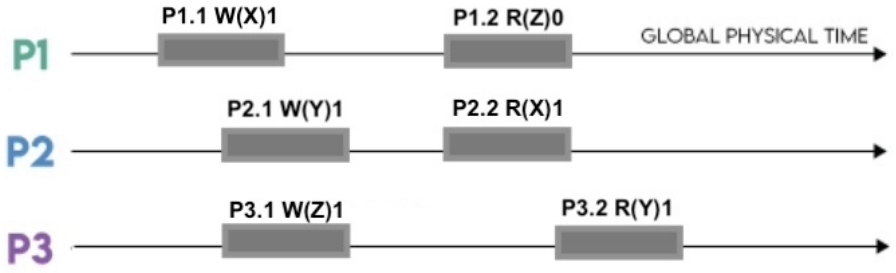
CS582 Distributed Systems
Quiz 3

Student Name:		**Student ID:**
Time Allowed: 20 mins.	**Total Marks:** 10	**Marks Obtained:**

1. (4 marks) Consider the following distributed system, with 3 processes P1, P2, and P3, each running on a different machine but interacting with the same key-value datastore. Assume that the initial values of X, Y, and Z are 0.



The Distributed System adheres to the following semantics:

- W(X)n means that the value n has been written to variable 'X'
- R(X)n means that the value n has been read from variable 'X'

Your TA, Ahmed, claims that based on this output, the Distributed System adheres to Linearizability. Do you agree? If not, explain why the system does not satisfy Linearizability. Furthermore, does the system satisfy Sequential Consistency and Causal Consistency? Justify your response and mention the total global order at play, if applicable.

Disagree. (0.5 marks)

We know that for Linearizability, all replicas must execute operations in a total order that also preserves the global-time ordering of operations. In the given scenario, all the read operations (i.e., PX.2 where X = 1,2,3) occur after respective write operations (PX.1). Therefore, whatever the ordering of PX.2 processes are the values of X,Y and Z all should've been 1, since all processes should have observed the latest values for X, Y and Z. Since P1 sees the old value of Z (0), the system does not satisfy Linearizability. (1.5 marks)

The system satisfies Sequential Consistency as the read operations are consistent with the order of operations on each of the individual processes. (0.5 marks)

A possible total order that explains this output is: (1 mark) P1.1 $\rightarrow$ P2.1 $\rightarrow$ P1.2 $\rightarrow$ P2.2 $\rightarrow$ P3.1 $\rightarrow$ P3.2

We know that Causal Consistency is strictly weaker than sequential consistency. Therefore, If the system is sequentially consistent, it's also causally consistent. (0.5 marks)

2. (3 marks) Your TA, Ayain, was using the Daraz mobile app to purchase an umbrella and an overcoat. Last week, he added the umbrella to his shopping cart. Today, while using the app, he selected the overcoat and added it to the cart. The mobile app was connected to Server A. However, due to ongoing issues with LUMS WiFi for iPhone users, Ayain switched to Daraz's web app on his laptop to complete the checkout process. The web app is connected to Server B. Yet, due to network latency issues in Pakistan nowadays, Server B has not yet received the updates from Server A.

   (i) (1.5 marks) What items will Ayain see in his shopping cart when he switches to the laptop, and how might this impact his checkout process?

   Ayain will likely only see the umbrella in his shopping cart (0.5 marks) on his laptop, as the overcoat added through the mobile app (connected to Server A) hasn't yet synchronized with Server B (0.5 marks). If he proceeds to checkout, only the umbrella will be included in the order. (0.5 marks).

   (ii) (1.5 marks) Which consistency model does this system follow, and how does it explain the behavior Ayain experiences?

   The system is following the Eventual Consistency model (0.5 marks), which allows for temporary inconsistencies between replicas (Server A and Server B). Eventually, the cart will synchronize and show both items (0.5 marks), but during the delay, the cart may appear incomplete on different devices (0.5 marks).

3. (3 marks) An international airline, Qatar Airways, manages its flight booking system through multiple data centers in different regions to ensure high availability and fast response times for customers booking flights. They need to keep track of available seats on flight in real-time to prevent overbooking. Due to network partition between data centers in North America and the Middle East, users in both regions continue to book seats on the same flight.

   You've been hired as a consultant to advise them on how to handle bookings across multiple data centers in different regions.

   Would you prioritize consistency or availability during a network partition? Justify your recommendation and discuss the trade-offs that come with your choice. How will this decision impact both the airline's operations and customer satisfaction?

