CS4224/CS5424 Quiz 9: Query Optimization & Quorum Consensus Protocol — Wk 10, Sem 1, 2023/24

1. Consider the query Customers $\bowtie_{cust\#}$ Orders $\bowtie_{city}$ Suppliers on the following database.

   - Customers (cust#, cname, city)
   - Orders (order#, cust#, odate)
   - Suppliers (supp#, sname, city)

Customers

cust#	cname	city
1	Alice	Singapore
2	Bob	Penang
3	Carol	Bangkok
4	Dave	Mumbai
5	Eve	Beijing
6	Fred	Penang
7	George	Bangkok

Orders

order#	cust#	odate
302	1	June 2013
304	2	May 2013
307	3	Nov 2013
308	1	April 2013
309	5	May 2013
311	6	Dec 2013
312	3	July 2013

Suppliers

supp#	sname	city
32	A	Bangkok
33	B	Singapore
34	C	Jakarta
36	D	Mumbai
37	E	Penang
38	F	Hanoi
39	G	Shanghai

Identify all the dangling tuples in each relation wrt the query.

Solution: There following are dangling tuples wrt the query.

Customers

cust#	cname	city
4	Dave	Mumbai
5	Eve	Beijing
7	George	Bangkok

Orders

order#	cust#	odate
309	5	May 2013

Suppliers

supp#	sname	city
34	C	Jakarta
36	D	Mumbai
38	F	Hanoi
39	G	Shanghai

2. Consider the following query on a distributed database system with relations R_1, R_2, R_3 & R_4, where relation R_i is located at site i.

SELECT	*
FROM	R_1, R_2, R_3, R_4
WHERE	$R_1.A = R_2.A$
AND	$R_2.B = R_3.B$
AND	$R_2.B = R_4.B$
AND	$R_3.B = R_4.B$

Identify all the beneficial semijoins based on the following database statistics.

relation X	size(X)
R_1	1000
R_2	1000
R_3	2000
R_4	1000

attribute X.A	$SF_{SJ}(X.A)$	$size(\pi_A(X))$
$R_1.A$	0.5	200
$R_2.A$	1.0	100
$R_2.B$	0.2	100
$R_3.B$	0.9	300
$R_4.B$	0.4	150

Assume that $T_{MSG} = 20$ and $T_{TR} = 1$.

Solution:

There are five beneficial semijoins (with Benefit > Cost): $R_2 \ltimes_A R_1$, $R_2 \ltimes_B R_4$, $R_3 \ltimes_B R_2$, $R_3 \ltimes_B R_4$, and $R_4 \ltimes_B R_2$.

Semijoin	Cost	Benefit	Benefit−Cost
$R_1 \ltimes_A R_2$	$20 + 100 = 120$	$1000 \times (1 - 1.0) = 0$	≤ 0
$R_2 \ltimes_A R_1$	$20 + 200 = 220$	$1000 \times (1 - 0.5) = 500$	280
$R_2 \ltimes_B R_3$	$20 + 300 = 320$	$1000 \times (1 - 0.9) = 100$	≤ 0
$R_2 \ltimes_B R_4$	$20 + 150 = 170$	$1000 \times (1 - 0.4) = 600$	430
$R_3 \ltimes_B R_2$	$20 + 100 = 120$	$2000 \times (1 - 0.2) = 1600$	1480
$R_3 \ltimes_B R_4$	$20 + 150 = 170$	$2000 \times (1 - 0.4) = 1200$	1030
$R_4 \ltimes_B R_2$	$20 + 100 = 120$	$1000 \times (1 - 0.2) = 800$	680
$R_4 \ltimes_B R_3$	$20 + 300 = 320$	$1000 \times (1 - 0.9) = 100$	≤ 0

3. (4 points) Consider a distributed database consisting of a single object x that is replicated across 8 sites (sites A to H).

   The replicas are managed using the quorum consensus protocol, and the following table shows the current state of the all the replicas of x (i.e., x_A, x_B, $\cdots$, x_H).

Replica of x	Weight of replica	Value of replica	Version of replica
x_A	3	40	4
x_B	2	40	4
x_C	1	30	3
x_D	2	20	2
x_E	2	40	4
x_F	2	40	4
x_G	1	30	3
x_H	2	20	2

   Let $T_r(x)$ and $T_w(x)$ denote, respectively, the read and write thresholds for object x.

   Write down all possible pairs of values for $(T_r(x), T_w(x))$.

   Solution: Total weight, Wt(x) = 15. Replicas with latest version number = $\{x_A, x_B, x_E, x_F\}$. Therefore, $T_w(x) \leq 3+2+2+2 = 9$. Since $2 \times T_w(x) > Wt(x)$, $T_w(x) \in \{8, 9\}$.

   Since $T_w(x) + T_r(x) > Wt(x)$, if $T_w(x) = 8$, $T_r(x) \geq 8$; and if $T_w(x) = 9$, $T_r(x) \geq 7$.

   Therefore possible values of $(T_r(x), T_w(x))$: $\{(r, 8) : r \in [8, 15]\} \cup \{(r, 9) : r \in [7, 15]\}$.

4. (2 points) Consider a distributed database that is fully replicated across n sites using the **quorum consensus protocol** where the weight assigned to each site is a positive integer w. The weight assignment for each object in the database follows the weight assignment for the sites. Assume that the read and write thresholds for each object O are $T_r(O) = \lfloor \frac{nw+1}{2} \rfloor$ and $T_w(O) = \lceil \frac{nw+1}{2} \rceil$, respectively.

   A quorum consensus protocol is defined to be *k-tolerant*, where $k \in [1, n)$, if it can tolerate a failure of up to k sites; i.e., it is still possible to perform read and write operations when any set of k sites fails.

   If $w = 2$, what is the minimum value of n for the protocol to be 3-tolerant?

   Solution: Answer = 5.

   For the protocol to be k-tolerant, $(n-k)w \geq \max\{T_w(O), T_r(O)\}$. Thus, $(n-k)w \geq \lceil (nw+1)/2 \rceil$. With k=3 & w=2, we have $3(n-2) \geq \lceil (3n+1)/2 \rceil$. If n is even, we have $3n - 6 \geq \frac{3n}{2} + 1$; i.e., $n \geq 5$. If n is odd, we have $3n - 6 \geq \frac{3n+1}{2}$; i.e., $n \geq 5$.