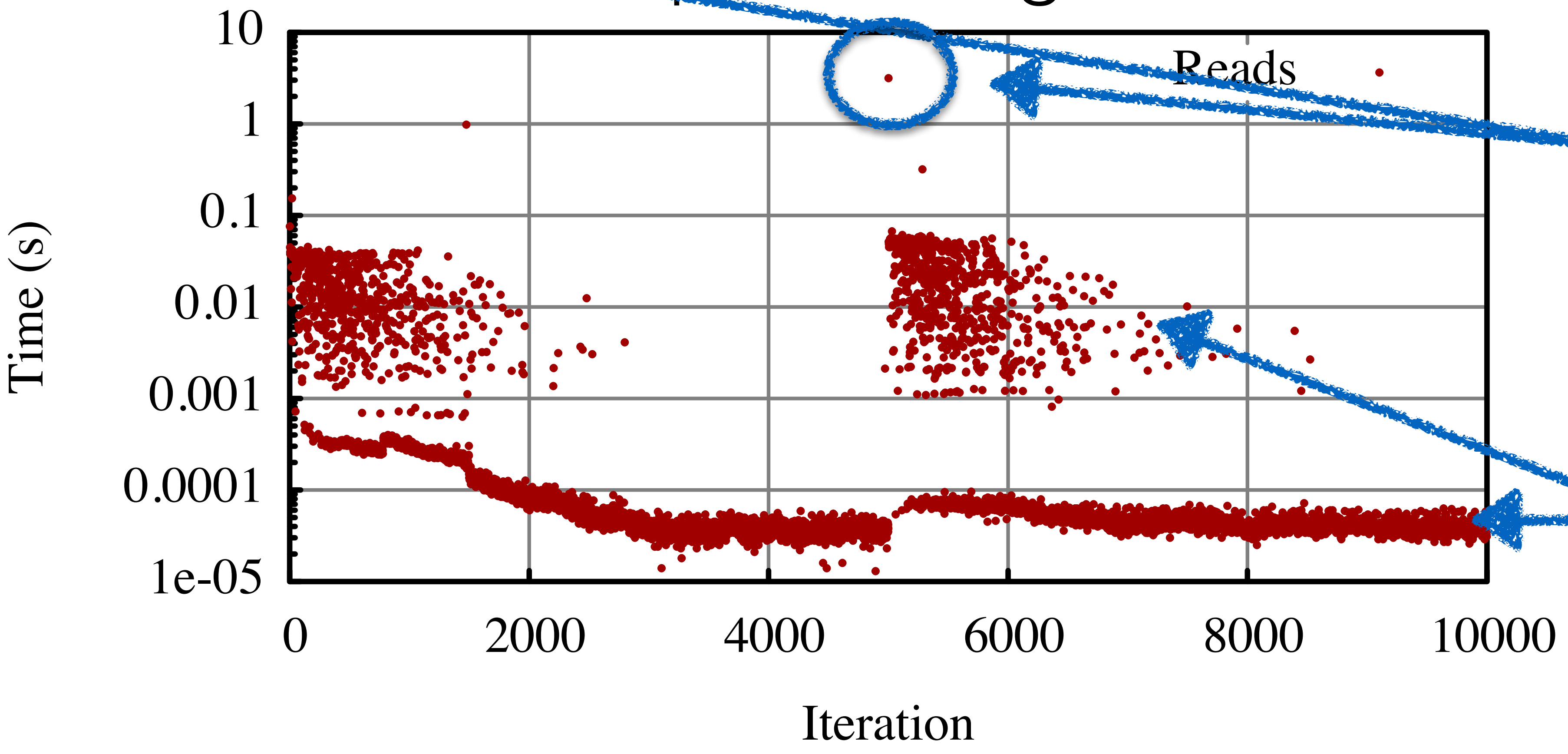
Cracker Index



Slow Convergence

33s (not shown)

