CSE 444: Database Internals

Section 4:

Operator Algorithms

Notations

- B(R) = # of blocks (i.e. pages) for relation R
- T(R) = # of tuples in relation R
- V(R, a) = # of distinct values of attribute a
- Memory M

Algorithms for Group By and Aggregate Operators

- Modified Tweet Example:

Tweet(tid, uid, tlen)   tlen = tweet length

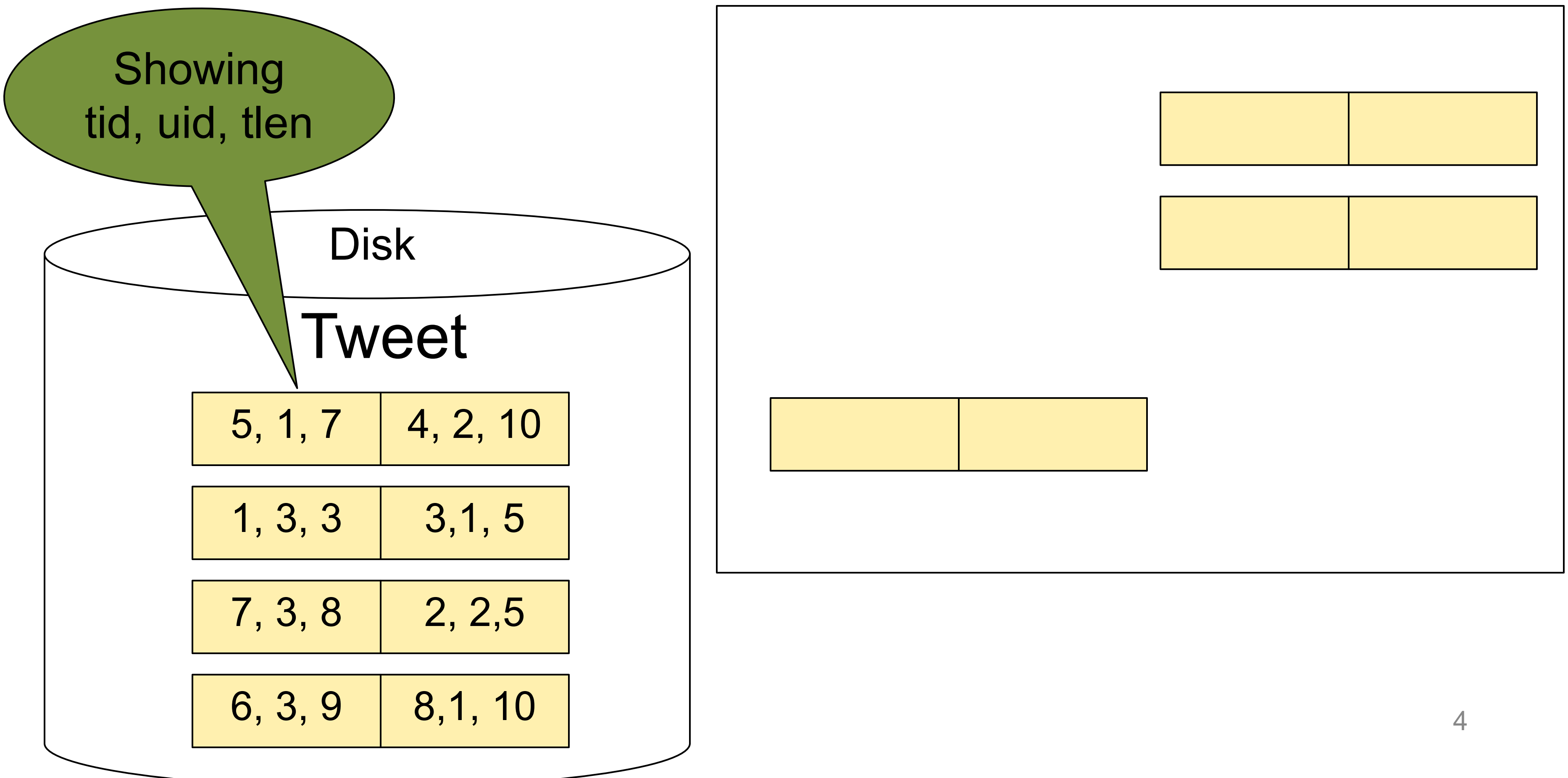
SELECT uid, MIN(tlen)

FROM Tweet

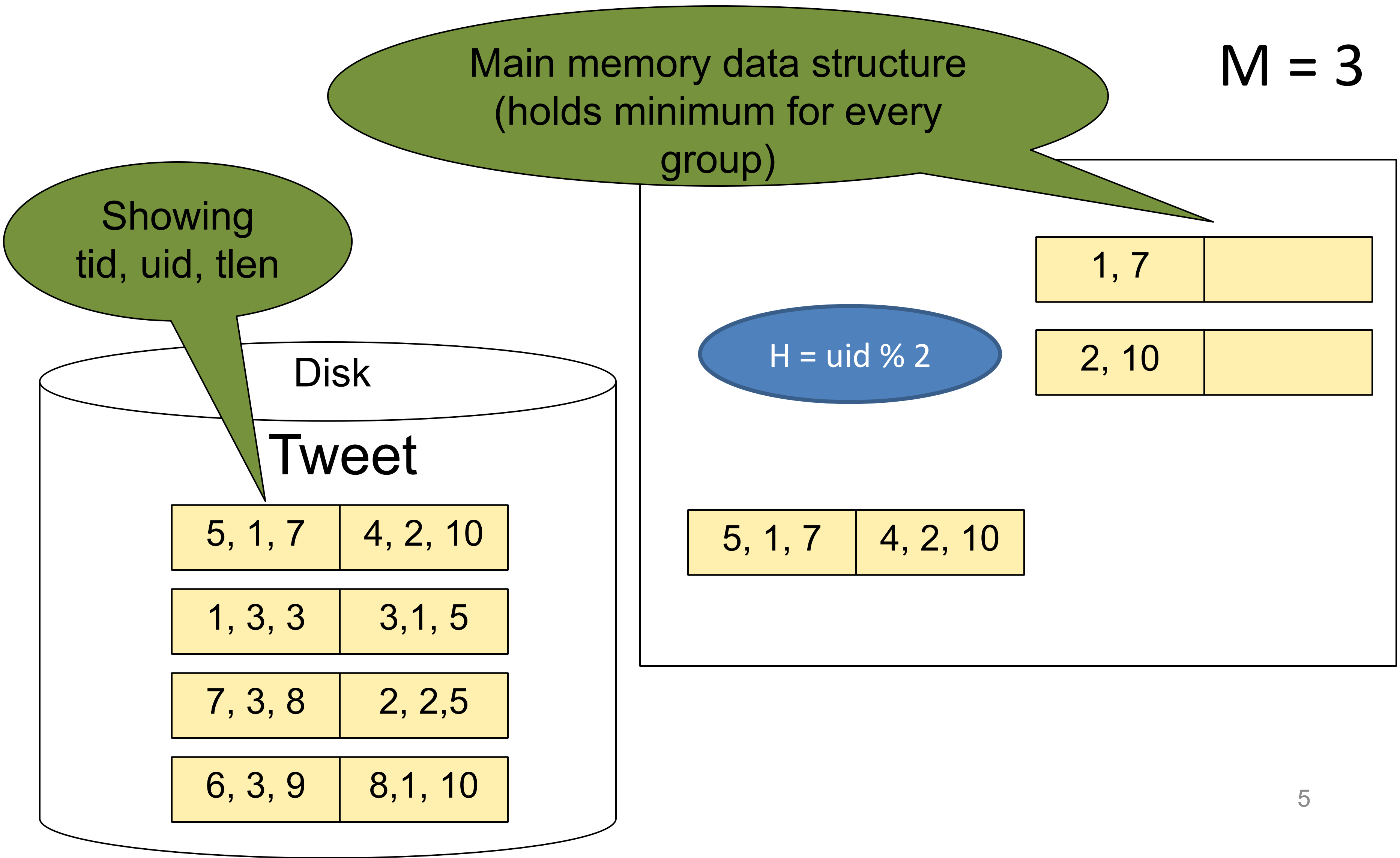
GROUP BY uid

One pass, hash-based grouping

M = 3



One pass, hash-based grouping



One pass, hash-based grouping

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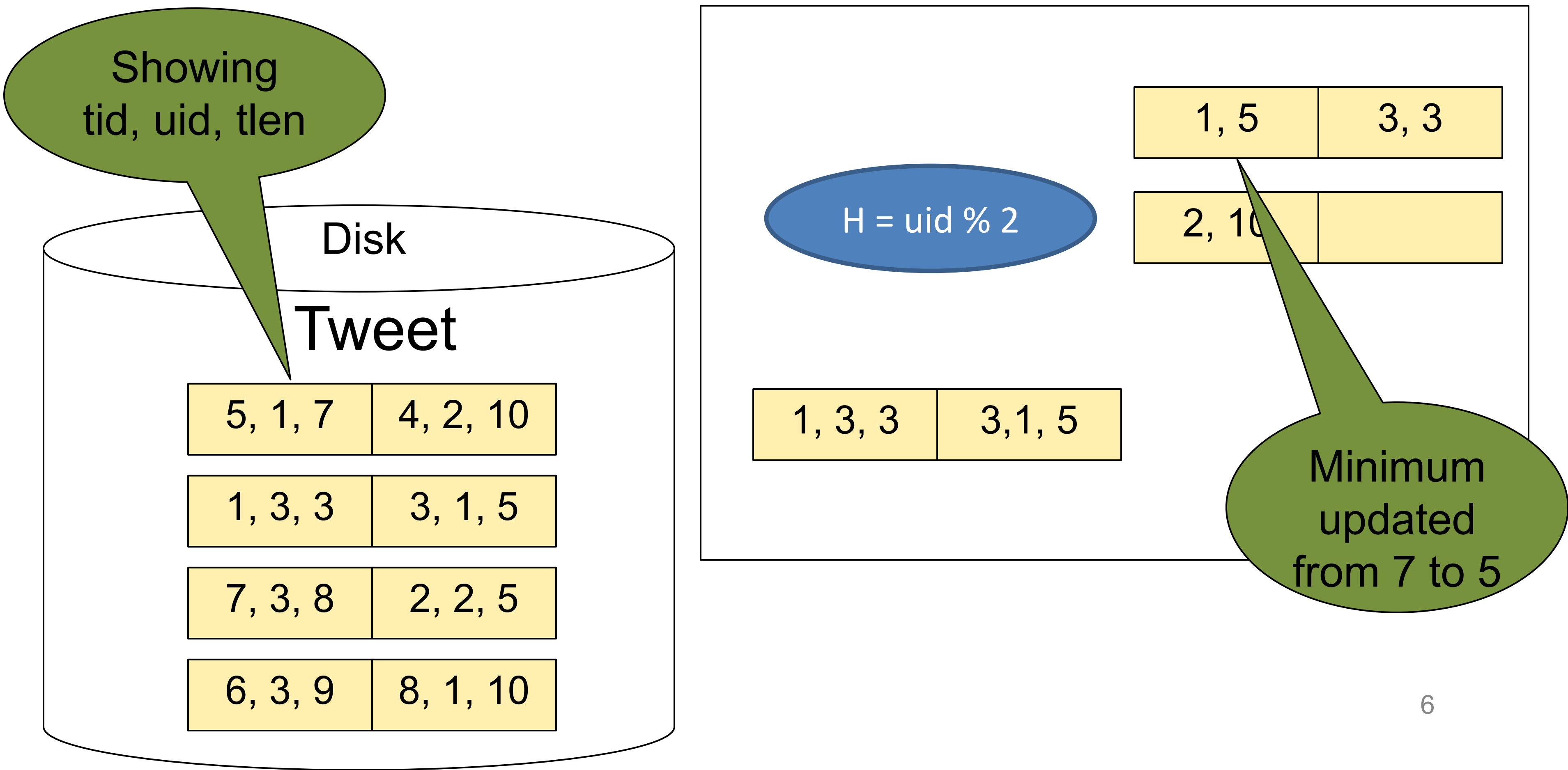


Discussion

Cost:

- Clustered?
- Unclustered?

