Indexing Tutorial

Database System Technology

Niv Dayan

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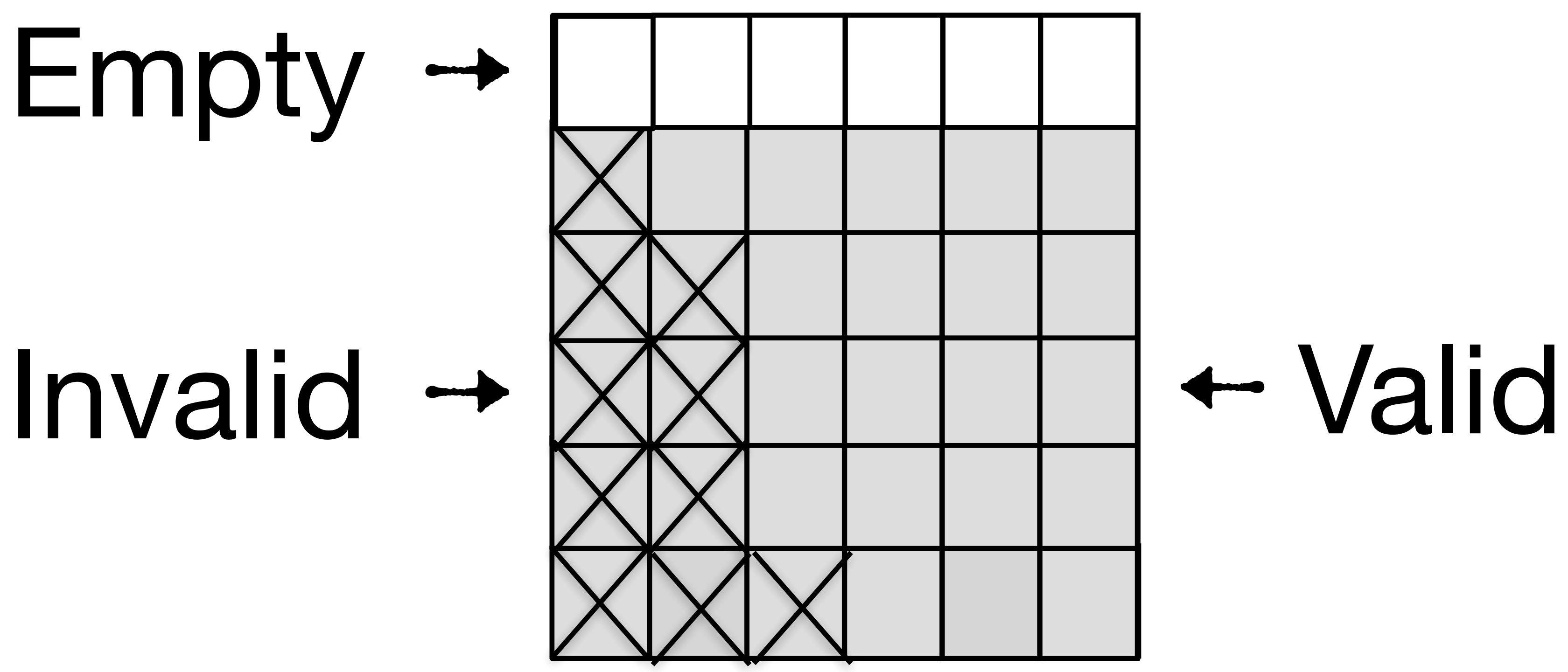

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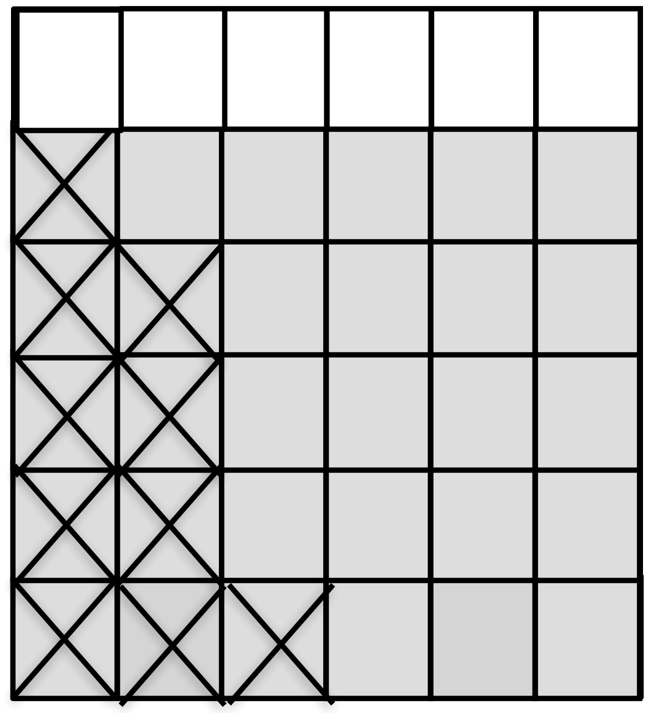

$$L/P = \frac{\%Valid}{\%Empty + \%Valid + \%Invalid}$$

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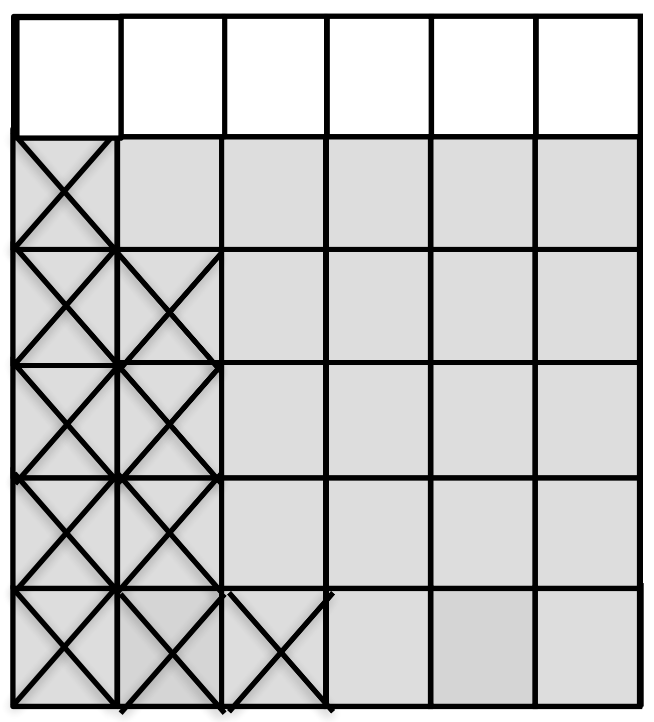

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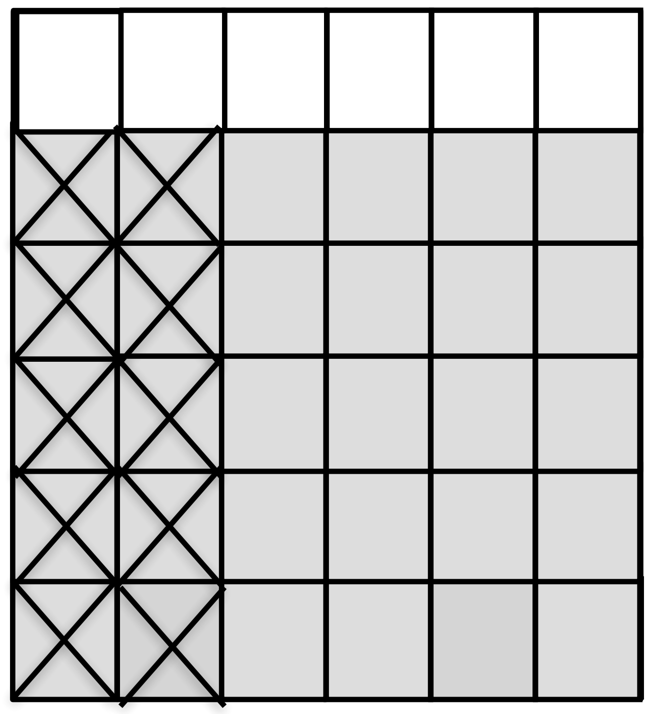
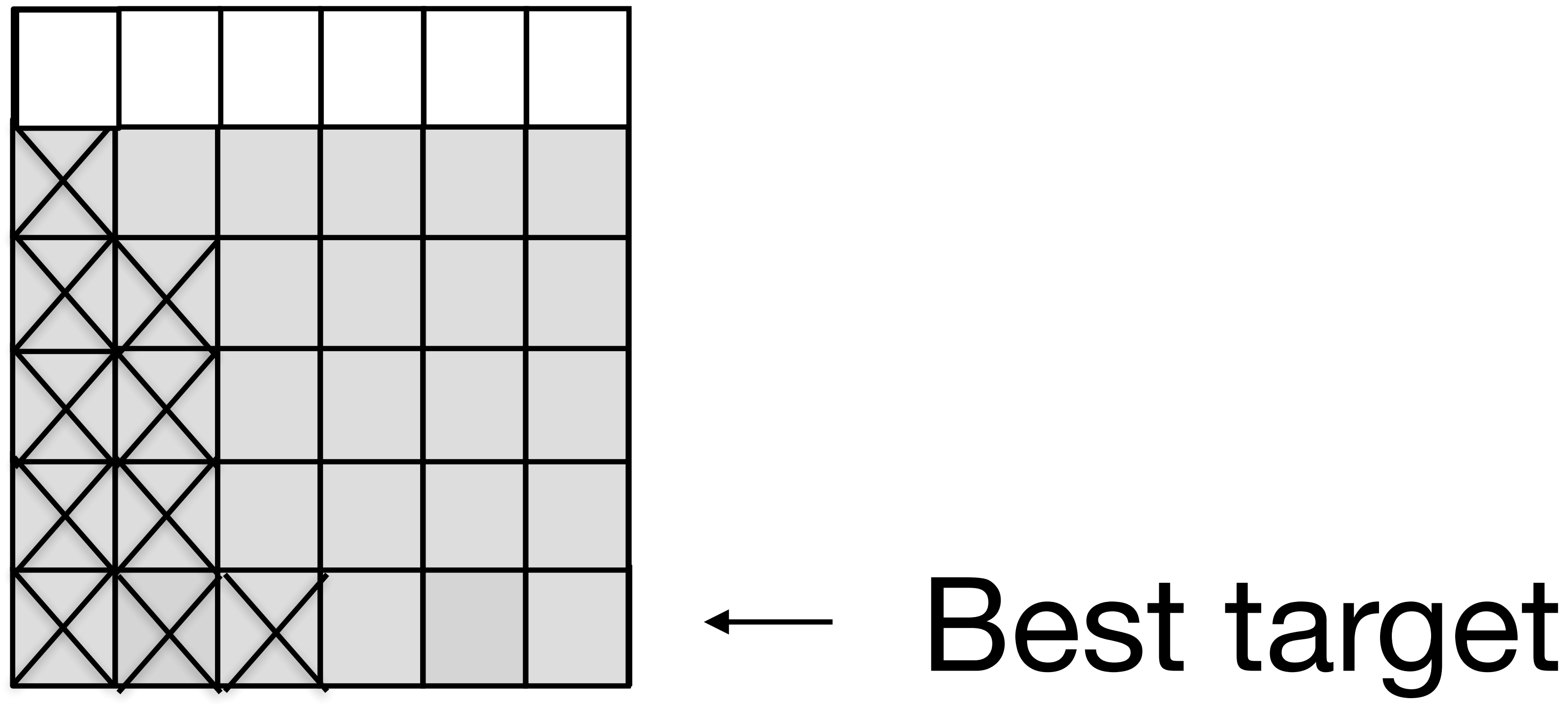
Worst case write-amplification (WA) occurs when each erase-unit has same number of invalid pages.