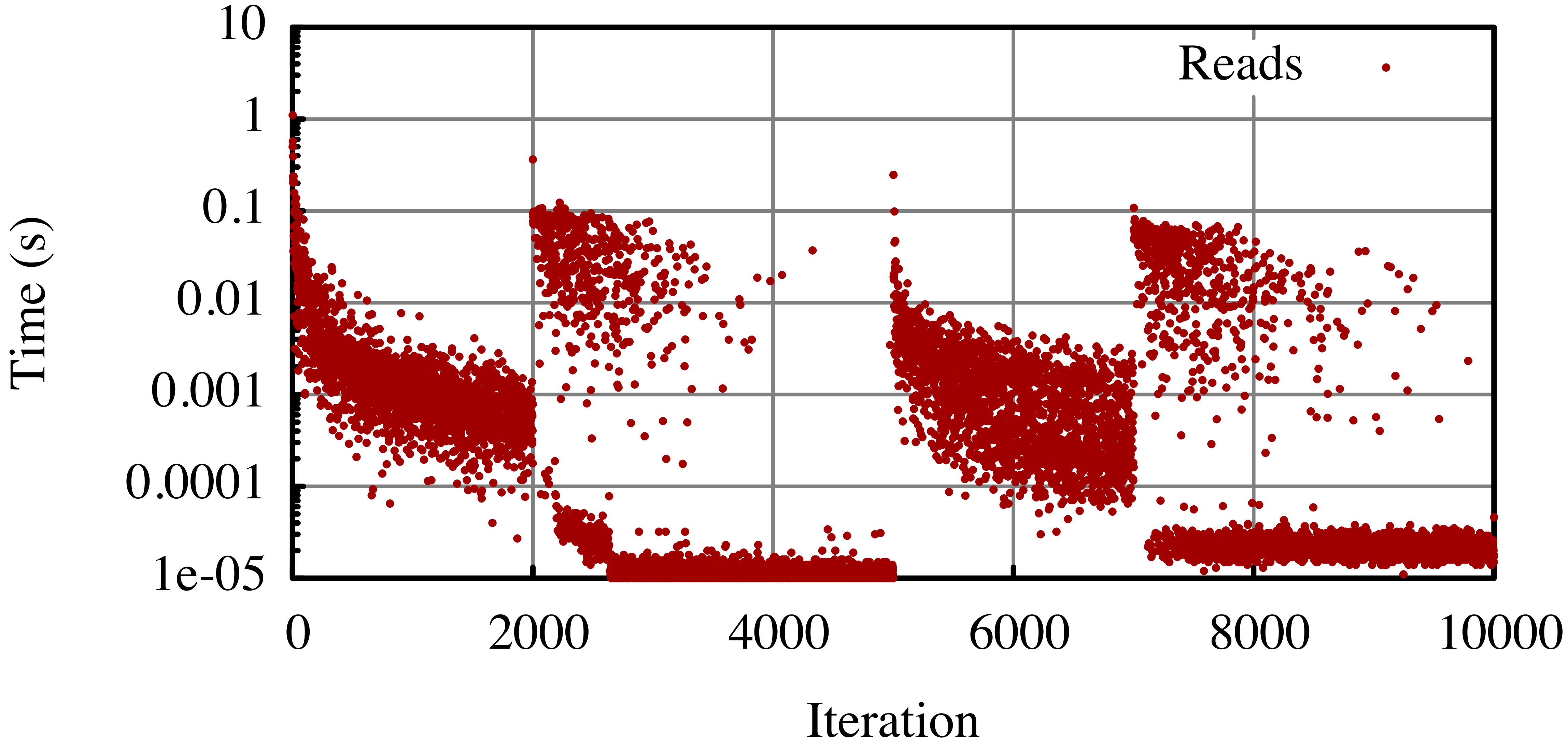
Adaptive Merge Tree



Super-High Initial Costs

Bimodal Distribution

Policy 1: Swap (Crack for 2k reads after write, then merge)



