BOSTON UNIVERSITY

CS 561: Data Systems Architectures

class 4

Systems & Research Project

Zichen Zhu

https://bu-disc.github.io/CS561/

Reminder: Presentations

The first **student presentation** (review) is in one week (on Feb 7th)!

If you haven't done already, **select the paper** you will work on for your **presentation** (groups of 2-3 students)

https://tinyurl.com/S24-CS561-presentations

Before the presentation, discuss with us slides in OH.

Late Submission Policy

Project-related submissions

(Project 0, Project 1, Project proposal, Mid-term report, final report):

5% deduction for late submission within 1 day,

15% deduction for late submission within 2 days,

30% deduction for late submission within 3 days.

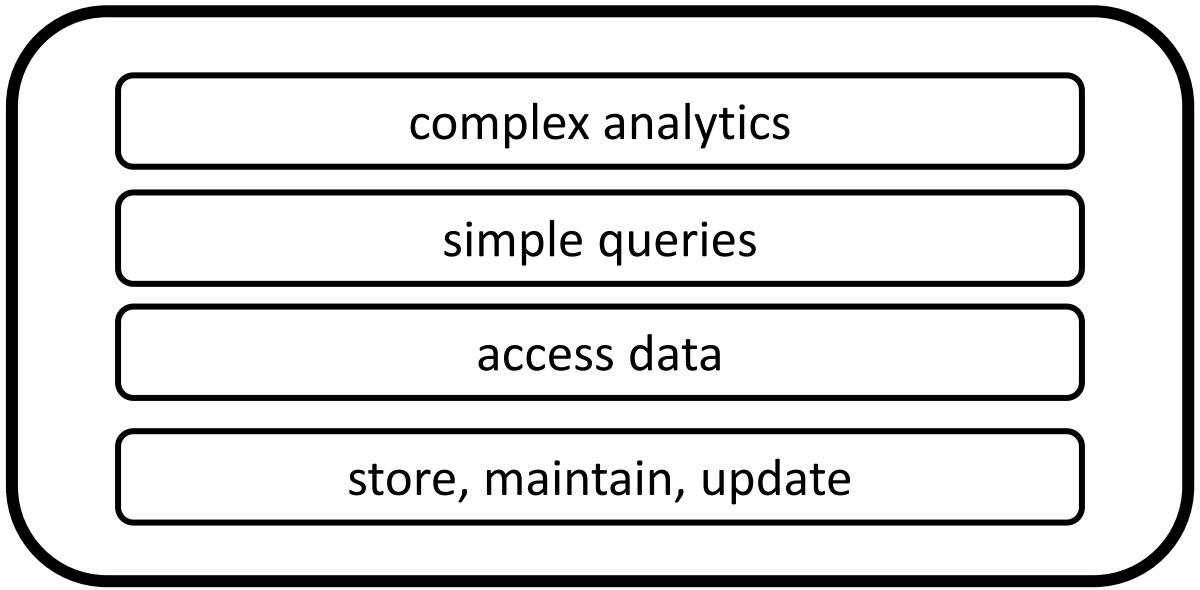
No late submissions will be accepted after 3 day

Reviews/Technical Questions

1 point deducted for late submission within 1 day

No late submissions will be accepted after 1 day

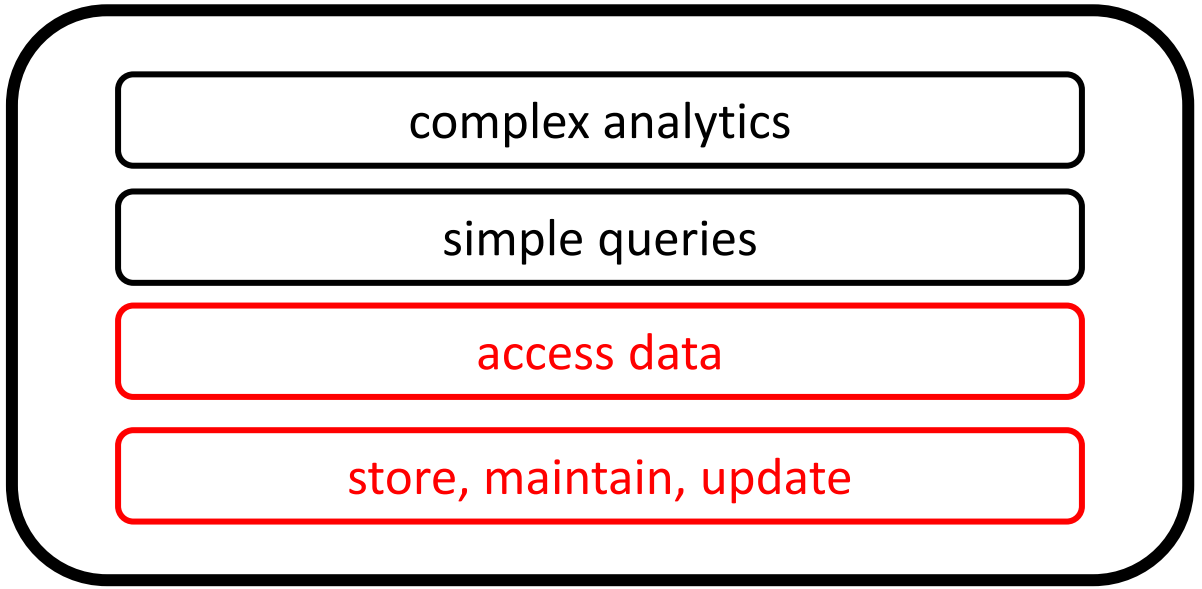
data systems



data systems

>$200B by 2020, growing at 11.7% every year

[The Forbes, 2016]



access methods*

***algorithms** and **data structures**
for organizing and accessing data

data systems core: storage engines

main decisions

how to ***store*** data?

how to ***access*** data?

how to ***update*** data?

let's simplify: **key-value** storage engines

collection of keys-value pairs

query on the key, return both key and value

remember

Couchbase

state-of-the-art design

how general is a key value store?

can we store relational data?

yes! {<primary_key>,<rest_of_the_row>}

example: { **student_id**, { **name**, **login**, **yob**, **gpa** } }

what is the caveat?

how to index these attributes?

other problems?

index: { **name**, { **student_id** } }

index: { **yob**, { **student_id**$_1$, **student_id**$_2$, … } }

how general is a key value store?

can we store relational data?

yes! {<primary_key>,<rest_of_the_row>}

how to efficiently code if we do not know the structure of the "***value***"

index: { **yob**, { **student_id$_1$, student_id$_2$, …** } }

how to use a key-value store?

basic interface

put(k,v)

{v} = get(k) {v_1, v_2, …} = get(k)

{v_1, v_2, …} = get_range(k_{min}, k_{max}) {v_1, v_2, …} = full_scan()

c = count(k_{min}, k_{max})

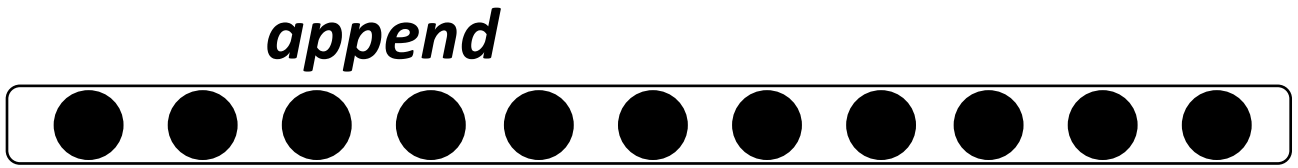
deletes: delete(k)

updates: update(k,v) is it different than put?

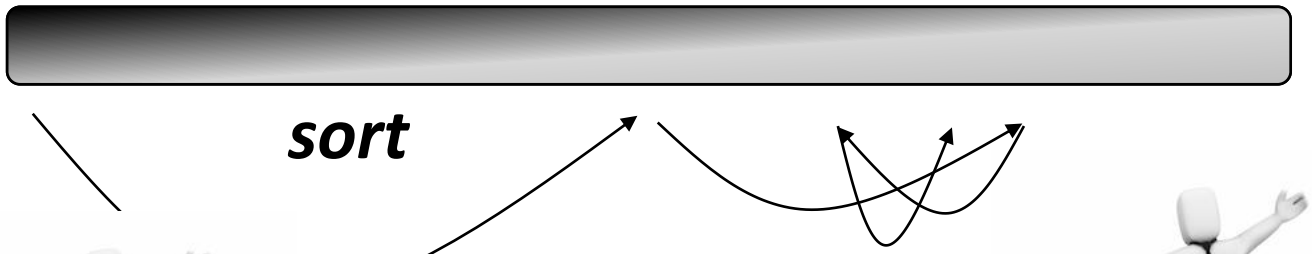
get set: {v_1, v_2, …} = get_set(k_1, k_2, …)

how to build a key-value store?