Worst case



Non-Worst Case



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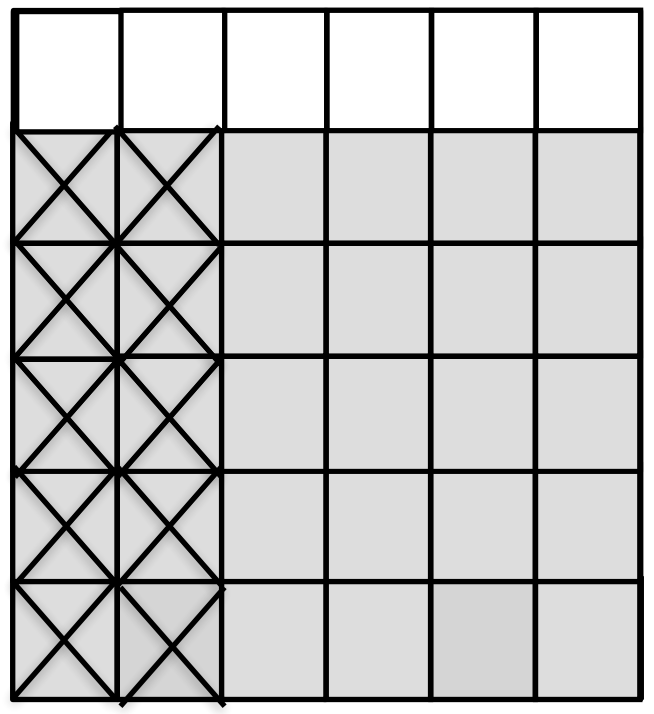

SSD WA Approx

$$1 + \frac{x}{1 - x}$$

x is avg. fraction of valid pages in the garbage-collected block

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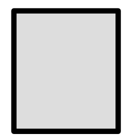

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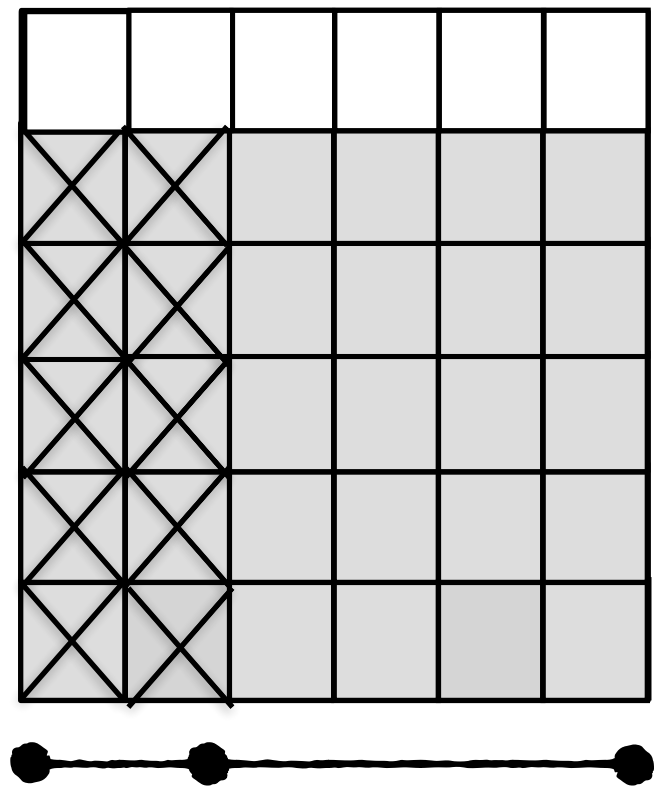

2/6 4/6

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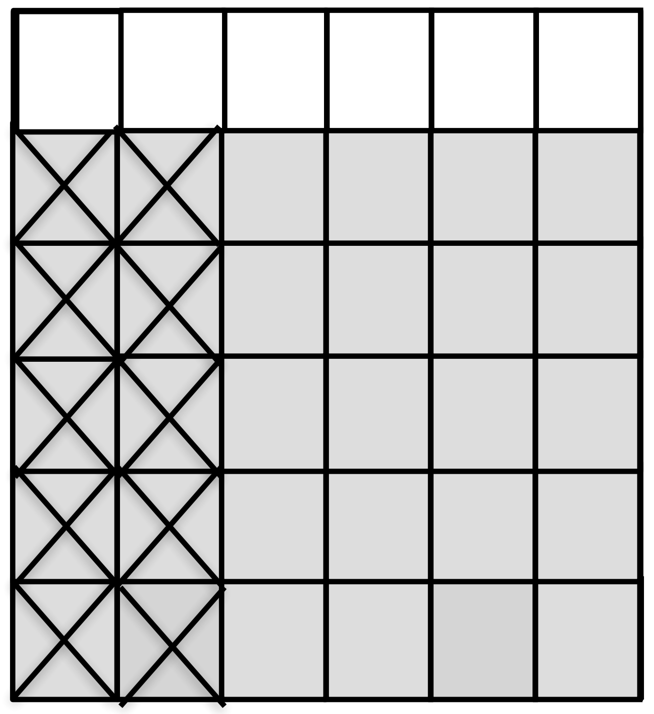

$$1 + \frac{4/6}{2/6}$$

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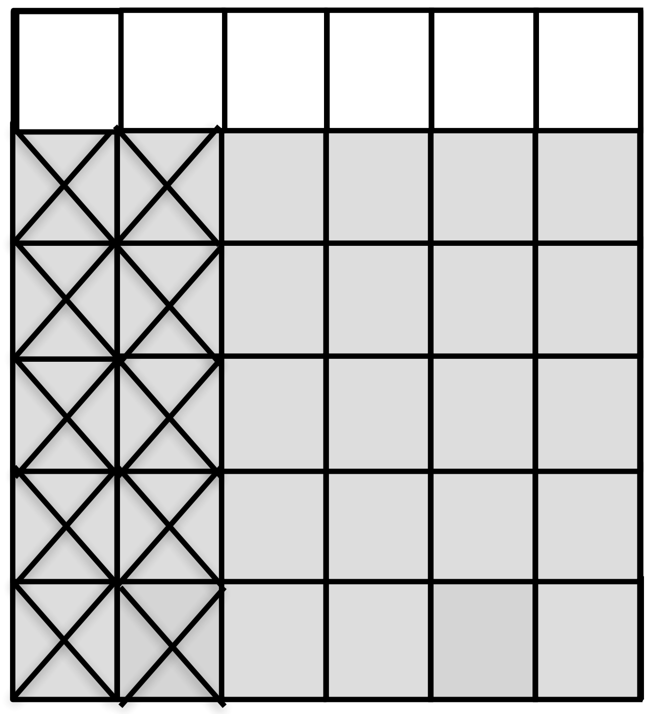

$$1 + \frac{4}{2} = \mathbf{3}$$

SSD WA Approx

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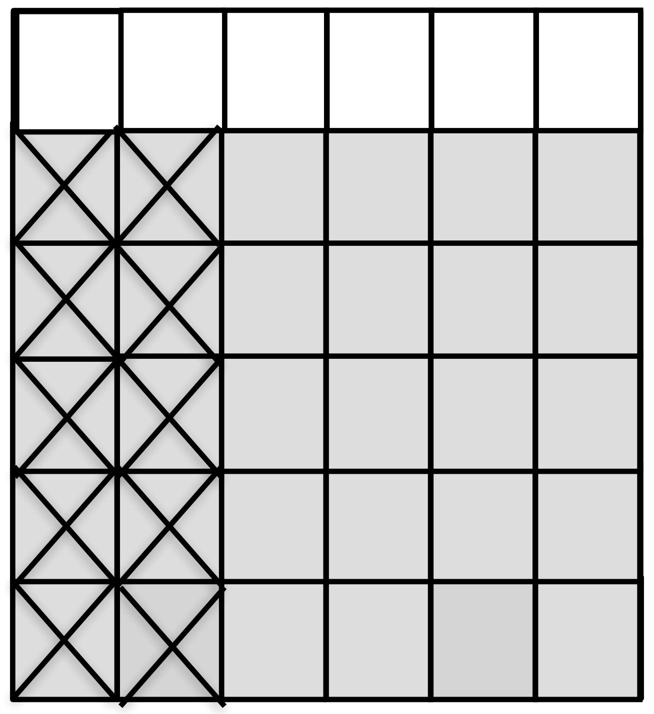

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In worst case: x = valid / total = 4/6 = L/P

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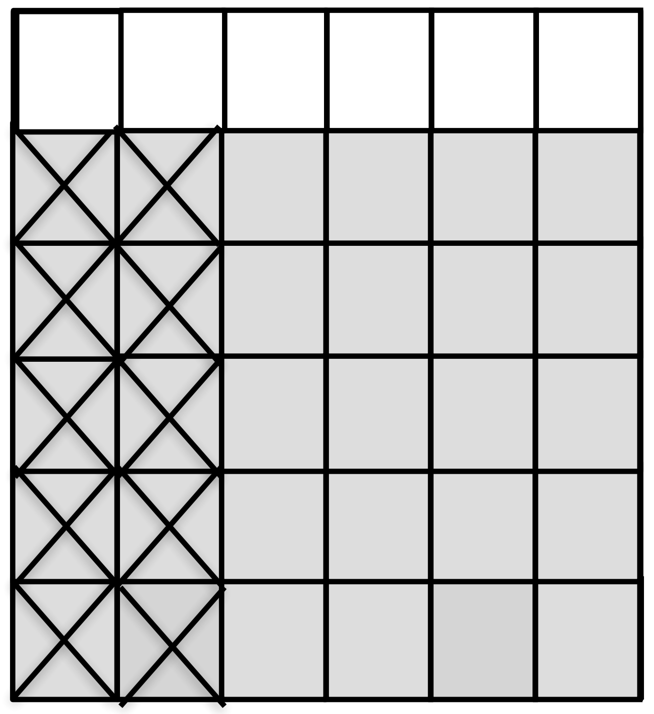


