Timestamp Ordering/1

- Algorithms that are based on **timestamp-ordering** do not maintain serializability by mutual exclusion, but select a serialization order a priori (based on timestamps) and execute transactions accordingly.
  - Transaction T_i is assigned a globally unique timestamp $ts(T_i)$.
  - Conflicting operations O_{ij} and O_{kl} are resolved by timestamp order, i.e., O_{ij} must be executed before O_{kl} iff $ts(T_i) < ts(T_k)$.
- To allow for the scheduler to check whether operations arrive in correct order, each data item is assigned a write timestamp (wts) and a read timestamp (rts):
  - $rts(x)$: largest timestamp of any transaction that read x
  - $wts(x)$: largest timestamp of any transaction that wrote x

Timestamp Ordering/2

- Then the scheduler has to perform the following checks:
  - Read operation, $R_i(x)$:
    - If $ts(T_i) < wts(x)$: T_i attempts to read overwritten data; abort T_i
    - If $ts(T_i) \geq wts(x)$: the operation is allowed and $rts(x)$ is updated
  - Write operations, $W_i(x)$:
    - If $ts(T_i) < rts(x)$: x was needed before by other transaction; abort T_i
    - If $ts(T_i) < wts(x)$: T_i writes an obsolete value; abort T_i
    - Otherwise, execute $W_i(x)$
- These checks and actions mean that the older transaction is aborted if there is a conflict.

Timestamp Ordering/3

- Generation of **timestamps** (TS) in a distributed environment
  - TS needs to be locally and globally **unique** and **monotonically increasing**
  - System clock, incremental event counter at each site, or global counter are unsuitable (difficult to maintain)
  - Concatenate local timestamp/counter with a unique site identifier: <*local timestamp, site identifier*>
    - site identifier is in the least significant position in order to distinguish only if the local timestamps are identical

Timestamp Ordering/4

- Schedules generated by the basic TO protocol have the following **properties**:
  - Serializable
  - Since transactions never wait (but are rejected), the schedules are deadlock-free
  - The price to pay for deadlock-free schedules is the potential restart of a transaction several times
  - Cascading rollbacks are possible
  - Recoverability requires additional steps that ensure that commits happen in the correct order

Timestamp Ordering/5

- **Multiversion timestamp ordering**
  - Write operations do not modify the DB; instead, a new version of the data item is created: $x_1, x_2, \ldots, x_n$
  - $R_i(x)$ is always successful and is performed on the appropriate version of x, i.e., the version of x (say x_v) such that $wts(x_v)$ is the largest timestamp less than $ts(T_i)$
  - $W_i(x)$ produces a new version x_w with $ts(x_w) = ts(T_i)$ if the scheduler has not yet processed any $R_j(x_r)$ on a version x_r such that

$$ts(T_i) < rts(x_r)$$

    i.e., the write is too late.
  - Otherwise, the write is rejected.

