

1. (10 points) Transactions T and U execute on a single server. In the table below, time proceeds from top to bottom, and the relative position of the operations indicate their relative order in time. Assume that a different lock is used for each variable w, x, y and z.

Assume that two-phase locking is used, and that each transaction acquires locks only when needed. For instance, in part (i) below, transaction T acquires lock for variable z right before it performs ~~read~~(z). All locks held by a transaction are released when it performs closeTransaction (but not before that).

Replace "read(z)" by "write(z,2)"

Determine whether the interleaving of operation as shown in parts (i) and (ii) below can occur under the assumption stated in each part (state YES or NO).

Notation: read (x) returns the value of variable x, and write(x,1) writes 1 to variable x.

(i) **Assume that Exclusive locks are used with two phase locking:** _____

If you answer NO, **delete** a minimum number of operations from the transactions so that the modified execution becomes possible while using exclusive locks. Assume that the relative order of remaining operations stays unchanged, even if some of the operations are deleted.

Transaction T	Transaction U
openTransaction a = read (x) write (z,2) d = read (z) closeTransaction	openTransaction b = read (y) c = read (x) write (z,1) write (x,5) closeTransaction

(ii) **Assume that Read-Write locks are used with two phase locking:** _____

(With read-write locking, a transaction acquires *read lock* when that is adequate. The transaction may promote a *read lock* to a *write lock* later if needed.)

See the execution on the next page.

If you answer NO, **change** a minimum number of **write** operations to **read** operations so that the modified execution becomes possible while using read-write locks.

Transaction T	Transaction U
openTransaction a = read (x) e = read (z) write(x,5) write (y,2) closeTransaction	openTransaction c = read (y) write (z,1) write(y,3) closeTransaction

2. (10 points) For each part in Question 16.9 in the textbook, determine whether the interleaving is serially equivalent (answer Yes or No for each part).

3. (10 points) In parts (a) and (b) both assume that only transactions T,U,V are performed.

(a) The table below shows the interleaving of the operations performed by transactions T, U and V. Suppose that optimistic concurrency control with *forward* validation is used. Validation is carried out when a transaction performs closeTransaction operation. When forward validation fails, **assume that the transaction performing the validation is immediately aborted**. Which of the transactions (if any) must be aborted?

Transaction T	Transaction U	Transaction V
openTransaction	openTransaction	openTransaction
a = read (v) write (y,1)	e = read(w)	c = read (y) write (w,5) closeTransaction
write (z,5)	d = read (w) write (w,5) closeTransaction	
b = read (w) write (v,5) closeTransaction		

(b) Answer the question above by replacing "forward validation" by "backward validation".

Recommended exercises below:

(i) Draw a wait-for graph that may arise due to a given interleaving of transactions, assuming that each transaction acquires an exclusive lock for each object when the transactions access that object for the first time.

(ii) Can deadlock occur if each transaction acquires at most one lock?