CSE 444: Database Internals

Section 3:

Operator Algorithms

Today

- Discuss algorithms for aggregate operators
- Questions for Homework 2

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

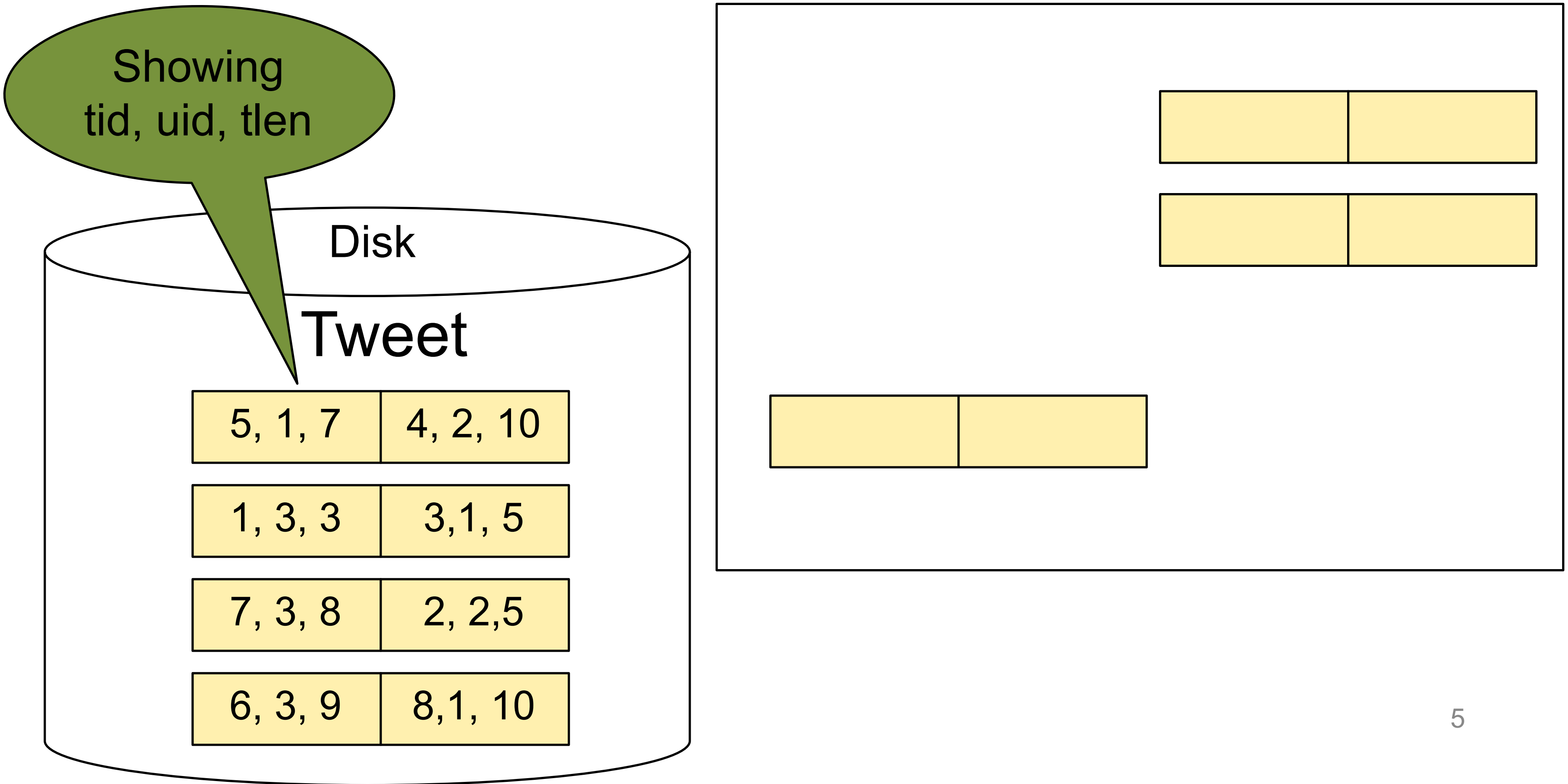
- Modified Tweet Example:

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

```
SELECT uid, MIN(tlen)
FROM Tweet
GROUP BY uid
```

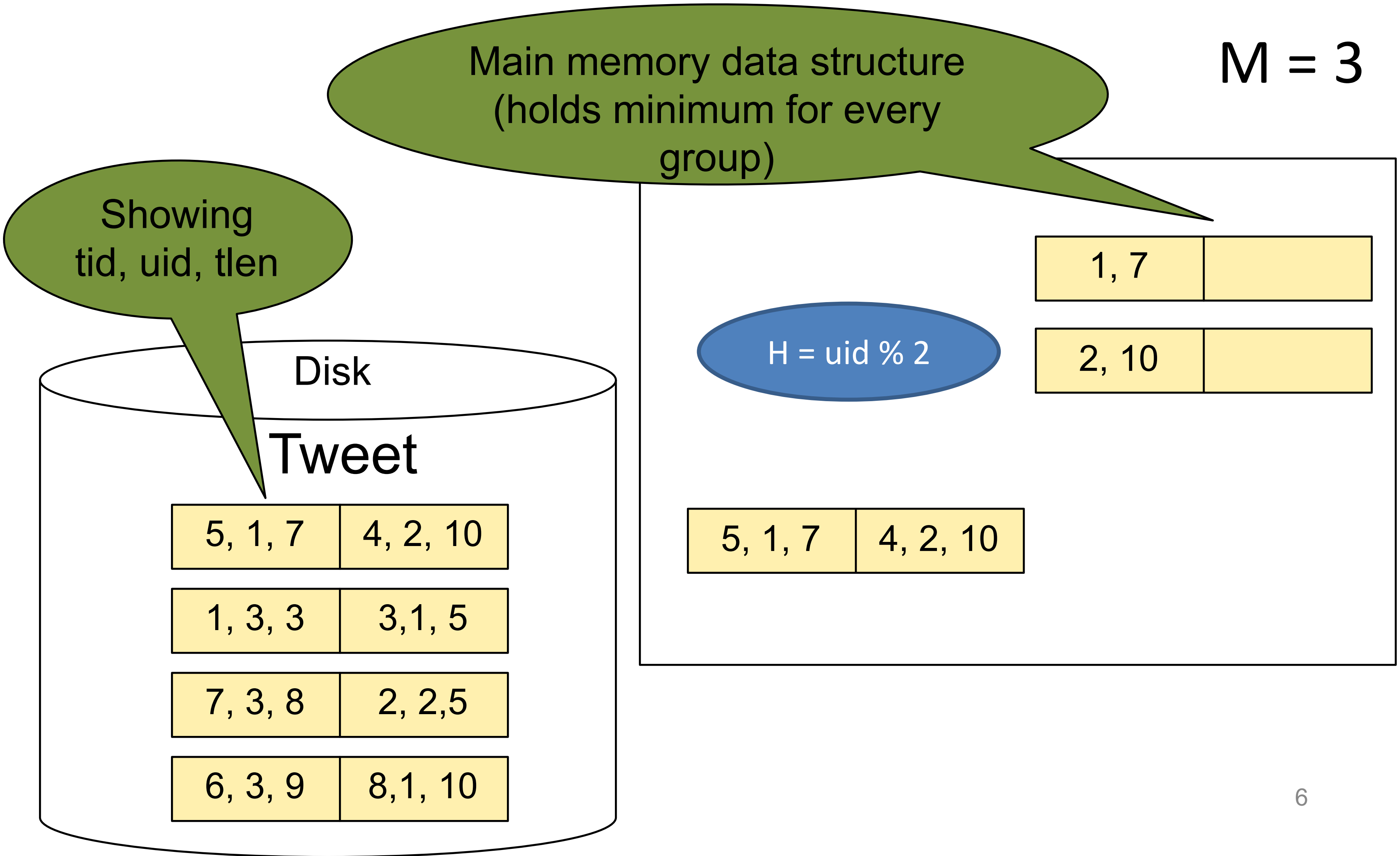
One pass, hash-based grouping

M = 3



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

One pass, hash-based grouping



Main memory data structure (holds minimum for every group)