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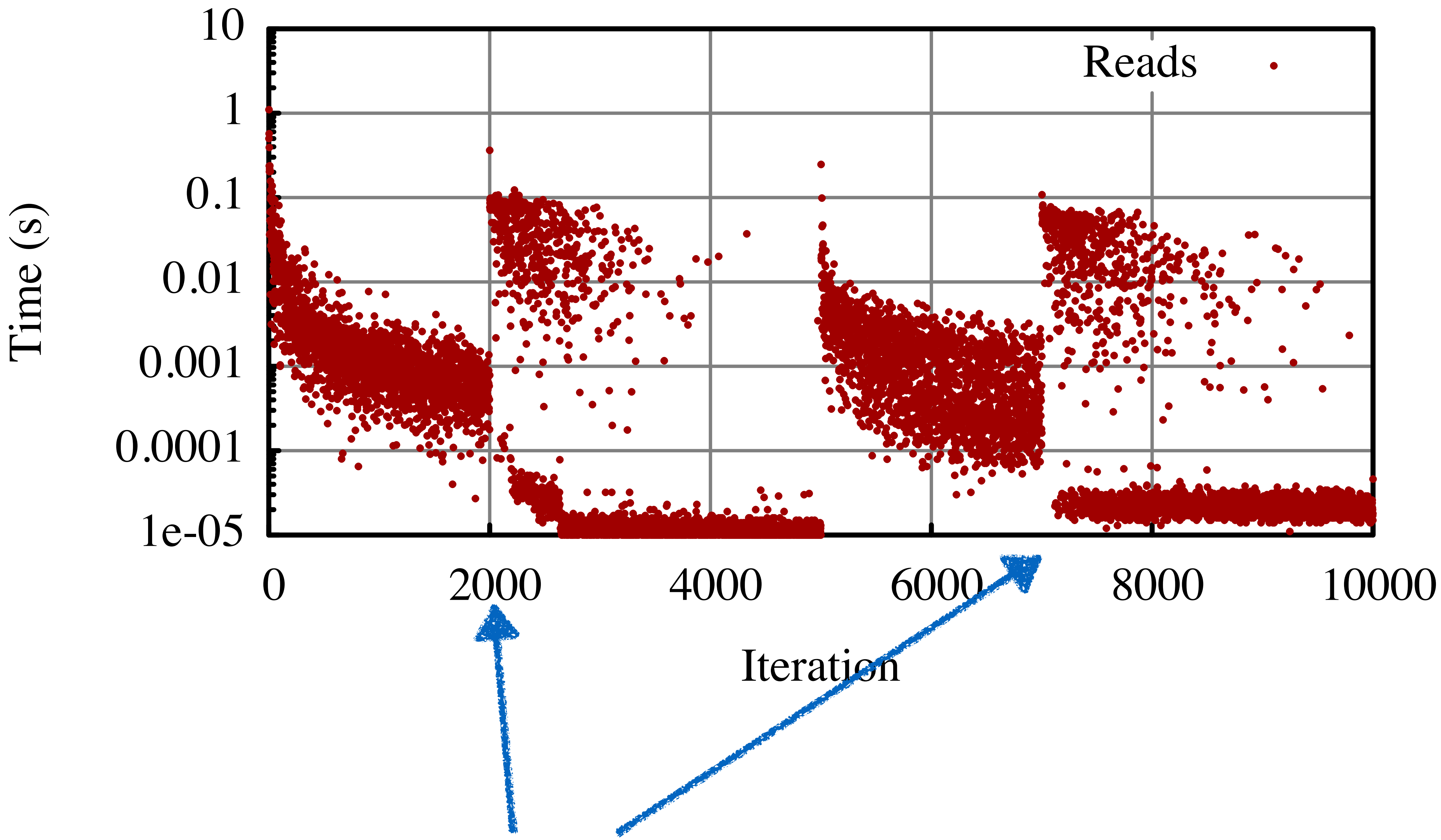
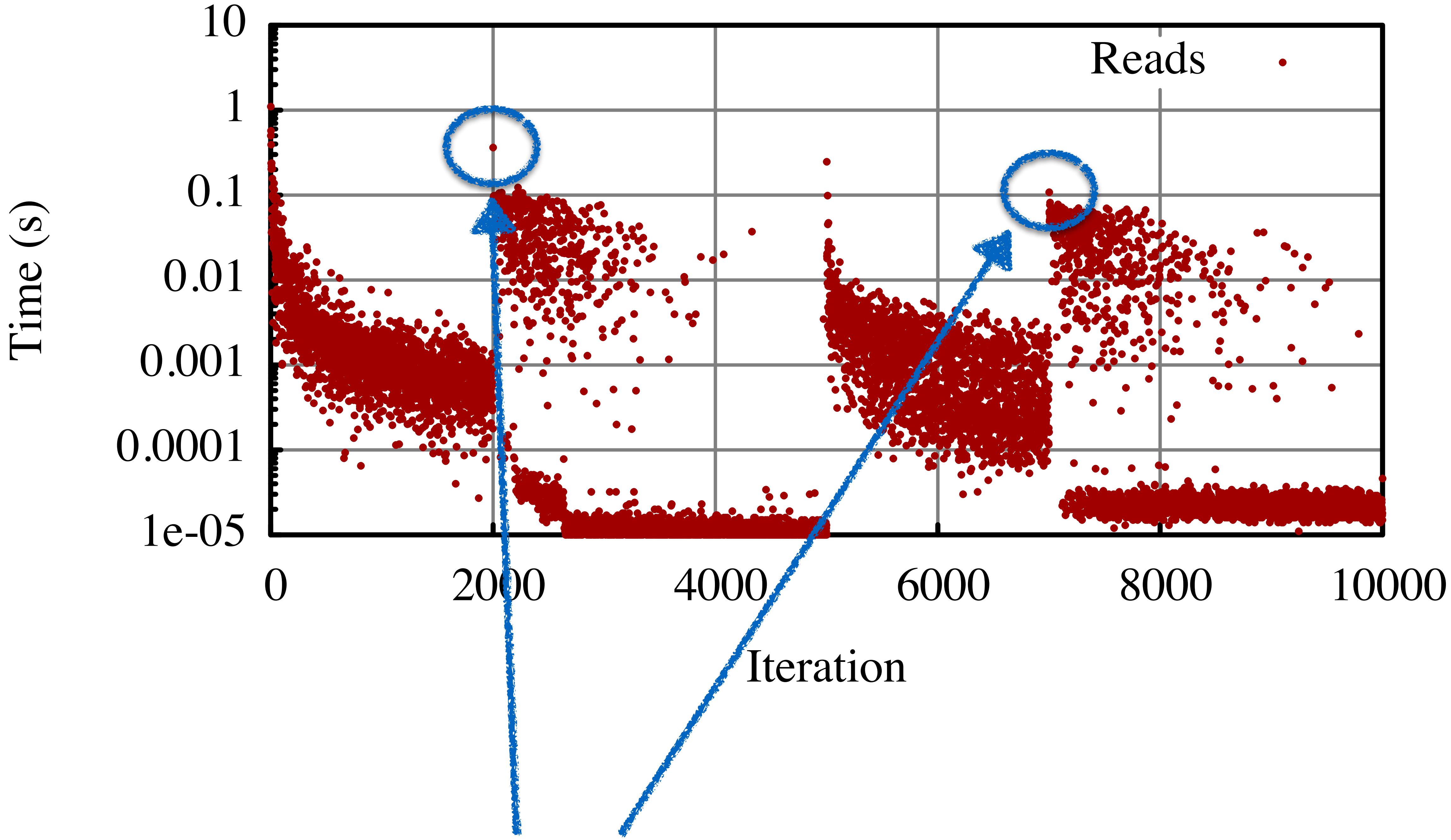