if we have only ***put*** operations



if we mostly have ***get*** operations

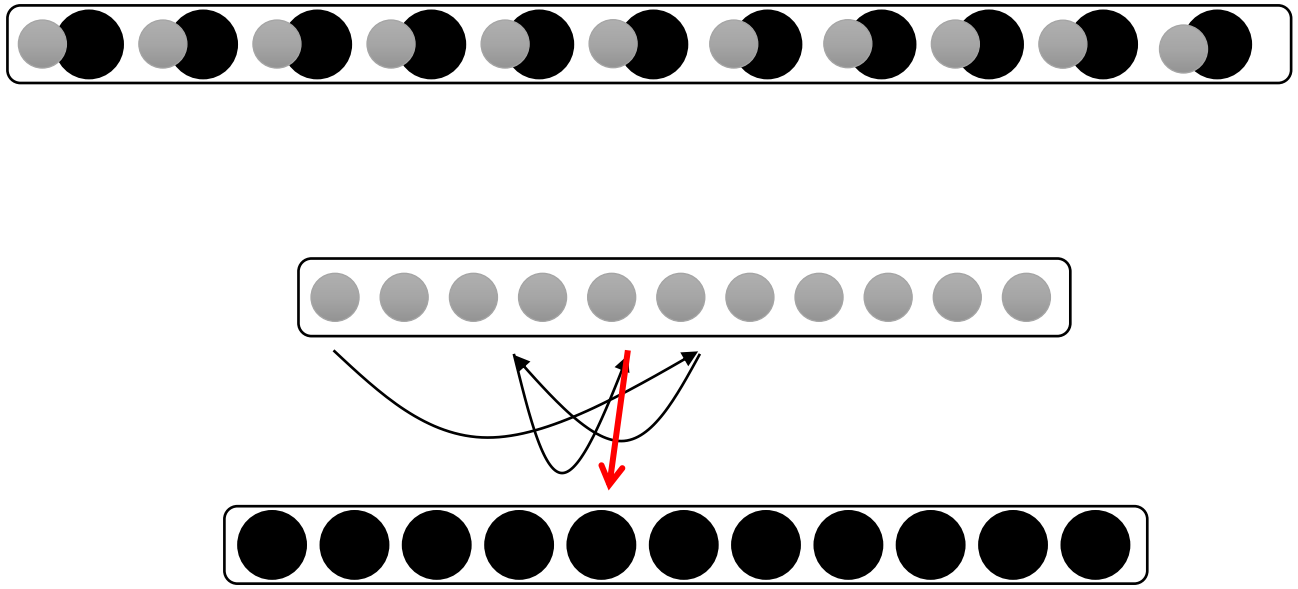


what about full scan?

and then

range queries?

can we separate keys and values?



at what price?

locality? code?

read queries
(point or range)

inserts
(or updates)

sort data

simply append

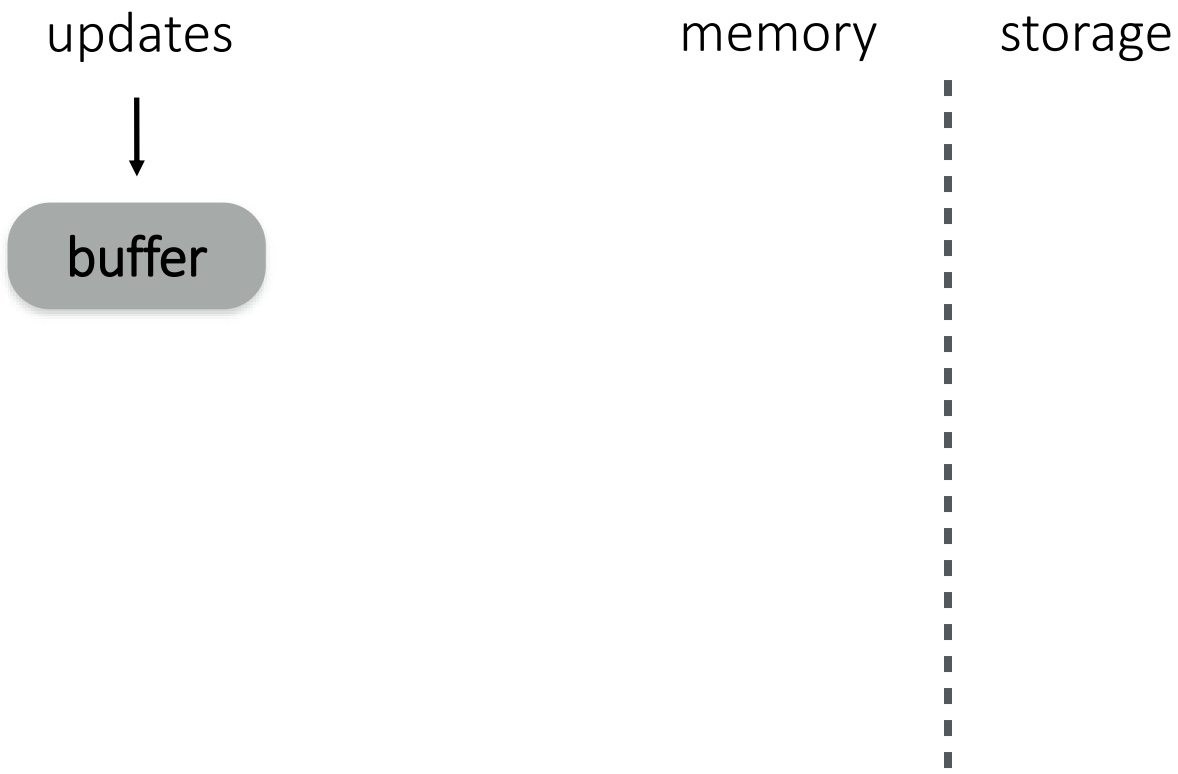
amortize sorting cost

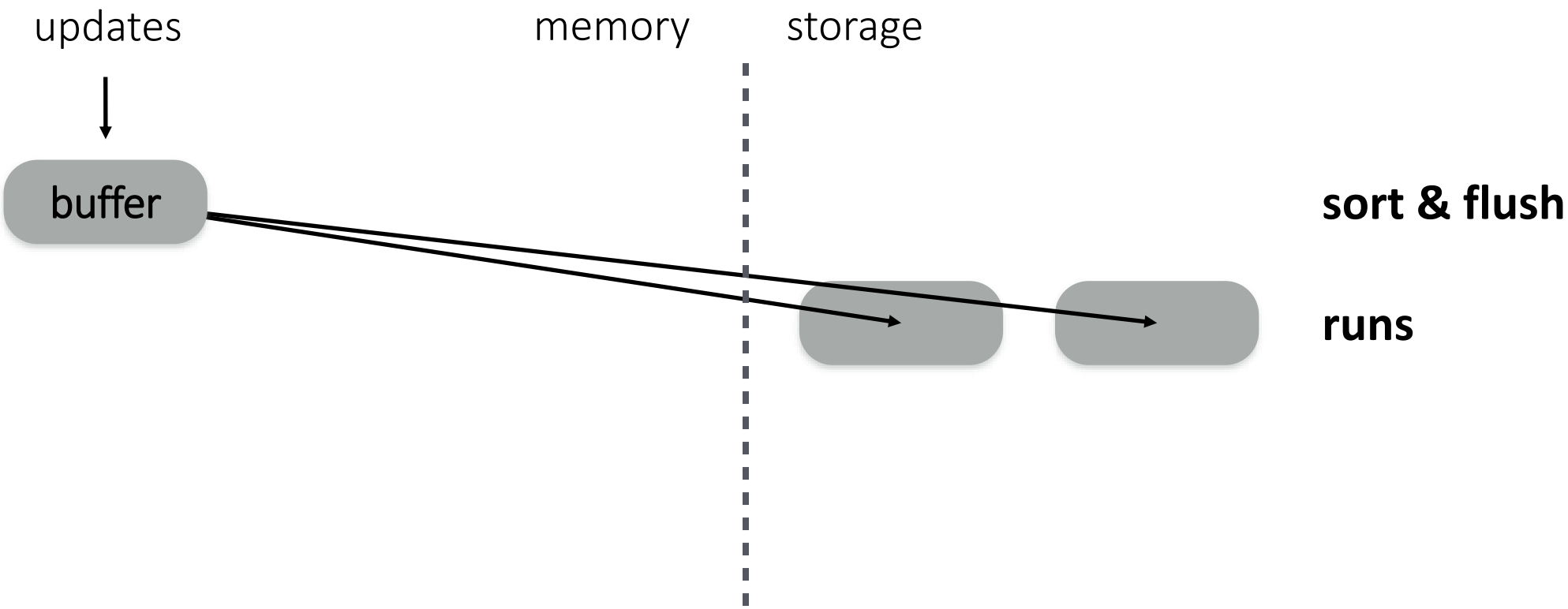
avoid resorting after every update

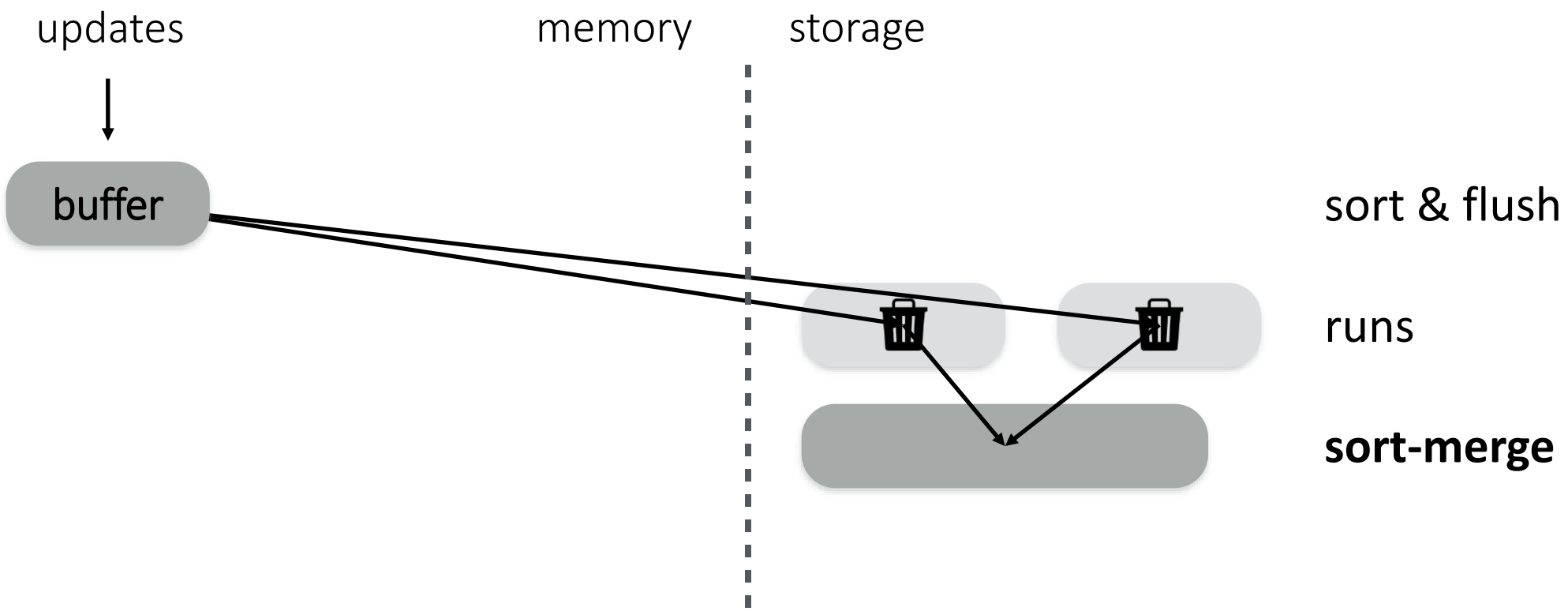
how to bridge?