Which operator method does the grouping?

open(), next(), or close()?

What to do for AVG(tlen)?

Discussion

Cost:

- Clustered?
  - B(R): assuming M – 1 pages can hold all groups – tuples for groups can be shorter or larger than original tuples
- Unclustered?
  - Also B(R)

Which method does the grouping:

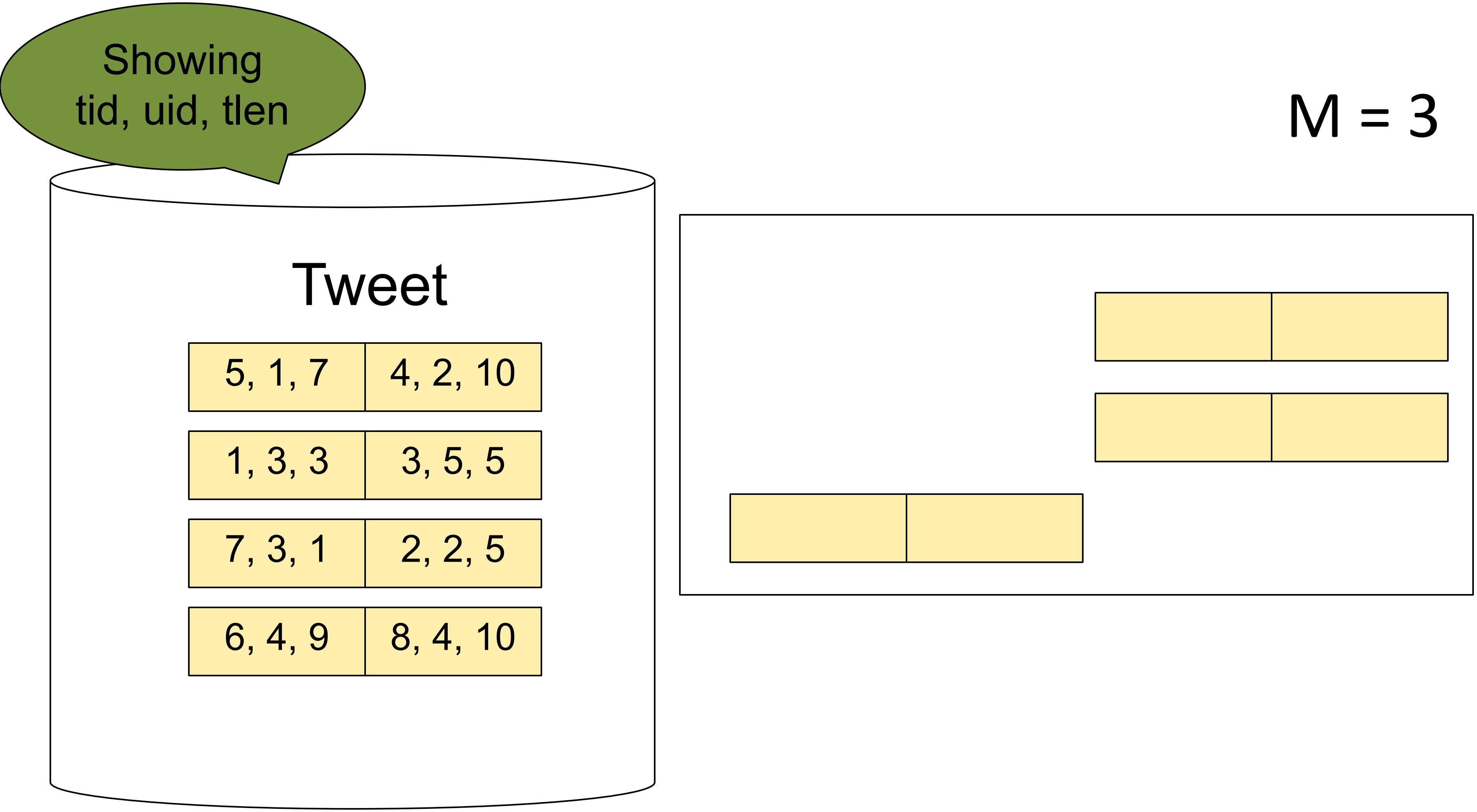
open(), next(), or close()?

- Cannot return anything until the entire data is read. Open() needs to do grouping

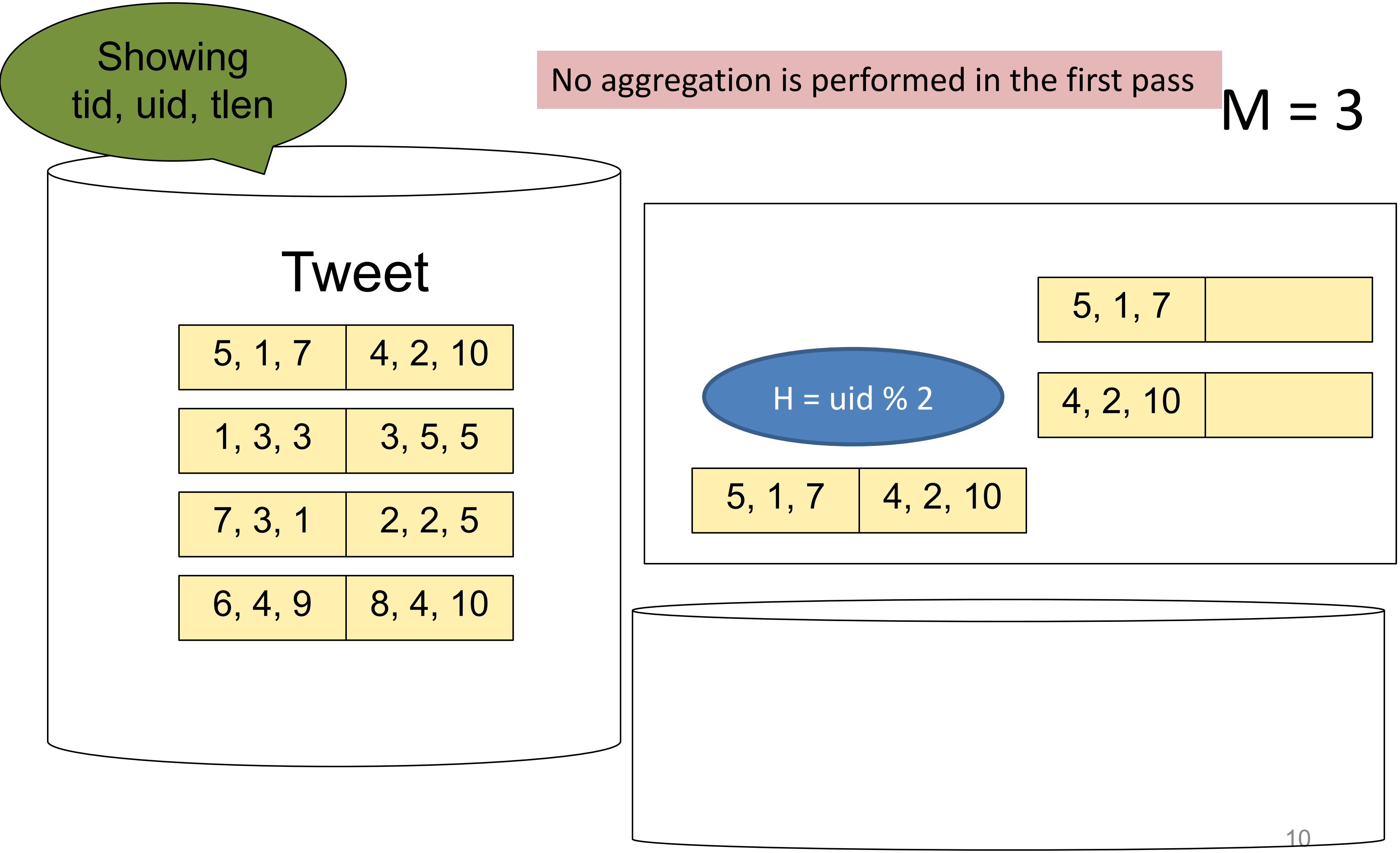
What to do for AVG(tlen)?

- Keep both SUM(tlen) and COUNT(*) for each group in memory

Two pass, hash-based grouping



Two pass, hash-based grouping



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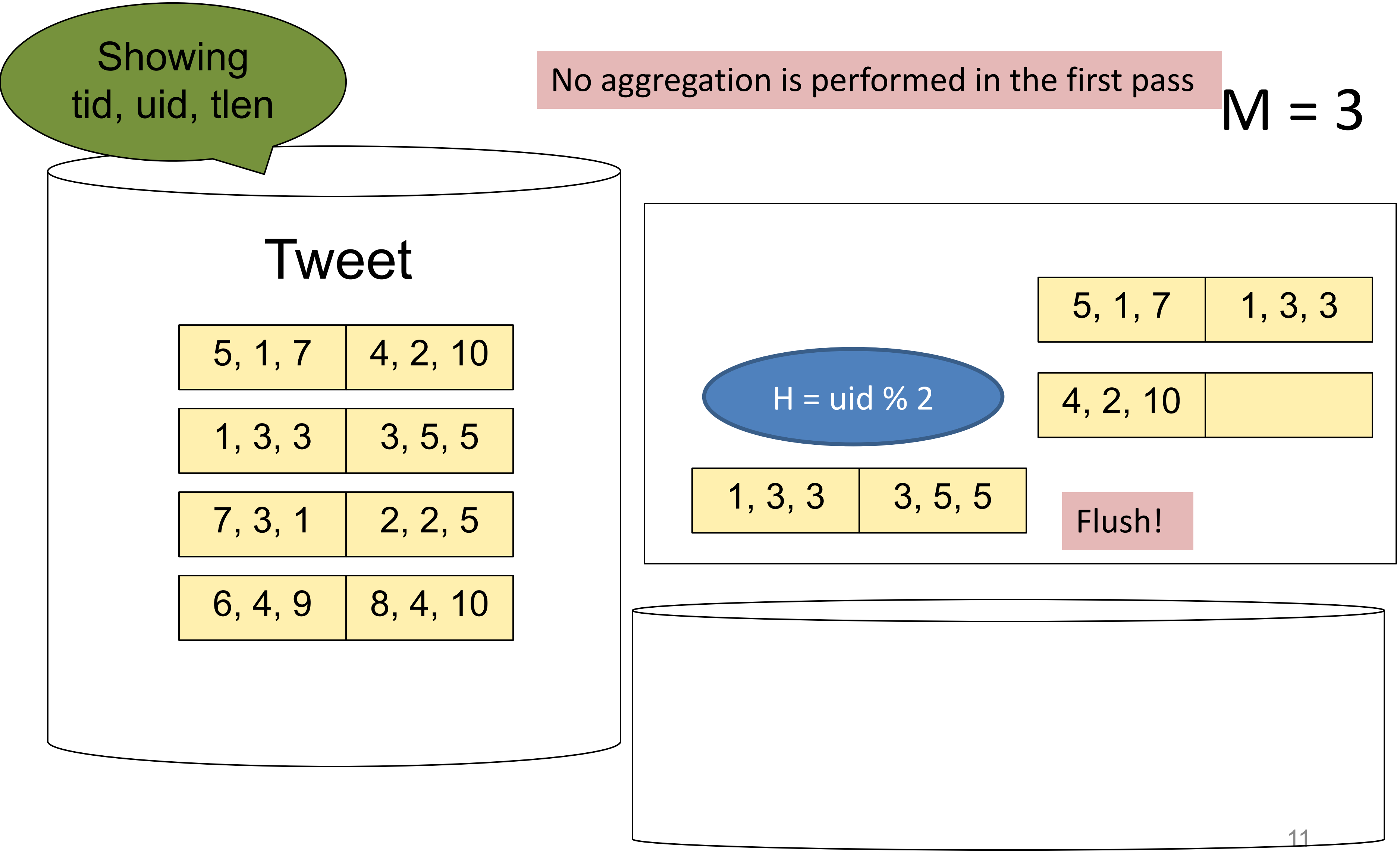