M = 3

Showing tid, uid, tlen

Disk

Tweet

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

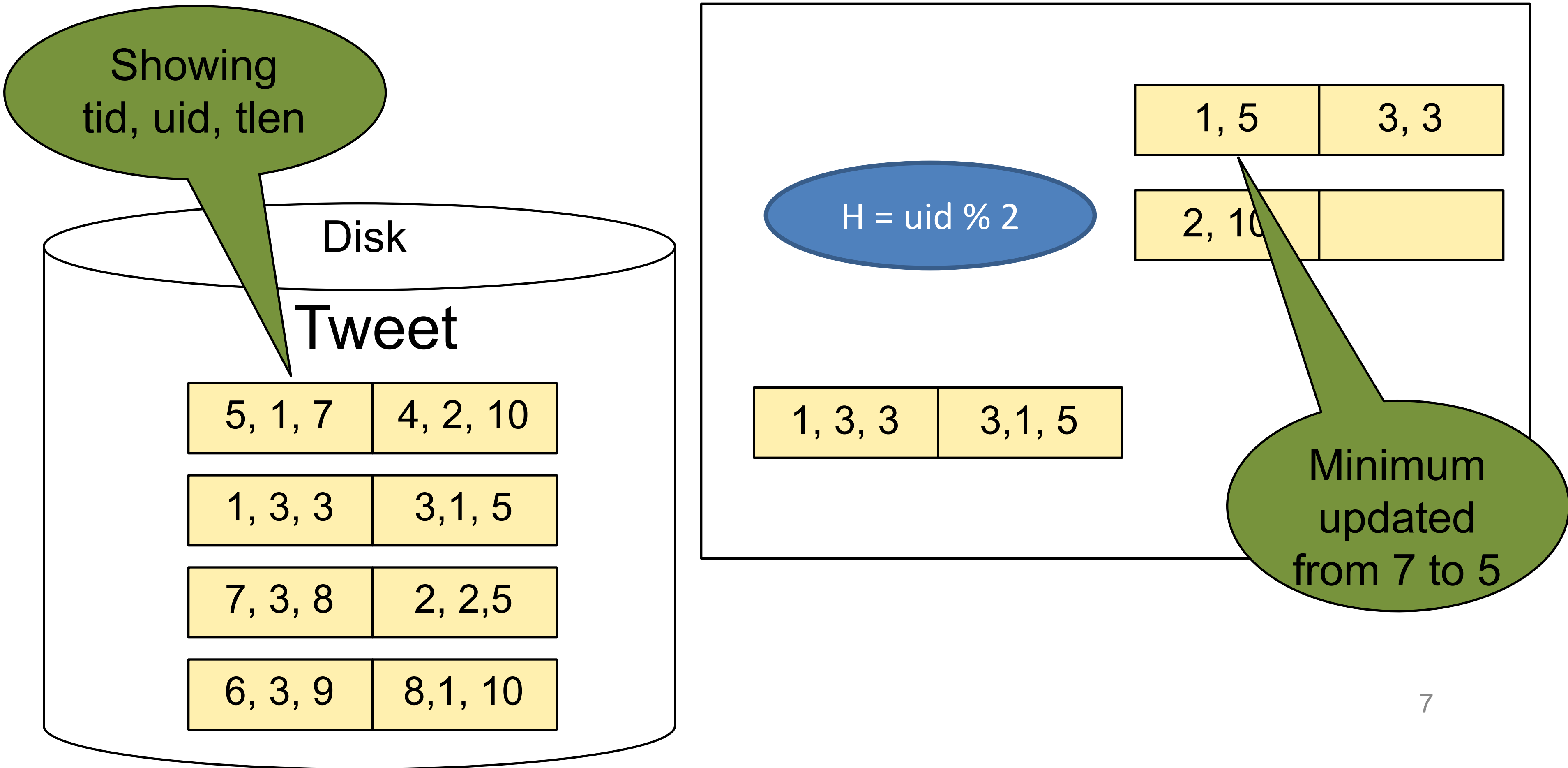
H = uid % 2

1, 7	
2, 10	

5, 1, 7	4, 2, 10

One pass, hash-based grouping

M = 3



Showing tid, uid, tlen

Disk

Tweet

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

H = uid % 2

1, 5	3, 3
2, 10	

1, 3, 3	3,1, 5

Minimum updated from 7 to 5

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?

  - T(R) : since we would need to fetch each row

Which method does the grouping:

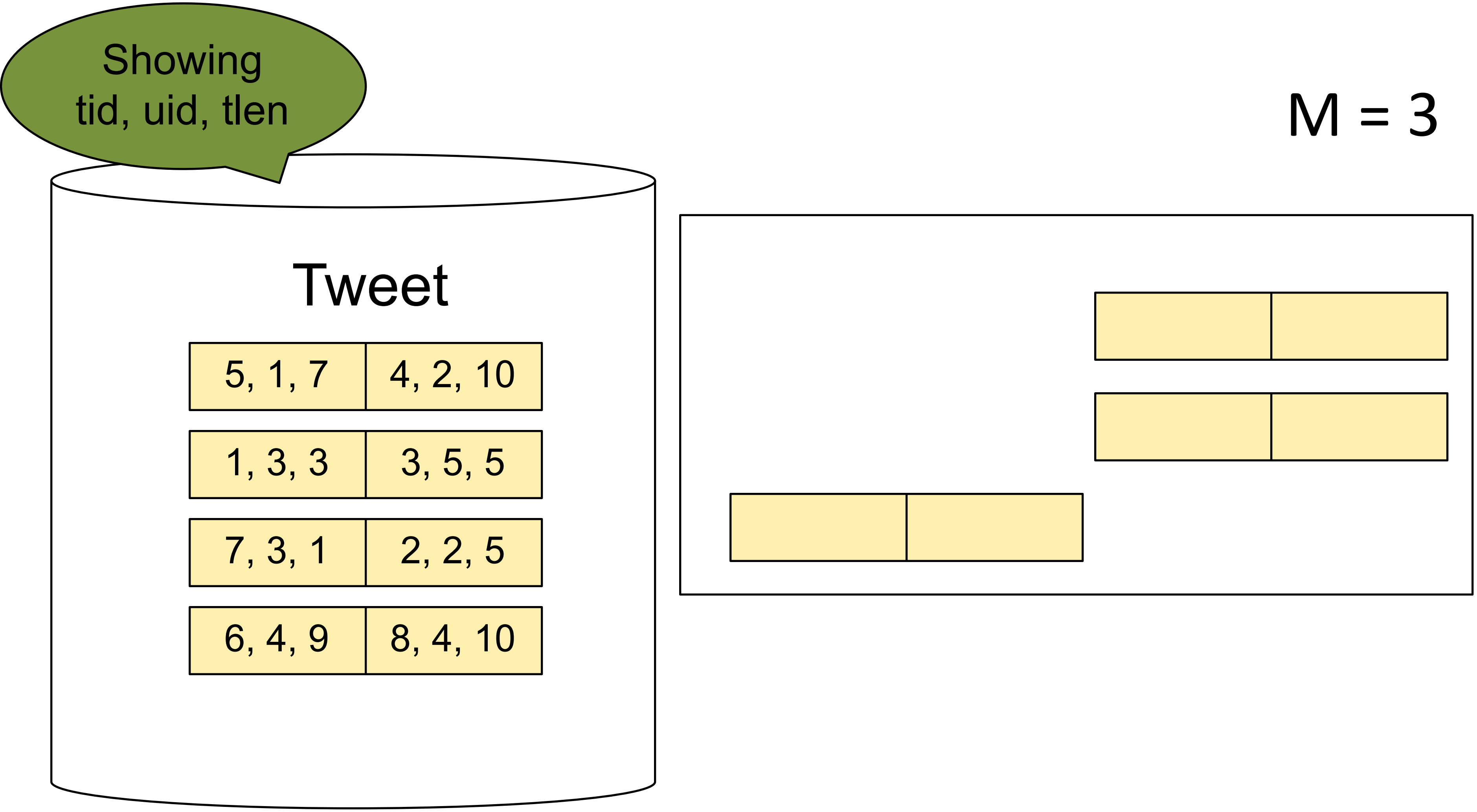
open(), next(), or close()?

- Cannot return anything until the entire data is read. This can be done in the open() or next() call

What to do for AVG(tlen)?