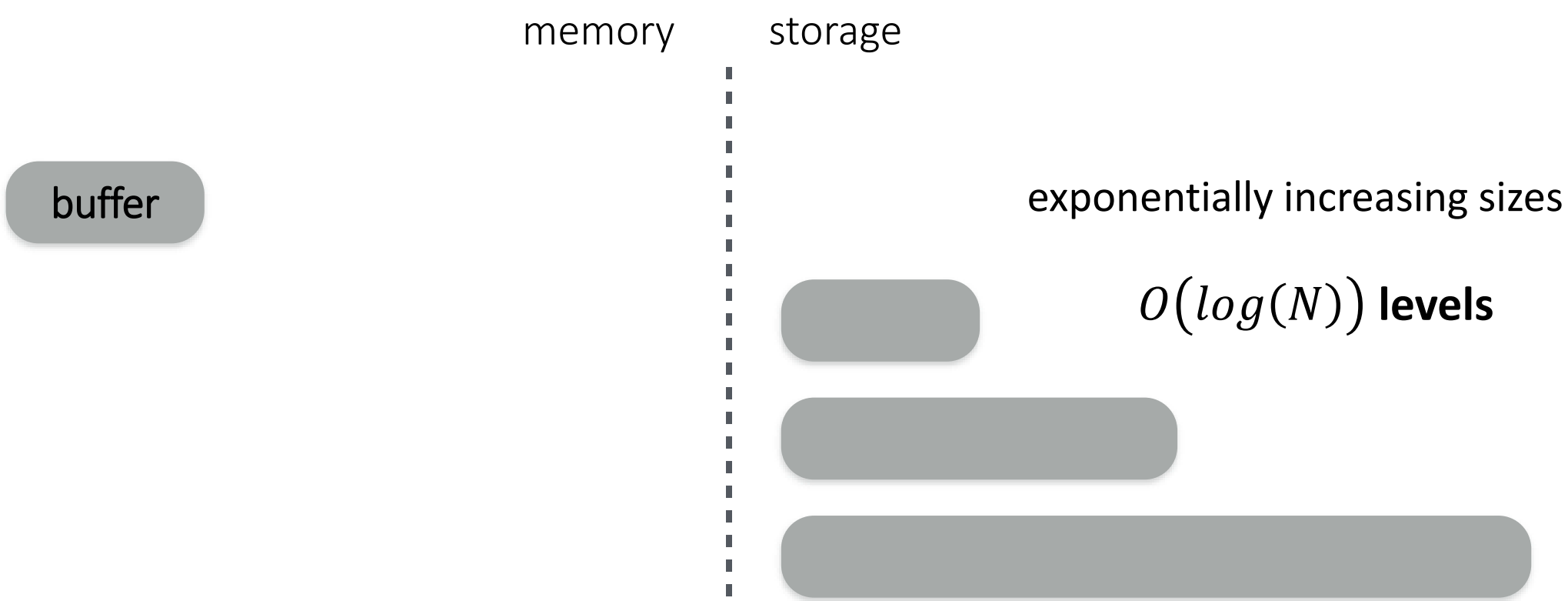
LSM-tree
Key-Value Stores

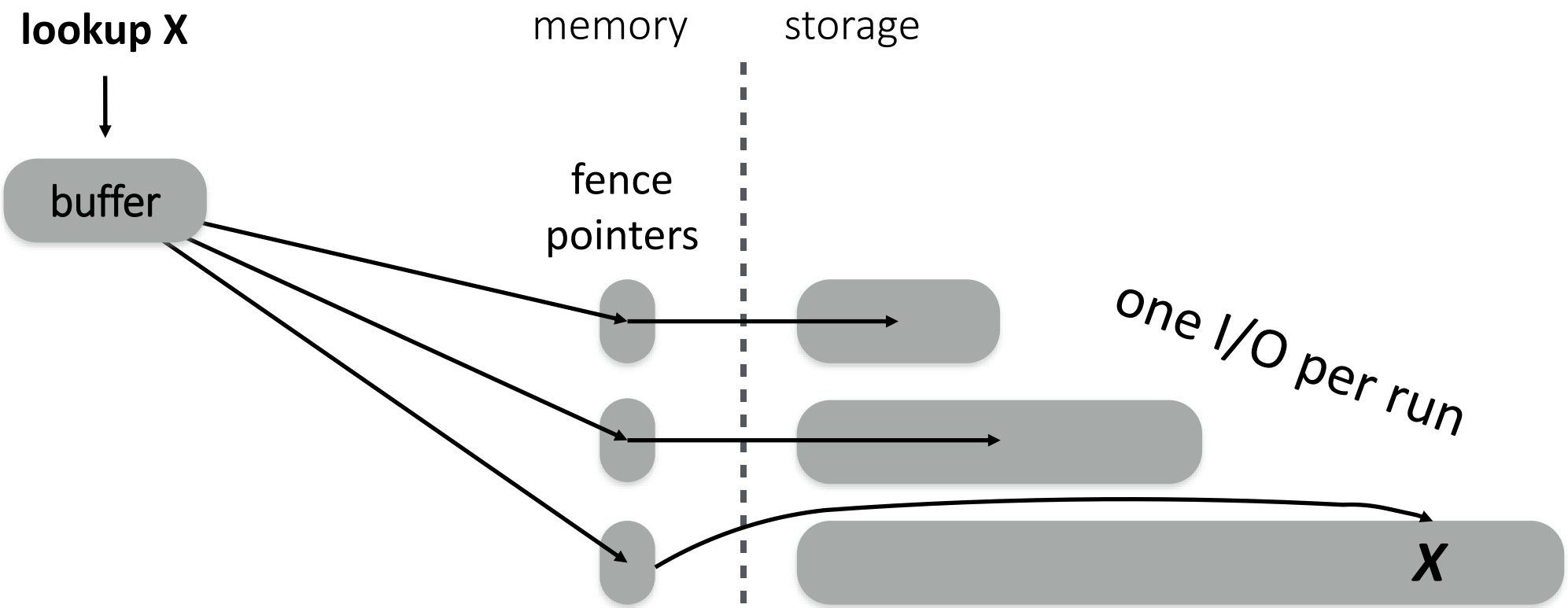
What are they really?