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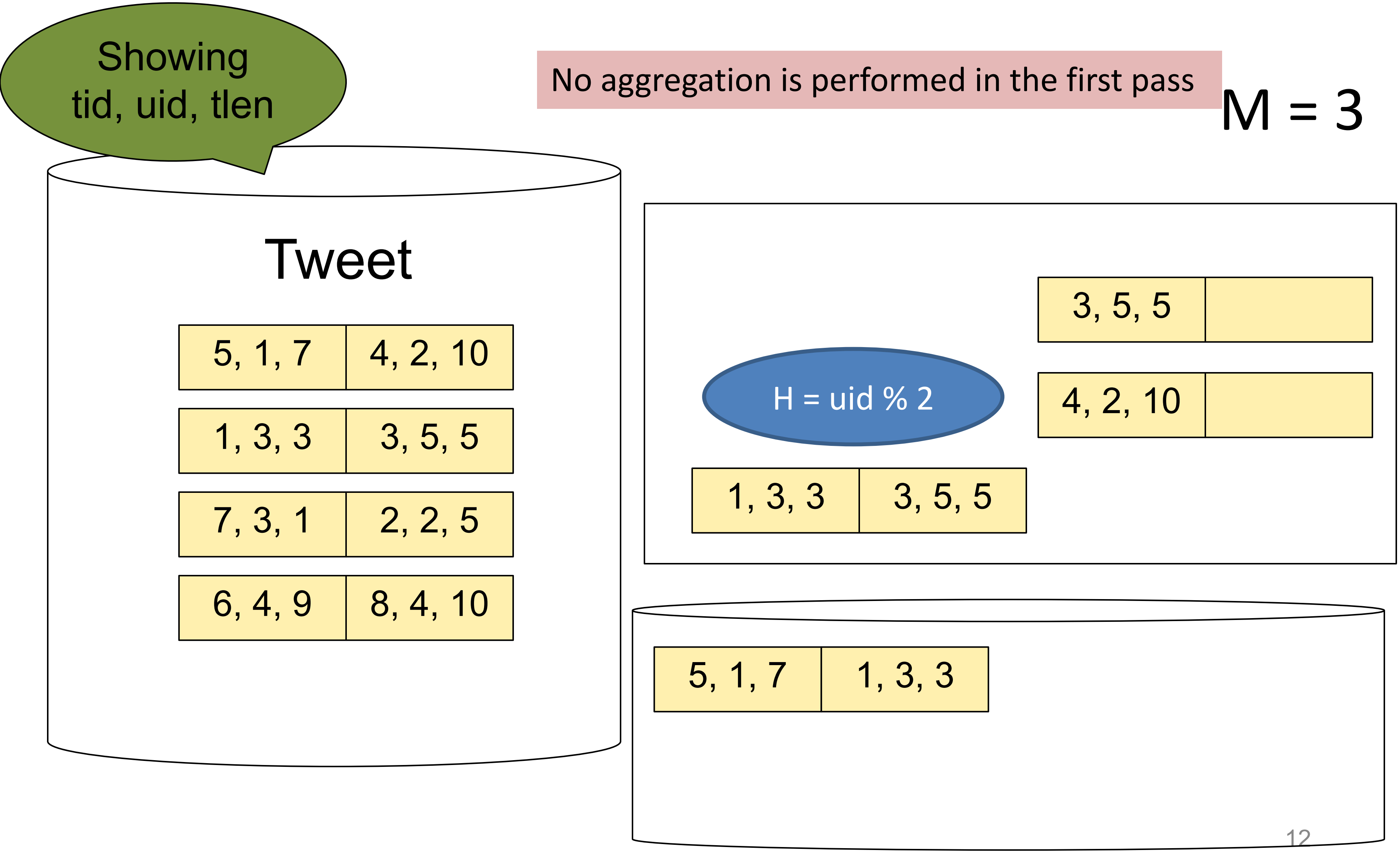
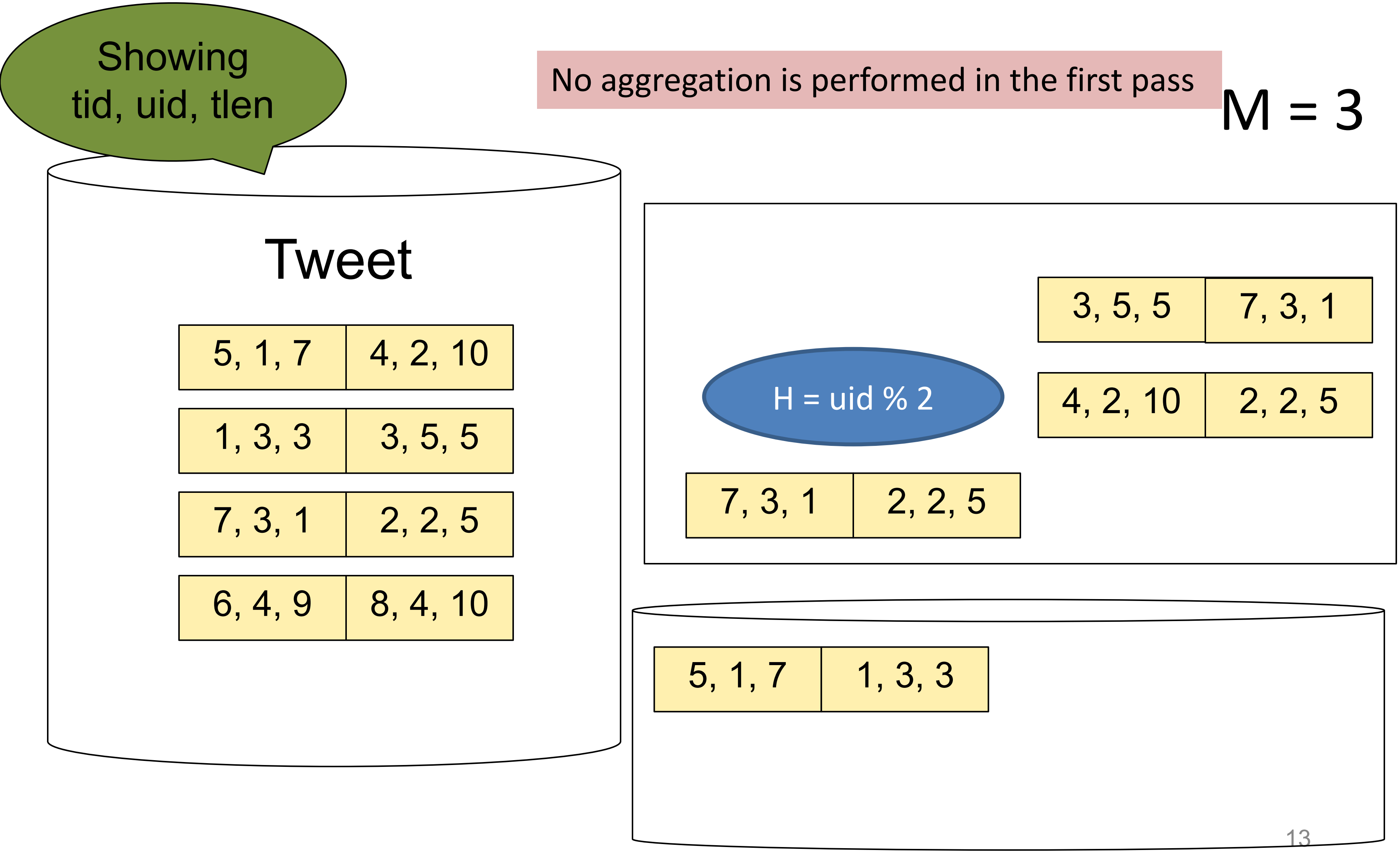
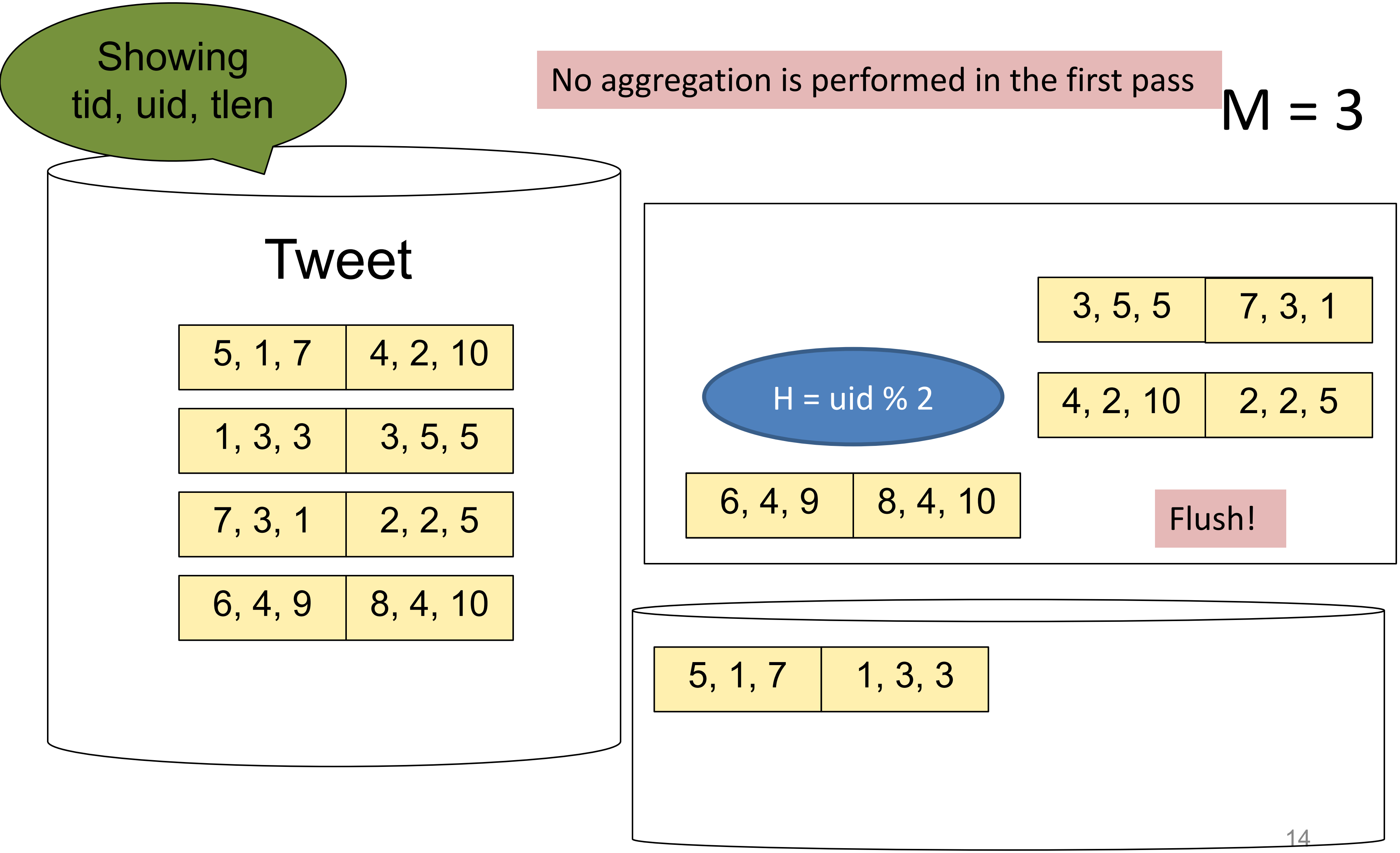