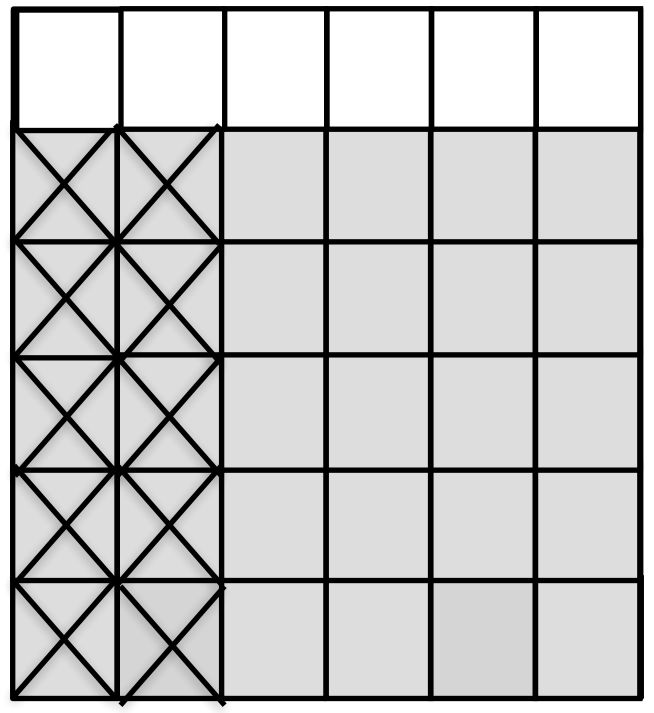
SSD WA Approx

$$1 + \frac{L/P}{1 - L/P}$$

In worst case: x = valid / total = 4/6 = L/P

Modeling SSD Write-Amp

But the worst-case hardly ever happens in practice



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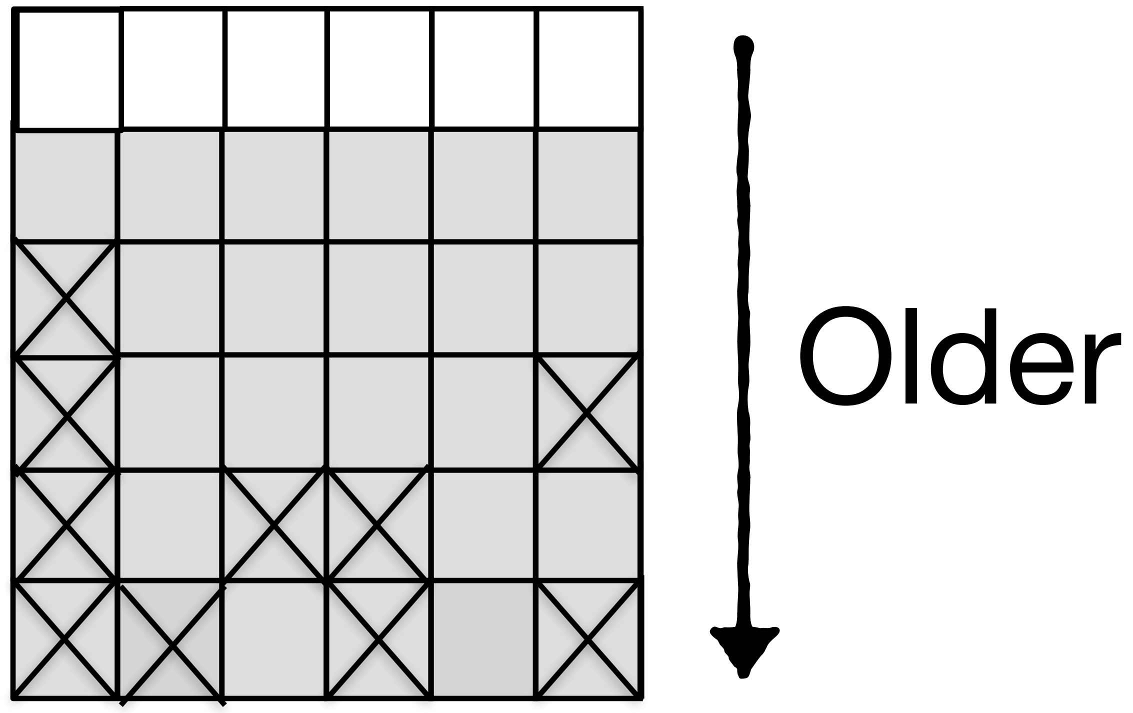
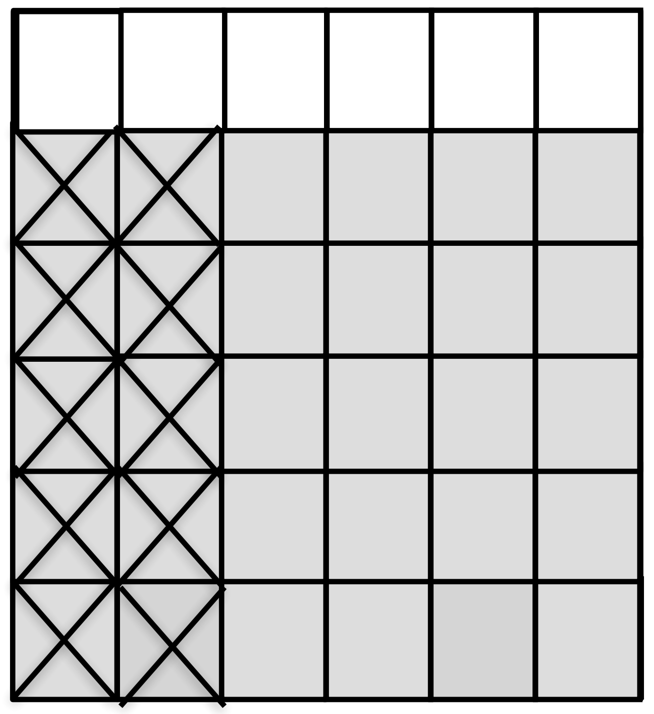
In practice, erase units written longer ago have more invalid pages, so GC is cheaper



Modeling SSD Write-Amp

Cost model assuming uniformly randomly distributed writes?



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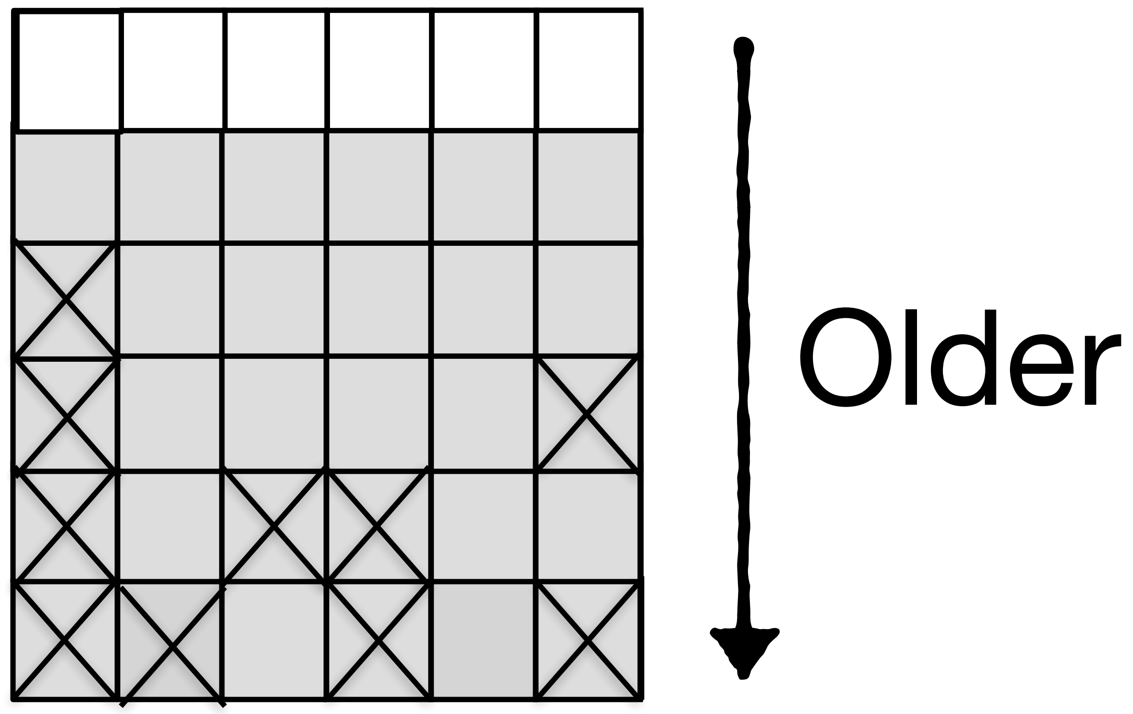

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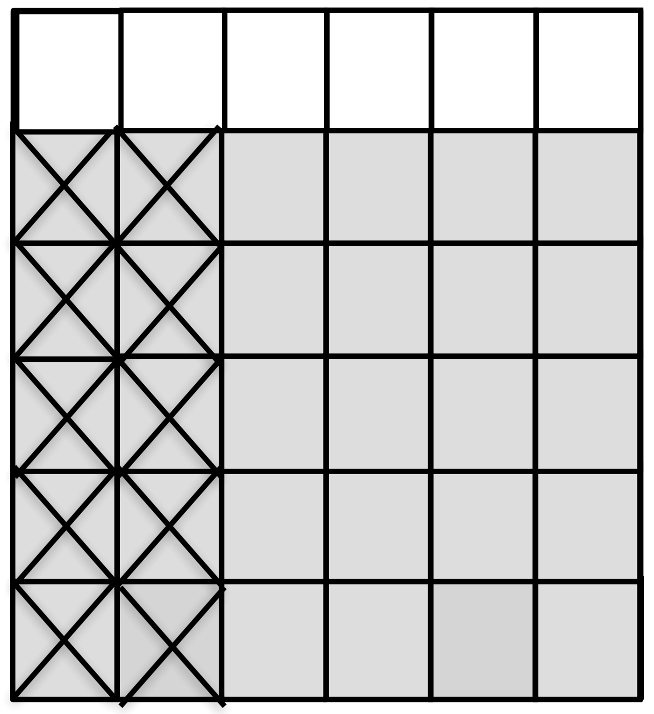
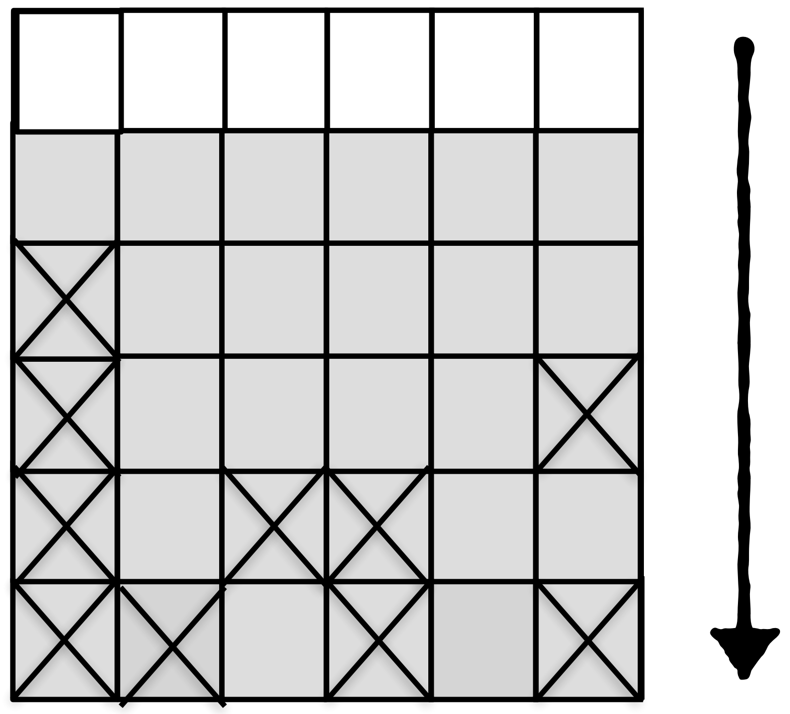