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

Two pass, hash-based grouping



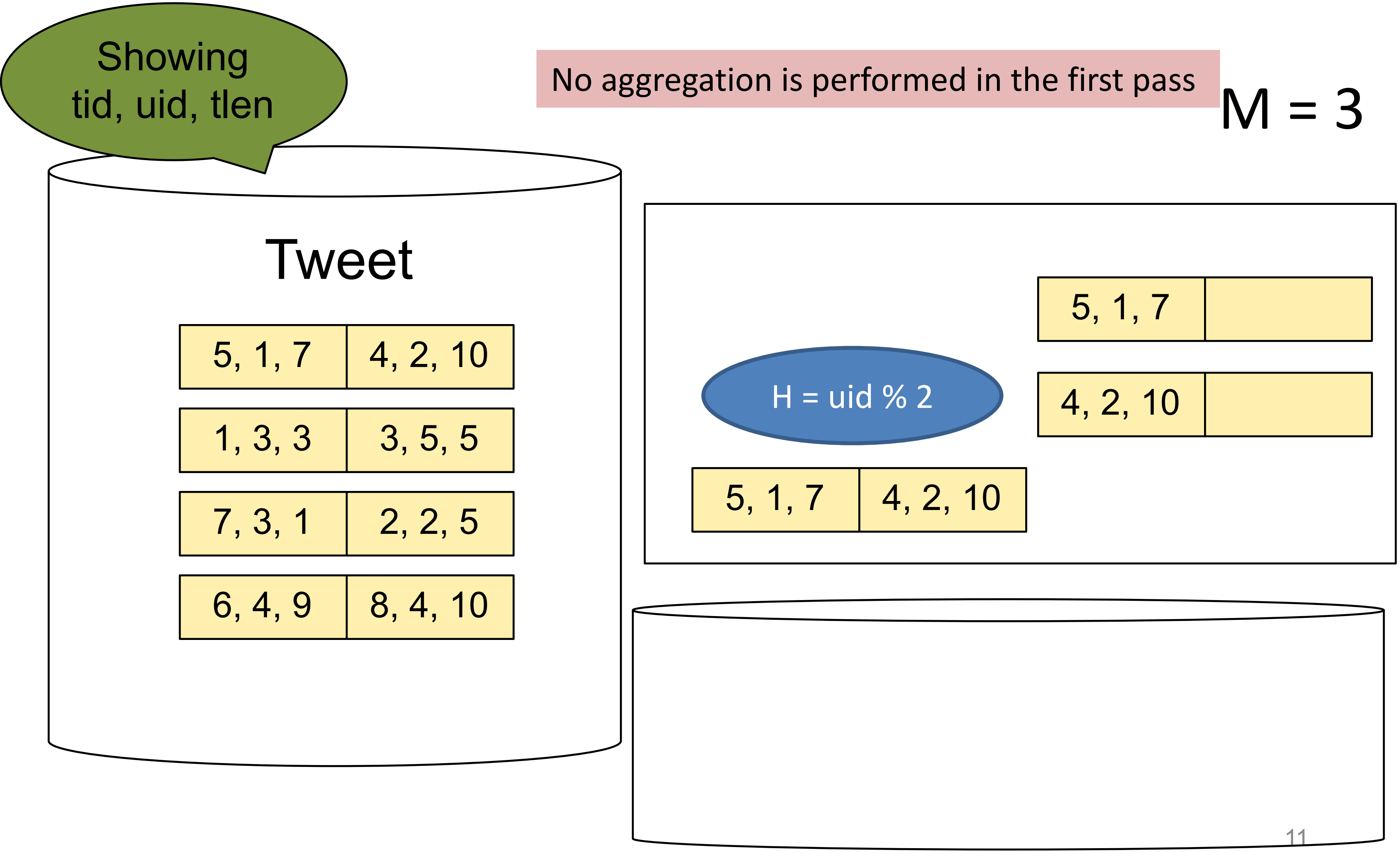
Showing
tid, uid, tlen

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

Two pass, hash-based grouping



Showing tid, uid, tlen

No aggregation is performed in the first pass

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

H = uid % 2

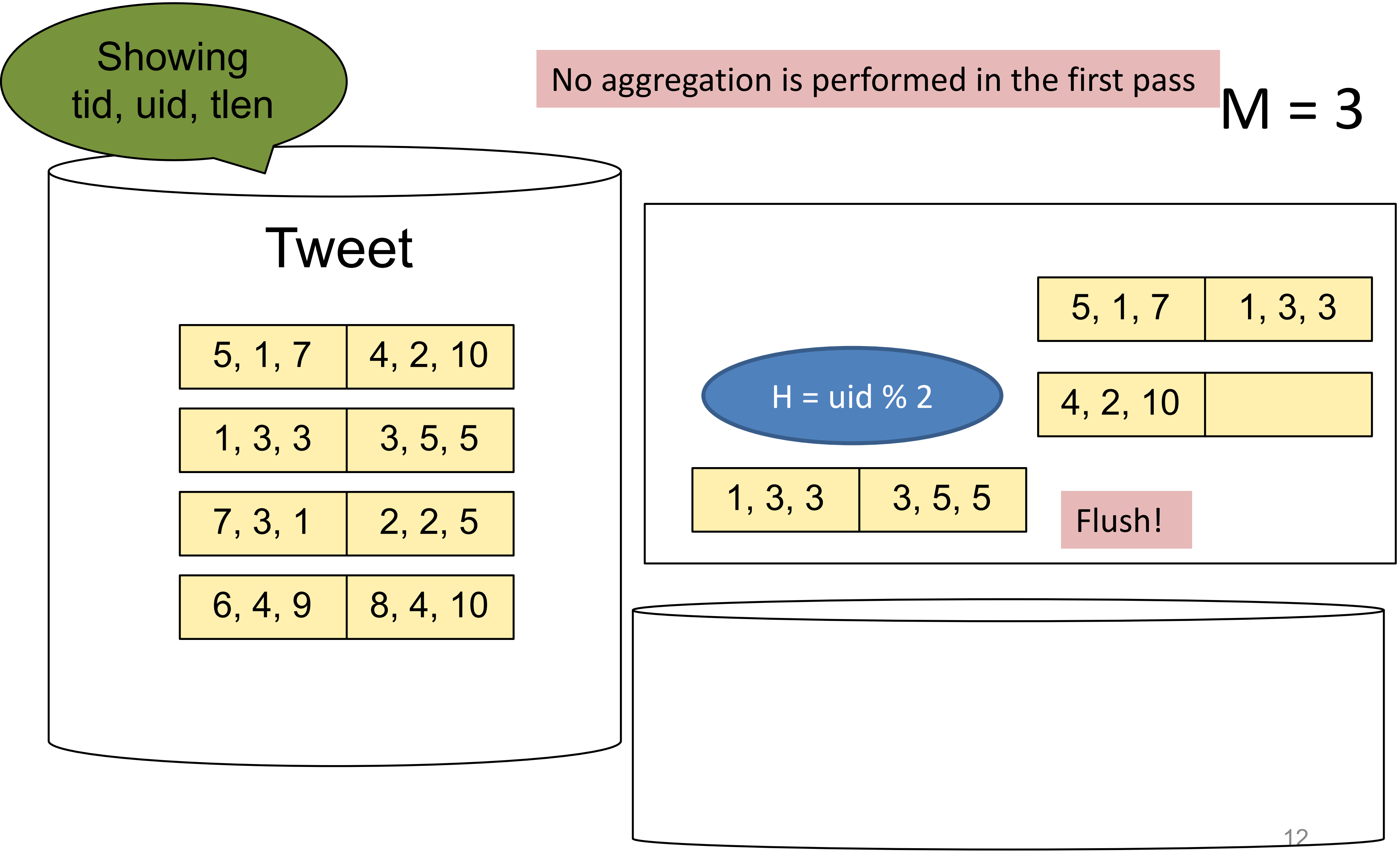
5, 1, 7	
4, 2, 10	

5, 1, 7	4, 2, 10

Two pass, hash-based grouping

No aggregation is performed in the first pass

M = 3



Showing
tid, uid, tlen

Tweet

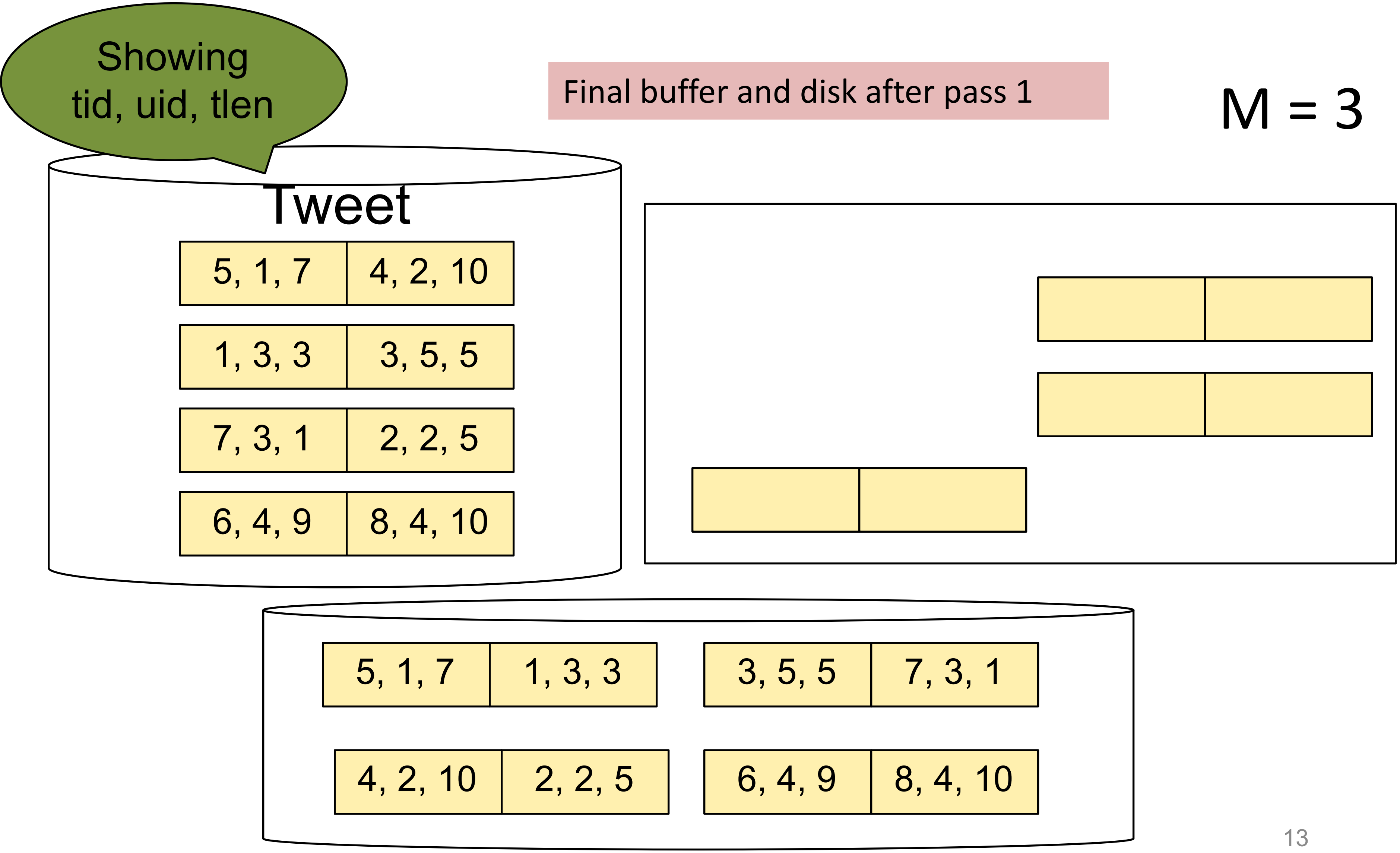
5, 1, 7	4, 2, 10
1, 3, 3	3, 5, 5
7, 3, 1	2, 2, 5
6, 4, 9	8, 4, 10

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

1, 3, 3	3, 5, 5

Flush!