Two pass, hash-based grouping



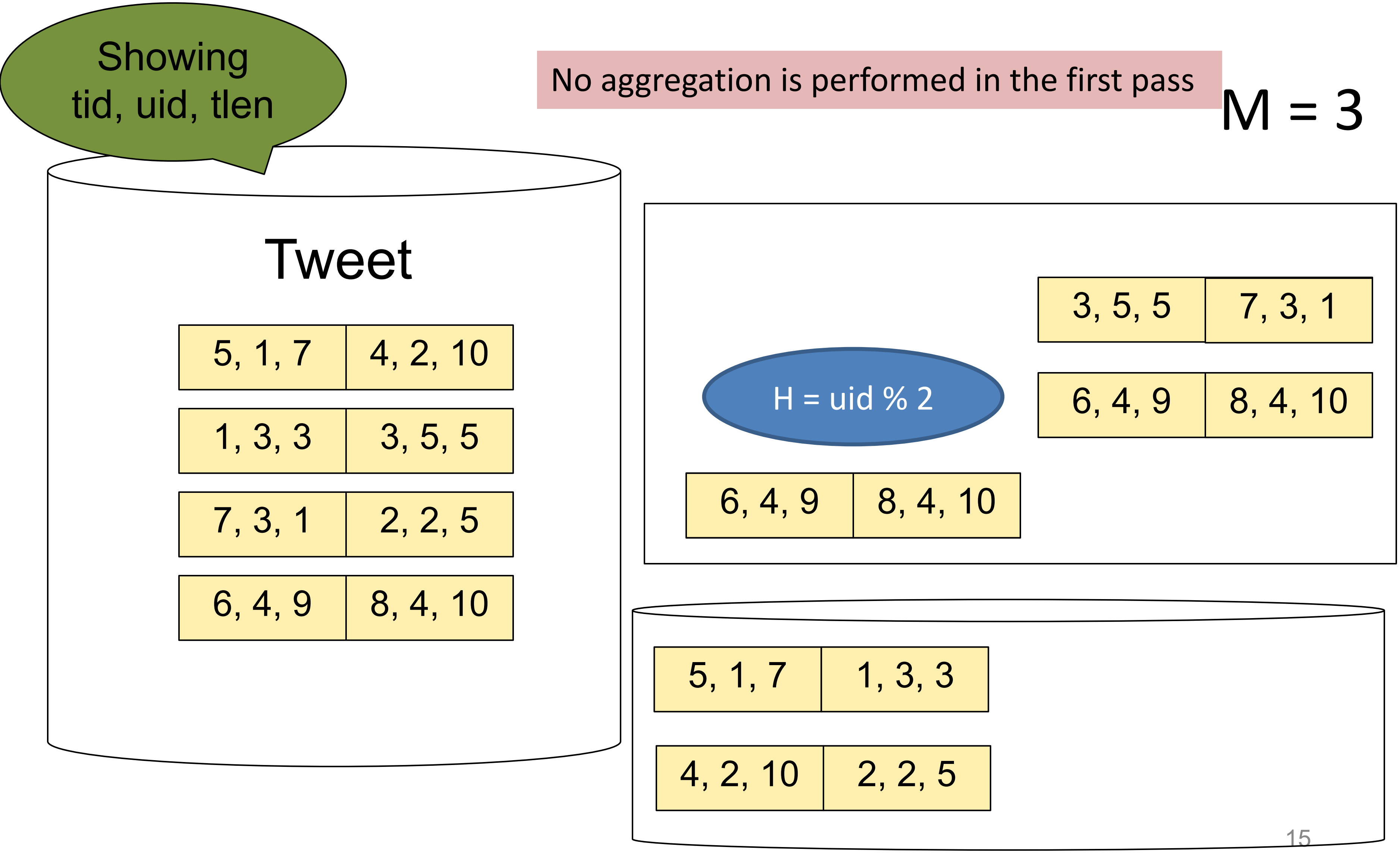
Two pass, hash-based grouping



Two pass, hash-based grouping

No aggregation is performed in the first pass

M = 3



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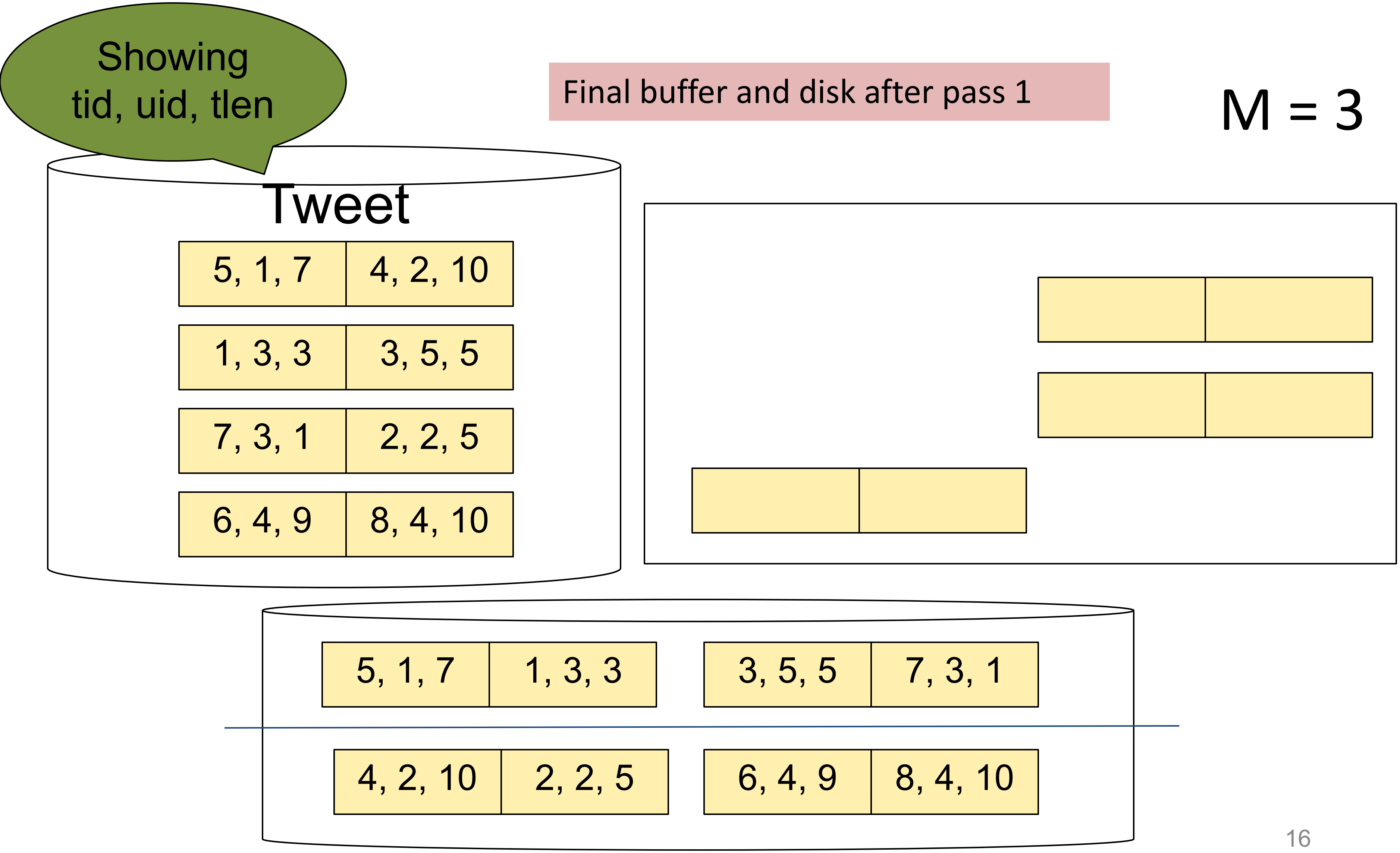
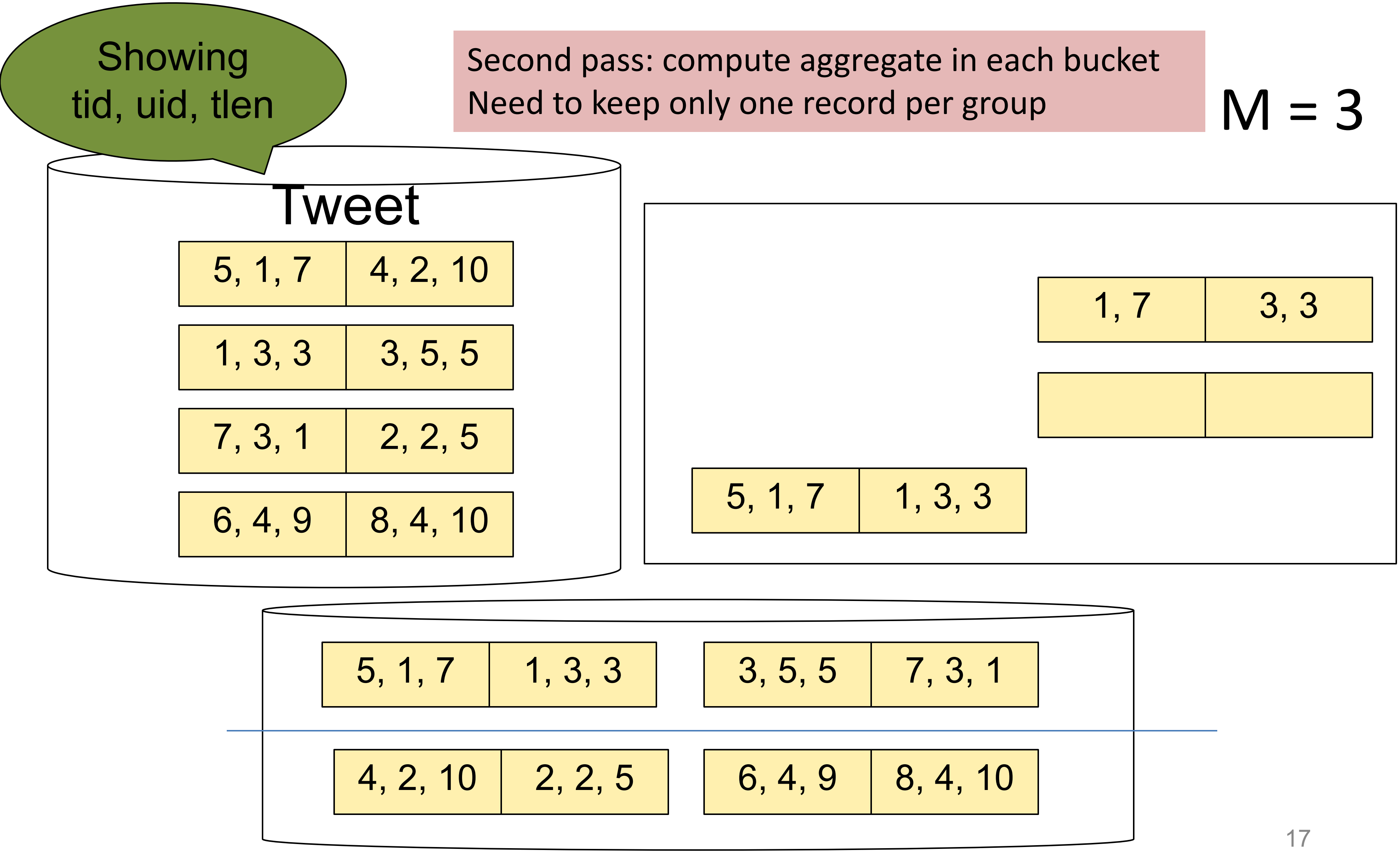


Two pass, hash-based grouping

Second pass: compute aggregate in each bucket
Need to keep only one record per group