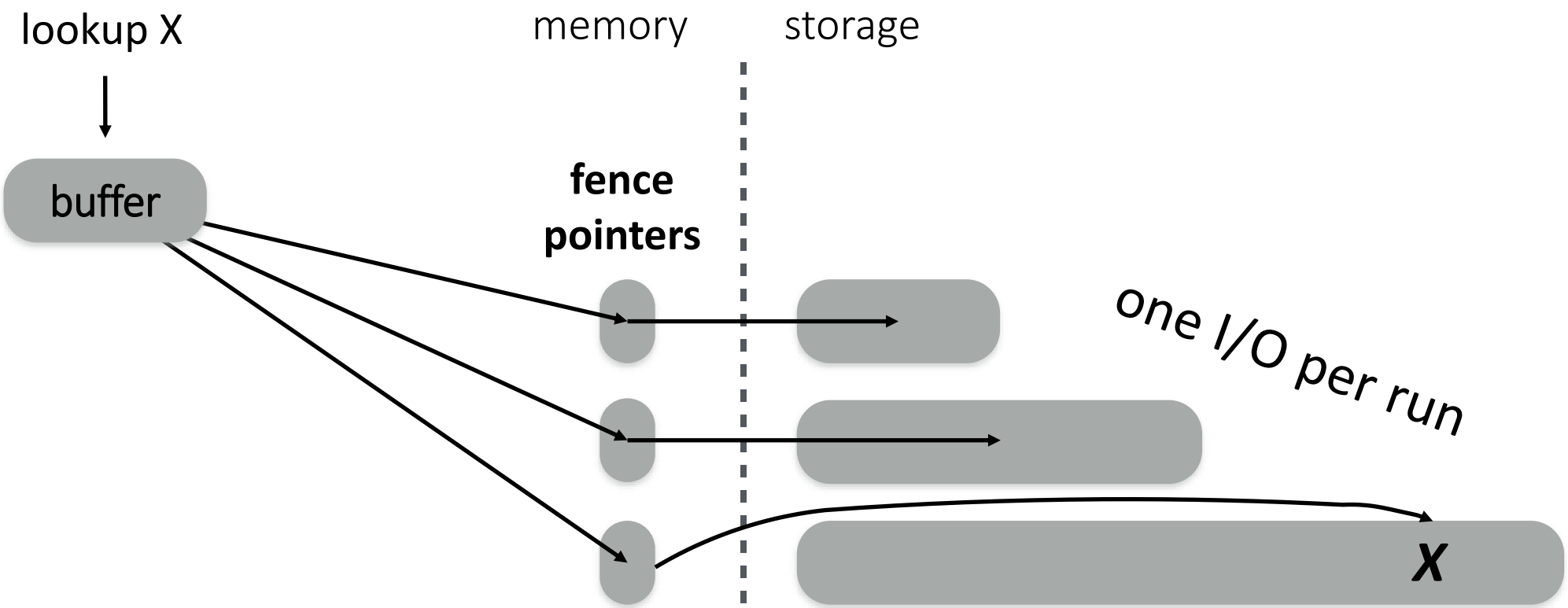


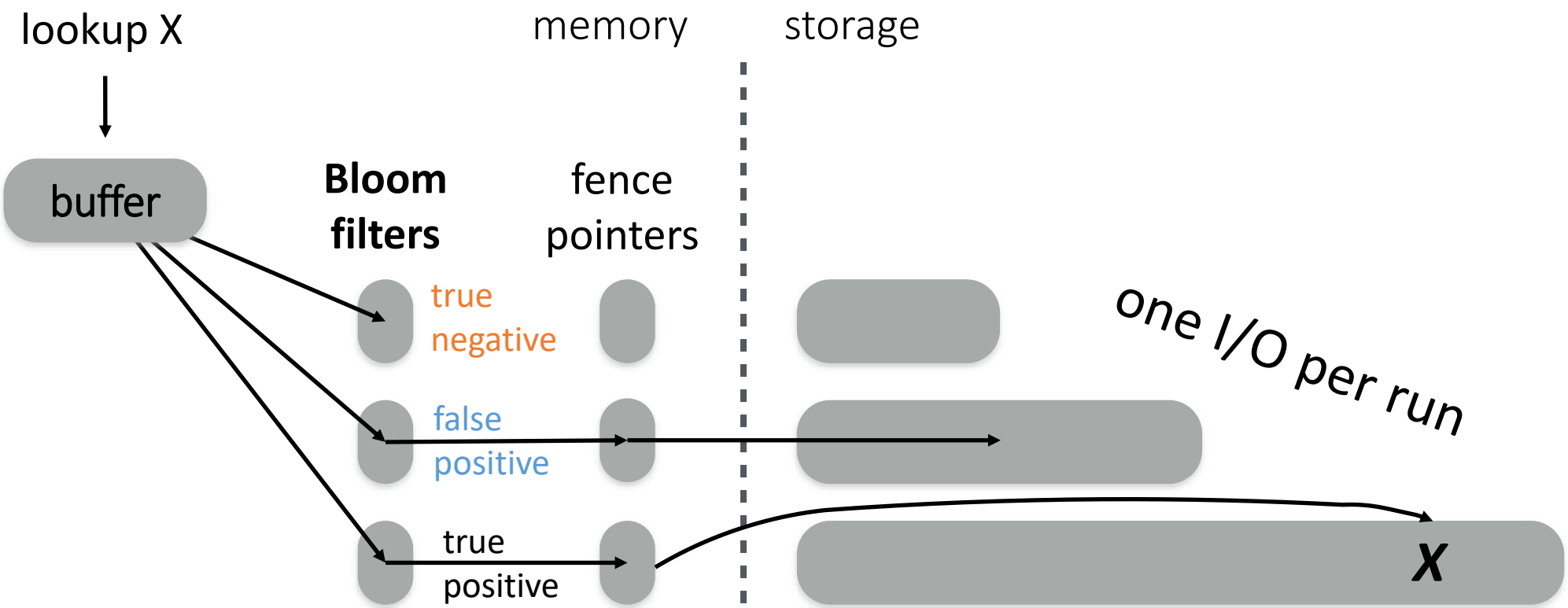




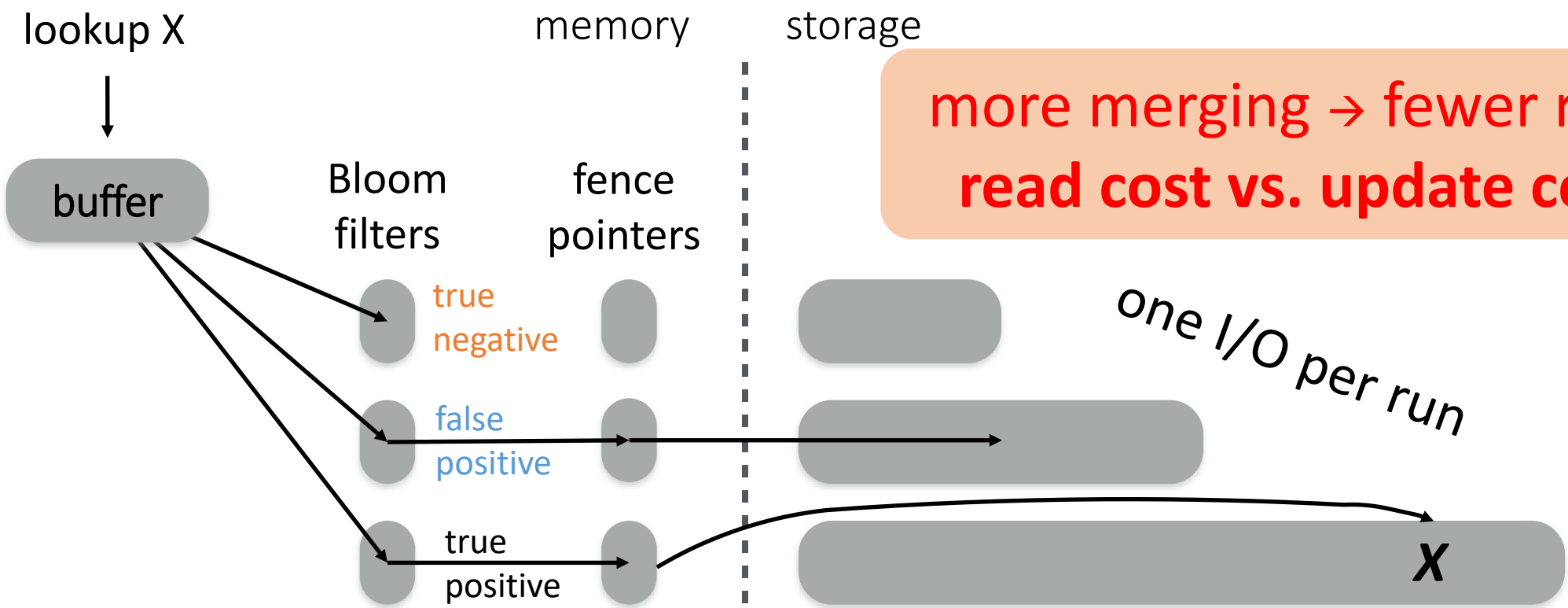








performance & cost trade-offs



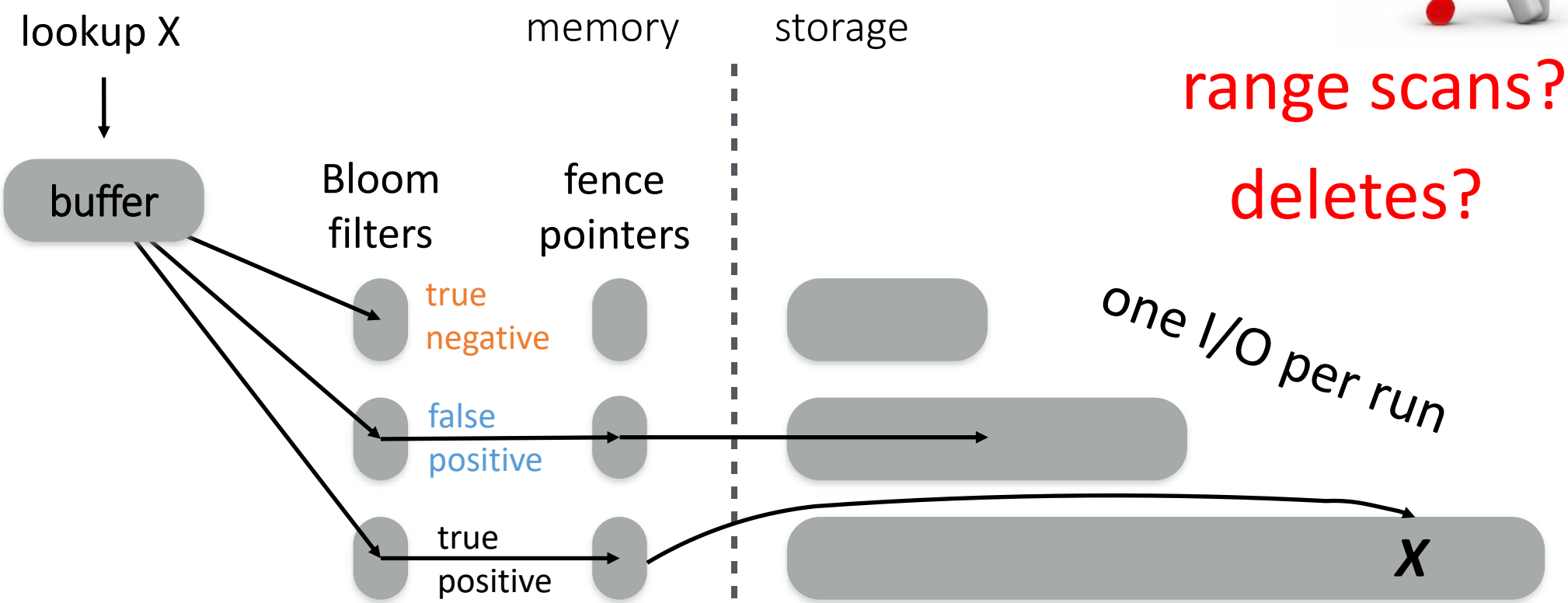
more merging → fewer runs

read cost vs. update cost

bigger filters → fewer false positives

memory space vs. read cost

other operations



range scans?

