Final Exam

CS386D Database Systems
Date: 5/14/2020
Version: 1.0

There are 7 sections totaling 390 points. Point weighting is in parenthesis. Start your answer for each section on a new page. You have 2 ½ hours, including the time it takes you to upload your exam paper, (as a single file), to Canvas. The Canvas upload is set to close at 12:31PM

Good luck. D.M.

1. Definitions – Define the following terms (70)
    a) Database
    b) Candidate key
    c) [Datalog] Dependency Graph
    d) Query Graph
    e) Commit
    f) Precedence Graph
    g) Two phase locking

2. **Data Partitioning for Parallel Databases** (60)

Fill in the blank, and multiple choice.

Consider a shared-nothing database cluster with 10 nodes and the relation, R(id integer, name varchar[]). Further, assume R is a real relation from the outside world. i.e. it may demonstrate data skew, so *do not* make any of our usual simplifying assumptions regarding data distributions.

Let

- id be a [SQL] primary key.
- V(R, id) = 100,000
- V(R, name) = 100
- B(R) = 1000 data pages.

A) There are _____ records per page

B) Suppose R is horizontally round-robin partitioned on id. Then each node will store
   i) 10 data pages
   ii) 100 data pages
   iii) 1000 data pages
   iv) 10,000 data pages
   v) between 0 and 1000 data pages, inclusive

C) Suppose R is horizontally hash partitioned on name. Then each node will store about
   i) 10 data pages
   ii) 100 data pages
   iii) 1000 data pages
   iv) 10,000 data pages
   v) between 0 and a 1000 pages, inclusive

D) Suppose R is horizontally hash partitioned on id. Then each node will store about
   i) 10 data pages
   ii) 100 data pages
   iii) 1000 data pages
   iv) 10,000 data pages
   v) between 0 and a 1000 pages, inclusive

E) Suppose the DBA has good visibility on the actual data, does the best job possible of horizontally range partitioning R on name. Then each node will store about
   vi) 10 data pages
   vii) 100 data pages
   viii) 1000 data pages
   ix) 10,000 data pages
   x) between 0 and a 1000 pages, inclusive

F) Suppose the DBA has good visibility on the actual data, does the best job possible of horizontally range partitioning R on id. Then each node will store about
   vi) 10 data pages
   vii) 100 data pages
   viii) 1000 data pages
   ix) 10,000 data pages

x) between 0 and a 1000 pages, inclusive

3. **On Transaction Logs and Durability** (30)

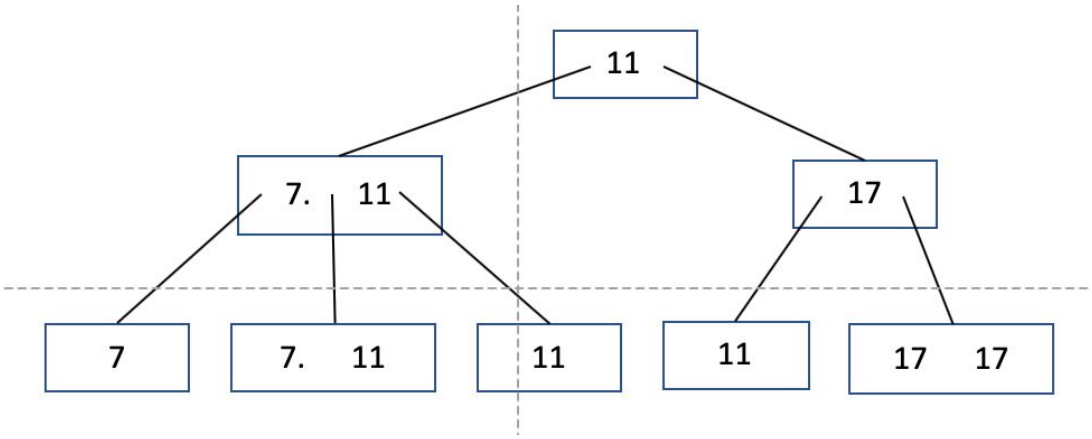
Intel and Micron have been jointly developing a new non-volatile memory technology, 3D XPoint, intended to replace the flash memory technology currently in use for SDDs. The products are sold under the brandnames Optane and Quantx, respectively. Not only do these companies promise the technology is superior to flash for use in SDDs, but that ultimately the technology could replace DRAM as the basis of main-memory. So, in addition to offering SDDs, after many missed delivery promises these companies are now selling, in limited quantities, plug-compatible DRAM modules (DIMMS) using 3DXPoint such that one can simply plug a DIMM into an existing server motherboard and the corresponding portion of the real-address space will be non-volatile.