M = 3



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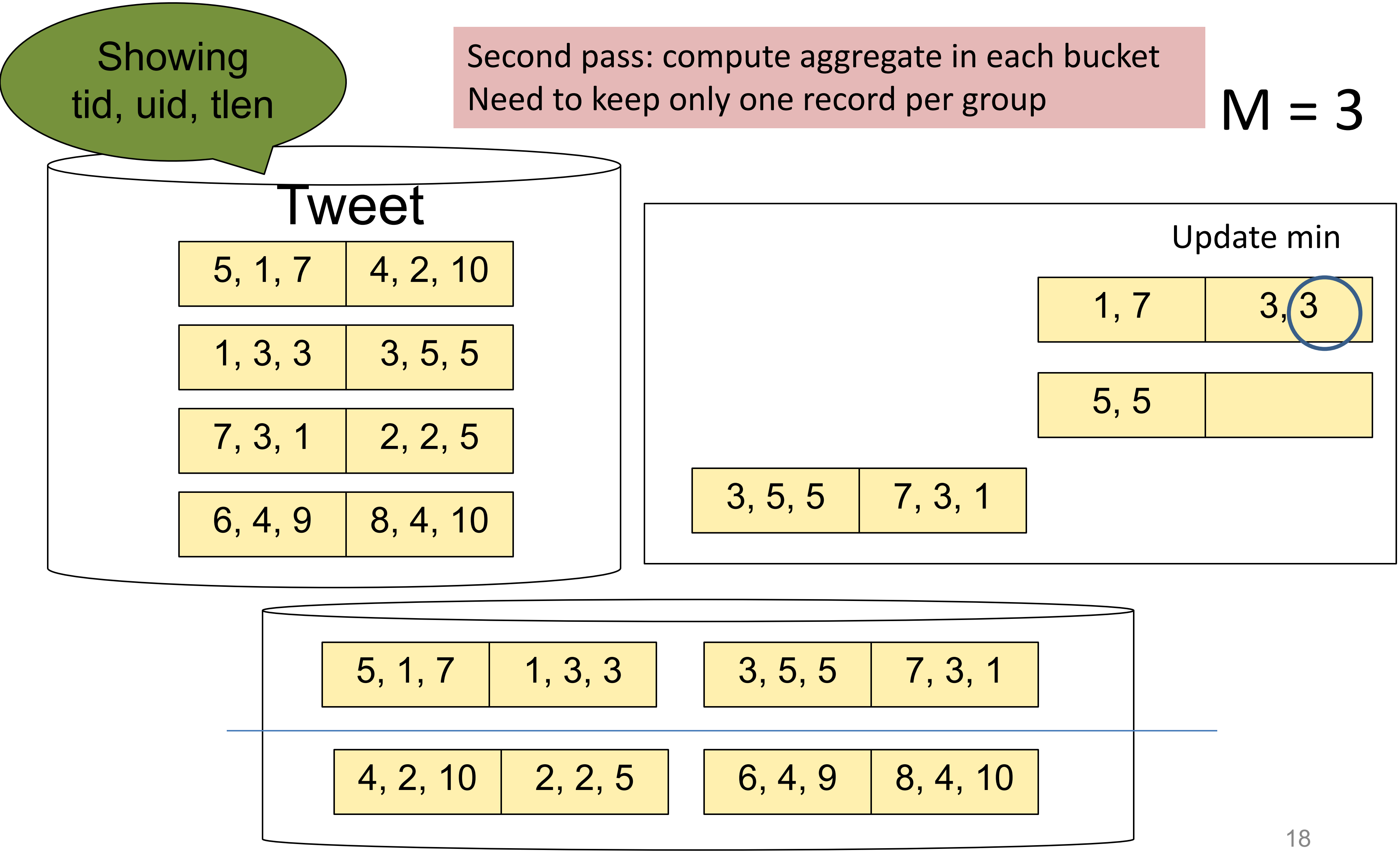


Discussion

Cost?

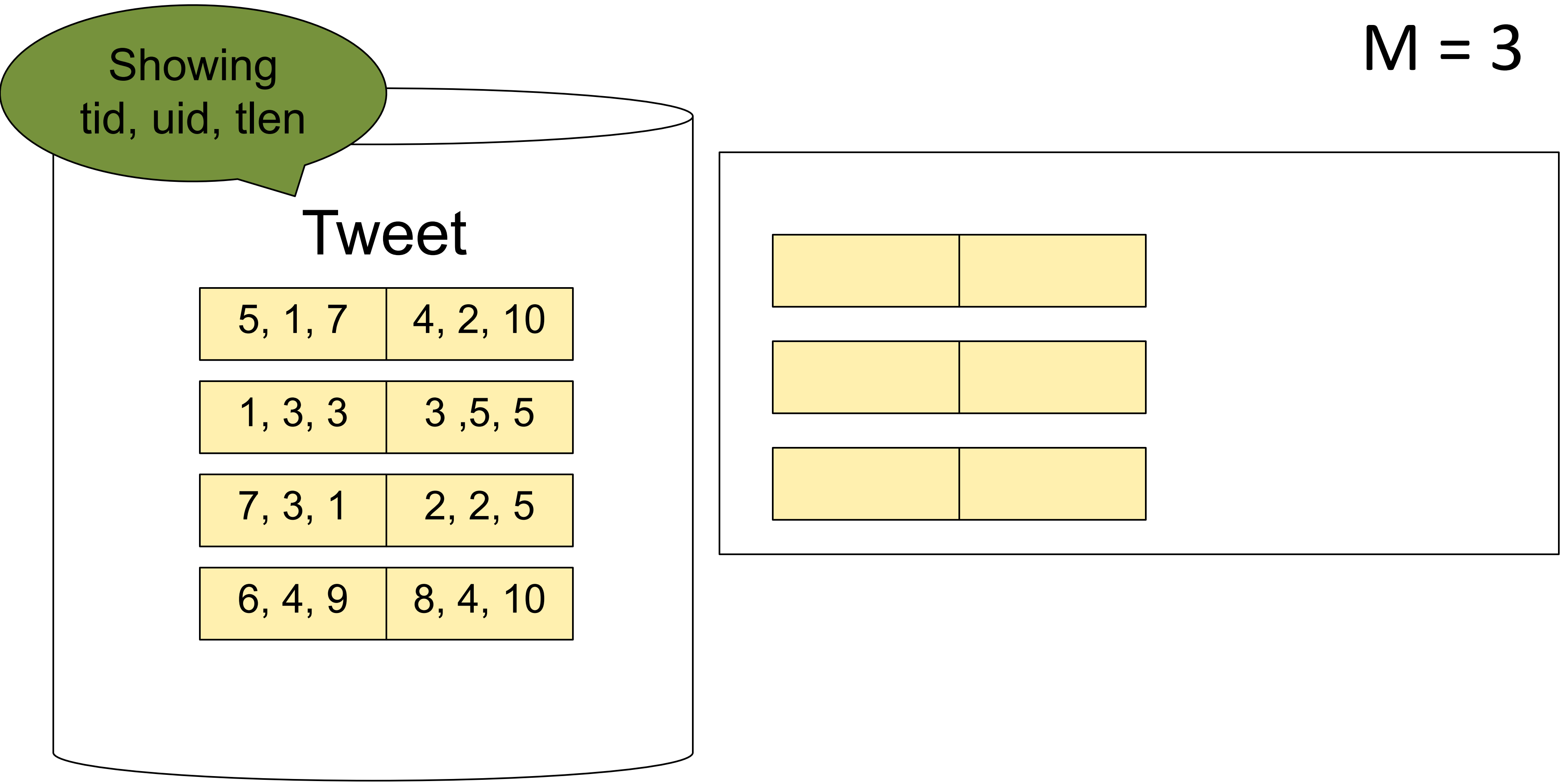
- 3B(R)

Assumptions?

- Need to hold all distinct values in the same bucket in M-1
- Assuming uniformity, B(R) <= M^2 is safe to assume
  - i.e. B(R)/M <= M

Two pass, sort-merge-based grouping

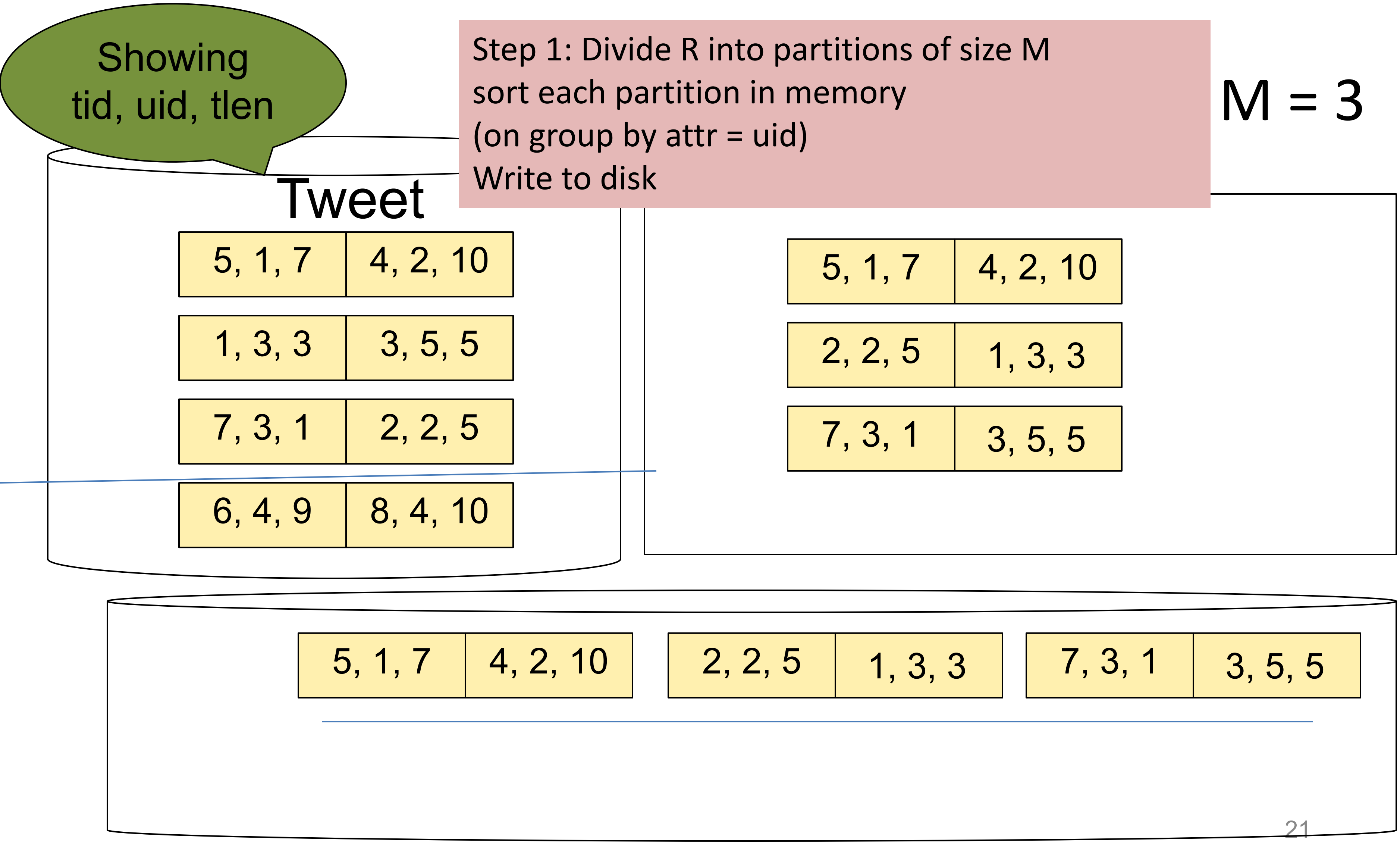
M = 3



Two pass, sort-merge-based grouping

Step 1: Divide R into partitions of size M
sort each partition in memory
(on group by attr = uid)
Write to disk