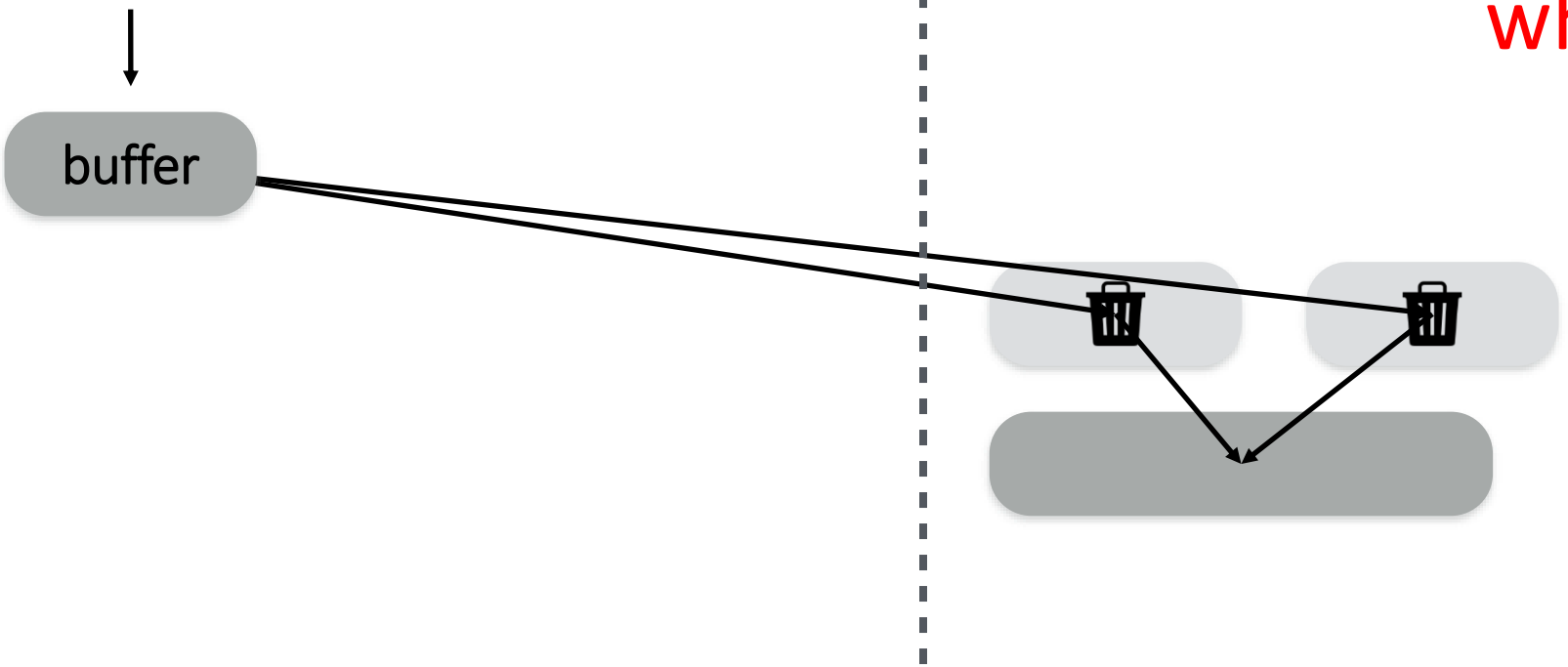
deletes?

remember merging?

updates

memory

storage



what strategies?

