

**NANYANG TECHNOLOGICAL UNIVERSITY****SEMESTER 2 EXAMINATION 2021-2022****CE4123/CZ4123 – BIG DATA MANAGEMENT**

Apr/May 2022

Time Allowed: 2 hours

**INSTRUCTIONS**

1. This paper contains 4 questions and comprises 5 pages.
  2. Answer **ALL** questions.
  3. This is a closed-book examination.
  4. Questions do not carry equal marks.
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1. For each the following questions, select one answer choice and write your answer in the answer sheet.
  - (a) Which of the following properties does NOT belong to Big Data 5V's?
    - A. Variance
    - B. Variety
    - C. Velocity
    - D. Value(3 marks)
  - (b) Which of the following statements about data models is NOT correct?
    - A. In graph data model, a graph is formed by nodes and edges.
    - B. Key-value data model is a kind of schema-less data model.
    - C. In key-value data model, the value uniquely decides the key.
    - D. An edge in the graph model may have labels.(3 marks)
  - (c) Which of the following statements about memory hierarchy is NOT correct?
    - A. Disk is a kind of secondary memory.
    - B. Secondary memory is slower than main memory regarding data access.
    - C. L1 cache is faster than L2 cache.

Note: Question No. 1 continues on Page 2

- D. It is better to have a higher memory miss rate for data access. (3 marks)
- (d) Which of the following statements about LSM-tree is NOT correct?  
 A. In LSM-tree, Bloom filters can reduce page reads when calling Get(key).  
 B. LSM-tree employs an out-of-place update scheme.  
 C. If size ratio is 4, then the number of key-value pairs stored in Level-2 is 4 times of the number of key-value pairs stored in Level-1.  
 D. Fence pointers can largely reduce the I/O cost. (3 marks)
- (e) Which of the following systems does not belong to NoSQL databases?  
 A. Key-value stores.  
 B. Relational database.  
 C. Wide-column database.  
 D. Graph database. (3 marks)
- (f) When comparing column store and row store, which of the following statements is correct?  
 A. Column-at-a-time processing is more cache-friendly than vector-at-a-time processing.  
 B. Reading a tuple in column store usually only requires reading 1 disk page.  
 C. Column store cannot handle relational data.  
 D. When updating a whole tuple, column store faces bigger challenges than row store. (3 marks)
- (g) Which of the following statements is NOT correct?  
 A. Master-slave mode and fully distributed mode are typical in a distributed system in organizing machines.  
 B. In a distributed system, data must be partitioned equally at each machine.  
 C. *Map* and *Reduce* are two most important interfaces in Hadoop.  
 D. In a distributed system, data may have multiple replicas stored at different machines. (3 marks)
- (h) We have an 8-integer array Z[0-7] in main memory: 1, 4, 9, 2, 5, 8, 3, 6. Cache size is 4 (integers), and cache line size is 2 (integers). Assume that the cache replacement mechanism is first-cached-first-evicted. Which of the following access patterns gives the worst cache performance?

Note: Question No. 1 continues on Page 3

- A. Z[0], Z[1], Z[2], Z[3], Z[4], Z[5], Z[6], Z[7]  
 B. Z[0], Z[2], Z[4], Z[6], Z[7], Z[1], Z[3], Z[5]  
 C. Z[0], Z[2], Z[4], Z[6], Z[1], Z[3], Z[5], Z[7]  
 D. Z[4], Z[5], Z[6], Z[7], Z[0], Z[1], Z[2], Z[3]
- (3 marks)

2. Figure Q2 shows a table T of four columns A, B, C, D. Table T is stored in a column store. Consider the query “**SELECT max(D) FROM T WHERE A>3 and B>5**” and answer the following questions.

