COMP 3311
DATABASE MANAGEMENT SYSTEMS

LECTURE 15 EXERCISES
QUERY PROCESSING: INTRODUCTION

EXERCISE 1

For the relation Apartment(code, year, price, area), we want to process the query

Find the apartments in a given set of areas.

There are 1,000,000 apartments uniformly distributed over 100 areas. 10 Apartment records fit in one page. The records are ordered on price. There is a hash index on code and a dense, non-clustering B^+-tree index on area. Each B^+-tree node can fit 20 pointers (19 values). 100 record pointers can fit on a page. Assume that each non-leaf B^+-tree node holds the minimum number of values.

Is it advantageous, in terms of page I/Os, to use the B^+-tree on area to answer the query if there are 5 area values?

Cost for file scan: $\lceil 1{,}000{,}000 / 10 \rceil$ = 100,000 page I/Os

Query: Find the apartments in five areas.

Apartment records: 1,000,000
$bf_{Apartment}$: 10
Number of areas: 100
records / area: 10,000
B+-tree node: 20 entries
Record pointers/page: 100

EXERCISE 1 (CONT'D)

Cost to use B+-tree index

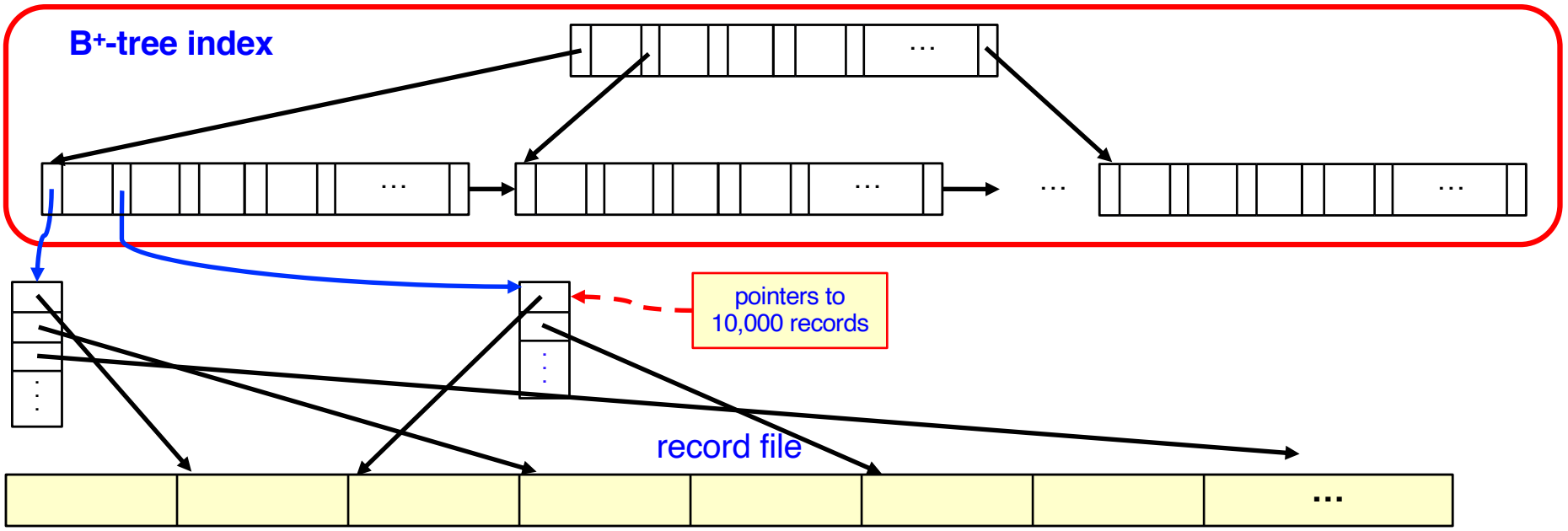
- The 1,000,000 apartments are distributed uniformly over 100 areas. Thus, there are on average 1,000,000/100=10,000 apartments per area.
- For the range of 5 values, on average, 5 * 10,000 = 50,000 records will be accessed.
- Since 10 Apartment records fit on a page, $\lceil 50{,}000/10 \rceil = 5{,}000$ pages are needed to store these records.
- The B+-tree on area will have a height of $\lceil \log_{\lceil 20/2 \rceil} 100 \rceil = 2$ (i.e., fan out is $\lceil n/2 \rceil = \lceil 20/2 \rceil = 10$ since we assume *minimum node occupancy*).
- Each B+-tree leaf node will point to a (indirection) list of apartment records in a specific area.
- Since there are 10,000 apartments per area and 100 record pointers can fit on a page, $\lceil 10{,}000/100 \rceil = 100$ pages are required to store the pointers for each area.

Query: Find the apartments in five areas.