Two pass, hash-based grouping



Showing
tid, uid, tlen

Final buffer and disk after pass 1

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

5, 1, 7 | 1, 3, 3   3, 5, 5 | 7, 3, 1

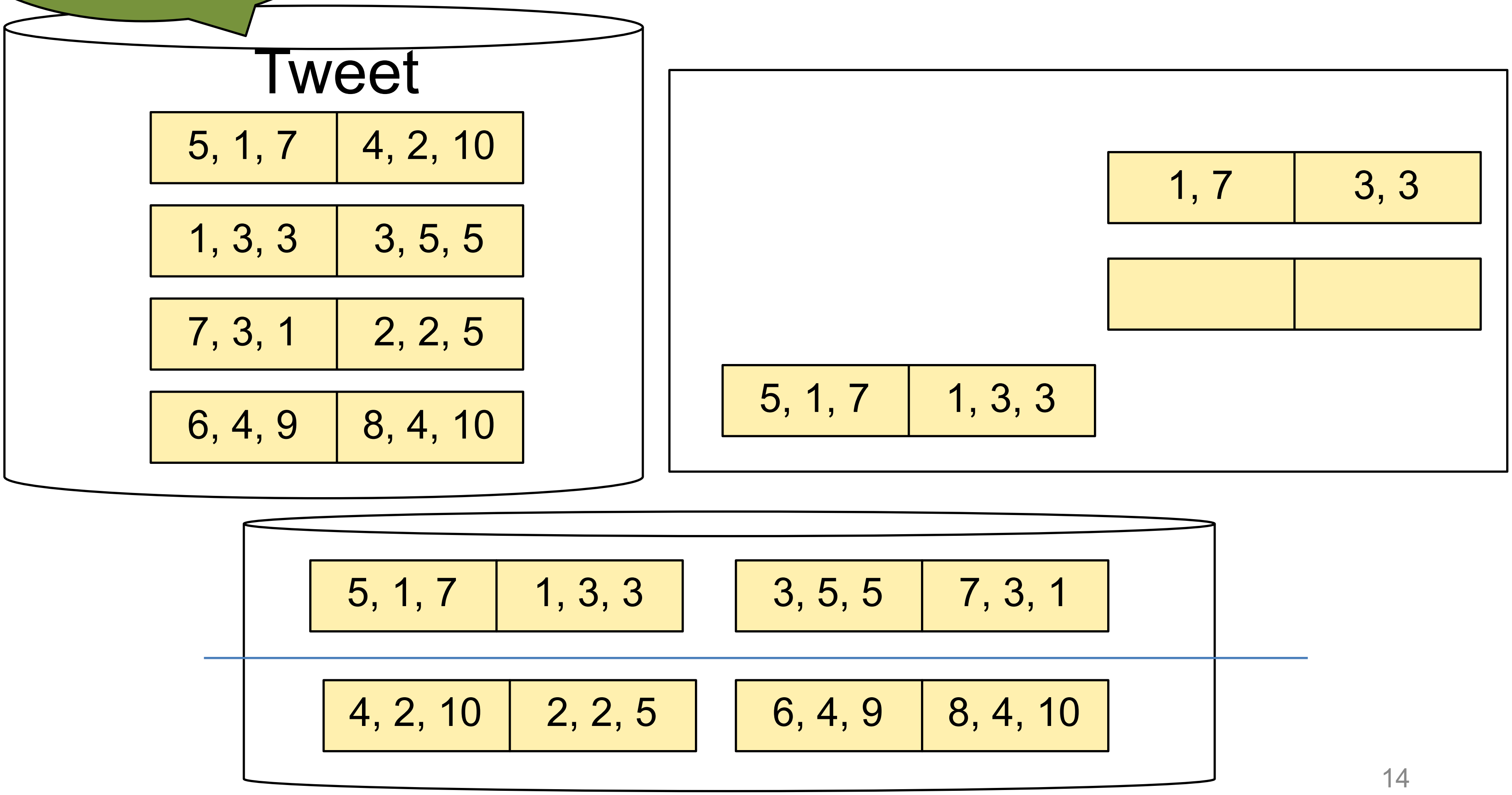
4, 2, 10 | 2, 2, 5   6, 4, 9 | 8, 4, 10

Two pass, hash-based grouping

Showing
tid, uid, tlen

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

1, 7 | 3, 3

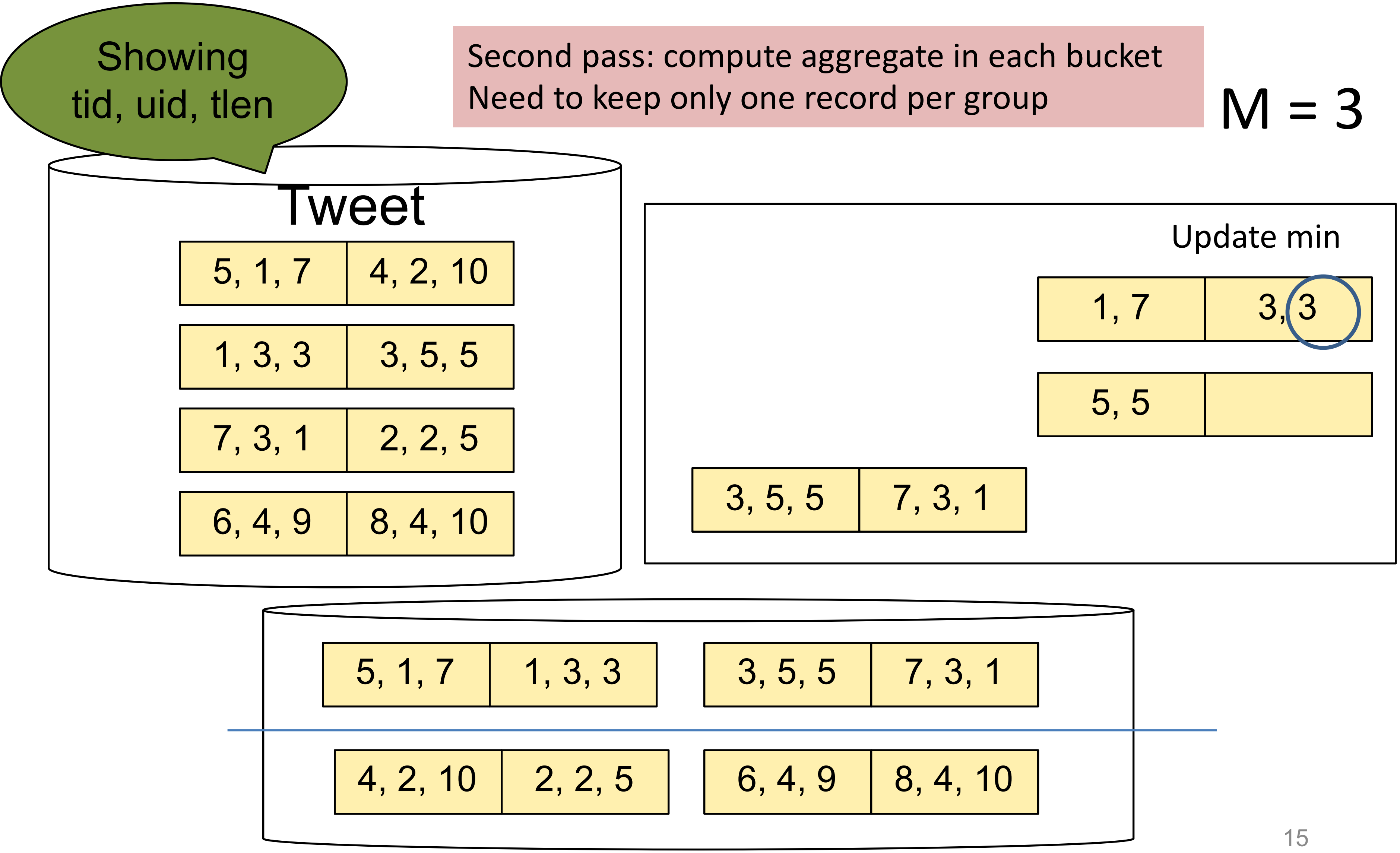
5, 1, 7 | 1, 3, 3

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

Two pass, hash-based grouping

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

M = 3



Showing
tid, uid, tlen

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

Update min

1, 7 | 3, 3
5, 5 |
3, 5, 5 | 7, 3, 1

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

Discussion

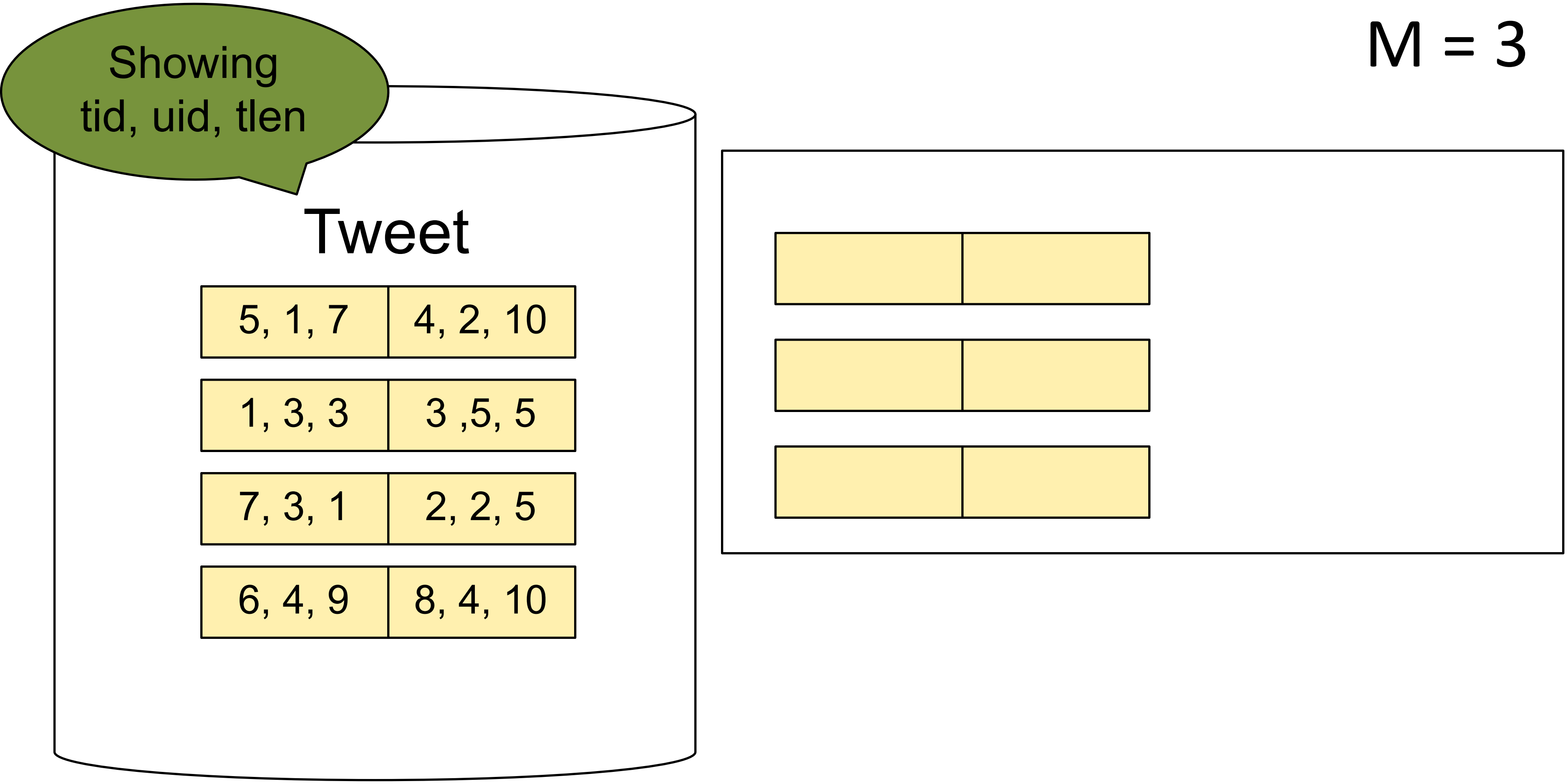
Cost?