M = 3



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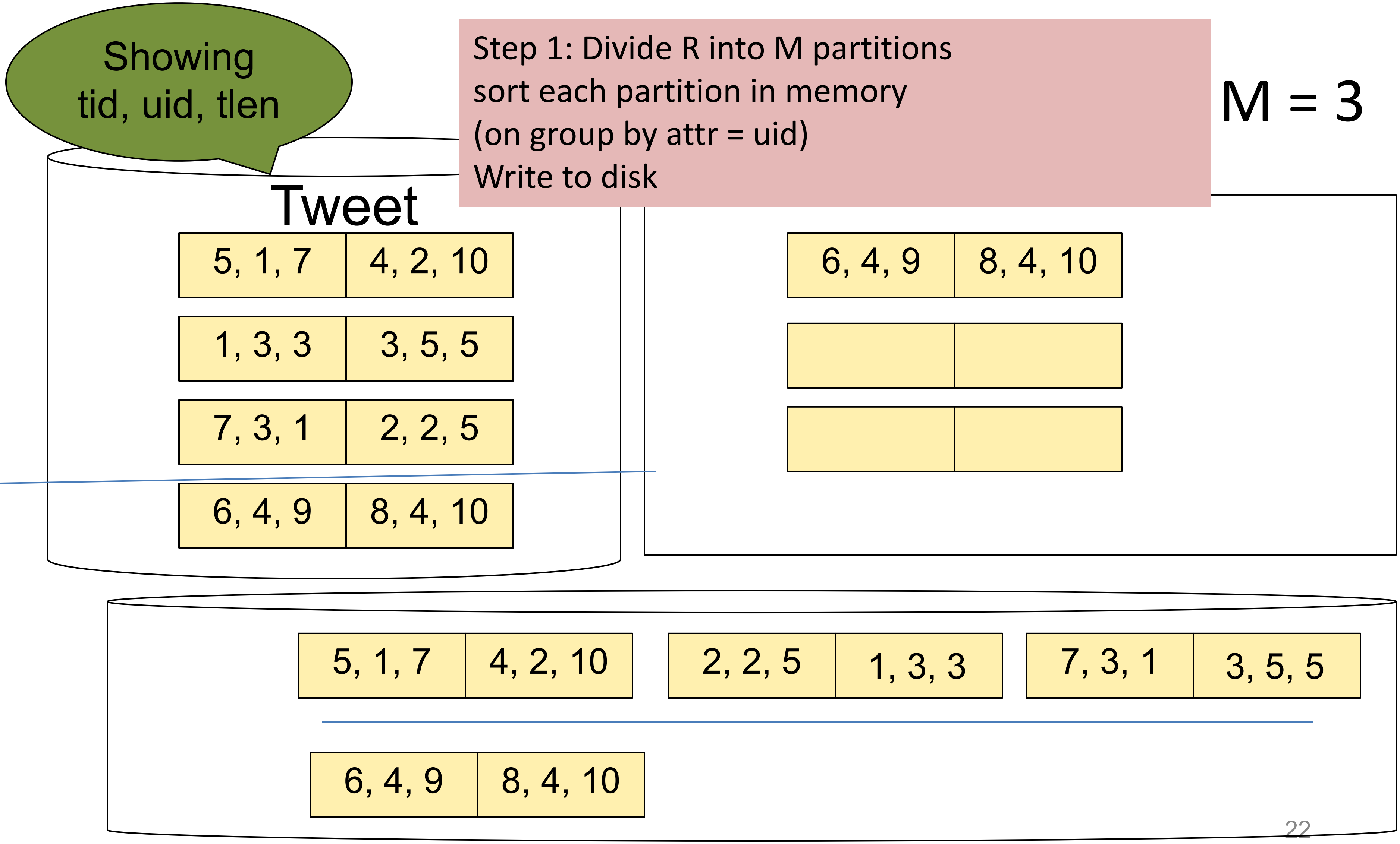
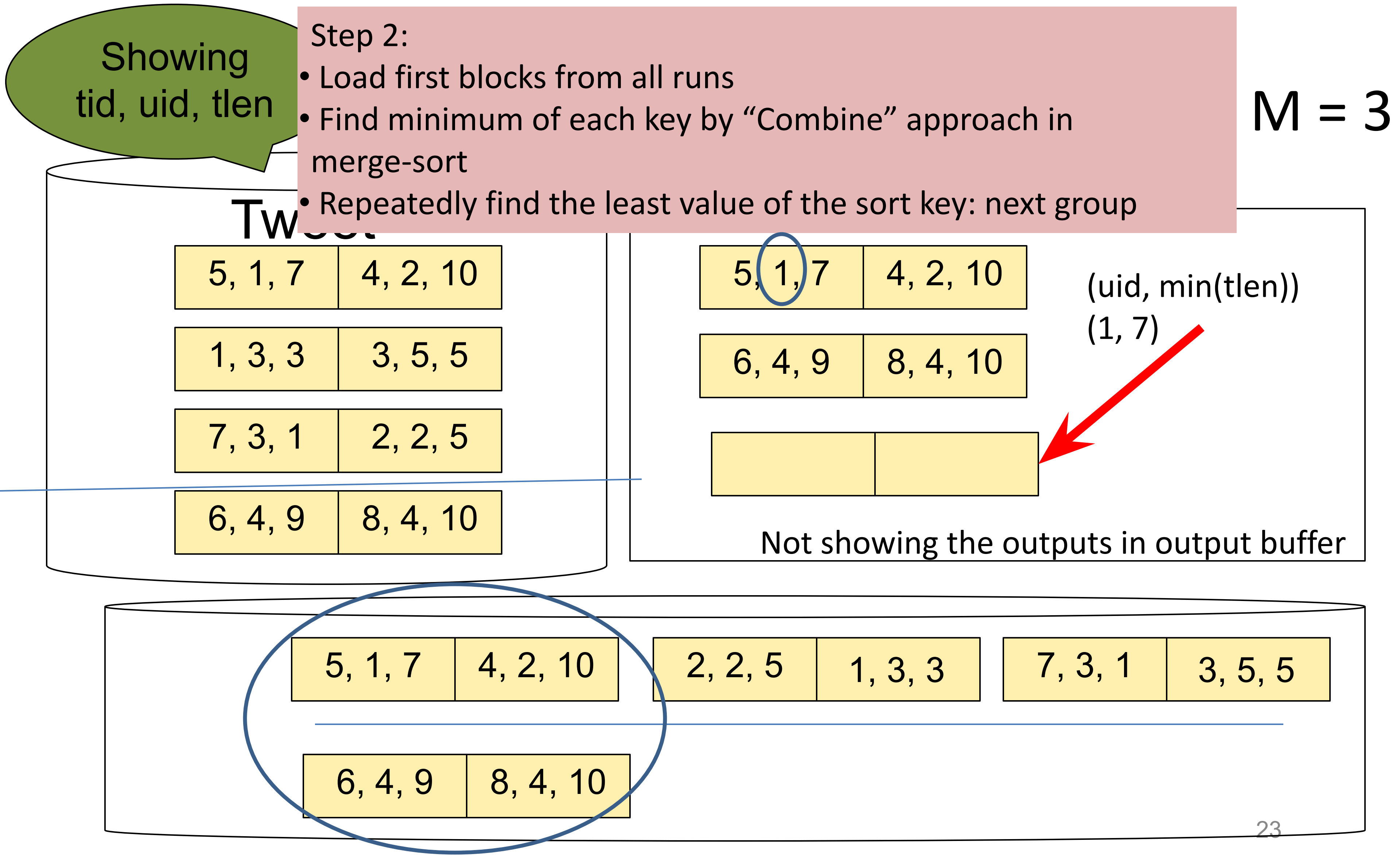


Two pass, sort-merge-based grouping

Step 2:

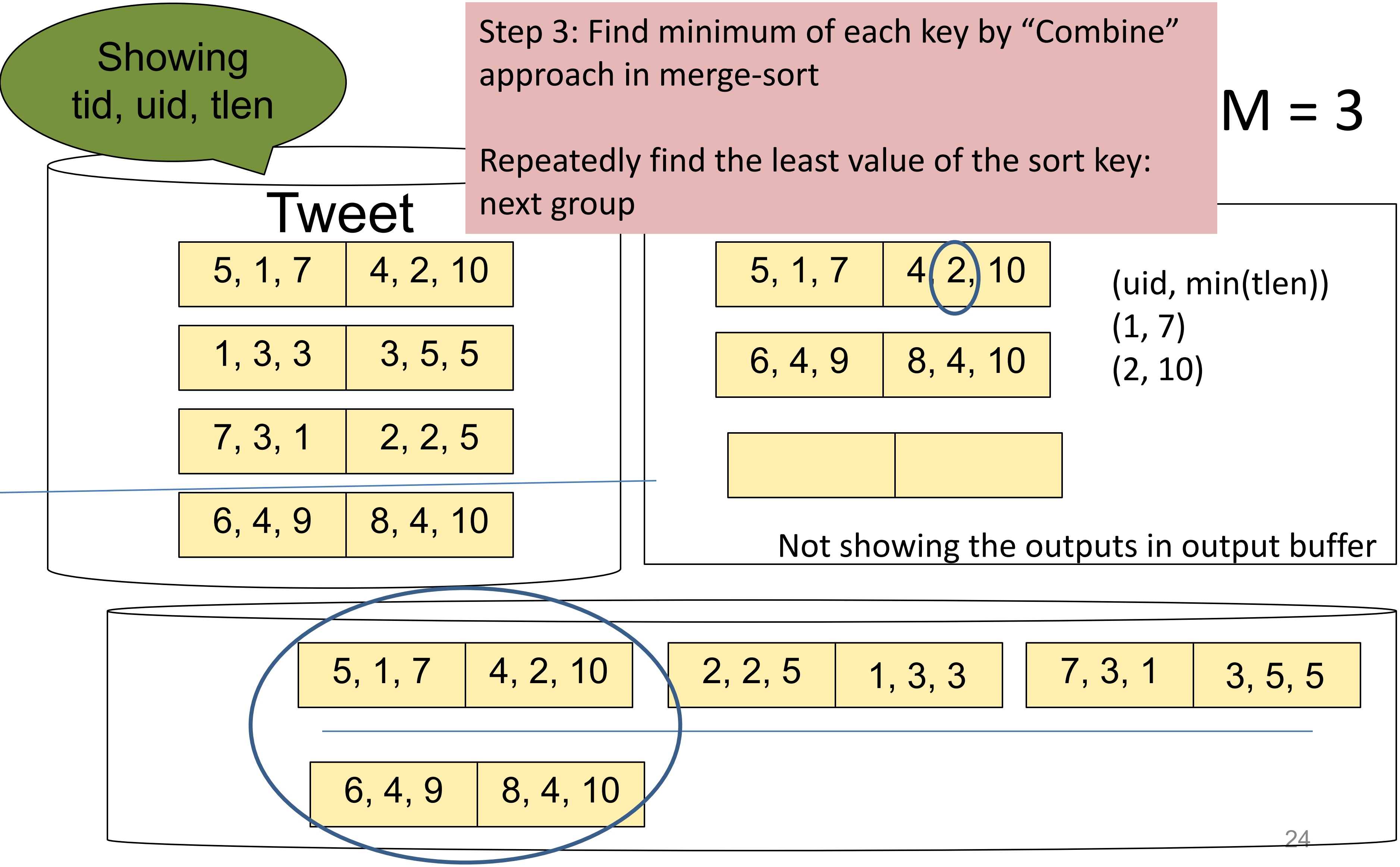
- Load first blocks from all runs
- Find minimum of each key by “Combine” approach in merge-sort
- Repeatedly find the least value of the sort key: next group