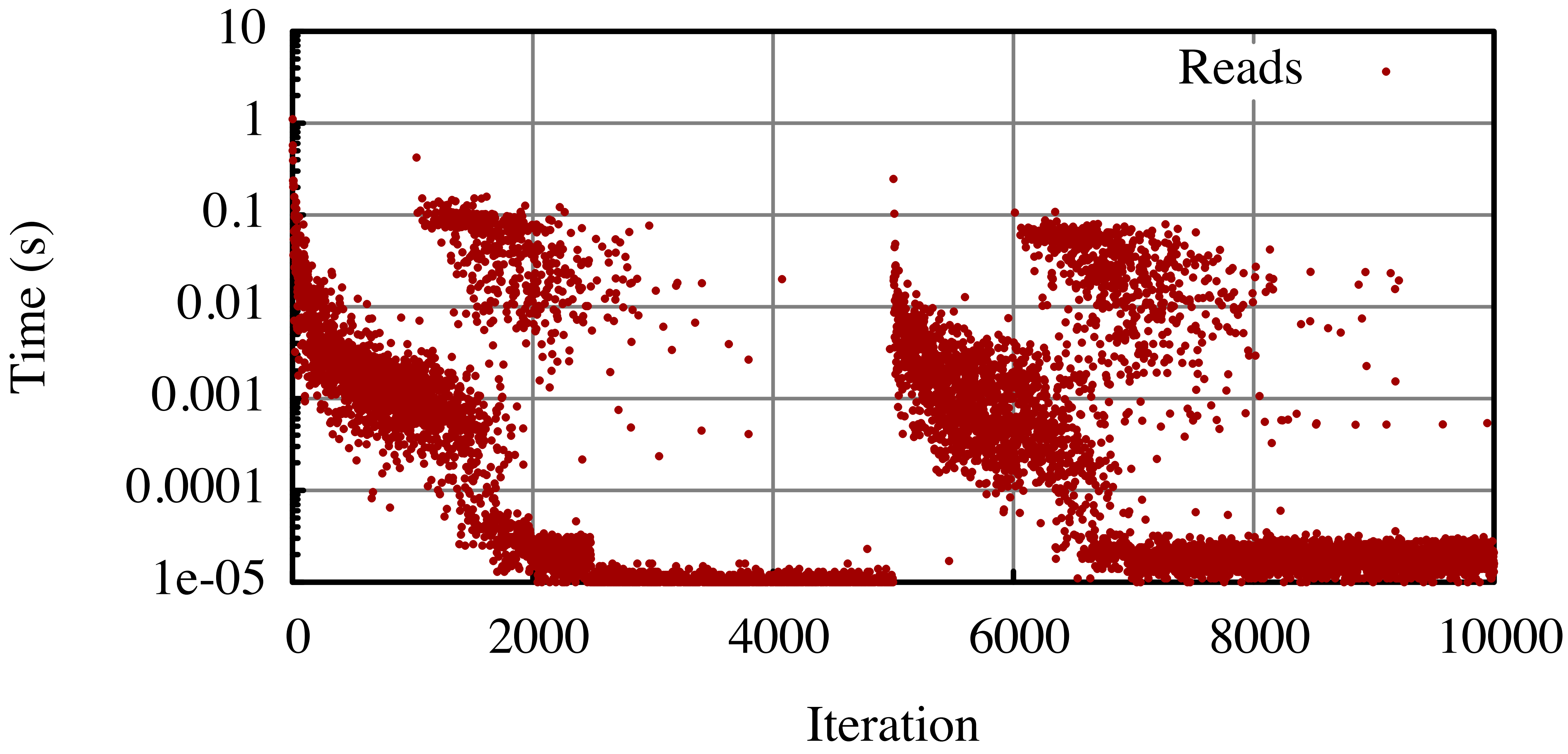
Switchover from Crack to Merge

Policy 1: Swap (Crack for 2k reads after write, then merge)