Thus, one can anticipate operating system support such that an RDBMS may exploit such memory for at least part of the transaction log, and/or buffering some of the transaction log.

A) How/why would the existence and OS support for persistent RAM be advantageous? Be specific wrt the operations, and the sequencing of operations, per undo/redo logging.(20)
B) Why, for applications with mission critical ACID requirements will it not be sufficient to use existing server motherboards?(10)

4. **B+ Trees** (20)

Given the following B+ tree, where each leaf may contain a maximum of two values, and the other nodes may contain a maximum of 2 split values and 3 pointers.



A) Show the tree that results after inserting another "7".
B) Show the tree that results after inserting another "11". (The original tree, not your answer to A)

5. **Bloom Filters** (20)

Given sets A and B and corresponding Bloom filters, BF(A) and BF(B), such that the filters comprise the same number of bits, and the identical set of hash functions were used in setting the bits, then the filter BF(C) = BF(A) AND BF(B), where AND is the bitwise anding of the two filters, can be used to check if an element if a data element, d is in A ∩ B.

i. Let C' = A ∩ B. Does BF(C) = BF(C') ? Explain.

ii. Similarly, let BF(D) = BF(A) OR BF(B) and D' = A ∪ B, Does BF(D) = BF(D')? Explain.

6. Physical Database and Query Optimization: (90)

Given the following database schema and corresponding data catalog

schema	R(a,b,c)	S(d, e, f)
blocks	B(R)= 1000	B(S)=2000
rows	T(R)= 1,000,000	T(S)= 6000
values	V(R,a) = 500,000	V(S,d)= 3000
	V(R,b) = 1,000,000	V(S,e)=2000
	V(R,c) = 50,000	V(S,f) = 6000

Suppose the workload for the database is defined as follows. Each of two queries is repeatedly executed.

Query 1	Query 2
SELECT * FROM R WHERE c = 0	SELECT R.c, S.d, S.f FROM R,S WHERE R.a = S.d and S.e = 'foo'

A) Per the cost models covered in class.

i) In the linear cost model, what is the I/O cost of tableScan(R)?

ii) What is the size, in records [rows], of the result of query 1?

iii) What is the size, in records [rows], of the result of query 2?

B) If, on average, each time the first query executes, the second query executes 10 times.

i) which attributes would you use for the primary key of table R? (explain)

ii) which attributes would you use for the primary key of table S? (explain)

iii) what secondary indexes, if any, would you create for table R? (explain)

iv) what secondary indexes, if any, would you create for table S? (explain)

C)Consider a new query,(20)

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Select *
From R,S
Where R.c > S.f
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Suppose the query optimizer chooses the standard block-nested loop join algorithm and the number of memory buffer B(M) = 500. Using the standard text I/O cost model, how long will this query take?

7. **Datalog and Some Relational Algebra** (100)

For the database schema, {R(a, b, c), S(a, b, c), T(a, b, c)}

A) Write one or more Datalog rules that implement the following expressions

V. $R \cap S$

VI. $(R \cup S) - T$

VII. $\Pi_{a,c}(R)$

B) For the following Datalog rules, write an equivalent expression in relational algebra, and, write the equivalent SQL query. (40)

i. M(x,y,z) := R(x,y,z) AND S(m, _, z)

ii. N(x,z) := R(x, m, n) AND S(p, x, g) AND T(g, h, k) AND k > 10

C) Is the Datalog rule whose head above is M(x, y, z) safe? (yes or no)

D) In addition to the rules defining M and N above, consider the rule
P(v, w) := M(v,w) AND N(w, v)

i. If the three rules are combined as a single Datalog program, is that program recursive? (yes or no)

ii. Suppose that three rule programs were evaluated using semi-naïve evaluation, how many evaluation cycles are needed to achieve fixed-point (but not necessarily to detect that fixed-point has been reached).