- 3B(R)

Assumptions?

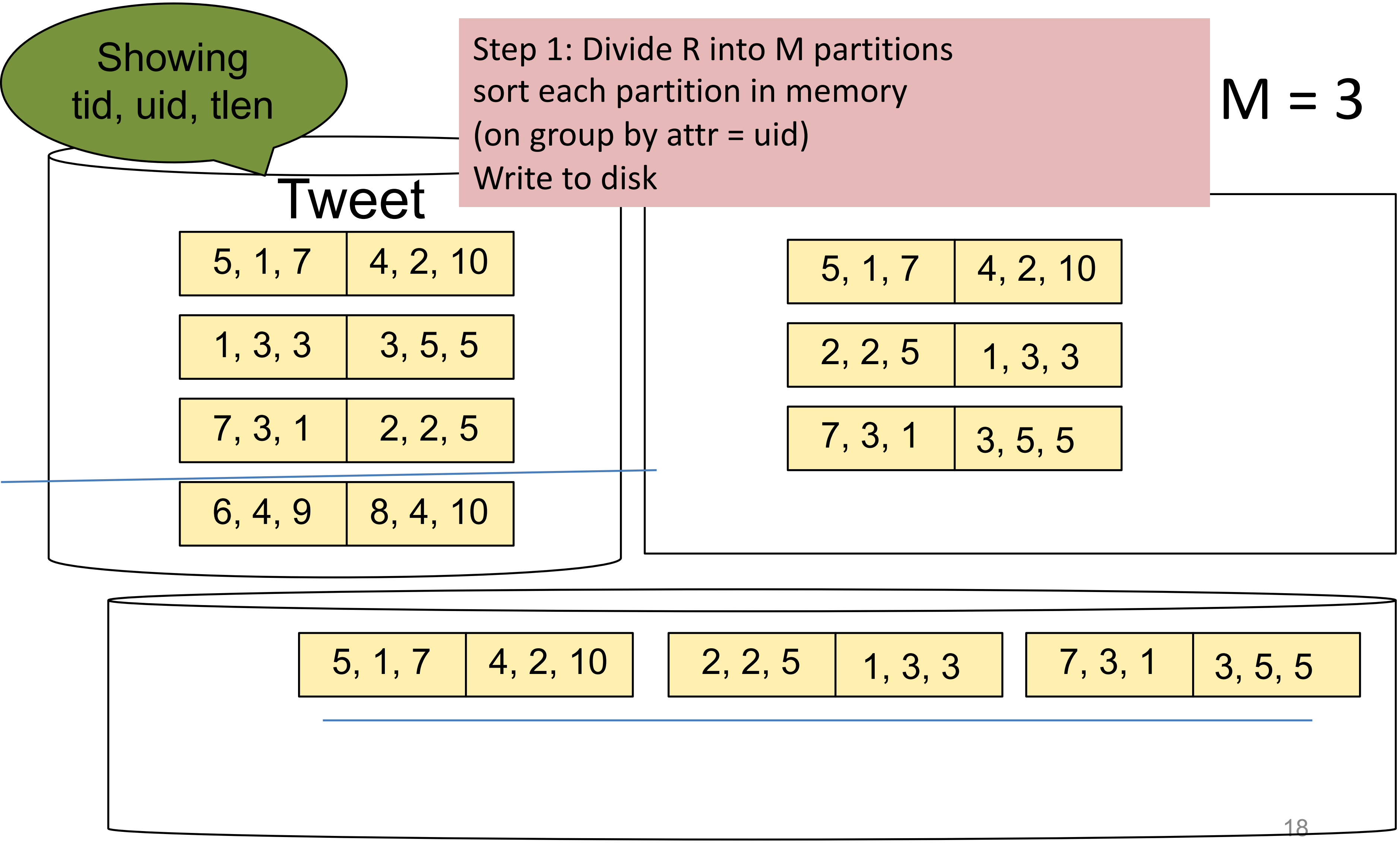
- Need to hold all distinct values in the same bucket in M-1
- Assuming uniformity, $B(R) <= M^2$ is safe to assume
  - i.e. B(R)/M <= M
  - Note: can handle cases when R has large partitions with small number of groupings