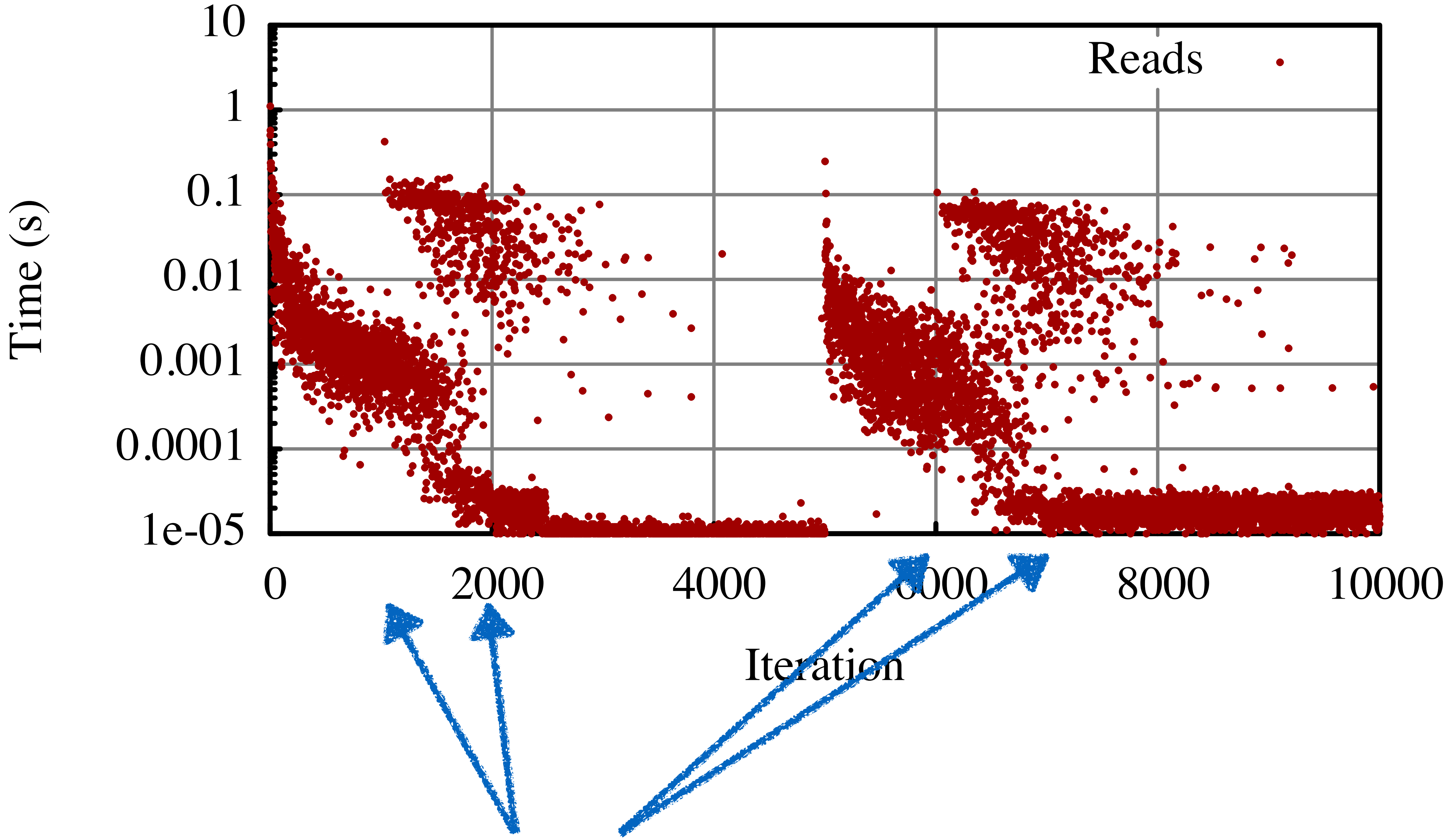


Synergy from Cracking (lower upfront cost)

Policy 2: Transition (Gradient from