CS4224/CS5424 Quiz 7: Data Consistency **Wk 8, Sem 1, 2023/24**

1. This question examines the different consistency levels for the baseball game example discussed in class. We have a replicated key-value database consisting of two records that keep track of the scores of the "home" and "visitors" teams in a baseball game. The database storage consists of a primary server containing the master copies of the data and several secondary servers containing replicas of the data. Updates are first performed on the master copies in the primary server and are lazily replicated to the secondary servers. All updates are transmitted to and received by the secondary servers in the same order as the sequence of updates performed at the primary server.

   Consider the following six participants in a baseball game.

   1. **Score keeper**. The score keeper updates the games scores as the game progresses. Specifically, whenever the visiting team scores a run, the score keeper will read the value of the "visitors" record from the database, increments its value by one, and updates the "visitors" record with the incremented value. The score keeper performs a similar update for the "home" record whenever the home team scores.
   2. **Umpire**. The umpire only cares about the game scores after the first half of the ninth inning. Specifically, the umpire performs the following actions. After the first half of the ninth inning has ended, the umpire will read both the "vistors" and "home" records from the database. If the home team's score is higher than the visiting team's score, the umpire will declare the game to be over and terminate the game.
   3. **Radio sports reporter**. The radio sports reporter reports the game scores at every 30 minutes interval. Specifically, the radio sports reporter performs the following actions iteratively: the radio sports reporter reads both the "vistors" and "home" records from the database and reports these scores on the radio; after that, the reporter will sleep for 30 minutes. Note that it is acceptable for the reporter to report games scores that are not completely up-to-date.
   4. **Sports writer**. The sports writer writes about the game after the game has ended. Specifically, after the game has ended for some time, the sports writer reads both the "vistors" and "home" records from the database and write about the game based on the retrieved game scores.
   5. **Team statistician**. The team statistician is the person who maintains the season-long statistics for the home team which is stored in a database record named "seasons-run". The "seasons-run" record stores the total number of runs scored by the home team this season. Specifically, the team statistician performs the following actions after the game has ended: the team statistician reads both the "home" and "seasons-run" records from the database, and updates the "seasons-run" record with a new value by incrementing its value with the value of the "home" record.
   6. **Statistics watcher**. The statistics watcher is a baseball fan who checks on the home team's season statistics daily. Specifically, the statistics watcher reads the "seasons-run" record from the database once a day. Note that the "seasons-run" record is updated at most once a day.

   For each of the six baseball participants, determine the most appropriate consistency level (strong consistency, eventual consistency, consistent prefix, bounded staleness, monotonic reads, read my writes) for the participant.

   Solution:

   1. Scorekeeper: read my writes
   2. Umpire: strong consistency
   3. Radio reporter: bounded staleness or (consistent prefix & monotonic reads)
   4. Sports writer: bounded staleness
   5. Team statistician: using bounded staleness for the read of 'home" followed by using read my writes for the read of seasons-run
   6. Statistics watcher: eventual consistency

2. Consider the execution of 5 transactions (T_1, T_2, T_3, T_4, T_5) in Pileus among three sessions shown below:

Client A: $R_1(x_0), W_1(x_1), C_1$, $R_4(x_1), R_4(y_2), W_4(x_4), W_4(y_4), C_4$
Client B: $R_2(x_1), R_2(y_0), W_2(y_2), C_2$, $R_5(x_4), W_5(x_5), C_5$
Client C: $R_3(x_1), C_3$

Assume that the commit timestamps of T_1, T_2, T_3, T_4, and T_5 are 100, 200, 300, 400, and 500, respectively. Assume that the initial database contains the object versions $\{x_0, y_0\}$ associated with a commit timestamp of 0.

(a) Suppose that Client A is starting a new transaction T_6 with consistency level ℓ and key-set K. For each of the following nine scenarios, determine $MARTS(T_6)$.

ℓ	K	$MARTS(T_6)$
Read My Writes	$\{y\}$	
Monotonic Reads	$\{x\}$	
Monotonic Reads	$\{y\}$	
Monotonic Reads	$\{x, y\}$	
Causal	$\{x\}$	
Eventual	$\{x, y\}$	
Strong	$\{x\}$	
Strong	$\{y\}$	
Strong	$\{x, y\}$	

(b) Assume that the database is replicated across 6 servers as follows:

Server	**Key-set**	**High timestamp**
S_1	$\{x\}$	500
S_2	$\{y\}$	400
S_3	$\{x, y\}$	200
S_4	$\{x\}$	400
S_5	$\{y\}$	200
S_6	$\{x\}$	100

Assume that the servers' high timestamp information maintained by Client A are identical to that maintained at the servers.

Suppose that Client A is starting a new transaction T_6 with monotonic reads consistency level and key-set $= \{x, y\}$. For each of the following four scenarios, determine $readTS(T_6)$.

Latency between Client A and Server S_i						$readTS(T_6)$
S_1	S_2	S_3	S_4	S_5	S_6	
100	200	300	250	350	250	
200	200	100	250	350	250	
300	200	300	150	100	250	
300	100	300	250	300	200	

Solution:

(a)

ℓ	K	$MARTS(T_6)$
Read My Writes	$\{y\}$	400
Monotonic Reads	$\{x\}$	200
Monotonic Reads	$\{y\}$	200
Monotonic Reads	$\{x, y\}$	200
Causal	$\{x\}$	400
Eventual	$\{x, y\}$	0
Strong	$\{x\}$	500
Strong	$\{y\}$	400
Strong	$\{x, y\}$	500

(b) From part (a), we know that $MARTS(T_6) = 200$. Let S_x and S_y denote the closest server to Client A for accessing x and y, respectively, such that the minimum acceptable read timestamp condition holds.

Based on the servers' high timestamps, $S_x \in \{S_1, S_3, S_4\}$ and $S_y \in \{S_2, S_3, S_5\}$.

Latency between Client A and Server S_i								
S_1	S_2	S_3	S_4	S_5	S_6	S_x	S_y	$readTS(T_6)$
100	200	300	250	350	250	S_1	S_2	400
200	200	100	250	350	250	S_3	S_3	200
300	200	300	150	100	250	S_4	S_5	200
300	100	300	250	300	200	S_4	S_2	400