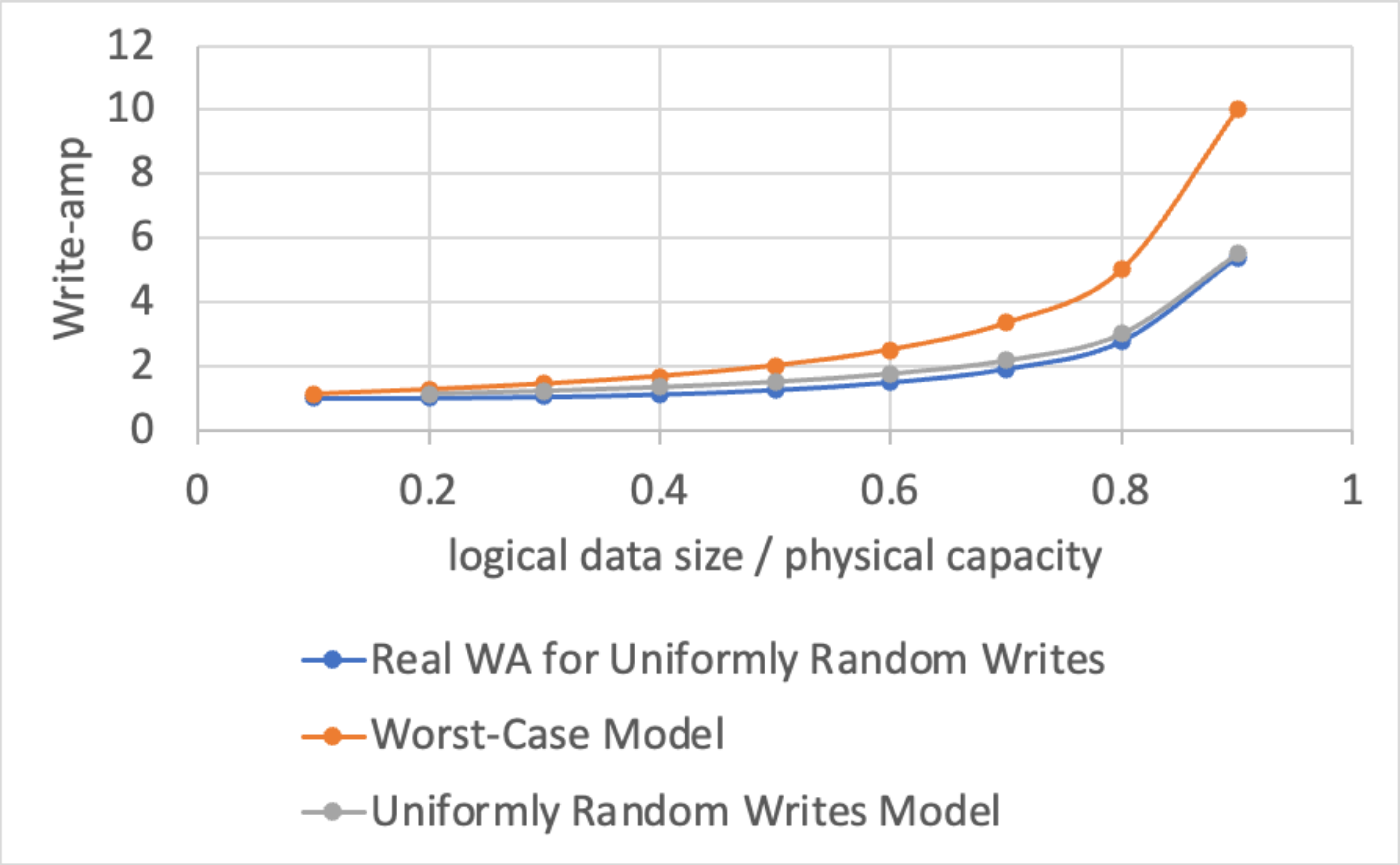
$$1 + \frac{L/P}{1 - L/P}$$

$$1 + \frac{1}{2} \cdot \frac{L/P}{1 - L/P}$$



Older

Modeling SSD Write-Amp



$$1 + \frac{L/P}{1 - L/P}$$

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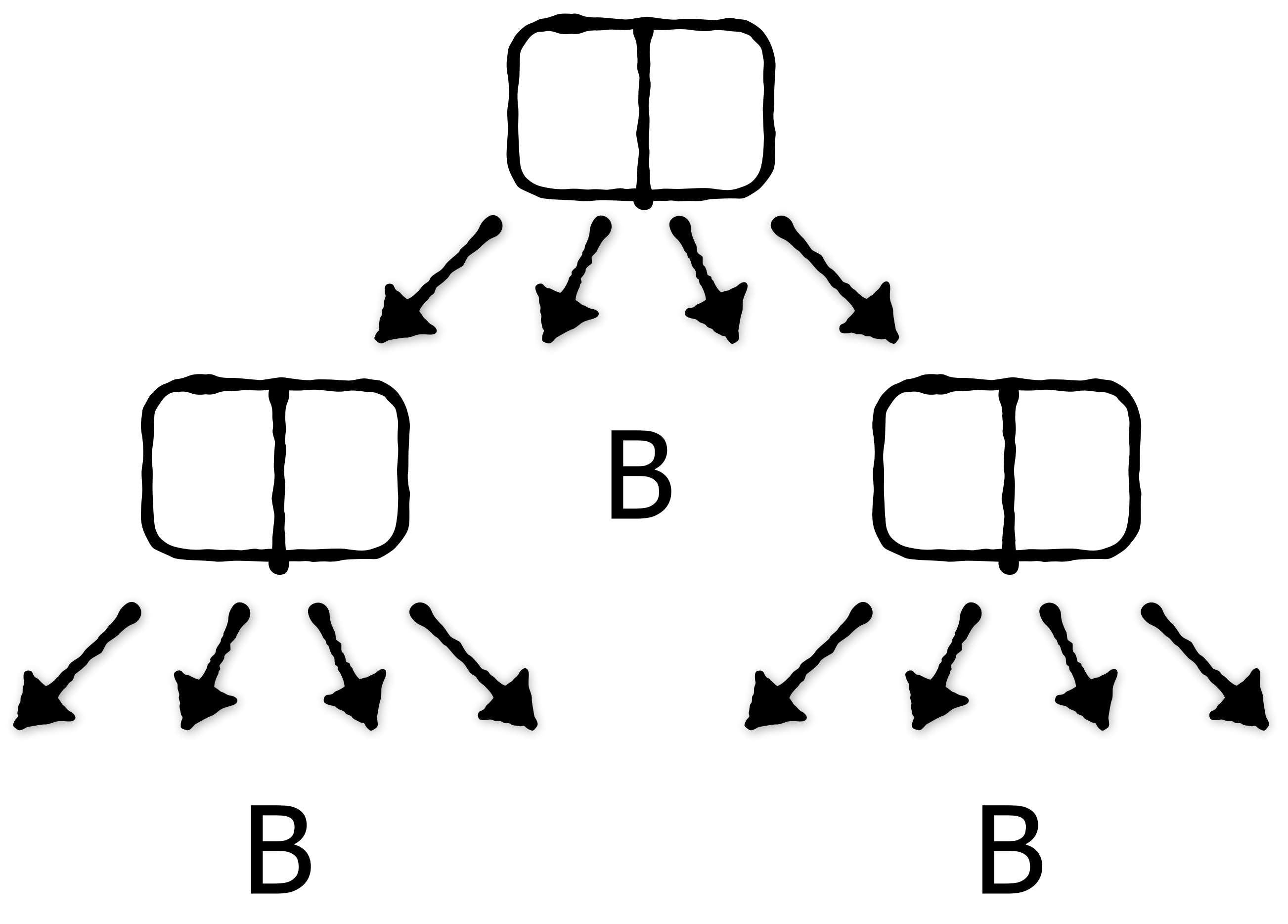
Question 1

Consider a B-tree subject to uniformly randomly distributed updates. There are 100 entries per page. The b-tree occupies 70% of the physical SSD capacity, while the rest is over-provisioned. What write-amplification would you expect? A back-of-the-envelope calculation is enough.



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SSD WA Model with uniformly random updates: $$1 + \frac{1}{2} \cdot \frac{L/P}{1 - L/P}$$

B-tree update cost: ≈ 1 write I/O

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Total write-amp: $100 \cdot (1 + \frac{1}{2} \cdot \frac{0.7}{1 - 0.7})$ = **216.67**

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Now suppose the workload exhibits skew (some entries are more likely to be updated). Which mechanism of a database allows us to reduce write-amplification in this case, and why?

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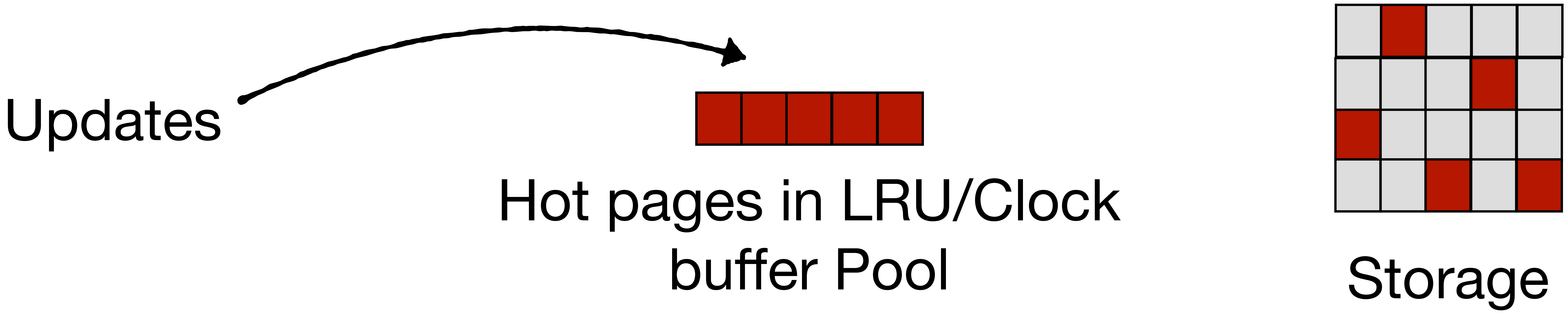
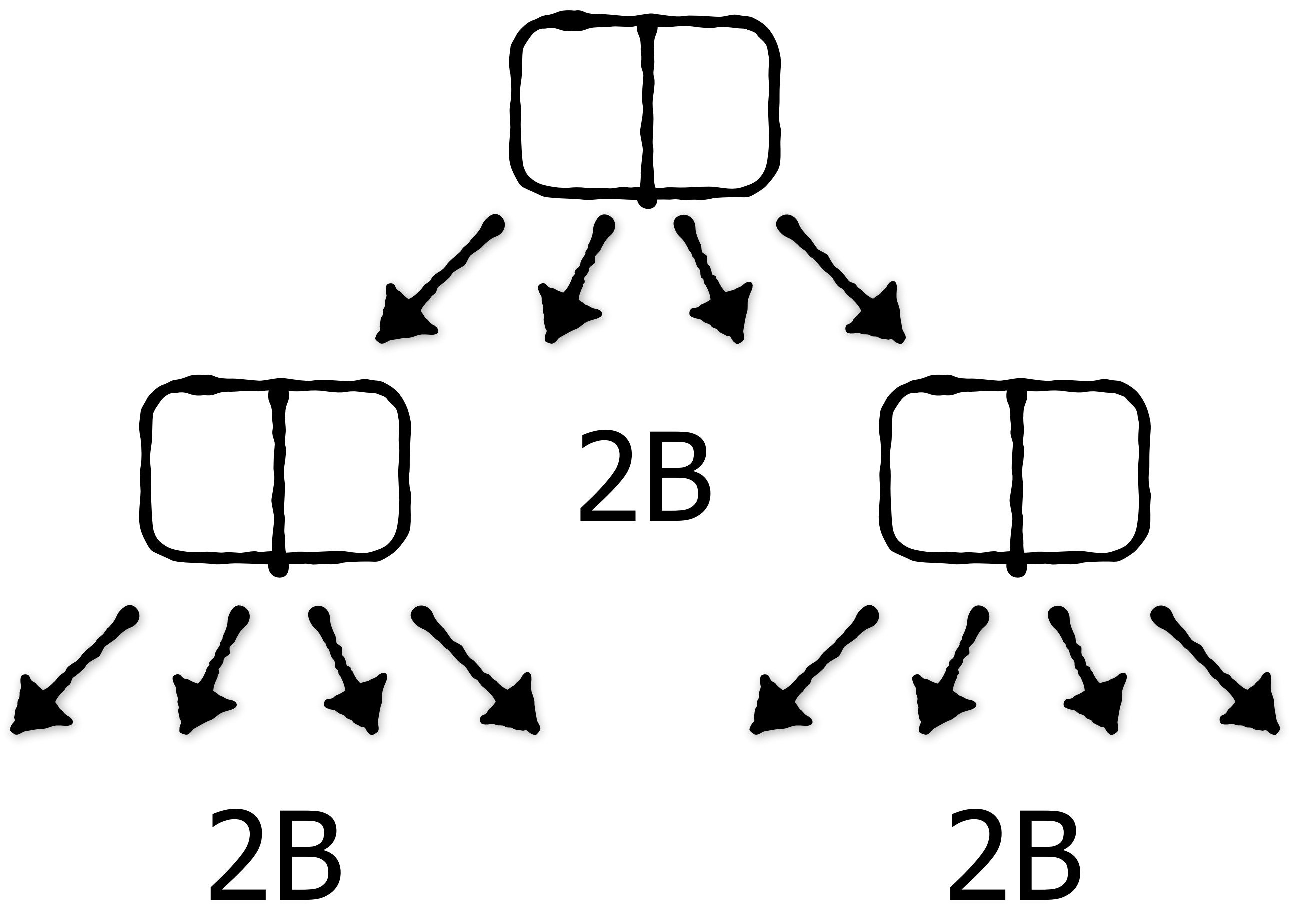


