5. Distributed Transactions

5.1. Foundations
   a) State the fundamental properties of a transaction.
   b) What extensions provide distributed transactions in comparison to local data base transactions?

5.2. The Two-Phase-Commit protocol is employed for the conclusion of distributed transactions.
   a) Illustrate by means of a sequence diagram the timely sequence of an error free communication.
   b) How does the protocol react to the failure of the coordinator after sending the “Prepare” message?
   c) Illustrate by means of a sequence diagram how the protocol reacts to the failure of a participant after sending the “Ready” message from the perspective of the coordinator, a participant that successfully completes the transaction and the participant that fails after sending the “Ready” message.

5.3. Concurrency control is essential to ensure the isolation of transactions.
   a) Clarify the terms pessimistic and optimistic concurrency control.
   b) Sketch the setting and release of locks for transaction T1 in the figure below according to the simple and strict Two-Phase-Locking (TPL) algorithms. It is assumed that the system uses write locks only and read and write operations have a duration of 1 time unit.
   c) From what point in time on, a second transaction T2 could perform the operations r(x) and w(y,5) for simple and strict 2PL.

\[ T_1 \]
\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \]
\[ r(x) \quad r(y) \quad w(x,2) \quad w(z,1) \quad w(y,5) \]

5.4. The reference model of the Open Group for Distributed Transaction Processing (DTP) introduces Resource Managers, Application Programs and Transaction Monitors as main components for distributed Transactions.
   a) Name the main responsibilities of these components.
   b) What operations are declared in the TX and XA interfaces?
   c) Sketch the necessary components and message exchange according to the DTP reference model to implement the Product Order Processing as described in slide 5.8 of the lecture.

5.5. Nested Transactions
   a) Which advantages do nested distributed transactions possess over simple transactions?
   b) Why must, in the case of nested distributed transactions, the locks of concluded partial transactions be kept in place until the conclusion of the whole encompassing transaction?