Crack to Merge at 1k)

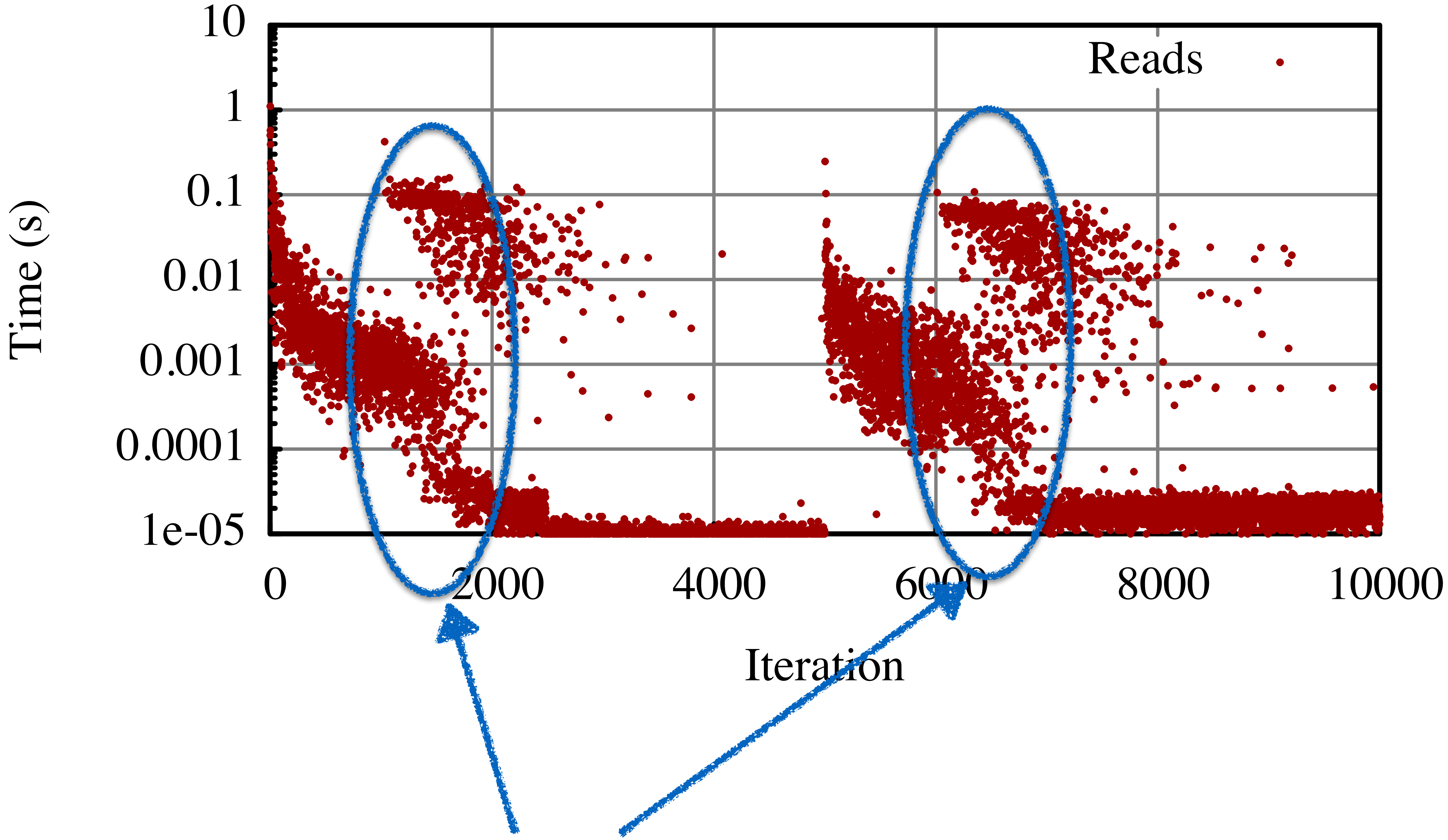


Policy 2: Transition (Gradient from Crack to Merge at 1k)