Question 2

We have a B-tree on an SSD. the workload is read-intensive, so we only care about read performance. Each node and each SSD page are 4 KB. Consider making each B-tree node take up two rather than one flash pages (i.e., 8KB rather than 4KB). This can make the tree shallower. Is this a good idea?



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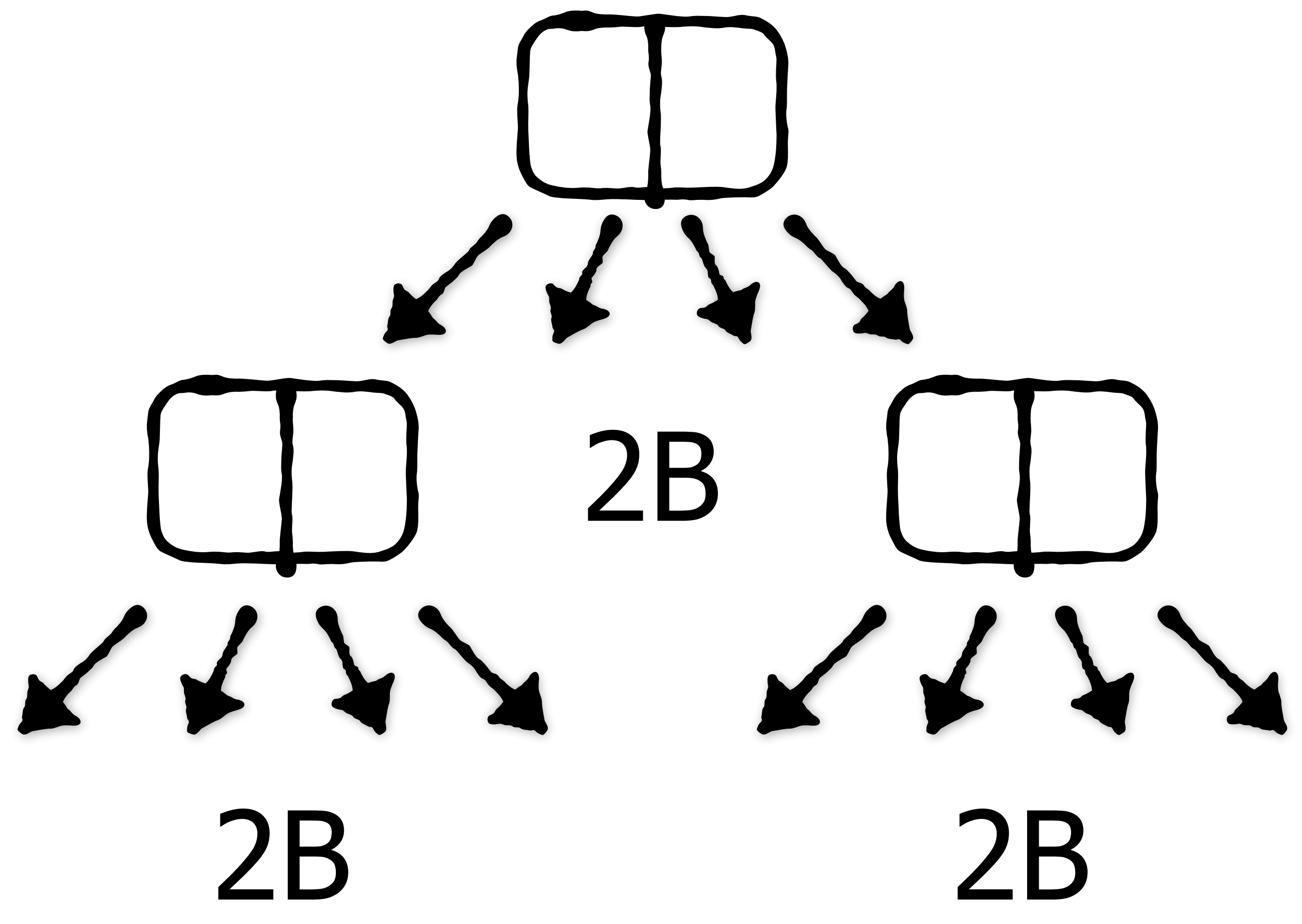
$$= 2 \cdot \log_{2B}(N)$$



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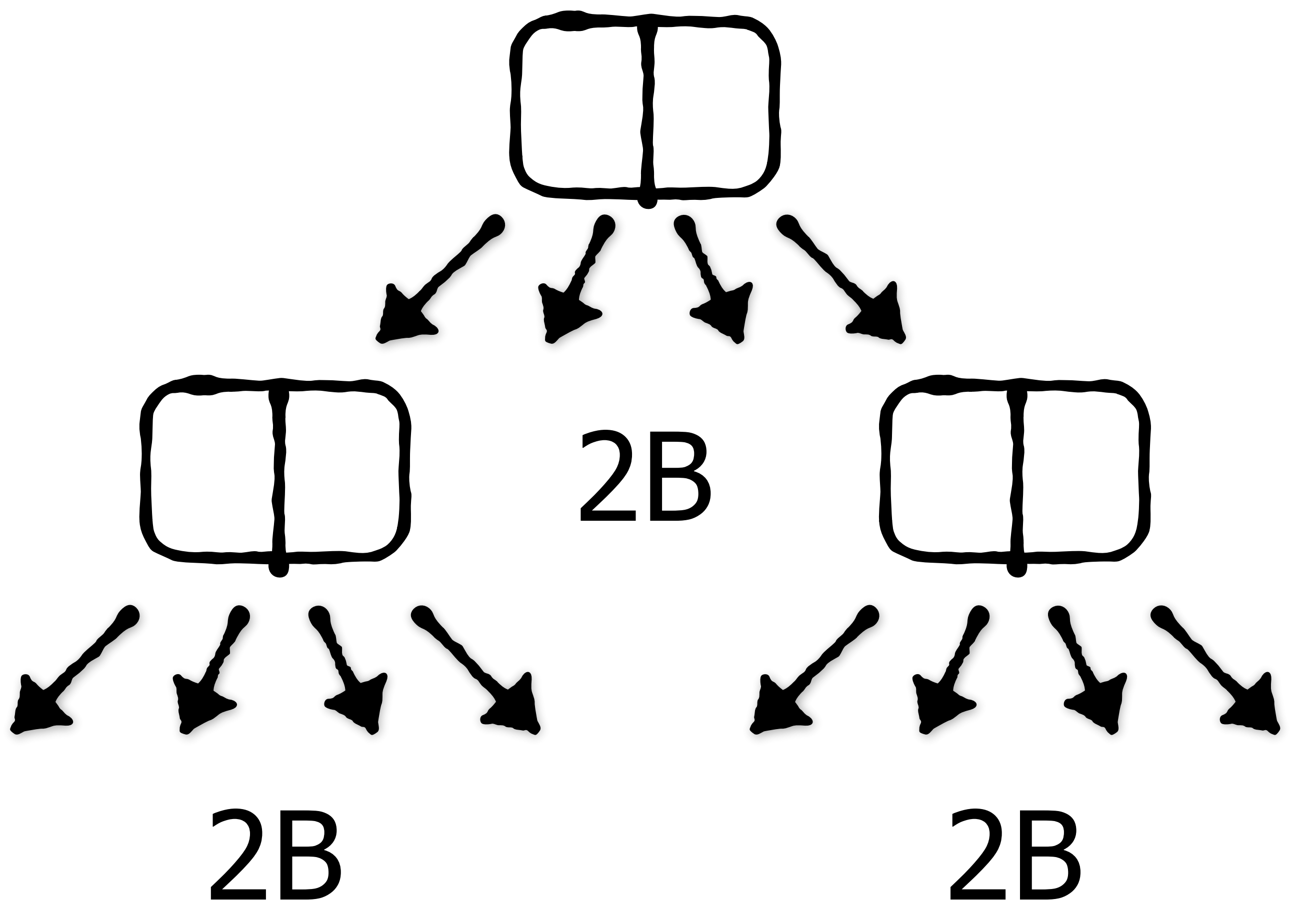
$$2 \cdot \log_{2B}(N) \leq \mathbf{\log_B(N)}$$