sort & flush

runs

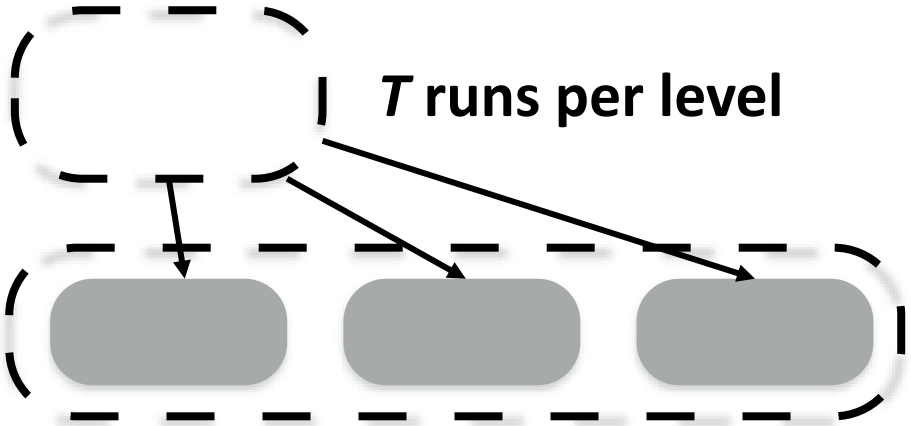
sort-merge

Merge Policies

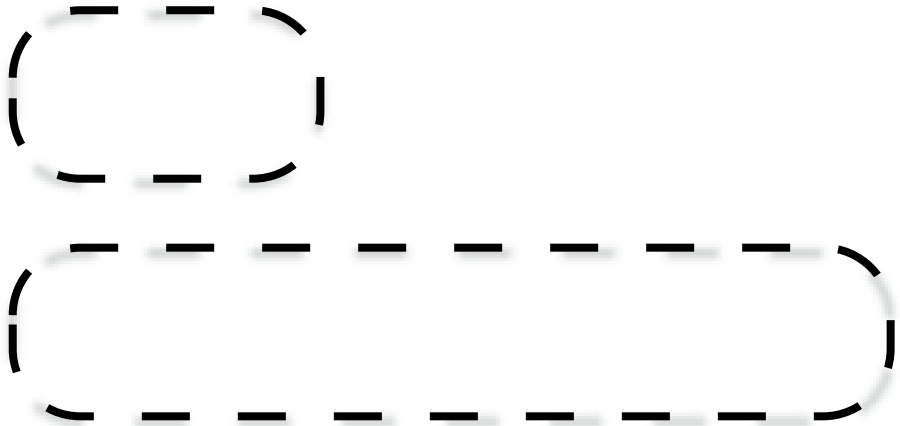
Tiering
write-optimized

Leveling
read-optimized

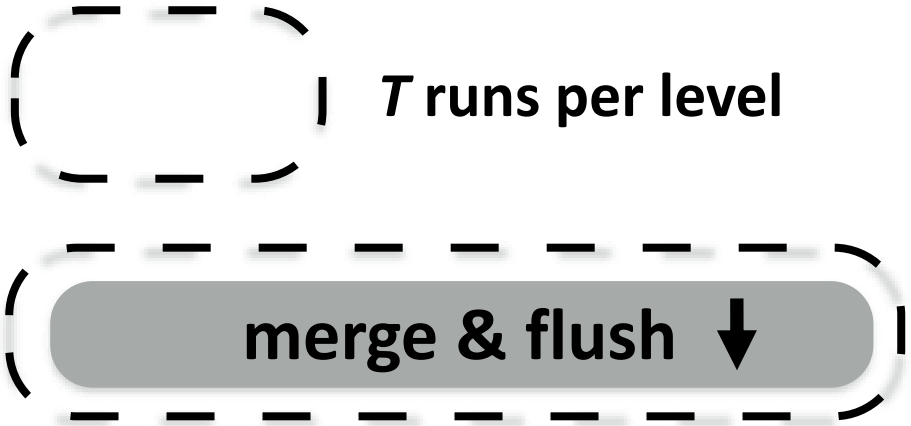
Tiering
write-optimized



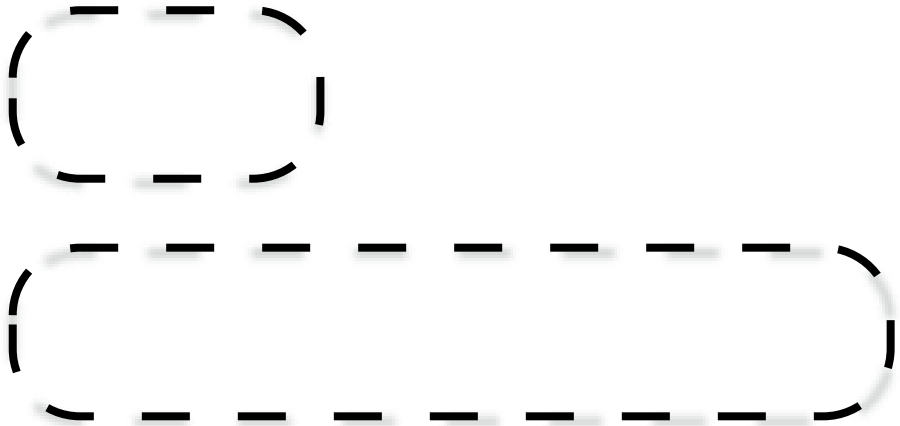
Leveling
read-optimized



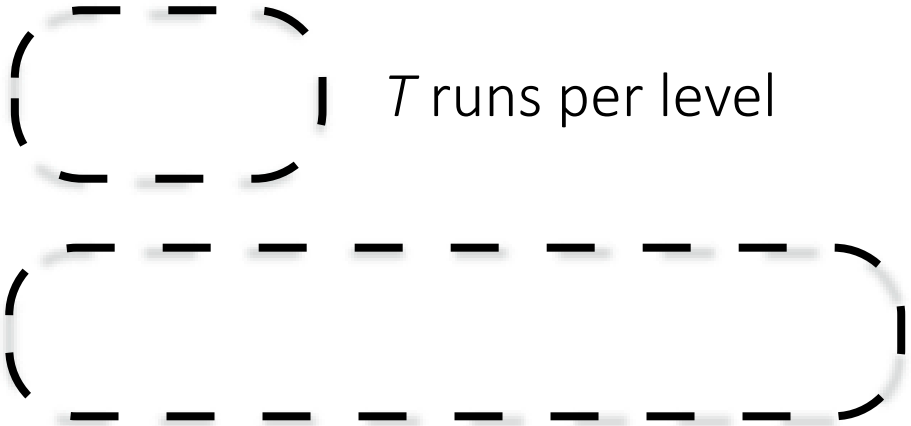
Tiering
write-optimized



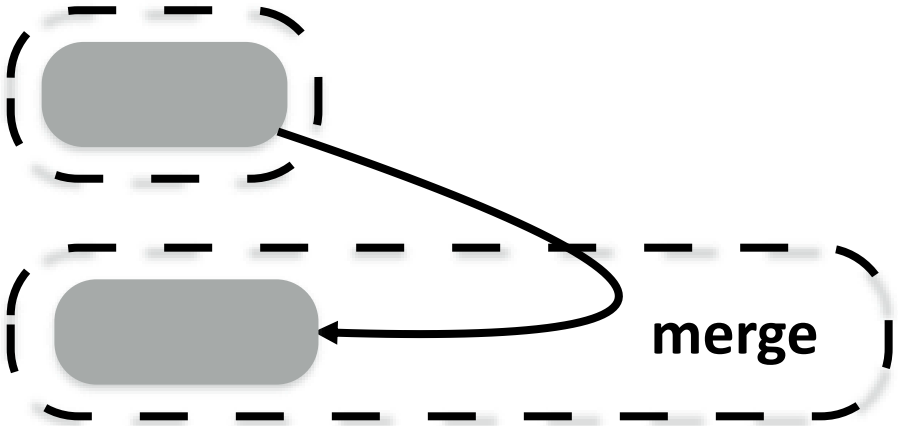
Leveling
read-optimized



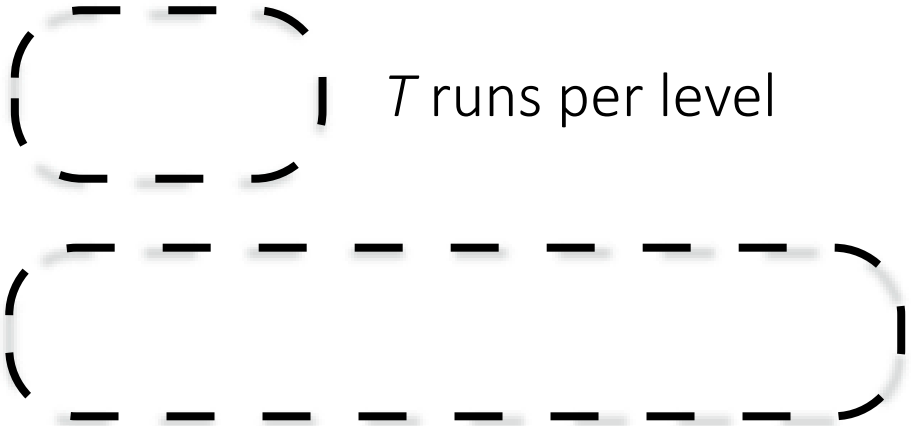
Tiering
write-optimized



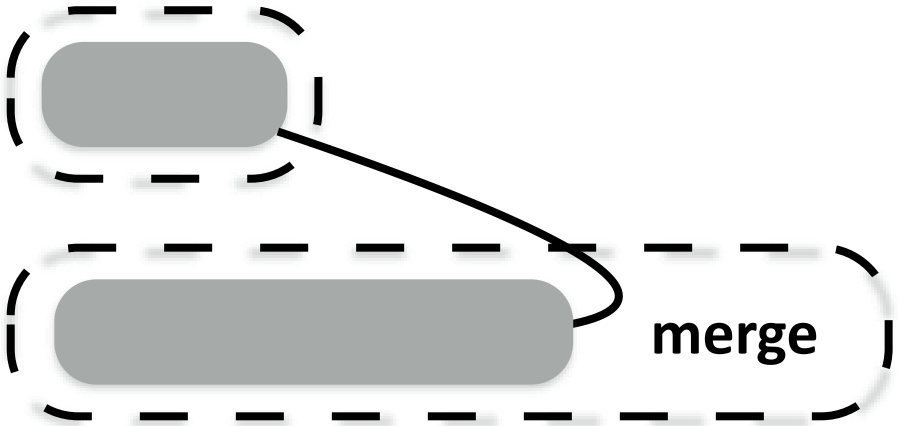
Leveling
read-optimized



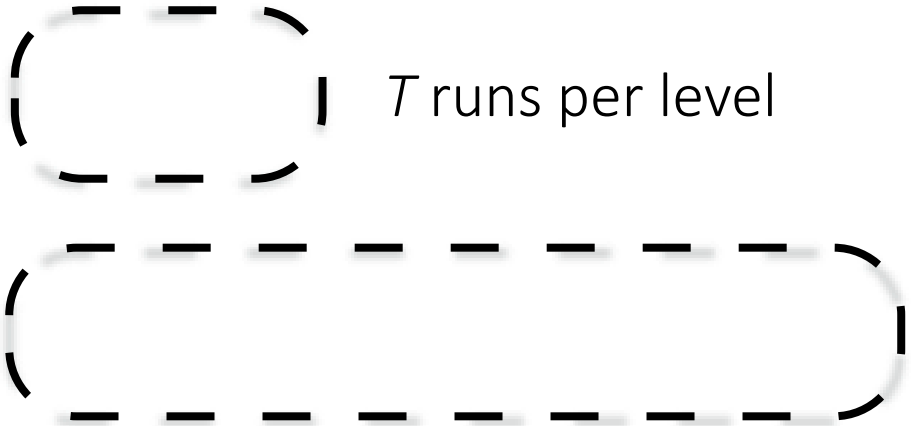
Tiering
write-optimized



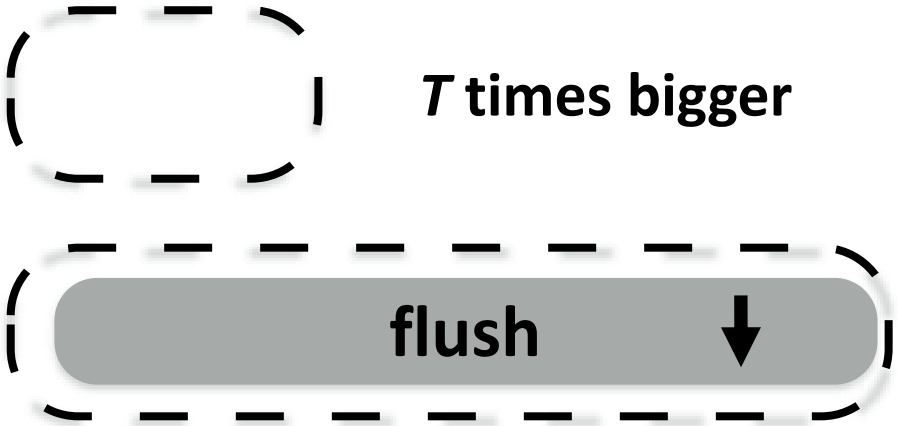
Leveling
read-optimized



Tiering
write-optimized

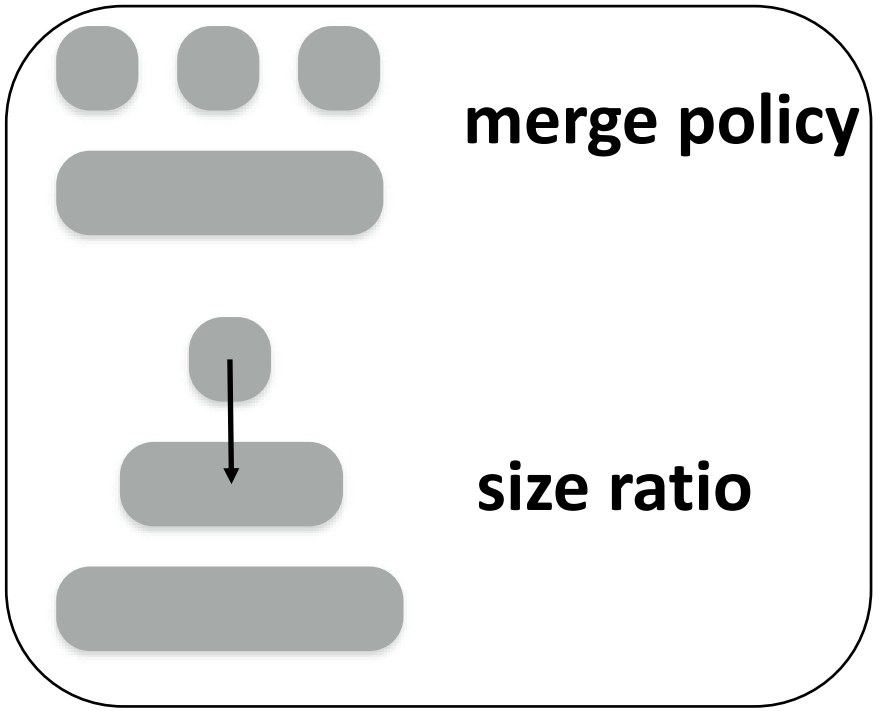


Leveling
read-optimized



Systems Project: LSM-Trees

tuning knobs



lookup X

memory

storage

buffer

Bloom filters

fence pointers

true negative

false positive

true positive

one I/O per run

X

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more on LSM-Tree performance