Apartment records: 1,000,000
$bf_{Apartment}$: 10
Number of areas: 100
records / area: 10,000
B+-tree height: 2
Record pointers/page: 100

File scan cost:
100,000 page I/Os

EXERCISE 1 (CONT'D)



Cost to retrieve the apartment records for 5 areas using B+-tree index.

Cost to search B+-tree: # areas * B+-tree height = 5 * 2 = 10 page I/Os

Cost to retrieve indirection pointers to records: 5 * 100 = 500 page I/Os

Cost to retrieve all records: 5 * 10,000 = 50,000 page I/Os

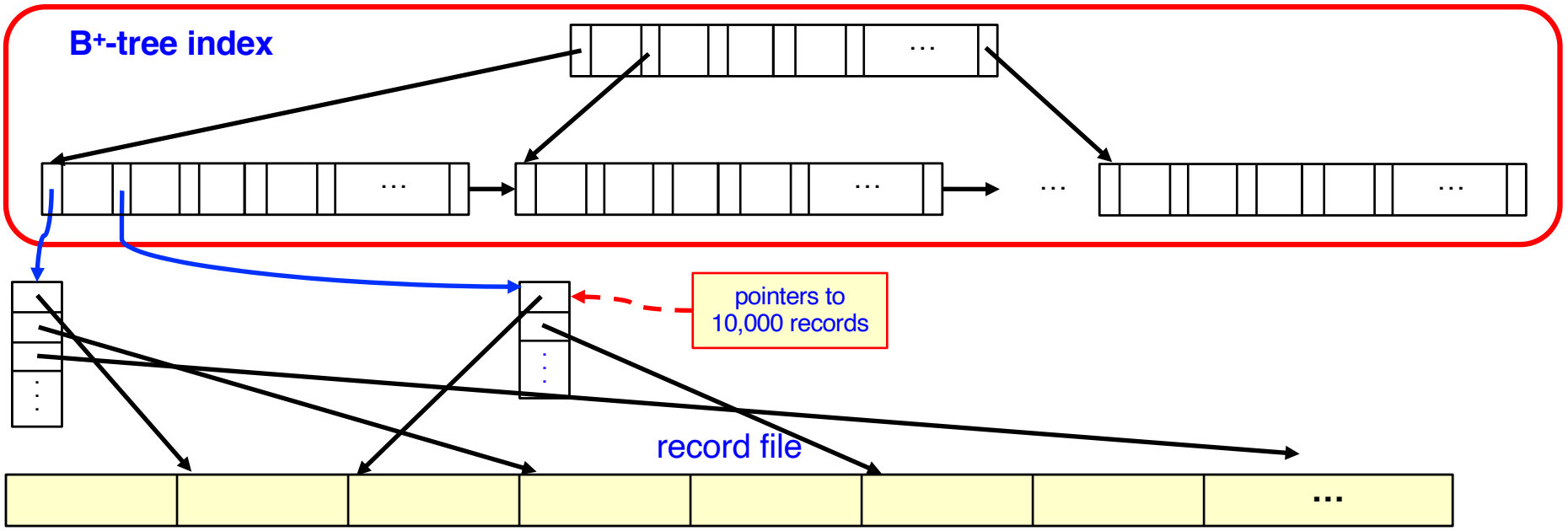
Total cost: 10 + 500 + 50,000 = 50,510 page I/Os

Query: Find the apartments in ten areas.

File scan cost:
100,000 page I/Os

EXERCISE 1 (CONT'D)

Apartment records: 1,000,000
$bf_{Apartment}$: 10
Number of areas: 100
records / area: 10,000
B+-tree height: 2
Record pointers/page: 100



Suppose the range of area is increased to 10. How does the cost change?

Cost to search B+-tree: # areas * B+-tree height = 10 * 2 = 20 page I/Os

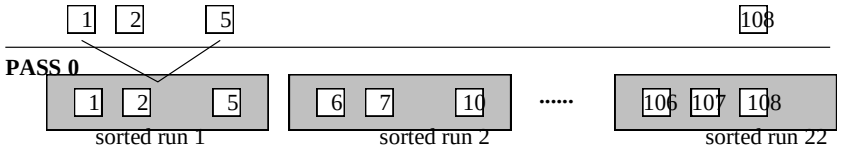
Cost to retrieve indirection pointers to records: 10 * 100 = 1,000 page I/Os

Cost to retrieve all records: 10 * 10,000 = 100,000 page I/Os

Total cost: 20 + 1,000 + 100,000 = 101,020 page I/Os

EXERCISE 2

How many passes are needed to sort a file that has 108 pages, using only 5 pages of main memory? What is the I/O cost?