Table T			
A	B	C	D
1	9	1	2
3	9	9	9
5	7	2	3
7	8	3	2
2	6	3	3
3	4	2	2
1	7	1	8
2	7	2	6
2	1	1	6

**Figure Q2**

- (a) Draw the two flow charts for the query using two ways of column scans (i.e., scanning column A first, or scanning column B first), respectively.
- (8 marks)
- (b) Based on your answer to (a), which of the two methods (i.e., scanning column A first, or scanning column B first) is more efficient in answering the query? Please explain your answer.
- (5 marks)
- (c) If zone map is applied in column A with zone size 3. For the method that scans A first, which zone(s) can be skipped during scanning? Please explain your answer.
- (5 marks)

3. Consider the MapReduce paradigm and answer the following questions.
- (a) In a MapReduce job, the output of *Map* phase is a list of key-value pairs: (A, 1), (C, 2), (A, 5), (C, 6), (B, 3), (E, 3), (C, 8). Please list the possible input to the *Reduce* function. (4 marks)
- (b) Based on the answer to Q3(a), write a *Reduce* function (in pseudocode) so that the MapReduce output is: (2, A), (3, C), (6, A), (7, C), (4, B), (4, E), (9, C). (6 marks)
- (c) Consider an employee table containing three columns (*EmployeeID*, *age*, *monthly-salary*) where *age* and *monthly-salary* are integers. Use MapReduce to collect the number of employees falling into each of the following two categories:
- **Category 1:** The age of the employee is between 30 and 40 (including 30 and 40). His/her monthly salary is at most 7000.
  - **Category 2:** The age of the employee is between 40 and 50 (including 40 and 50). His/her monthly salary is more than 7000.
- Please use only **one** MapReduce Job to achieve this task and write down the pseudocode of the *Map* function and *Reduce* function. The input key and value for *Map* function are an employee's *age* and *monthly-salary* respectively.
- (Example: if there are 100 employees in Category 1 and 50 employees in Category 2, then the MapReduce output will contain two key-value pairs: (1, 100), (2, 50)) (8 marks)
- (d) Consider the same setting as Q3(c). Please use **one** MapReduce job to finish the same task, but **only** output the information of the category with more employees. If the two categories have the same size, then output the information of Category 1 only. Write down the pseudocode of the *Map* function and *Reduce* function.
- (Example: if there are 100 employees in Category 1 and 50 employees in Category 2, then the MapReduce output will only contain one key-value pair: (1, 100)) (10 marks)

4. Consider a leveling LSM-tree with a size ratio 2. The memory buffer (Level 0) can store 1000 key-value pairs. The LSM-tree is incorporated with Bloom filters and fence pointers. The function  $\text{Get}(K)$  extracts the value corresponding to key  $K$ . Assume that a key-value pair is always entirely stored within a disk page.
- (a) Compute the total capacity (in terms of the number of key-value pairs) of Level 1 to Level  $T$  of the LSM-tree. (6 marks)
- (b) If the LSM-tree has  $L$  levels (excluding the memory buffer level), what are the best case and worst case I/O costs of calling  $\text{Get}(K)$ ? Please explain your answer. (note: key  $K$  does not necessarily exist in the LSM-tree.) (6 marks)
- (c) If the LSM-tree has  $L$  levels (excluding the memory buffer level) and a key  $K$  only exists in the Level- $h$  ( $h>0$ ) of the LSM-tree, what are the best case and worst case I/O costs of calling  $\text{Get}(K)$ ? Please explain your answer. (6 marks)
- (d) Let  $P_i$  be the FPR (False-Positive Rate) of the Bloom filter for Level- $i$  (for  $i=1, 2, \dots, L$ ). Consider a general case that you can assign different values to  $P_1, P_2, \dots, P_L$  as long as the following conditions are satisfied:
- $P_1+P_2+\dots+P_L = 0.5L$
  - $0 \leq P_i \leq 1$ , for  $i=1, 2, \dots, L$

If a key  $K$  only exists in Level- $h$  ( $h>1$ ) of the LSM-tree, give one possible setting of  $P_1, P_2, \dots, P_L$  so that the average I/O cost of calling  $\text{Get}(K)$  is minimized. Please explain your answer.

(Note: the average I/O cost of calling  $\text{Get}(K)$  is defined as the sum of the expected I/O cost at each level.)

(12 marks)

END OF PAPER





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Please read the following instructions carefully:

- 1. Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**
2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.
3. Please write your Matriculation Number on the front of the answer book.
4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.