Two pass, sort-merge-based grouping

Step 3: Find minimum of each key by "Combine" approach in merge-sort

Repeatedly find the least value of the sort key: next group



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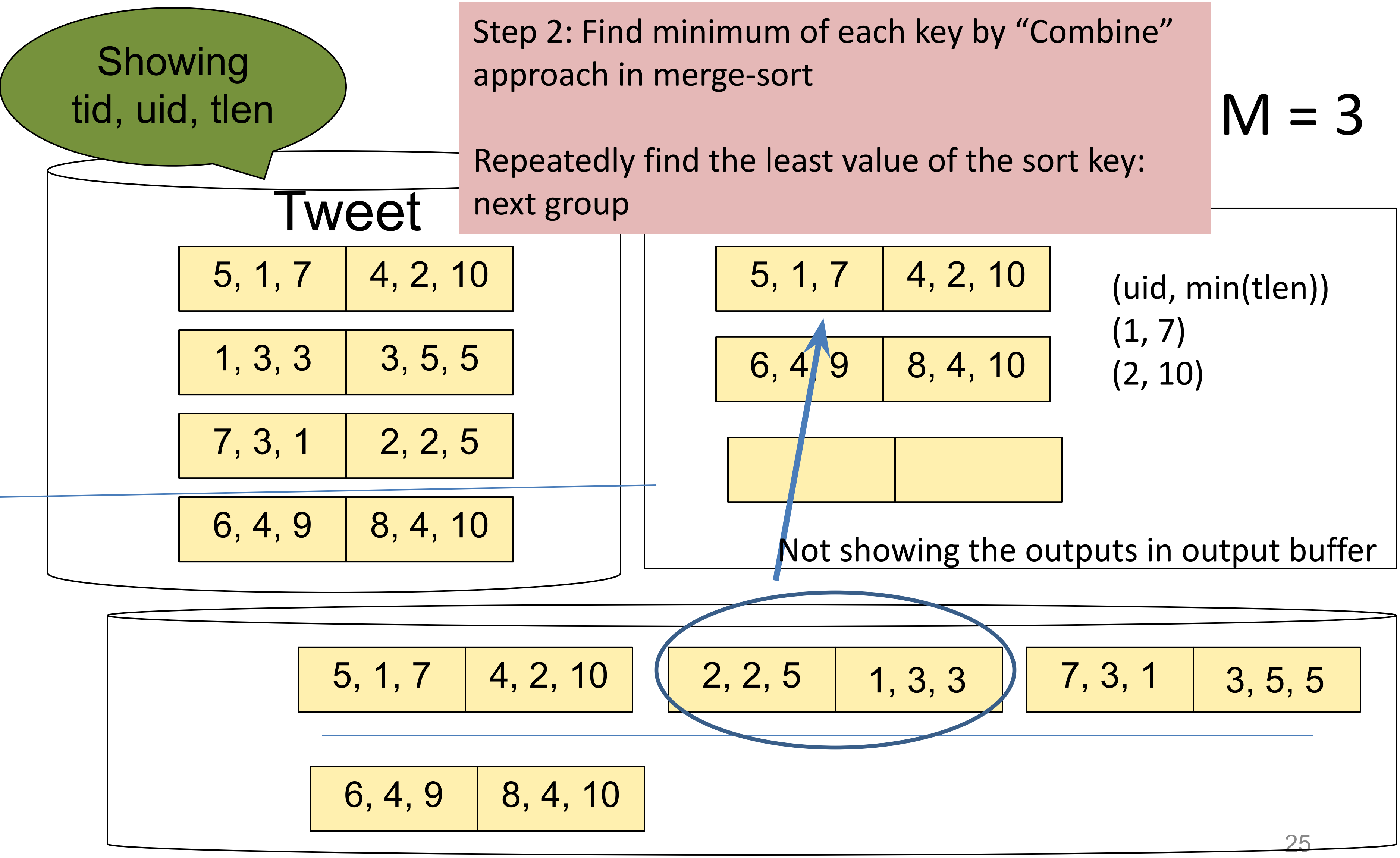

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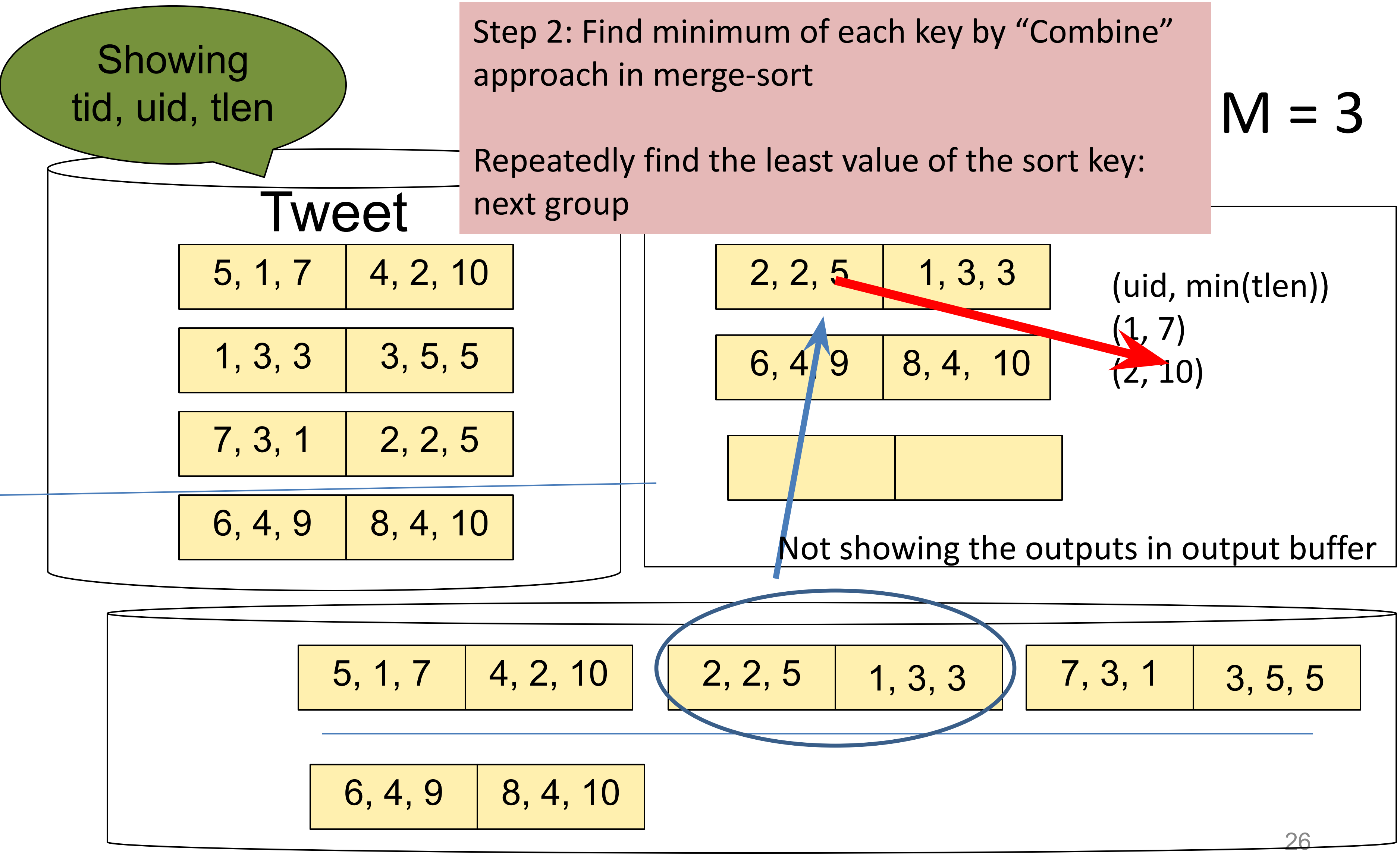

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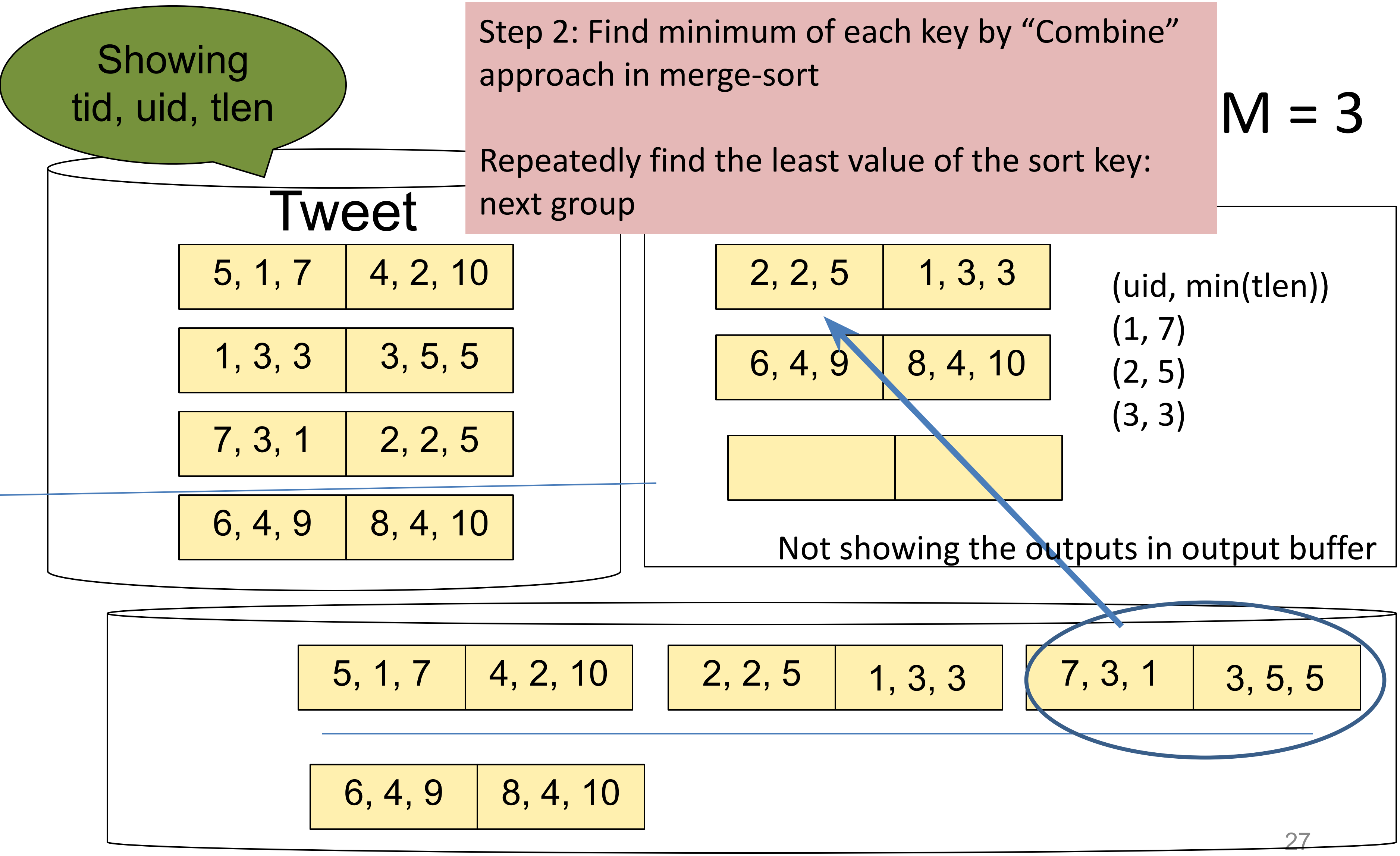

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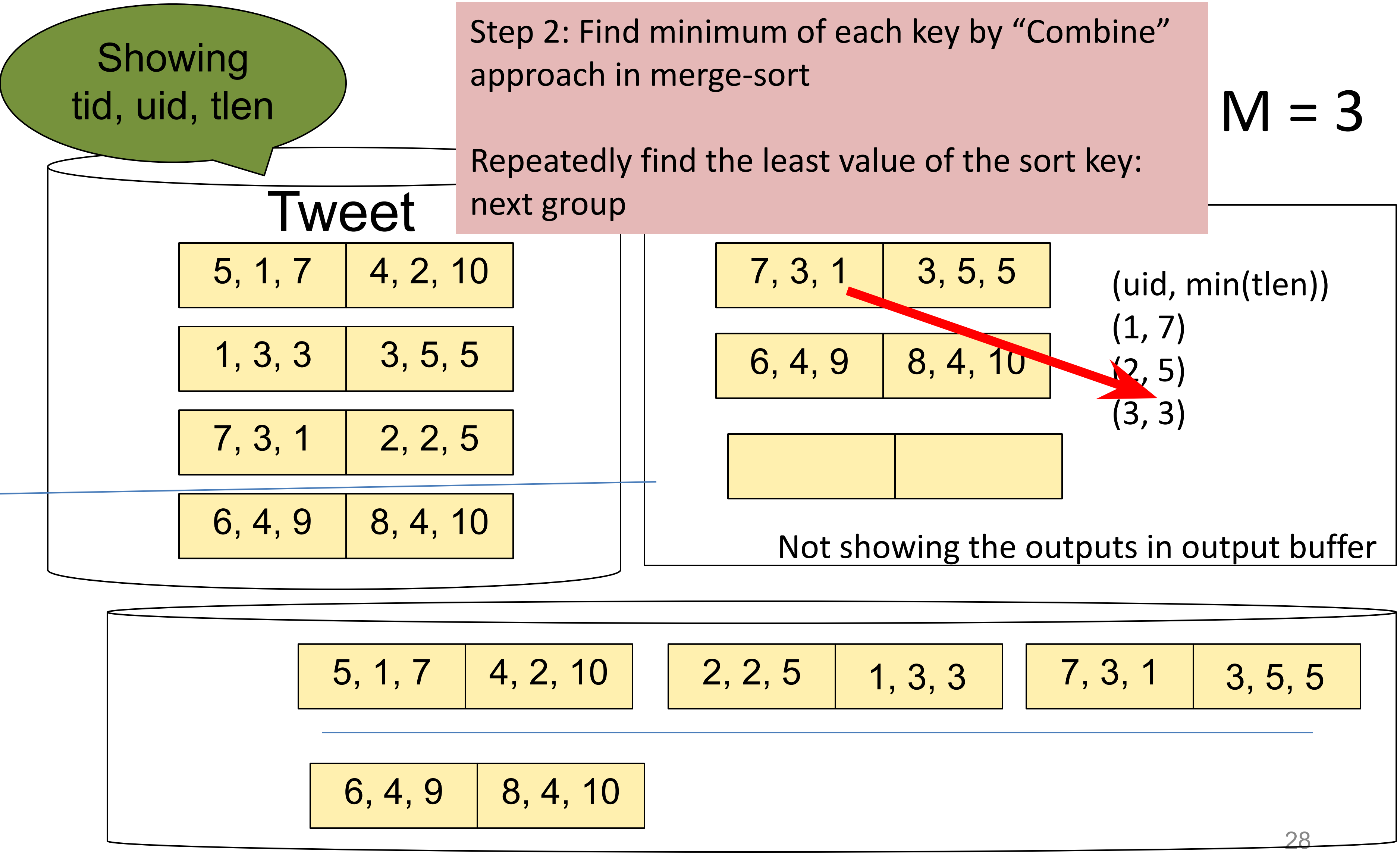