Tiering
write-optimized

Leveling
read-optimized

lookup cost: $O\left(T \cdot log_T(N) \cdot e^{-M/N}\right)$

runs per level — levels — false positive rate

$O\left(log_T(N) \cdot e^{-M/N}\right)$

levels — false positive rate

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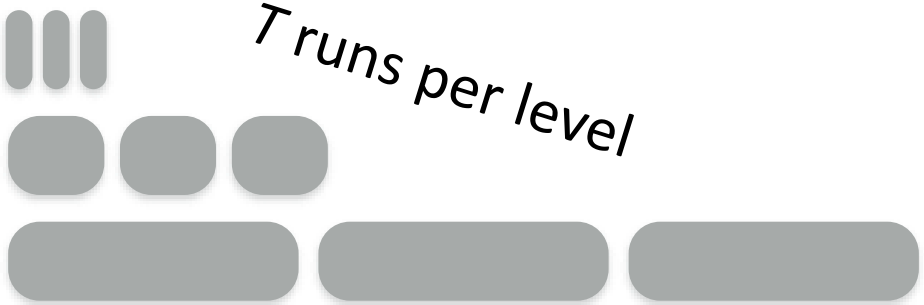
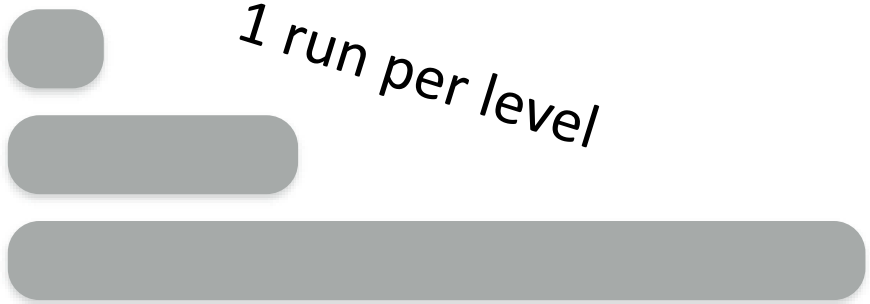
Tiering
write-optimized



Leveling
read-optimized



lookup cost: $O\left(T \cdot log_T(N) \cdot e^{-M/N}\right)$

update cost: $\boldsymbol{O\left(log_T(N)\right)}$

levels

$O\left(log_T(N) \cdot e^{-M/N}\right)$

$\boldsymbol{O\left(T \cdot log_T(N)\right)}$

merges per level

levels

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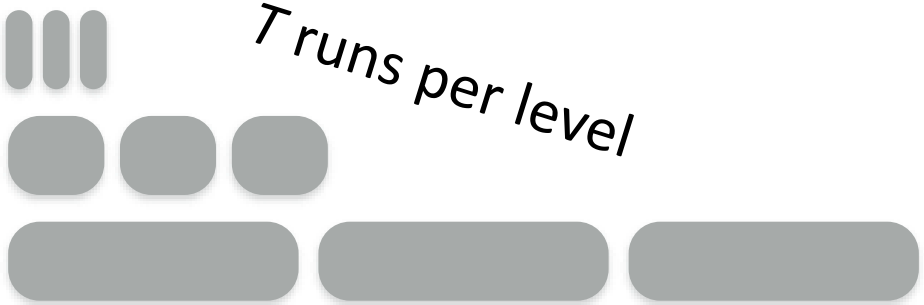
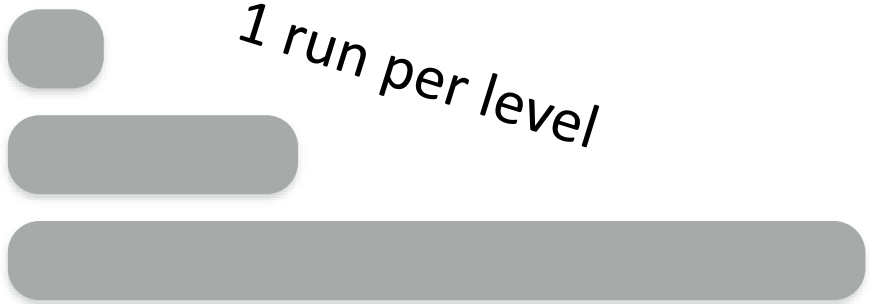
Tiering
write-optimized



Leveling
read-optimized

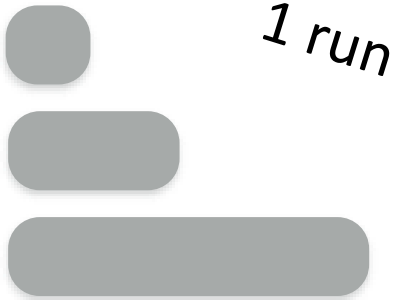


lookup cost: $O\left(T \cdot log_T(N) \cdot e^{-M/N}\right)$ $O\left(log_T(N) \cdot e^{-M/N}\right)$

update cost: $O\left(log_T(N)\right)$ $O\left(T \cdot log_T(N)\right)$

for size ratio T ⌄⌄

Tiering
write-optimized



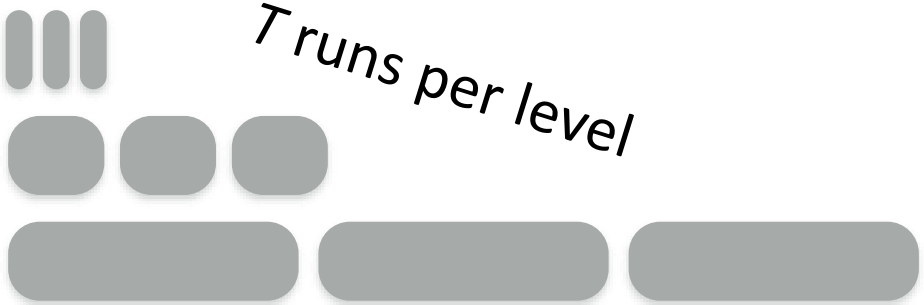
Leveling
read-optimized

lookup cost: $O\left(log_T(N) \cdot e^{-M/N}\right) = O\left(log_T(N) \cdot e^{-M/N}\right)$

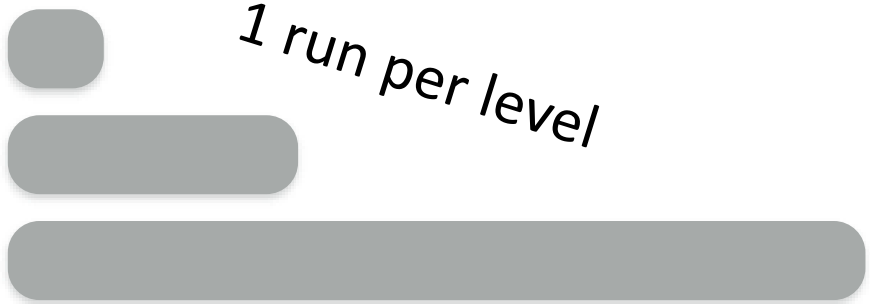
update cost: $O\left(log_T(N)\right) = O\left(log_T(N)\right)$

for size ratio T ⌄⌄

Tiering
write-optimized



Leveling
read-optimized



lookup cost: $O\left(T \cdot log_T(N) \cdot e^{-M/N}\right)$ $O\left(log_T(N) \cdot e^{-M/N}\right)$

update cost: $O\left(log_T(N)\right)$ $O\left(T \cdot log_T(N)\right)$

for size ratio T ⌃⌃

Tiering
write-optimized

$O(N)$ runs per level

log

Leveling
read-optimized

1 run per level

sorted array

lookup cost: $O\left(T \cdot log_T(N) \cdot e^{-M/N}\right)$ $O\left(log_T(N) \cdot e^{-M/N}\right)$

update cost: $O\left(log_N(N)\right) = \boldsymbol{O(1)}$ $O\left(N \cdot log_N(N)\right) = \boldsymbol{O(N)}$

for size ratio T **N** ≫

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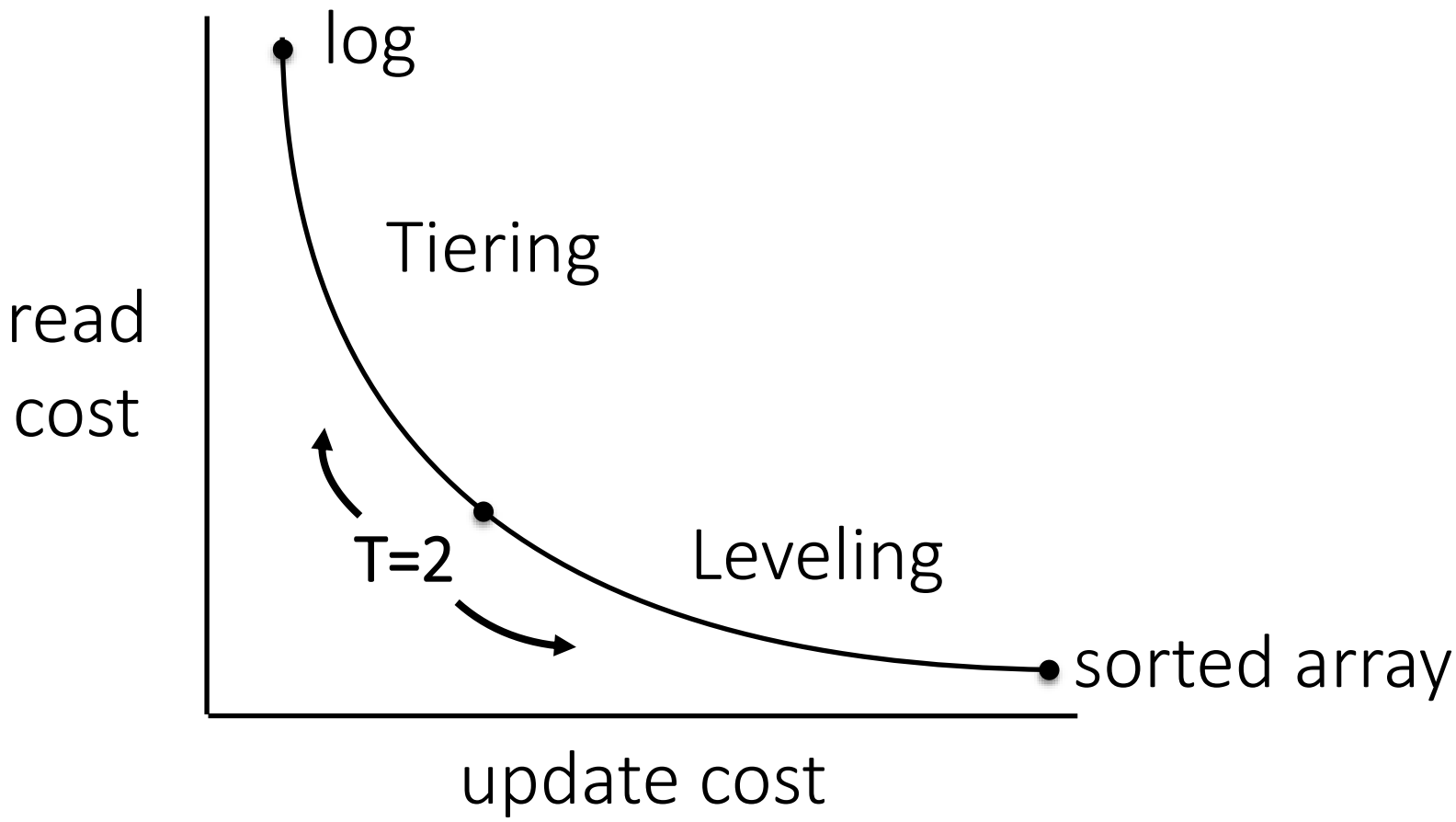