Two pass, sort-merge-based grouping



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

Two pass, sort-merge-based grouping



Showing
tid, uid, tlen

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

M = 3

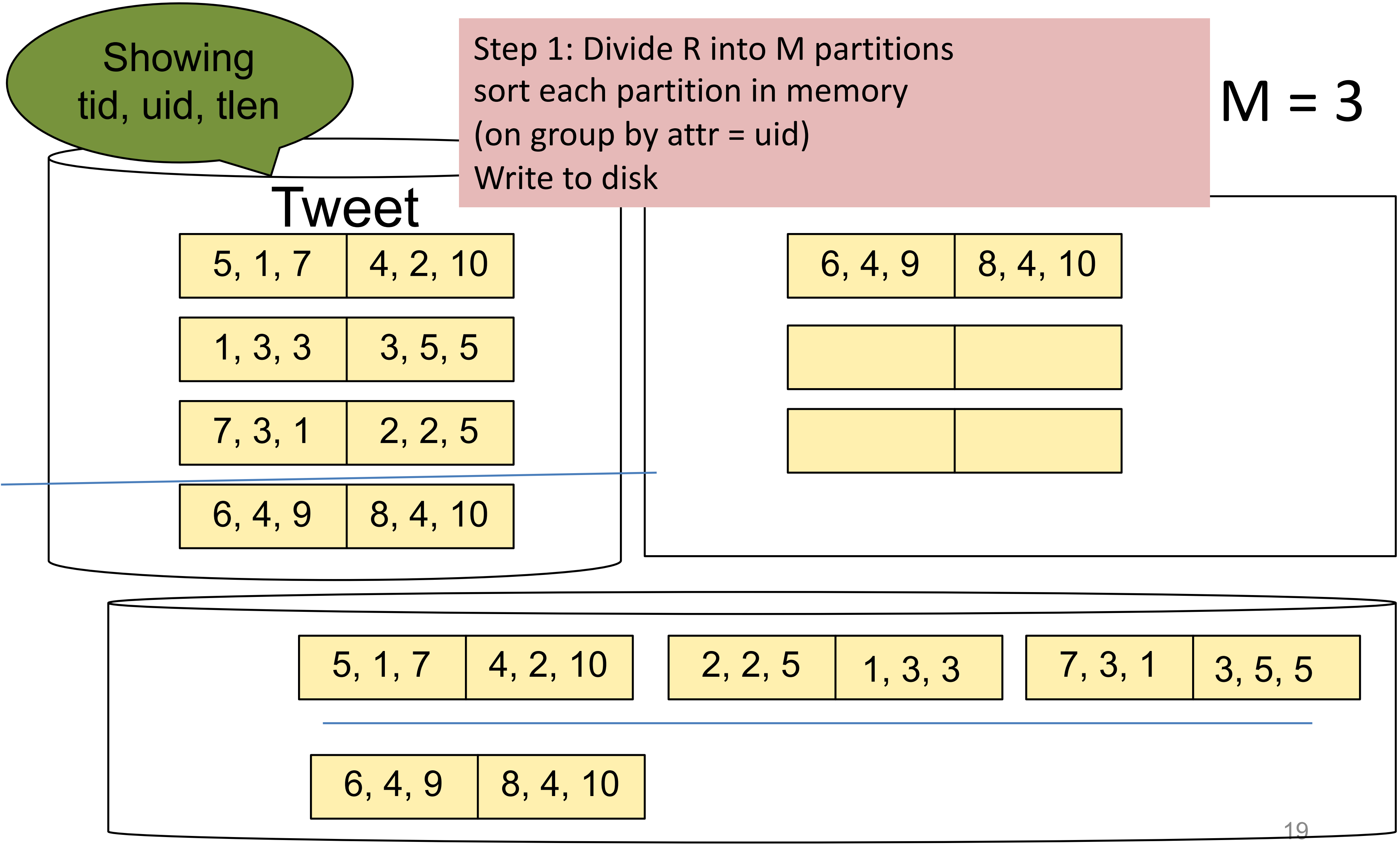
Tweet

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

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

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

Two pass, sort-merge-based grouping



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

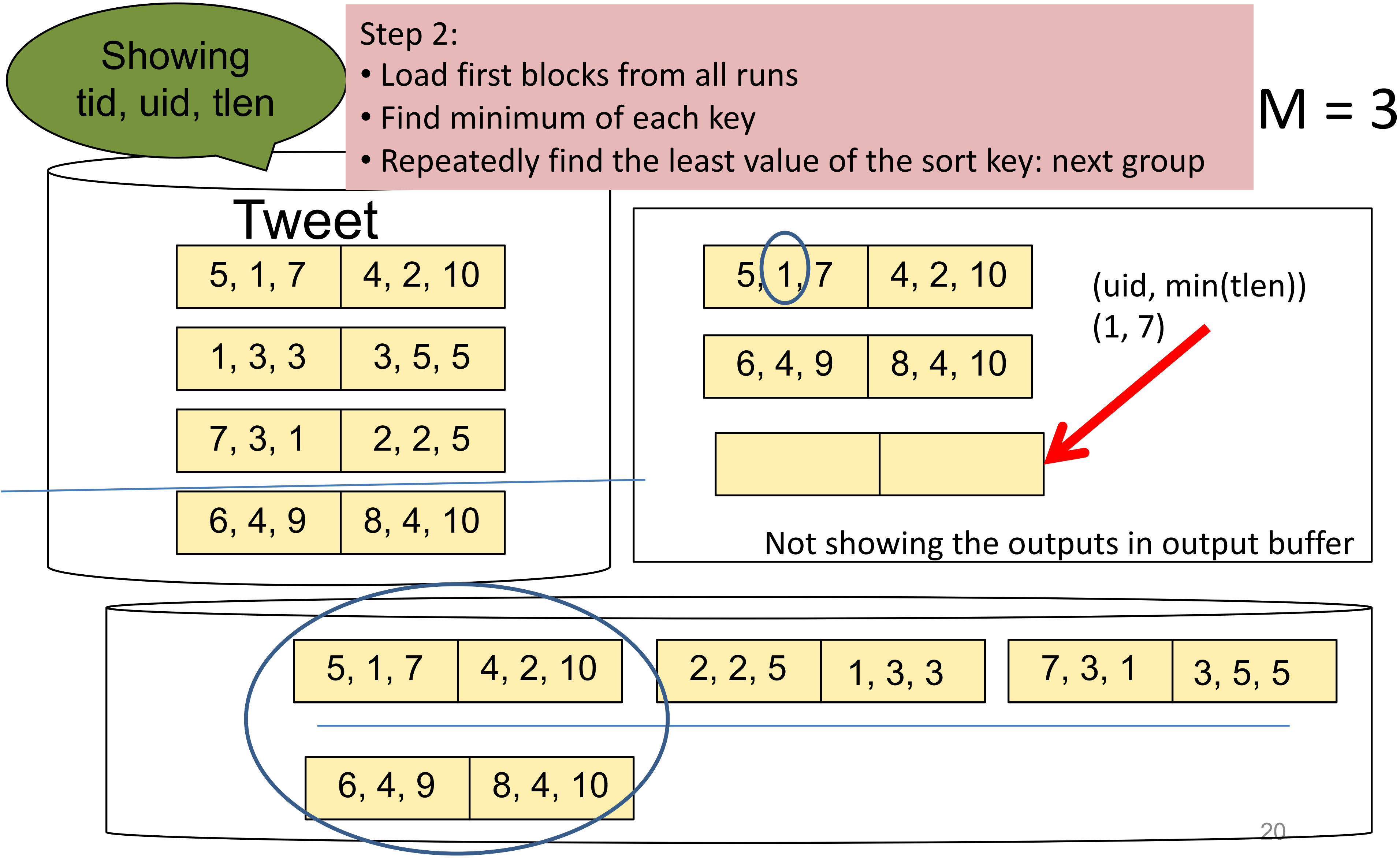
M = 3

Two pass, sort-merge-based grouping

Step 2:

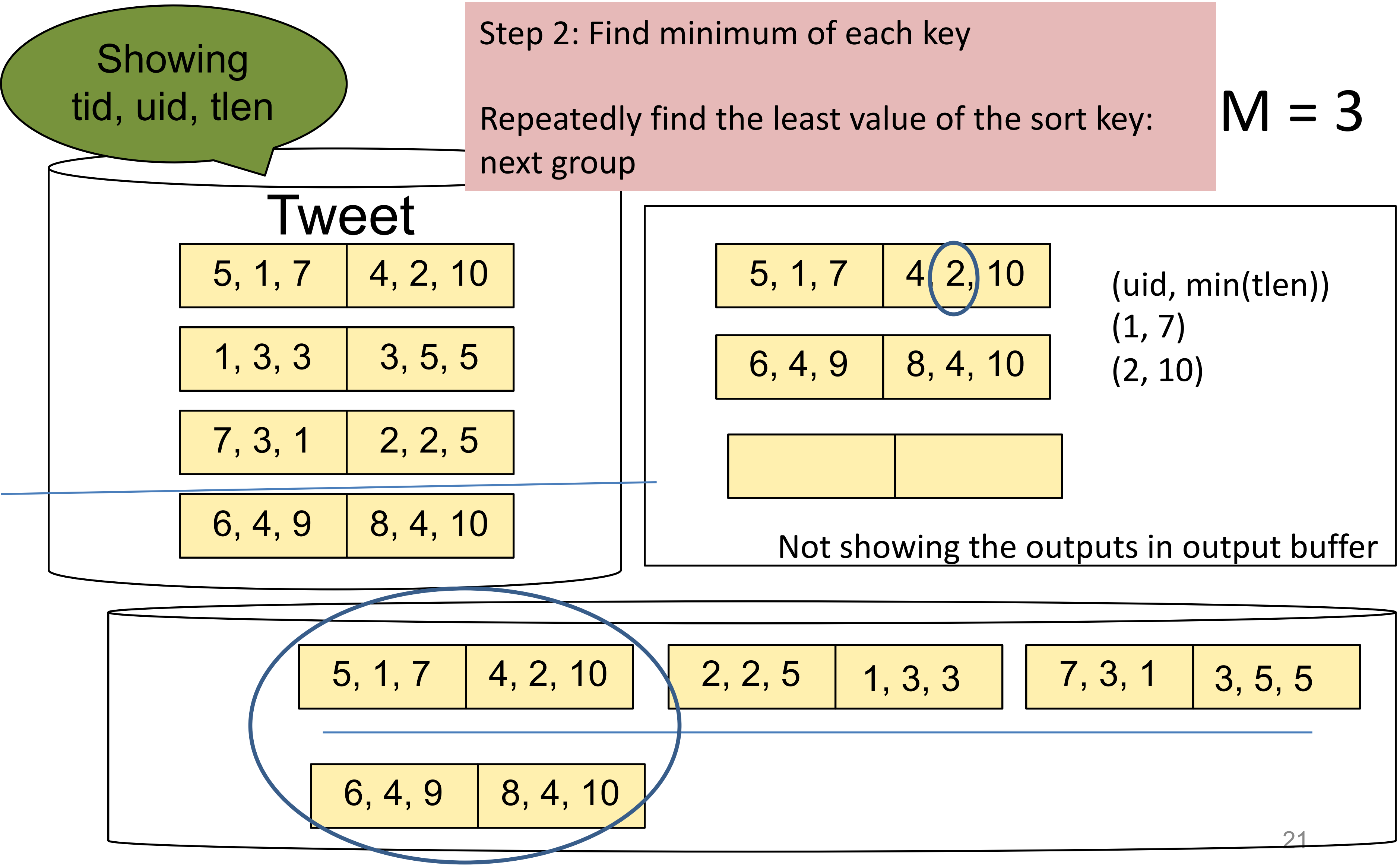
- Load first blocks from all runs
- Find minimum of each key
- Repeatedly find the least value of the sort key: next group