Condition for being cheaper than standard B-tree



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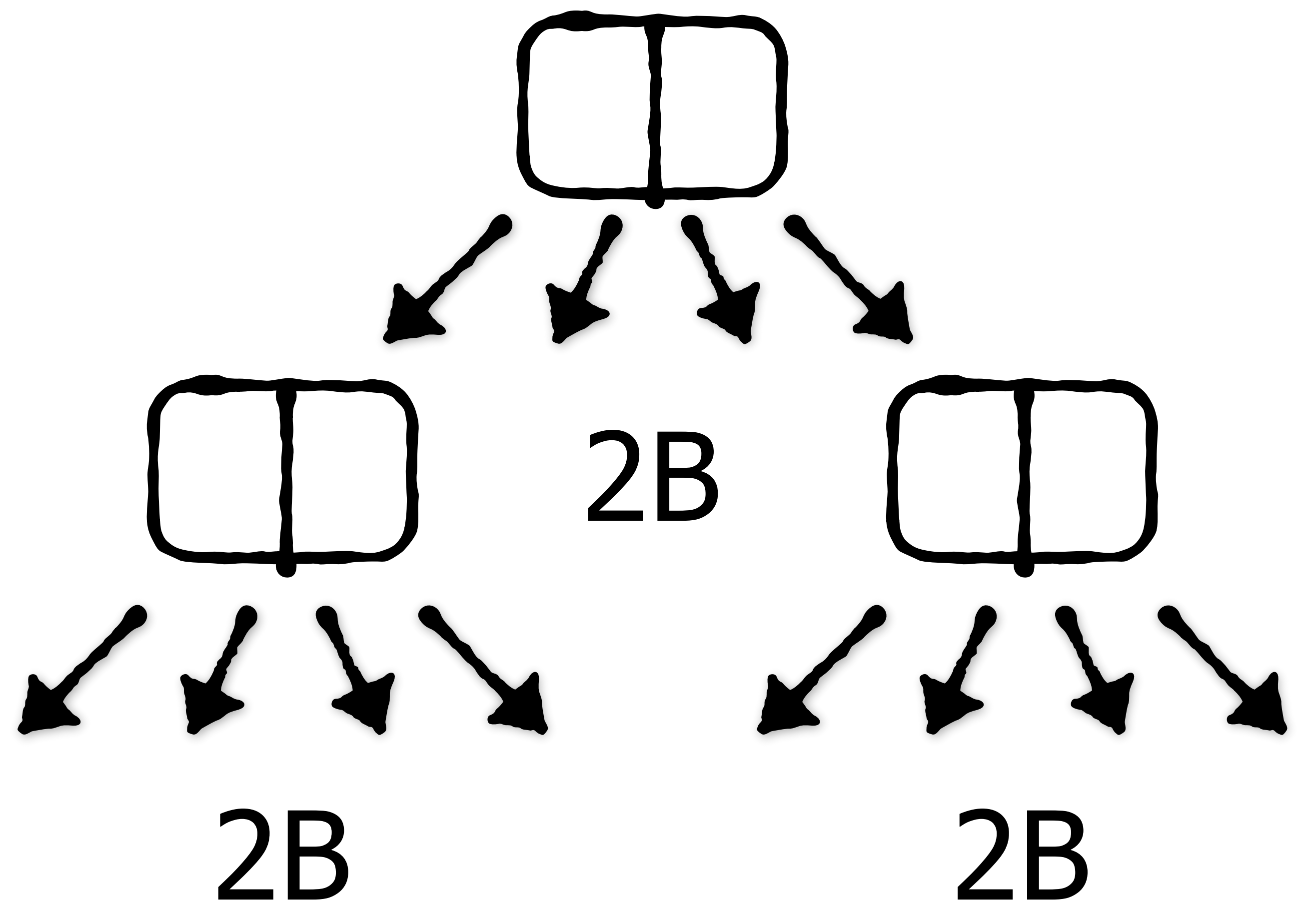
Simplifies to: $\mathbf{B \leq 2}$



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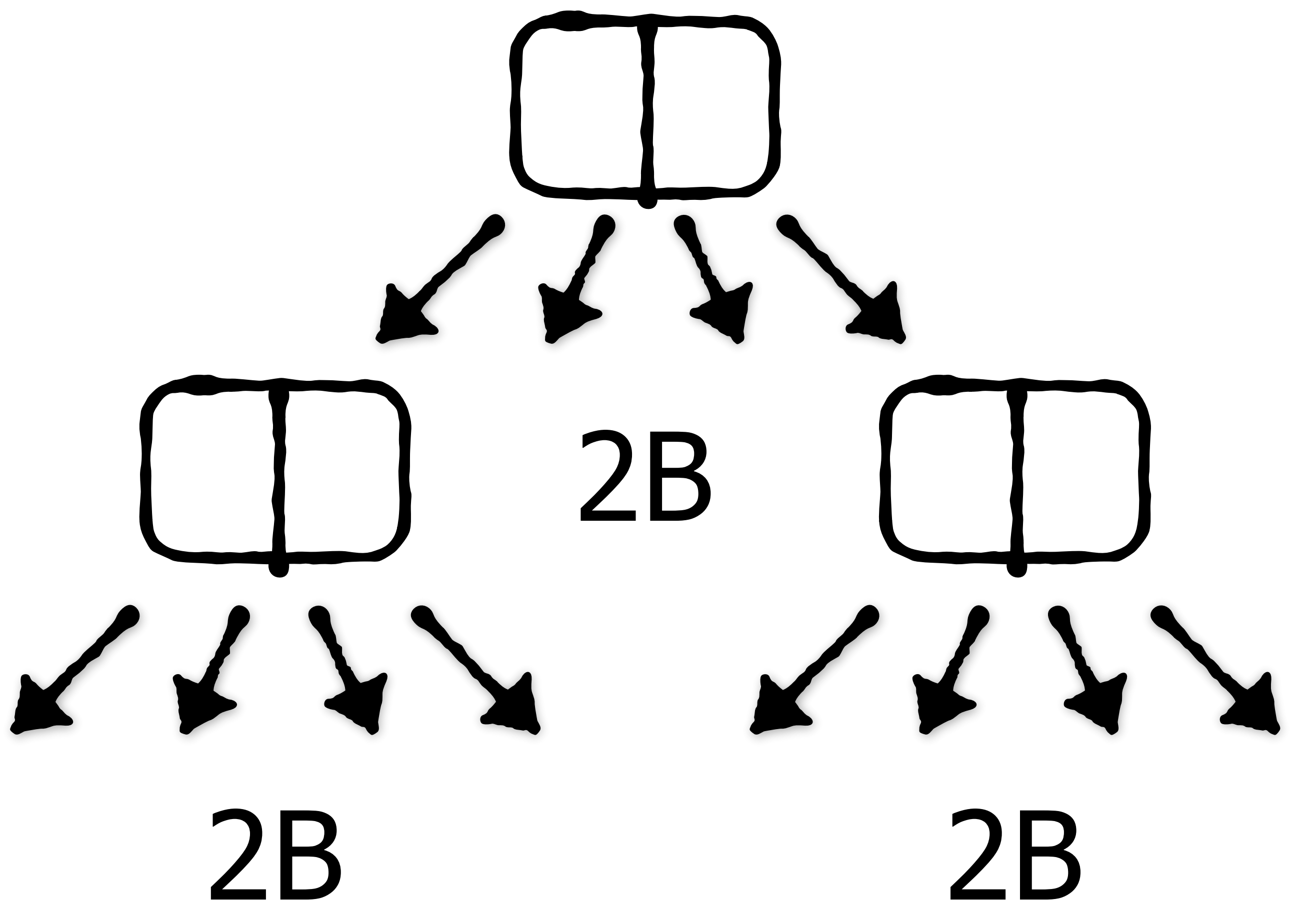
But B is typically larger. So it's not generally a good idea.



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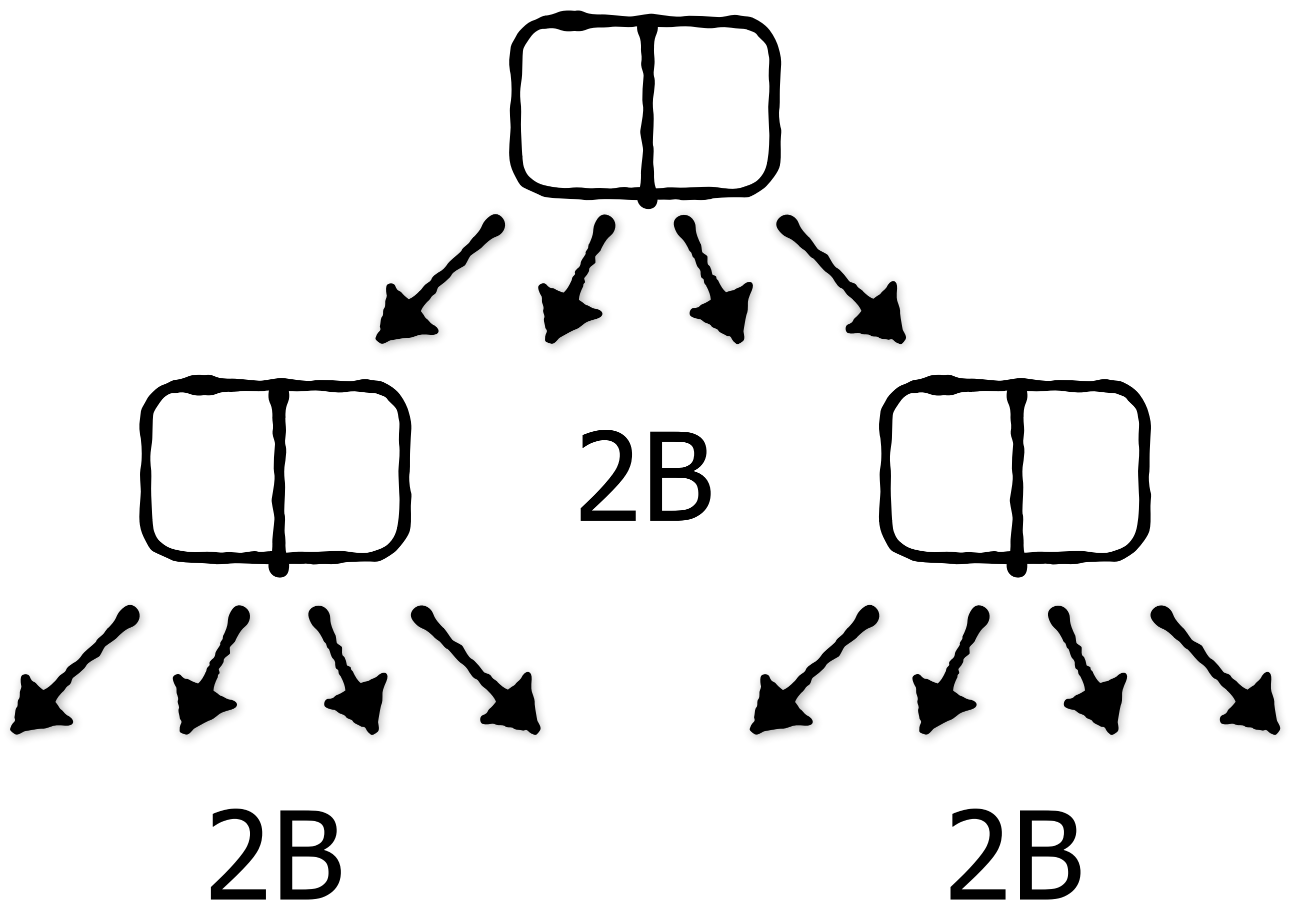

What if we use disk instead of SSD?