Distributed Reliability

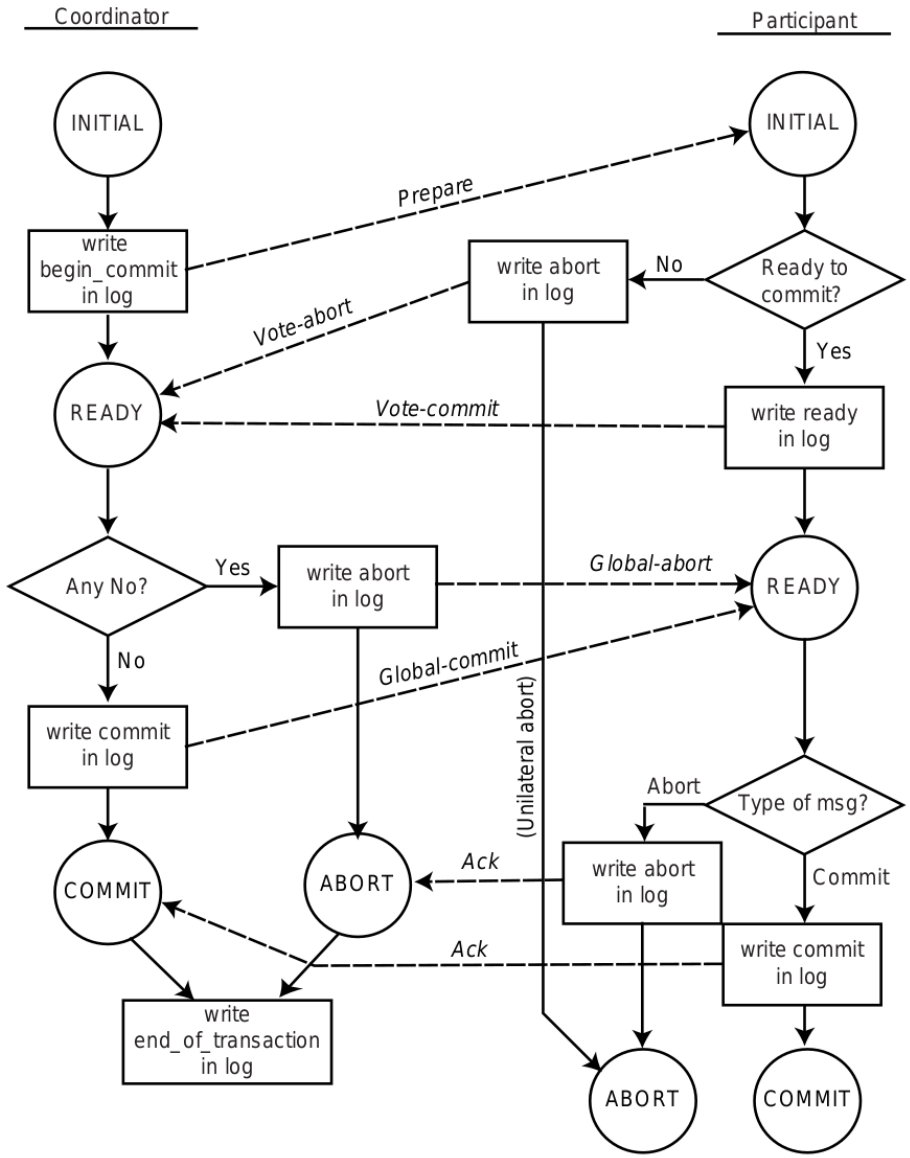
- Distributed reliability maintain is about **atomicity and durability** of distributed transactions that execute over a number of databases.
- Distributed reliability handles the distributed execution of **begin transaction**, **read**, **write**, **abort**, **commit**, and **recover** commands.
- The execution of the begin transaction, read, and write commands does not cause any significant new problems.
- The reliability techniques in distributed database systems consist of **commit**, **termination** and **recovery protocols**.

Termination and Recovery Protocols

- The termination and recovery protocols specify how the recover command is executed.
  - **Termination protocols** specify what active sites must do after a failure.
    - The termination protocols handle timeouts for coordinator and participants.
    - A timeout occurs if a site does not get an answer within the expected time period.
  - **Recovery protocols** specify actions that must be done when a site restarts after a failure
    - Protocol to recover when sites fail and then restart.
    - Use logs to undo and redo.
    - May have to communicate with other sites to figure out decisions.

Two Phase Commit (2PC)

- The 2PC protocol insists that **al sites agree** to commit before the changes of the transaction are made permanent.
- **Global commit rule**:
  - If even one site votes to abort, the coordinator must reach a global abort decision.
  - If all sites vote to commit, the coordinator must reach a global commit decision.
- Each site can **unilaterally abort**
- Sites cannot change their votes.
- **Timers** are used to limit the waiting time.



Conclusion

- A **transaction** is a set of operations with a partial order
- The **transaction manager** ensures atomicity, consistency, isolation, and durability
- A **schedule** is some order of the operations of the given transactions. If a set of transactions is executed one after the other, we have a serial schedule.
- There are two main groups of serializable concurrency control algorithms: **lock based** and **timestamp based**
- Local properties do not ensure global properties but can be generalized.
- 2PC to commit in distributed database systems.

Course Project

- Hand in of project: December 17, 2018
- Report
  - problem definition
  - running example
  - description of solution
  - evaluation
  - strength, weaknesses, limitations
- Report (5 pages) and implementation (source code, sample data, steps to install and run) as zip/tar file
- Send by email to boehlen@ifi.uzh.ch and wellenzohn@ifi.uzh.ch

Course Exam

- Exam date: Monday 7.01.2019
- Exam time: 14:00 - 17:00
- Exam location: BIN 2.E.13

- Exam form and procedure
  - oral, 20 minutes
  - 10 minutes about project (demo, code, algorithm)
  - 10 about a topic of the course
    - Distributed Database Systems
    - Distributed Database Design
    - Distributed Query Processing
    - Distributed Query Optimization
    - Distributed Transactions and Concurrency Control

- During exam: present solutions on examples
- Prepare suitable examples beforehand