M = 3



Not showing the outputs in output buffer

Two pass, sort-merge-based grouping



Showing
tid, uid, tlen

Step 2: Find minimum of each key

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

5, 1, 7 | 4, 2, 10

6, 4, 9 | 8, 4, 10

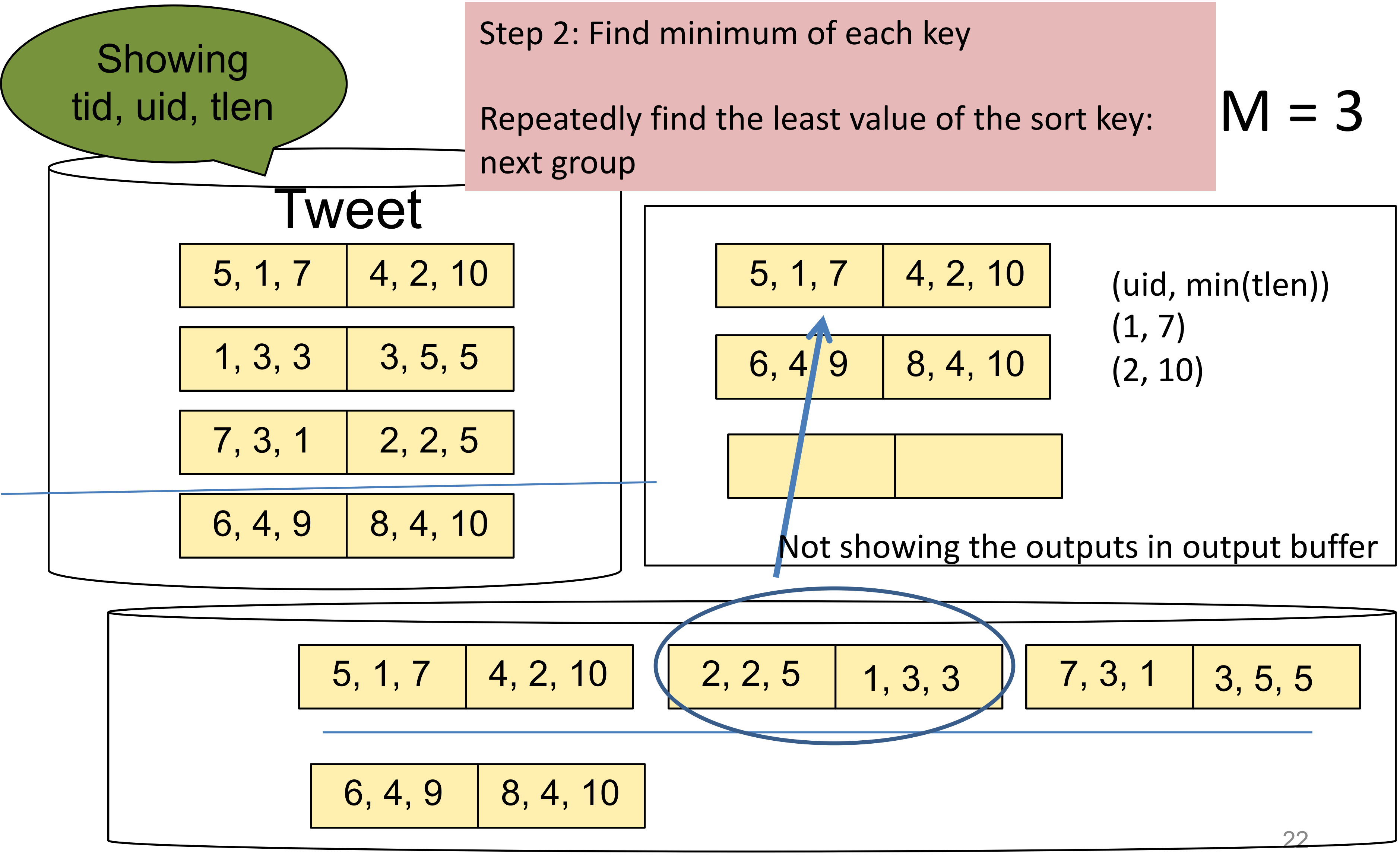
(uid, min(tlen))
(1, 7)
(2, 10)

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

Two pass, sort-merge-based grouping



Showing tid, uid, tlen

Step 2: Find minimum of each key

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

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

(uid, min(tlen))
(1, 7)
(2, 10)

Not showing the outputs in output buffer

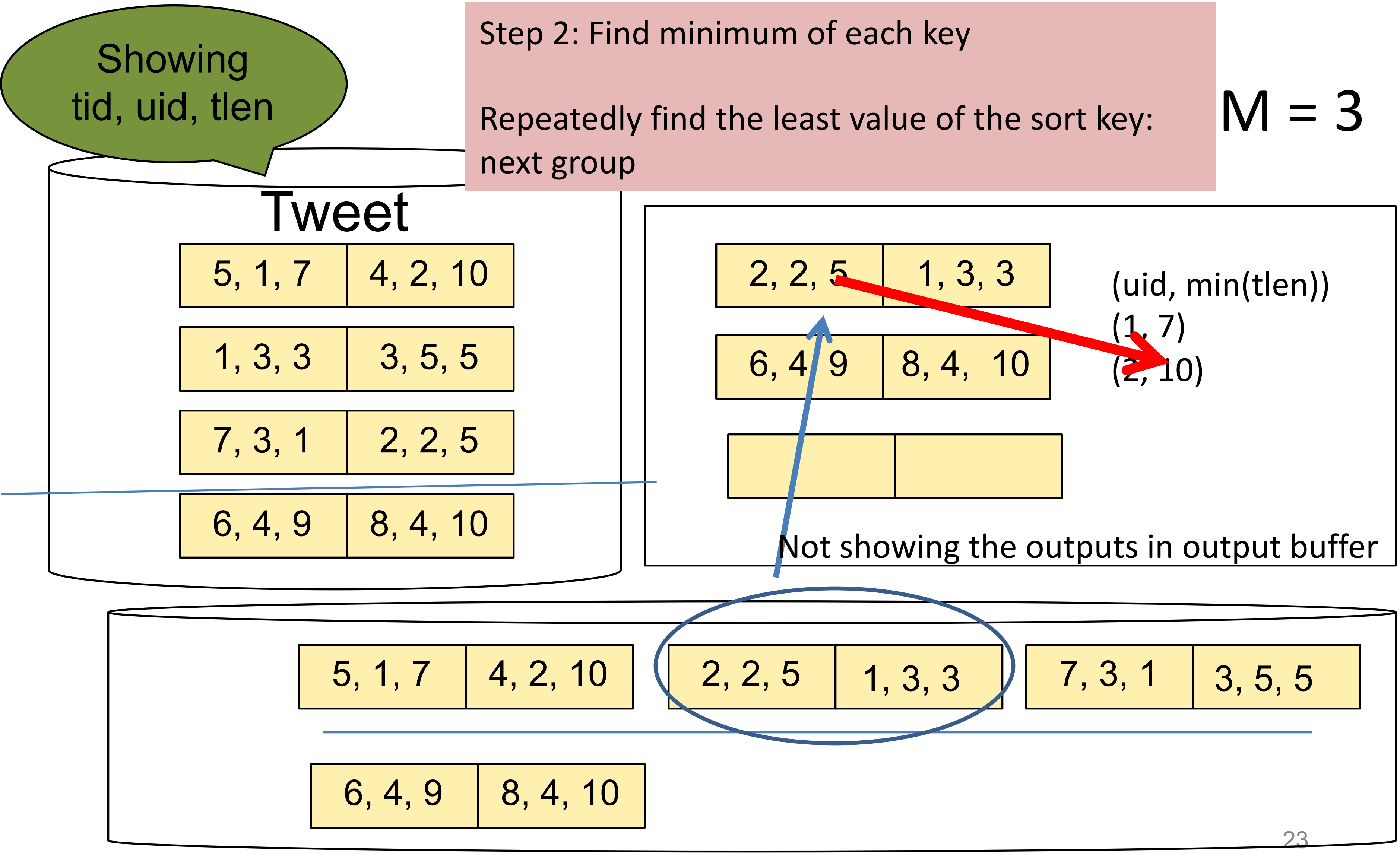
5, 1, 7	4, 2, 10	2, 2, 5	1, 3, 3	7, 3, 1	3, 5, 5
6, 4, 9	8, 4, 10				