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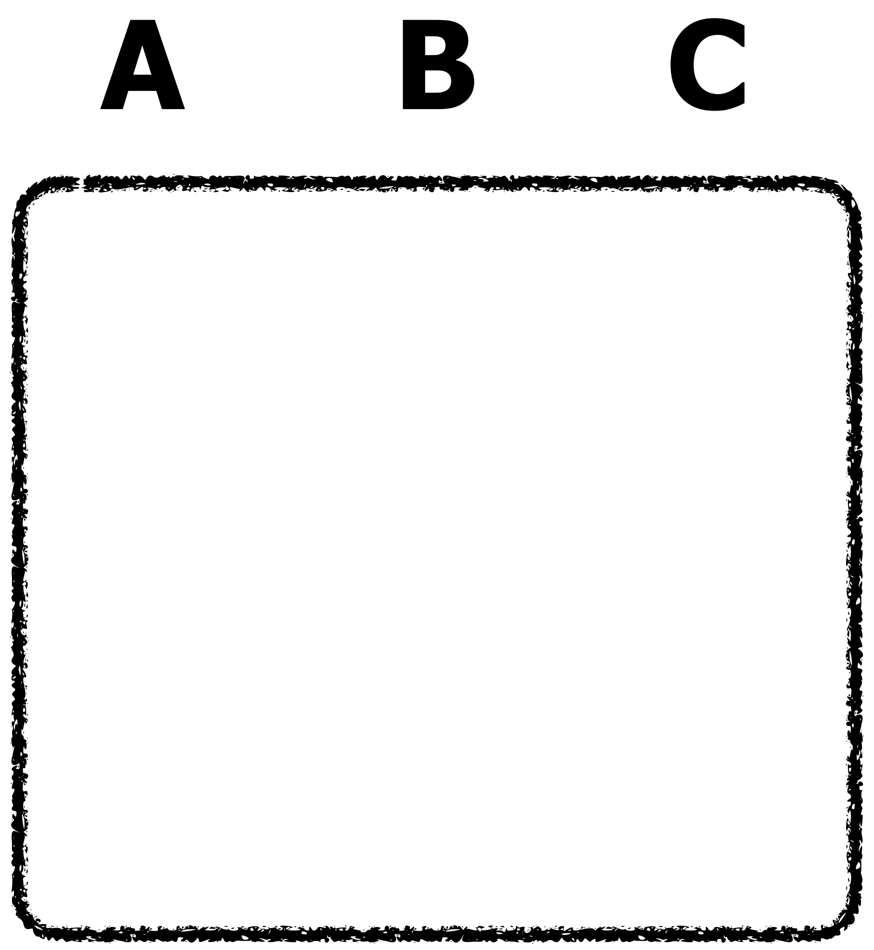
What if we use disk instead of SSD?

On disk, seek & rotational delay dominates, while data transfer is negligible. So this is a good idea. A node size in the area of a few MB is common for disk. Beyond that, we begin to incur a penalty for long sequential accesses.

Question 3

Consider a table with columns A, B and C. Suppose we employ buffered insertions at a cost of O(1/B) each.



Workload:

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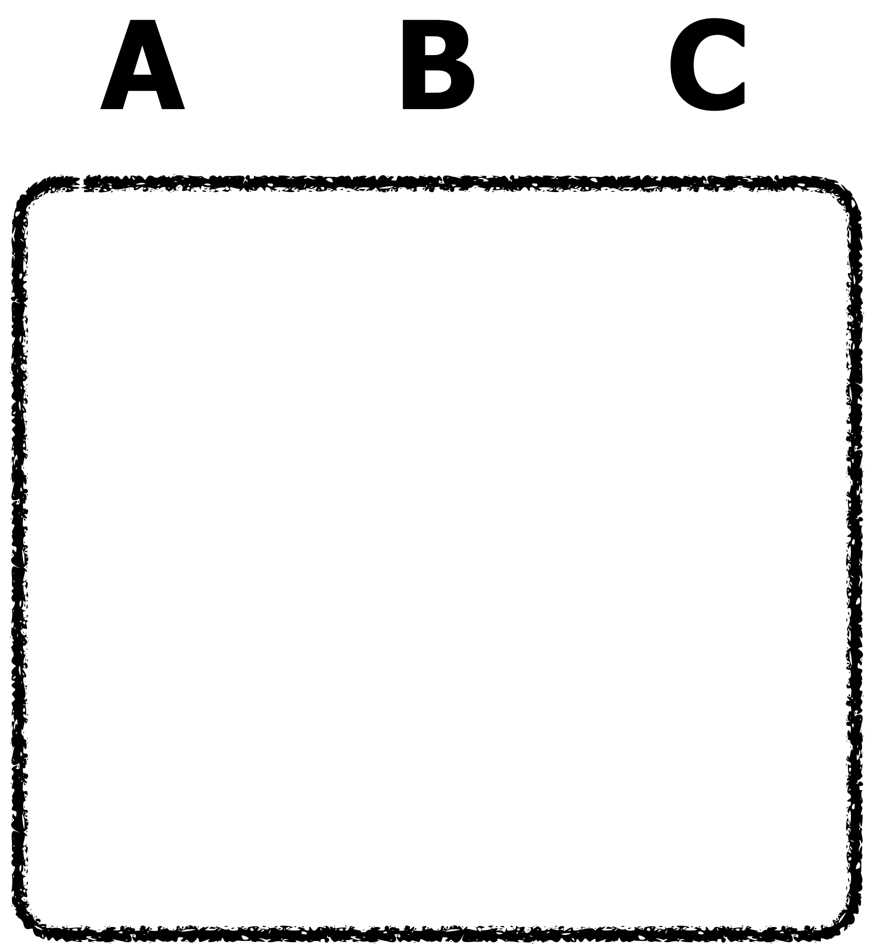

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Should we employ a B-tree index on any of the columns?
Estimate the overall I/O cost of both operations with & without it.
(Back-of-the-envelope reasoning is sufficient)

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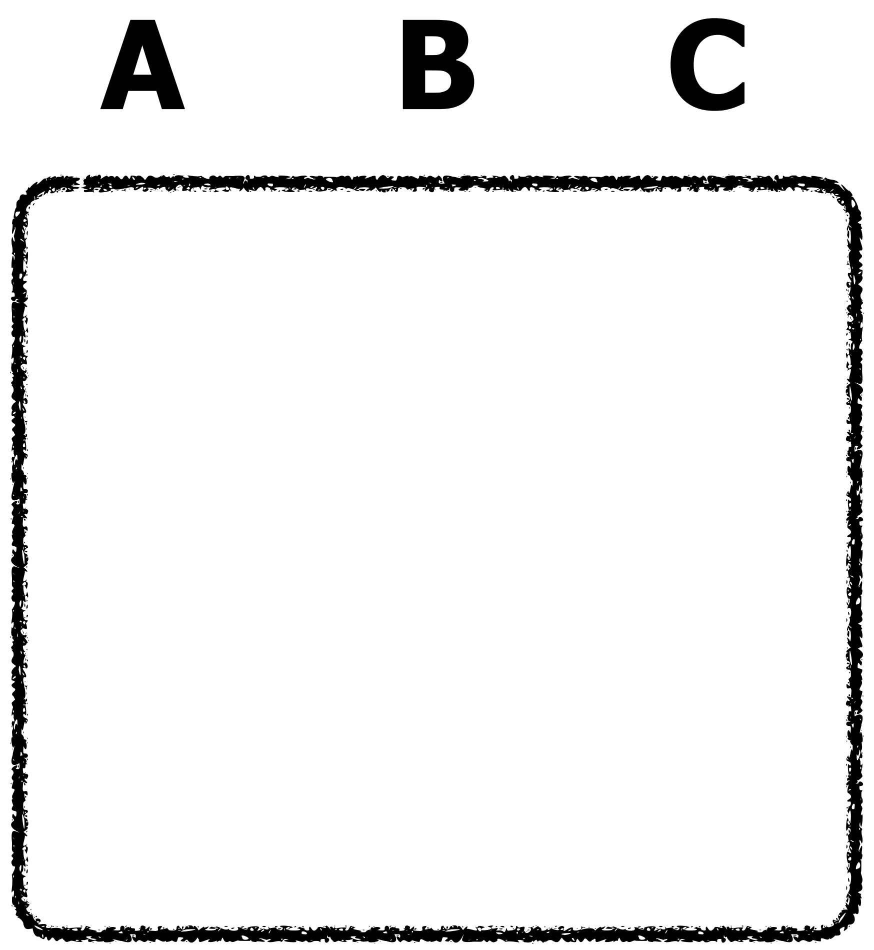

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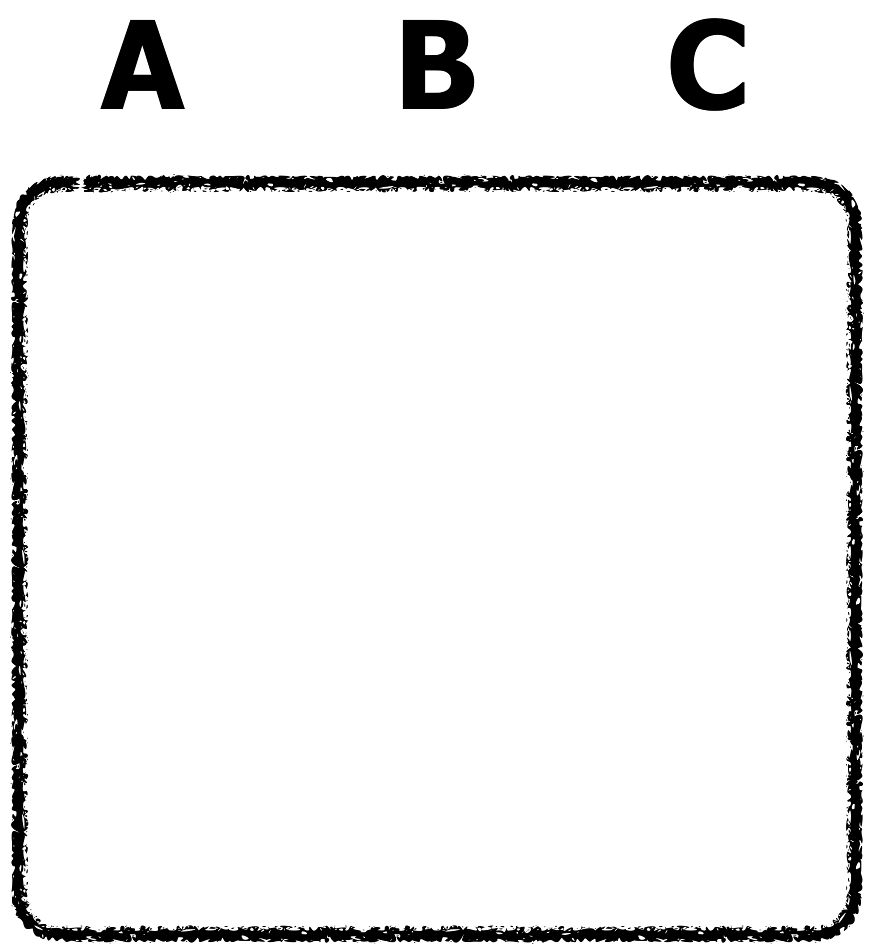