Gradient Period (% chance of Crack or Merge)

Policy 2: Transition (Gradient from Crack to Merge at 1k)



Tri-modal distribution: Cracking and Merging on a per-operation basis

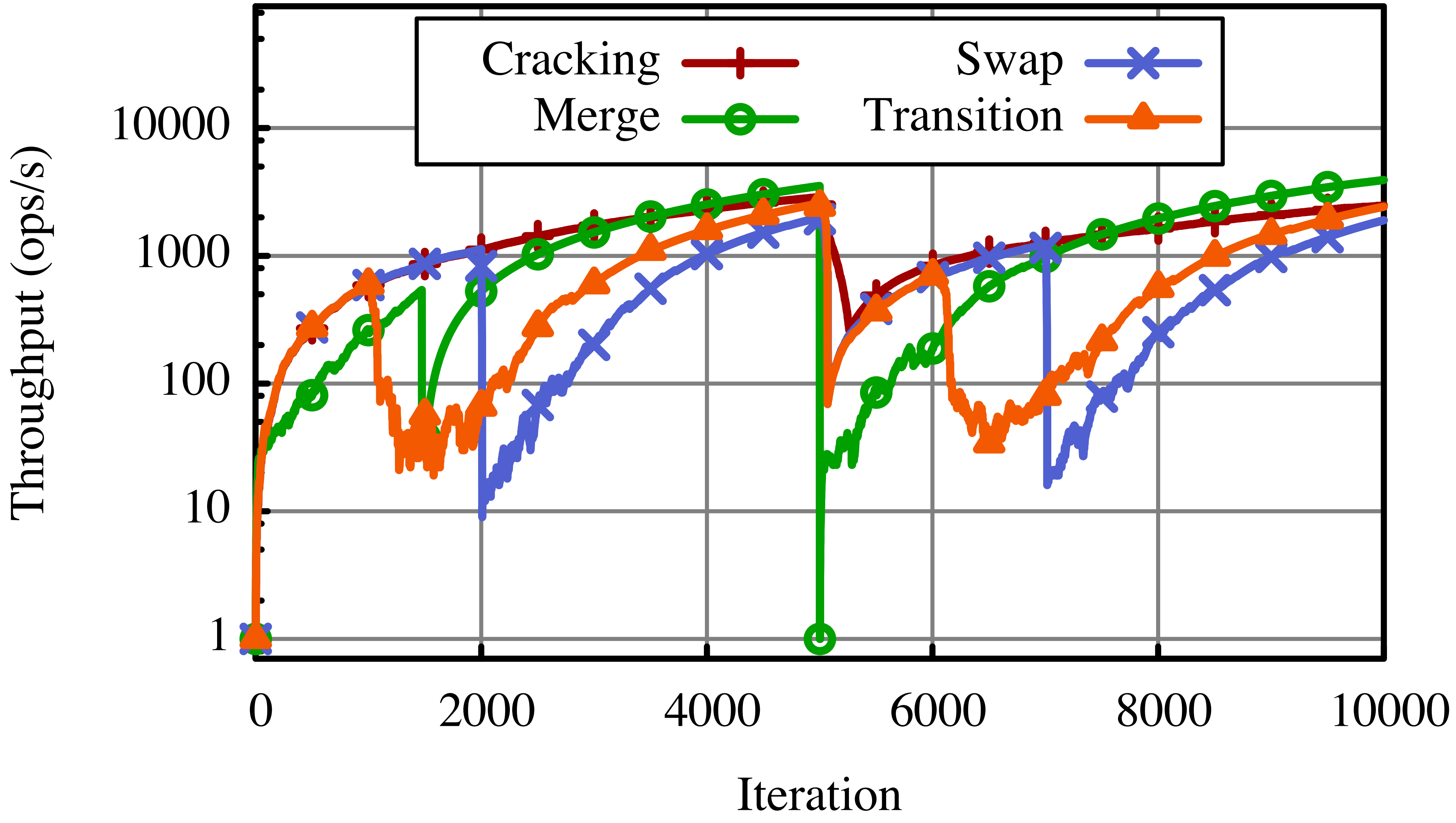
`

- Separate **logic** and **structure/semantics**
  - Composable Building Blocks
  - Local Rewrite Rules
- Result: Flexible, hybrid data structures.
- Result: Graceful transitions between different behaviors.
- https://github.com/okennedy/jitd