Two pass, sort-merge-based grouping

Step 2: Find minimum of each key

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

M = 3



Not showing the outputs in output buffer

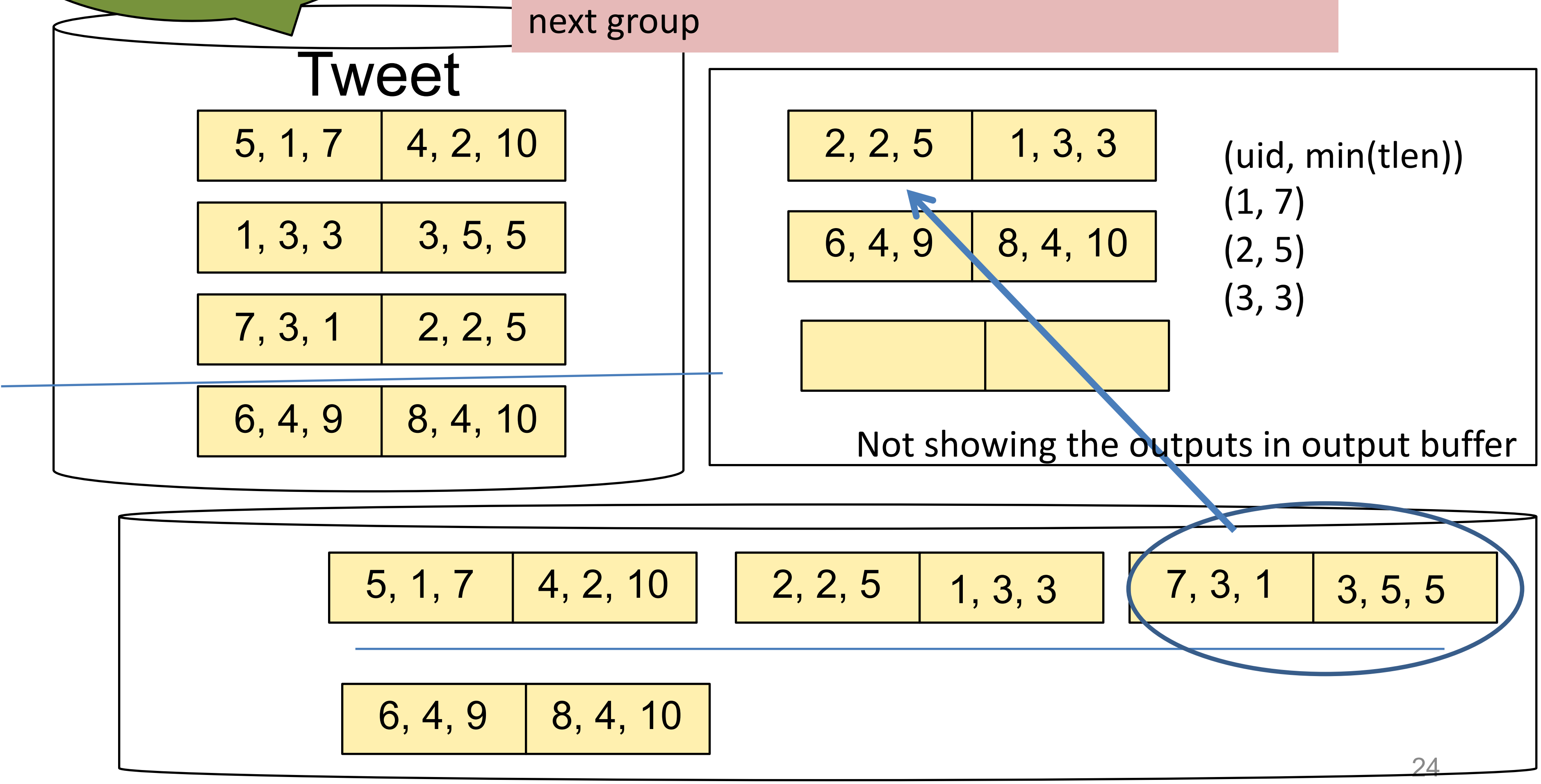
Two pass, sort-merge-based grouping

Showing
tid, uid, tlen

Step 2: Find minimum of each key

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

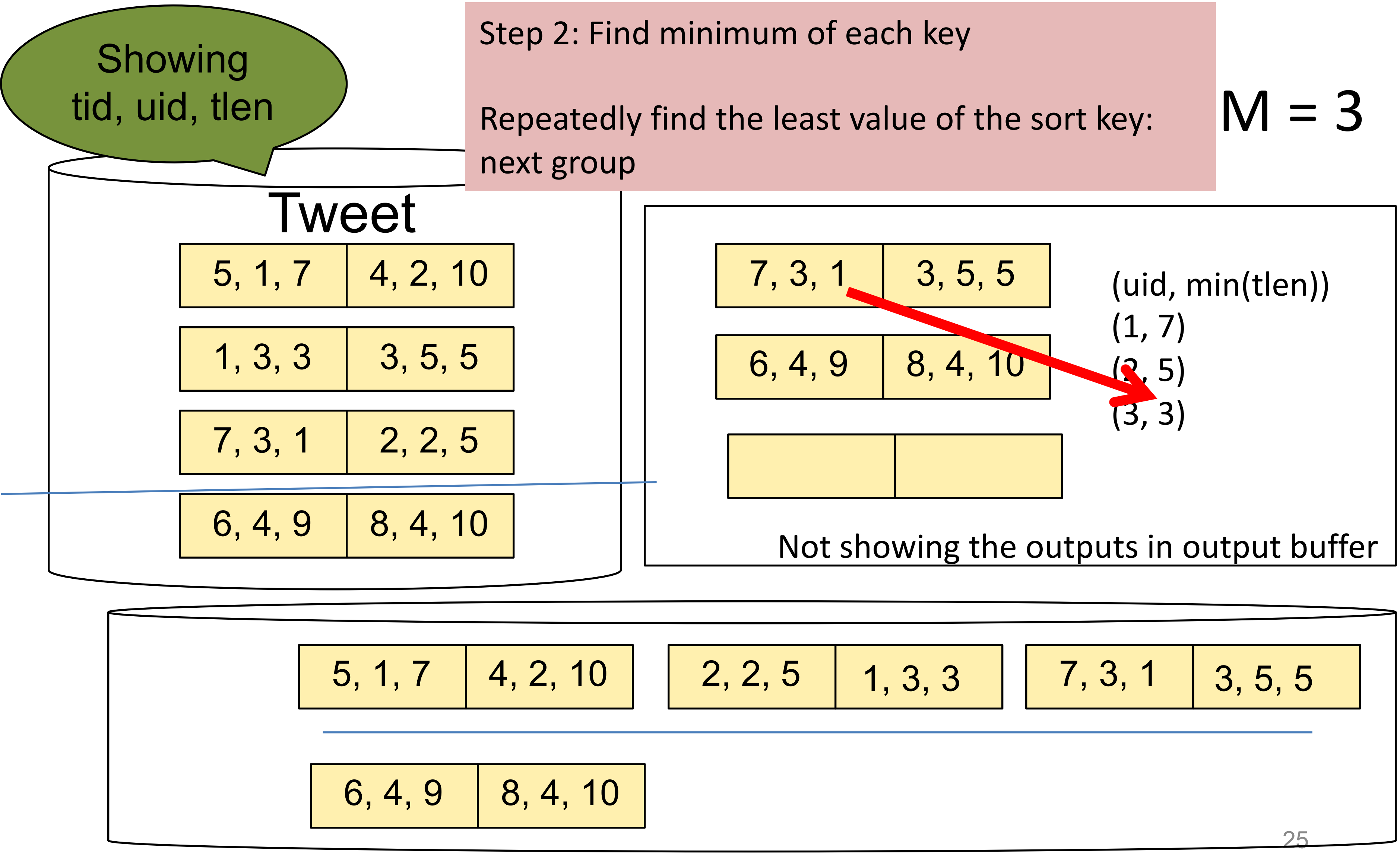
2, 2, 5	1, 3, 3
6, 4, 9	8, 4, 10

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

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				

Two pass, sort-merge-based grouping



Step 2: Find minimum of each key

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

M = 3

Showing tid, uid, tlen

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

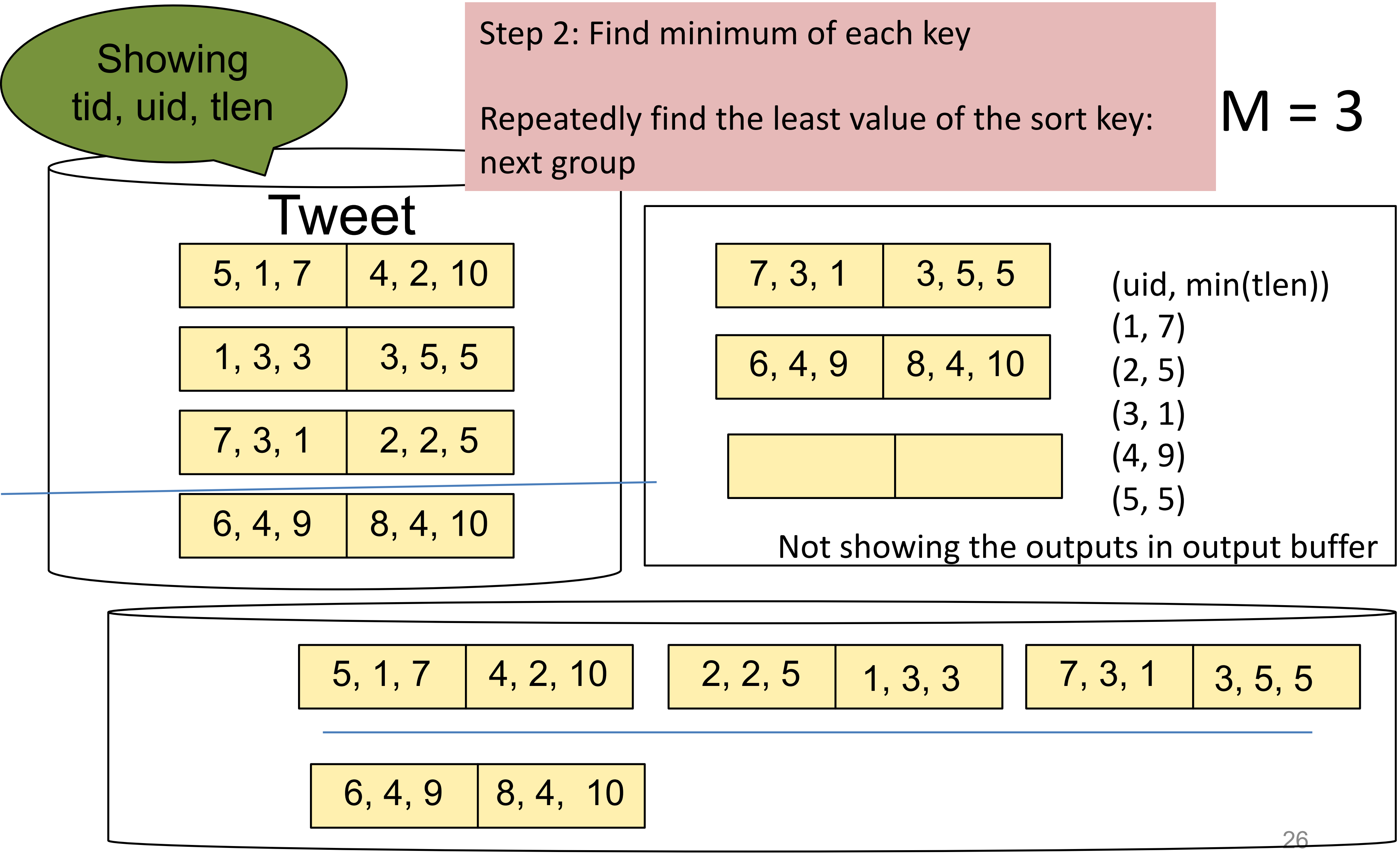
7, 3, 1	3, 5, 5
6, 4, 9	8, 4, 10

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

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				

Two pass, sort-merge-based grouping



Showing tid, uid, tlen

Step 2: Find minimum of each key

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: 5B(R) + 5B(S)
      - For R, S: sort runs/sublists (2 I/O, read + write)
      - Merge sublists to have entire R, S sorted individually (2 I/O, read + write)
      - Join by combining R and S (only read, write not counted - 1 I/O)
    - If #runs <= M-1, then cost: 3B(R) + 3B(S)

Homework 2

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