   Availability:

   - Users in both regions will continue to book flights without disruption, even during the network partition.
   - trade-off is that it risks overbooking, as different data centers may not be synchronized, leading to multiple bookings for the same seat

   Consistency:

   - Airline would block bookings during the network partition to ensure that seat availability is accurate and up-to-date across all data centers. This would in turn prevent overbooking.
   - The trade-off, however, is reduced availability—customers might not be able to book flights during the partition, leading to frustration, potential revenue loss, and missed business opportunities if users turn to competitors.

   Full Credit for any plausible explanation

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1. (3 marks) Your TA, Ayain, was using a calendar app on his iPhone to manage his schedule. Last week, he added an event titled "Distributed Systems Office Hours" to his calendar, scheduled for Tuesday and Thursday at 11:50 AM. Today, while using the app on his iPhone (which is connected to Server A), he edits the Tuesday event time to 10:50 AM. However, due to ongoing issues with LUMS WiFi for iPhone users, Ayain switches to the calendar app on his MacBook (connected to Server B) to export the updated schedule as PDF and upload it to the LMS for students. Yet, due to network latency issues in Pakistan nowadays, Server B has not yet received the updates from Server A.

   (i) (1.5 marks) What event times will Ayain see on his calendar when he checks it on the MacBook, and how might this impact the office hours schedule uploaded to LMS?

   Ayain will likely see the original time of 11:50 AM for both the Tuesday and Thursday events (0.5 marks) on his MacBook, as the updated time for the Tuesday event (10:50 AM) made through the iPhone (connected to Server A) hasn't yet synchronized with Server B (0.5 marks). If Ayain exports and uploads this schedule to LMS, the students will see the outdated time (11:50 AM) for Tuesday's office hours, leading to confusion (0.5 marks).

   (ii) (1.5 marks) Which consistency model does this system follow, and how does it explain the behavior Ayain experiences?

   The system is following the Eventual Consistency model (0.5 marks), which allows for temporary inconsistencies between replicas (Server A and Server B). Eventually, the calendar will synchronize, and both devices will show the updated time for the Tuesday event (0.5 marks), but during the delay, Ayain might export and upload an outdated schedule to LMS, causing students to rely on incorrect information (0.5 marks).

2. (3 marks) HSBC, known for its global banking network, operates a distributed system with data centers located across multiple regions to provide fast and reliable services to customers worldwide. The system needs to maintain accurate account balances, allowing customers to perform transactions such as withdrawals, deposits, and transfers. These transactions are processed in real-time to prevent overdrafts and ensure account balances remain correct. Due to a network partition between HSBC's data centers in Europe and Asia, customers in both regions continue to perform transactions on their accounts.

   You've been hired as a consultant to advise HSBC on how to handle banking transactions across multiple data centers during network partitions.

   Would you prioritize consistency or availability during a network partition? Justify your recommendation and discuss the trade-offs that come with your choice. How will this decision impact both the bank's operations and customer satisfaction?

   Availability:

   - Customers in both regions (Europe and Asia) will continue to perform transactions, such as withdrawals and deposits, without disruption during the network partition.
   - The trade-off is that it risks inconsistent account balances, leading to overdrafts or double spending, as the data centers are not synchronized in real-time. This could create operational challenges and customer dissatisfaction once the partition is resolved and discrepancies are noticed.

   Consistency:

   - HSBC would block transactions during the network partition to ensure account balances are accurate and up-to-date across all data centers, preventing overdrafts or conflicting transactions.
   - The trade-off, however, is reduced availability—customers might be unable to perform transactions or access their accounts during the partition, leading to frustration, potential loss of trust, revenue loss, and missed business opportunities if users turn to competitors.

   Full Credit for any plausible explanation

3. (4 marks) Consider the following distributed system, with 3 processes P1, P2, and P3, each running on a different machine but interacting with the same key-value datastore. Assume that the initial values of X, Y, and Z are 0.

The Distributed System adheres to the following semantics:

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Disagree. (0.5 marks)

We know that for Linearizability, all replicas must execute operations in a total order that also preserves the global-time ordering of operations. In the given scenario, all the read operations (i.e., PX.2 where X = 1,2,3) occur after respective write operations (PX.1). Therefore, whatever the ordering of PX.2 processes are the values of X,Y and Z all should've been 1, since all processes should have observed the latest values for X, Y and Z. Since P1 sees the old value of Y (0) and Z(0), the system does not satisfy Linearizability. (1.5 marks)

The system satisfies Sequential Consistency as the read operations are consistent with the order of operations on each of the individual processes. (0.5 marks)

A possible total order that explains this output is: (1 mark) P1.1 $\rightarrow$ P1.2 $\rightarrow$ P3.1 $\rightarrow$ P3.2 $\rightarrow$ P2.1 $\rightarrow$ P2.2

We know that Causal Consistency is strictly weaker than sequential consistency. Therefore, If the system is sequentially consistent, it's also causally consistent. (0.5 marks)