Number of passes

Pass 0: Sort records producing
$\lceil 108/5 \rceil$ = 22 runs

Pass 1: 4-way merge producing
$\lceil 22/4 \rceil$ = 6 runs

Pass 2: 4-way merge producing
$\lceil 6/4 \rceil$ = 2 runs

Pass 3: 2-way merge producing
1 run (final sorted file)

☞ 1 sort pass

☞ 3 merge passes

I/O cost (sort & merge)

Each pass we read and write
108 pages times 4 passes =
2*108*4 = 864

EXERCISE 3

Assume that for the relation Sailor(sailorId, sName, rating, age) each record is 50 bytes, a page can hold 80 records, there are 500 pages of records and the file is unordered. We want to process the following two queries:

i. $\sigma_{sailorId<50000}(Sailor)$ ii. $\sigma_{sailorId=50000}(Sailor)$

Estimate the number of pages retrieved for each query given the information in a) and b) below.

a) Assume that we have a B+-tree index on the search key sailorId with height 5, 50 index pages, low index value 1, high index value 100,000.

i. Since this is a range query and the file is not ordered on sailorId, the best strategy is to do a linear scan of all pages.

Total cost: 500 page I/Os

ii. Use the B+-tree index to search for sailorId=50000. The cost is that to search the B+-tree, 5 page I/Os, plus the cost to retrieve the record, 1 page I/O.

Total cost: 6 page I/Os

How does the cost change if the file is ordered on sailorId?

EXERCISE 3 (CONT'D)

Assume that for the relation Sailor(sailorId, sName, rating, age) each record is 50 bytes, a page can hold 80 records, there are 500 pages of records and the file is unordered. We want to process the following two queries:

i. $\sigma_{sailorId<50000}(Sailor)$ ii. $\sigma_{sailorId=50000}(Sailor)$

Estimate the number of pages retrieved for each query given the information in a) and b) below.

b) Assume that we have a hash index on the search key sailorId with 50 index pages, no overflow, low index value 1, high index value 100,000.

i. Since this is a range query, a hash index is not useful. Thus, the only option is to do a linear scan of all pages.

Total cost: 500 page I/Os

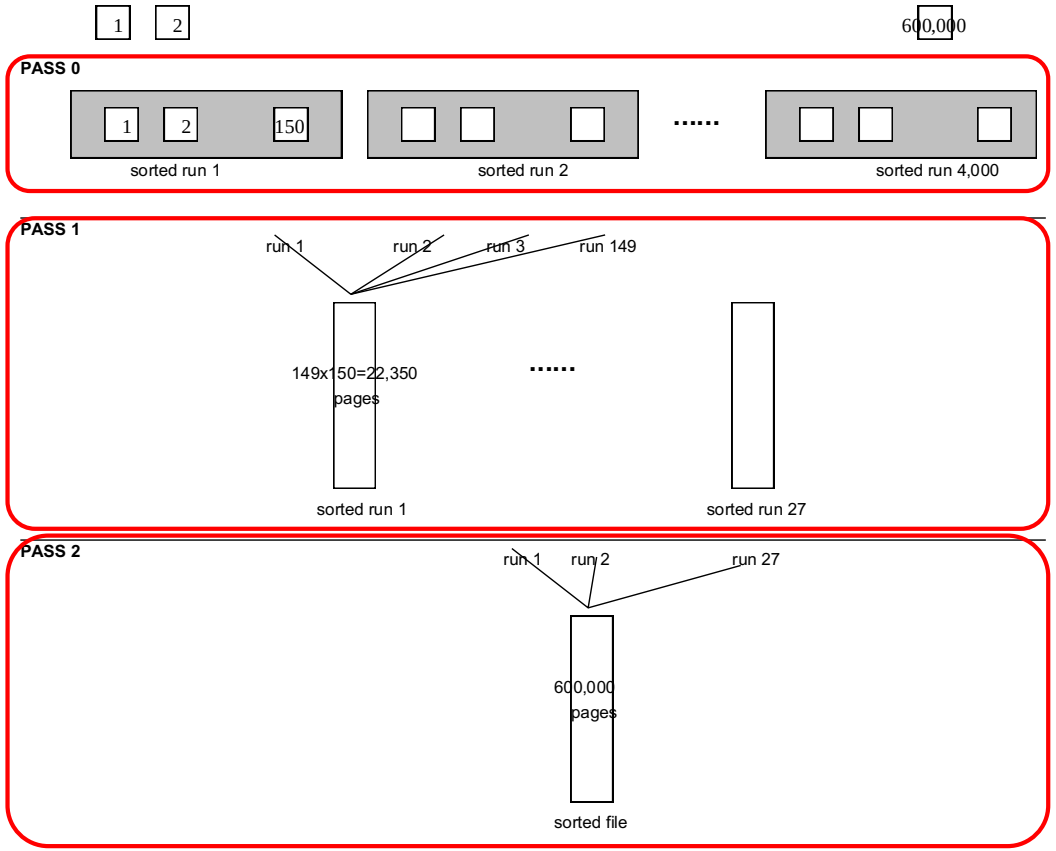
ii. Use the hash index to search for sailorId=50000. The cost is that to access the hash index, 1 page I/O, plus the cost to retrieve the record, 1 page I/O.