Two pass, sort-merge-based grouping

Showing
tid, uid, tlen

Step 2: Find minimum of each key by "Combine" approach in merge-sort

Repeatedly find the least value of the sort key: next group

M = 3

Tweet

5, 1, 7	4, 2, 10
1, 3, 3	3, 5, 5
7, 3, 1	2, 2, 5
6, 4, 9	8, 4, 10

7, 3, 1	3, 5, 5
6, 4, 9	8, 4, 10

(uid, min(tlen))
(1, 7)
(2, 5)
(3, 1)
(4, 9)
(5, 5)

Not showing the outputs in output buffer

5, 1, 7	4, 2, 10	2, 2, 5	1, 3, 3	7, 3, 1	3, 5, 5

6, 4, 9	8, 4, 10

Discussion

Cost?

- 3B(R)

Assumptions?

- Need to hold one block from each run in M pages
- $B(R) <= M^2$

One pass vs. Two pass

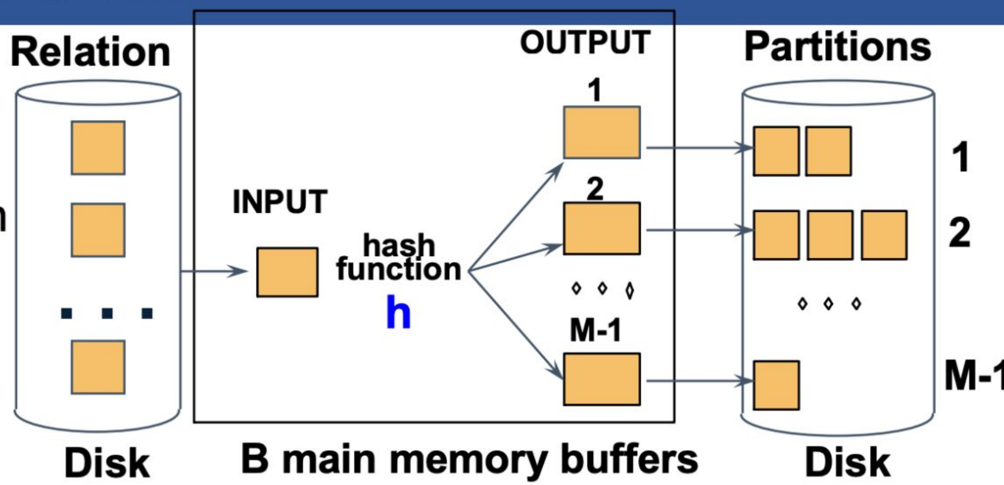
- One pass:
  - smaller disk I/O cost
    - e.g. B(R) for one-pass hash-based aggregation
  - Handles smaller relations
    - e.g. B(R) <= M
- Two/Multi pass:
  - Larger disk I/O cost
    - e.g. 3B(R) for two-pass hash-based aggregation
  - Can handle larger relations
    - e.g. B(R) <= M^2

Review for Joins

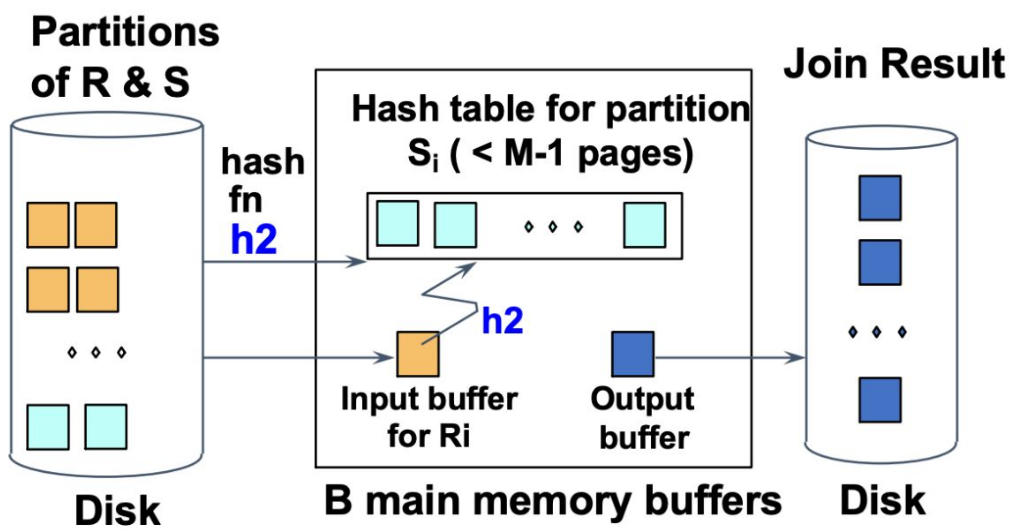
- Two-pass Hash-based Join
  - Cost: 3B(R) + 3B(S)
  - Assumption: Min(B(R), B(S)) <= M^2
- Two-pass Sort-merge-based Join
  - Implementation:
    - Cost: 3B(R) + 3B(S)
      - For R, S: sort runs/sublists (2 I/O, read + write)
      - Join by combining all runs of R and S (only read, write not counted - 1 I/O)

Partitioned Hash-Join

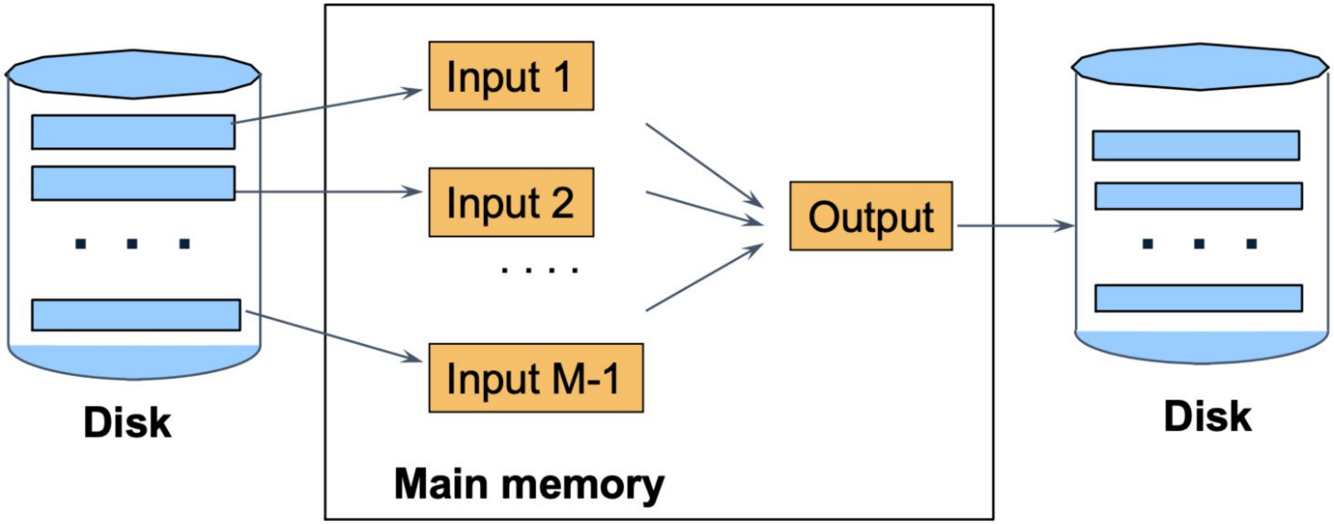
- Partition both relations using hash fn **h**: R tuples in partition i will only match S tuples in partition i.



- Read in a partition of R, hash it using **h2 (<> h!)**. Scan matching partition of S, search for matches.



Merge-Join



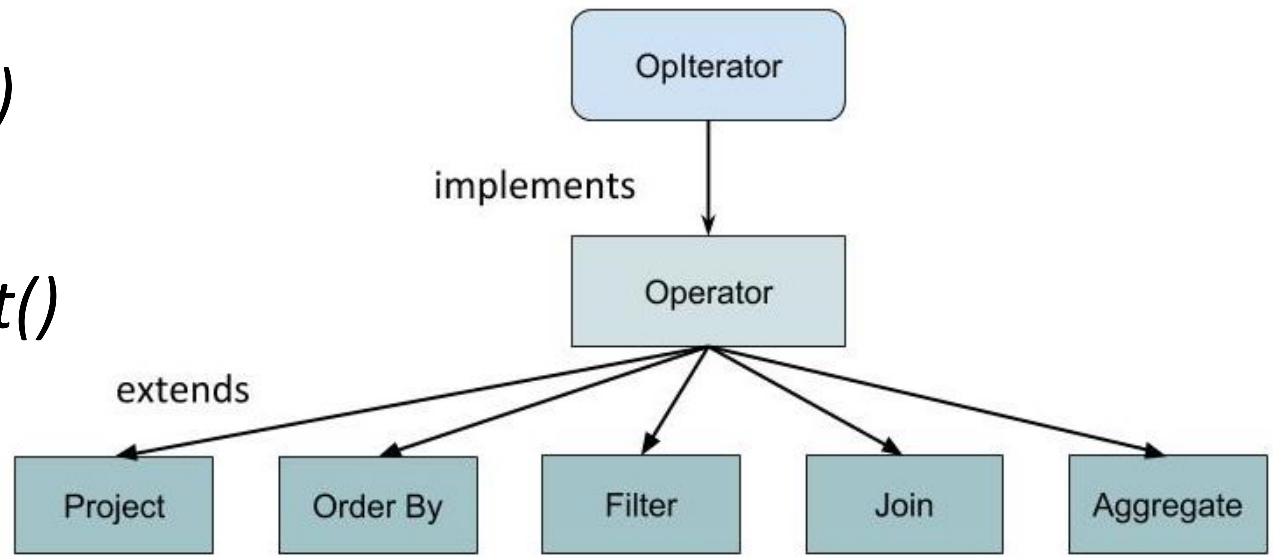
M_1 = B(R)/M runs for R
M_2 = B(S)/M runs for S
Merge-join $M_1 + M_2$ runs;
need $M_1 + M_2 <= M$ to process all runs
i.e. $B(R) + B(S) <= M^2$

Homework 2

- Problem 1
  - B+ Trees (inserting/deleting/lookups)
- Problem 2
  - Operator Algorithms
- Problem 3
  - Multi-Pass Algorithms

Lab 2: Operator

- TODO: Implement Operator *Filter*, *Join* and *Aggregate*
  - *open()*
  - *close()*
  - *hasNext()*
  - *next()*
  - *fetchNext()*



Lab2: Aggregator

- TODO: Implement *IntegerAggregator* and *StringAggregator*
  - mergeTupleIntoGroup(): merge a tuple into aggregate
  - iterator(): return *a OpIterator over group aggregate results*