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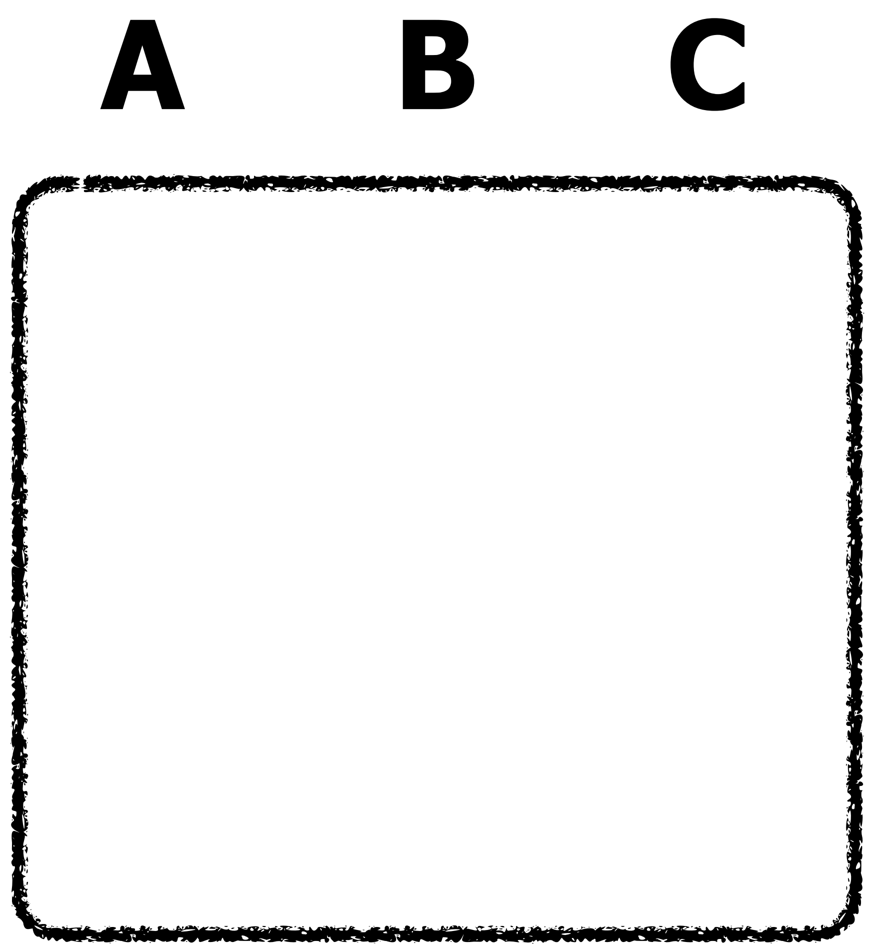

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Indexing column A significantly reduces overall costs.

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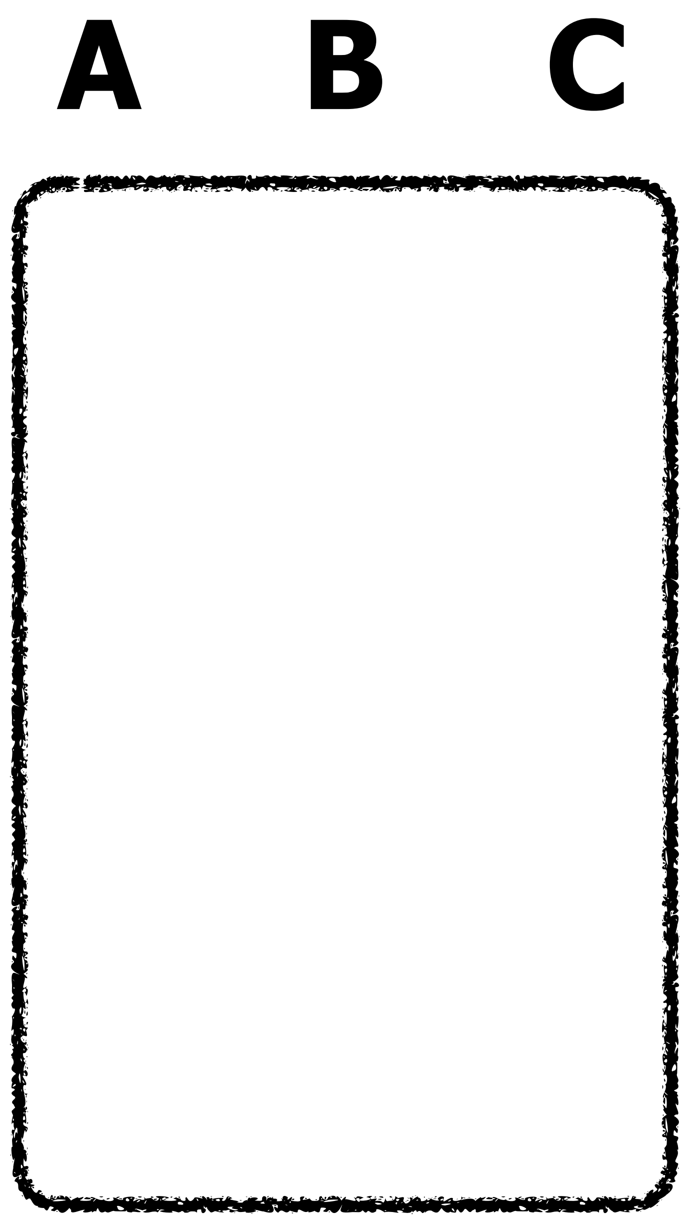
A table has columns A, B and C. The workload consists of two query types:



50% Select A from table where A = “…” Returns one row

50% Select * from table where B > x and B < y Returns avg. 10 rows

How should we index this table? B-tree or hash table? Clustered vs. unclustered? Estimate worst-case I/O cost with your plan for each query with these indexes assuming $N=2^{40}$ and $B=2^{10}$

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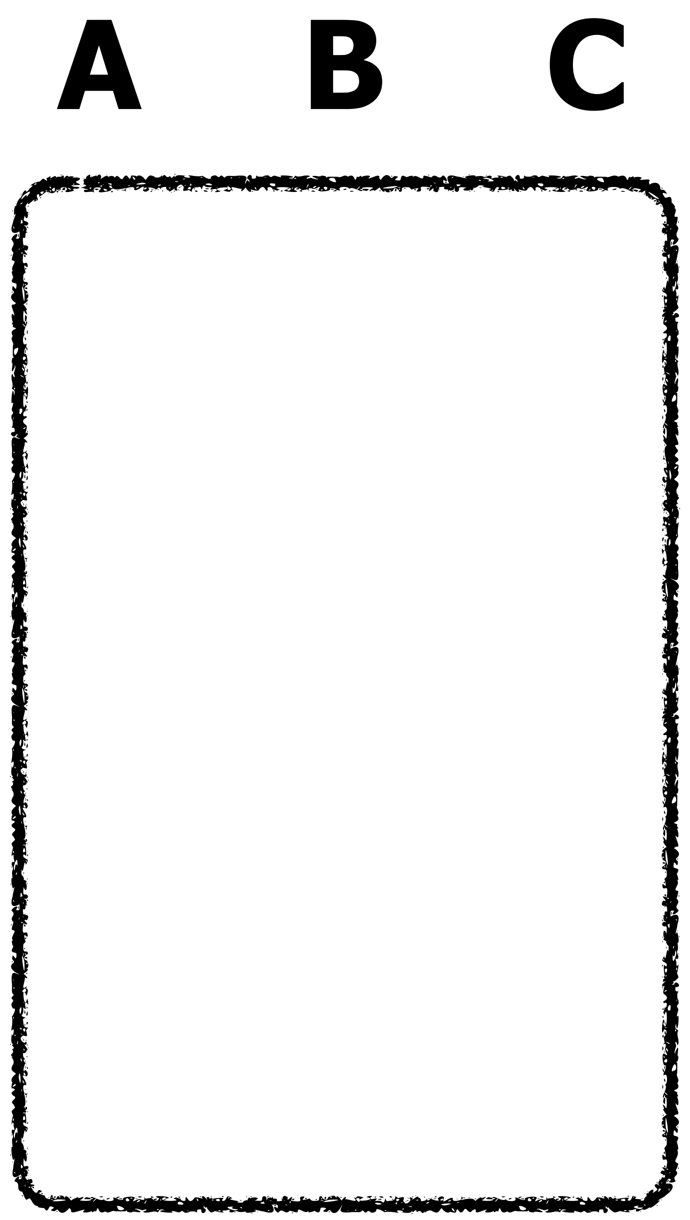

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Clustered B-tree on B **Unclustered Hash table on A**

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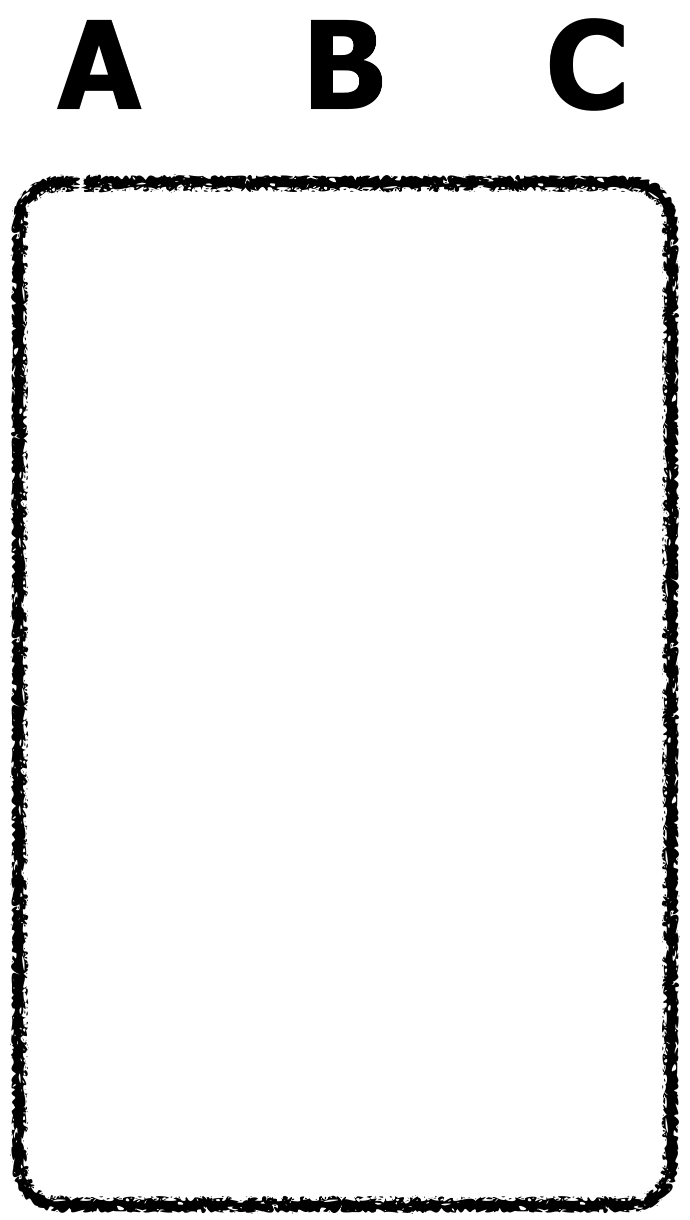

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Clustered B-tree on B

$$\lceil \log_B(N) \rceil + \lceil S/B \rceil$$

$$4 + 1$$

Unclustered Hash table on A

$\approx$1 I/O per query