Total cost: 2 page I/Os

How does the cost change if the file is ordered on sailorId?

EXERCISE 4

How many passes are needed to sort a file that has 600,000 pages, using 150 pages of main memory? What is the I/O cost?



M=150 B_r=600,000

Number of passes

Pass 0: Sort records producing $\lceil 600000/150 \rceil$ = 4000 runs

Pass 1: 149-way merge producing $\lceil 4000/149 \rceil$ = 27 runs

Pass 2: 27-way merge producing $\lceil 27/27 \rceil$ = 1 run

☞ 1 sort pass

☞ 2 merge passes

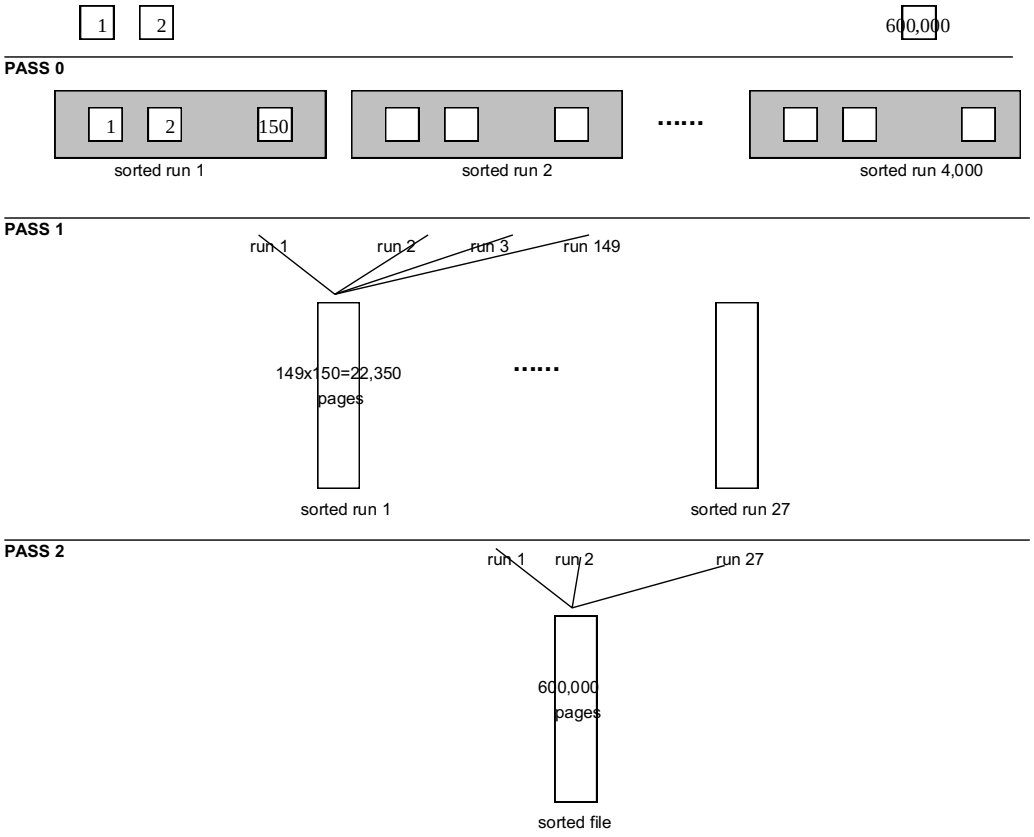
I/O cost (sort & merge)

Each pass we read and write 600,000 pages times 3 passes = 2*600000*3 = 3,600,000

r/w passes

EXERCISE 4 (CONT'D)

How many passes are needed to sort a file that has 600,000 pages, using 150 pages of main memory? What is the I/O cost?



M=150 B_r=600,000

Number of merge passes

$\lceil \log_{M-1}(B_r/M) \rceil =$

$\lceil \log_{149}(600000/150) \rceil = 2$

I/O cost (sort & merge)

$2*B_r*(\lceil \log_{M-1}(B_r/M) \rceil+1) =$

$2*600000*(\lceil \log_{149}(4000) \rceil+1) =$

$2*600000*(3) = 3{,}600{,}000$

EXERCISE 5

Let B be the size of a file in pages. How many memory pages M do you need to sort the file in 2 passes?

- At pass 0, we will create $k = \lceil B/M \rceil$ sorted runs.
- In order to merge these sorted runs in one more pass $k \leq M-1$.
- By combining these two equations we get:

$$M-1 \geq \lceil B/M \rceil \text{ or } M \geq \lceil B/M \rceil + 1.$$

- An approximate solution for the above inequality is that $M > \sqrt{B}$