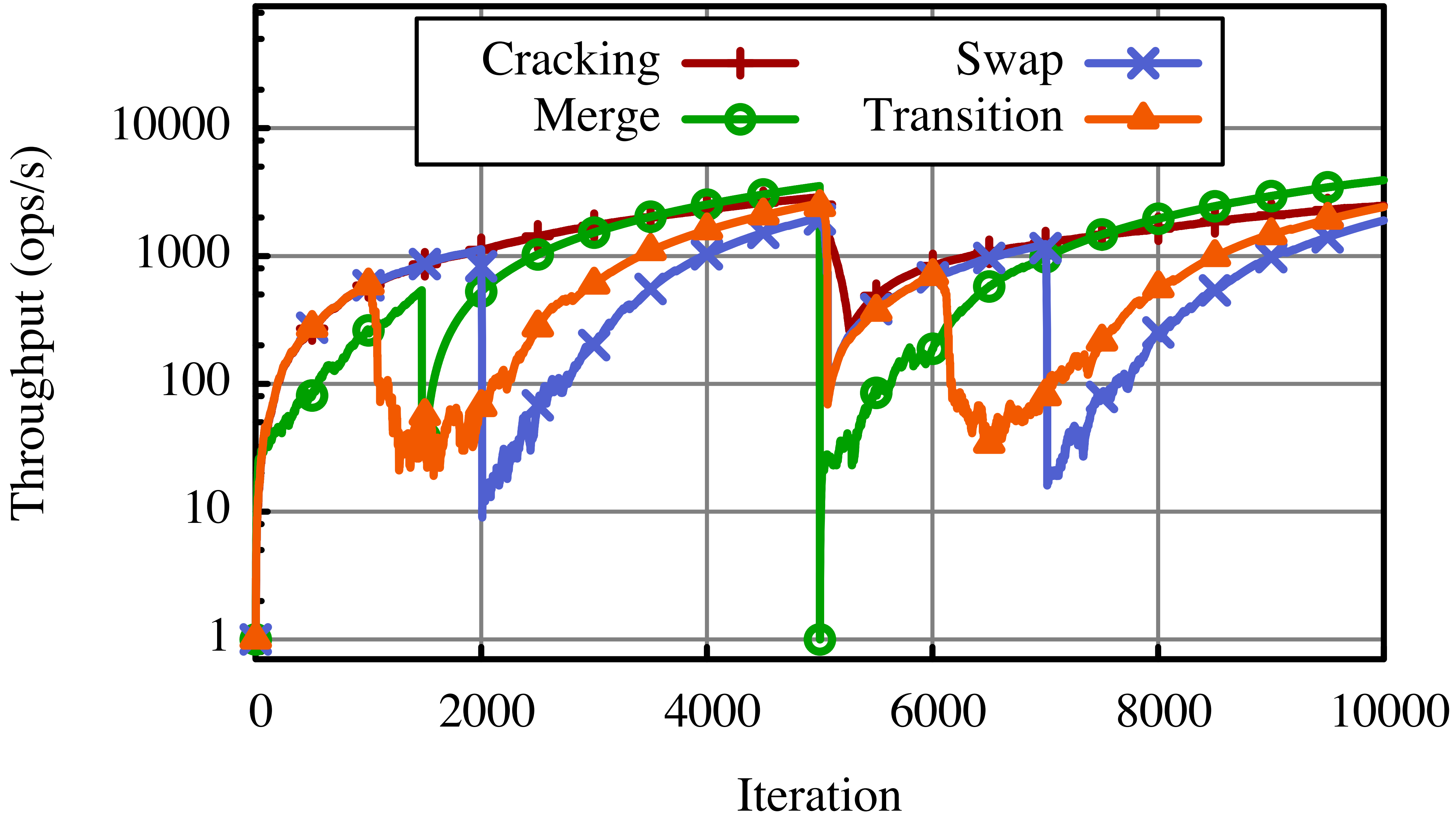
Questions?

Bonus Slides

Overall Throughput



Overall Throughput



JITDs allow fine-grained control over DS behavior