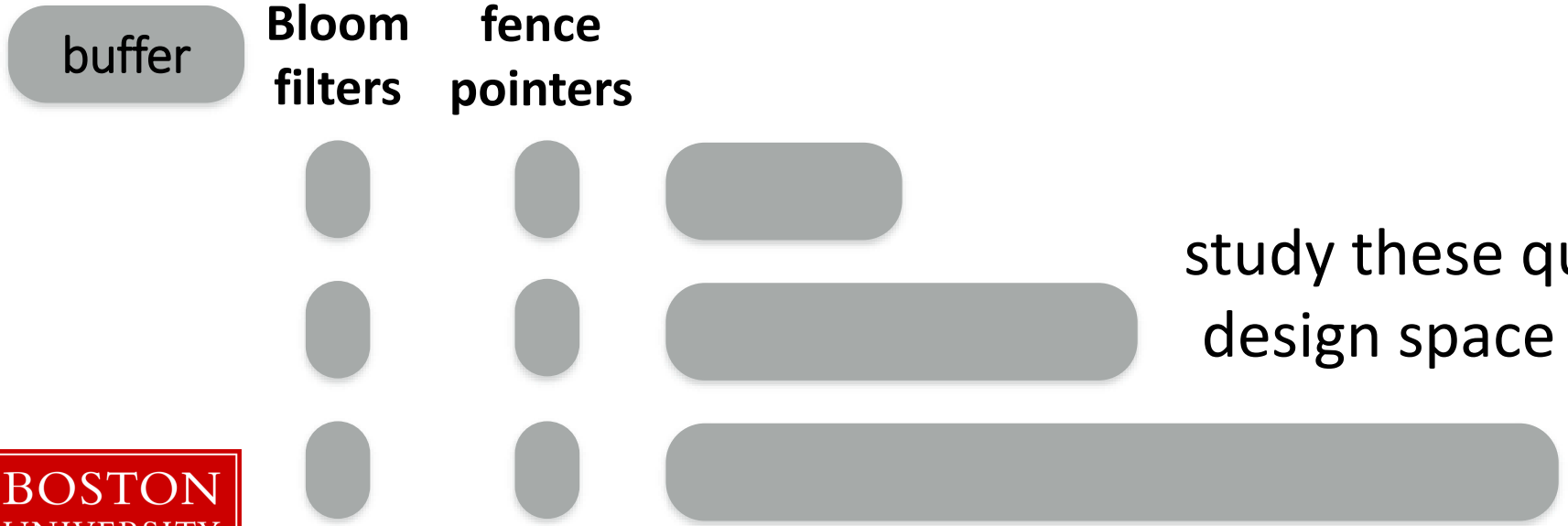
T : size ratio

Research Question on LSM-Trees

what if we are under memory pressure?

how to design fence pointers with optimal granularity

How much is the *real* write-amplification on SSDs?



study these questions and navigate LSM design space using Facebook's RocksDB

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RocksDB

Research on PostgreSQL

A state-of-the-art relational database

How can we implement a skew-aware efficient join algorithm?

How much a noise in the existing cardinality estimation can impact the selected query plan, and the overall query performance

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Benchmark Large Graph Processing Systems

TurboGraph: dl.acm.org/doi/10.1145/2487575.2487581

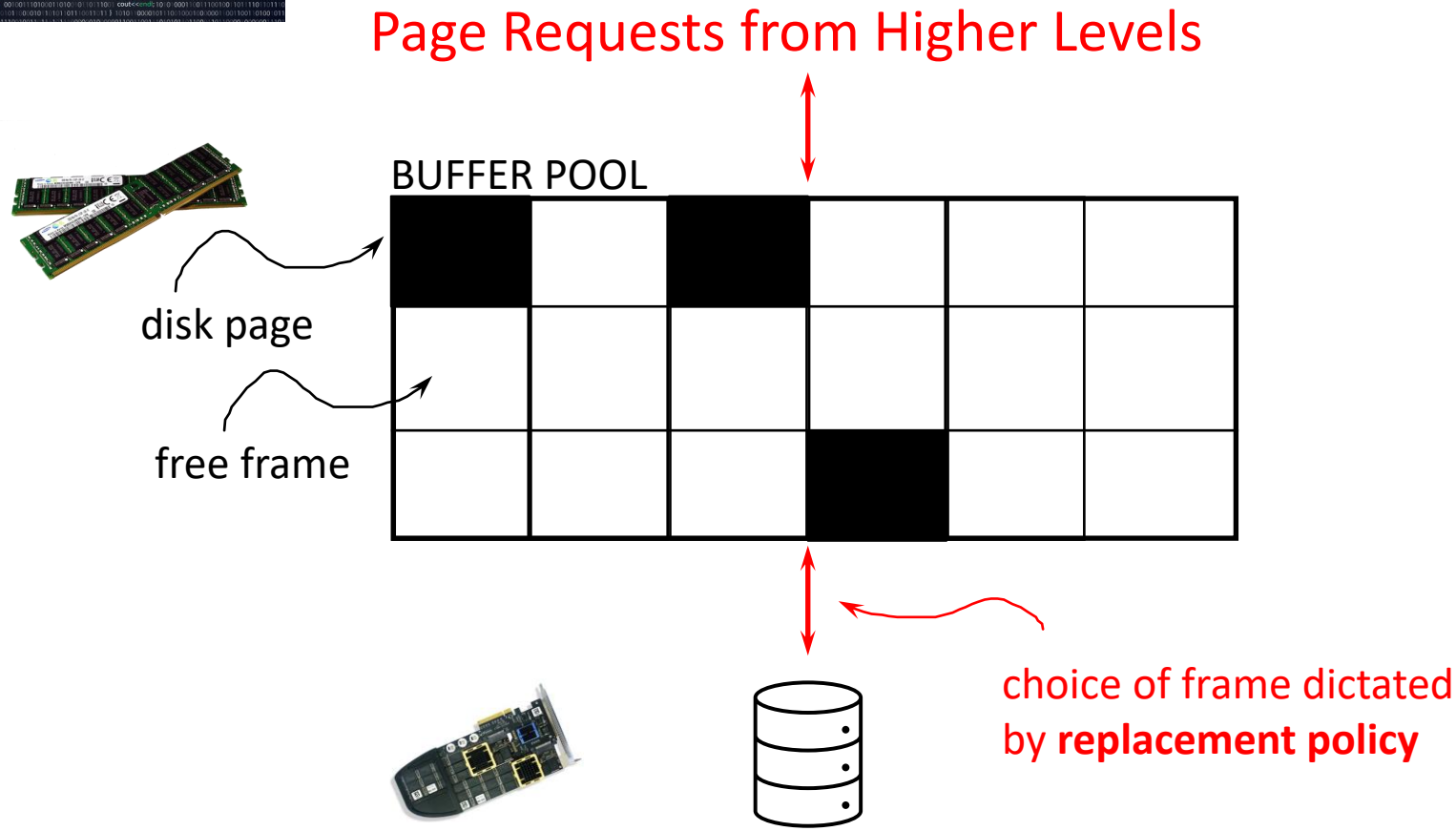
GridGraph: www.usenix.org/system/files/conference/atc15/atc15-paper-zhu.pdf

Other Research Topics

Designing Robust Spatial Indexes for Fast Insertion

Designing Sortedness-Aware Compression/Join Algorithm

Systems Project: Bufferpool



Implementation of a bufferpool

- **Application requests** a page
  - If **in the bufferpool** return it
  - If **not in the bufferpool** fetch it from the disk
    - If bufferpool is full select page to **evict**

Core Idea: Eviction Policy

- *Least Recently Used*
- *First In First Out*
- *more …*

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what to do now?

systems project
form groups of 2
(speak to me in OH if you want to work on your own)

research project
form groups of 3
pick one of the subjects & read background material
define the behavior you will study and address
sketch approach and success metric
(if LSM-related get familiar with RocksDB)

what to do now?

systems project
form groups of 2
(speak to me in OH if you want to work on your own)

research project

come to OH/Labs

submit project 0 this Friday on 2/2

start working on project 1 (due on 2/16)

submit semester project proposal on 2/23

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CS 561: Data Systems Architectures

class 4

Systems & Research Project

Zichen Zhu

https://bu-disc.github.io/CS561/