Module 54
Partha Pratim Das
Objectives & Outline
Recovery with Early Lock Release
Operation Logging
Transaction Rollback
Failure Recovery
Recovery Algorithm
Plan for Backup and Recovery
Module Summary

Database Management Systems

Module 54: Backup & Recovery/4: Recovery/3

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Module Recap

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- Learnt how Hot backup of transaction log helps in recovering consistent database
- Studied the recovery algorithms for concurrent transactions

Module Objectives

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- To understand Recovery with Early Lock Release
- To understand how to plan for backup and recovery

Module Outline

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- Recovery with Early Lock Release
- Planning Backup and Recovery

References :

- **Enterprise Systems Backup and Recovery: A Corporate Insurance Policy by Preston De Guise**
- **https://www.veritas.com/information-center/data-backup-and-recovery** (Accessed 19-Aug-2021)
- **https://www.sqlshack.com** (Accessed 19-Aug-2021)

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Recovery with Early Lock Release

Recovery with Early Lock Release

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- Any *index used in processing a transaction*, such as a B^+-tree, can be treated as normal data
- To increase concurrency, the B^+-tree concurrency control algorithm often allow locks to be released early, in a non-two-phase manner
- As a result of early lock release, it is possible that
  - a value in a B^+-tree node is updated by one transaction T_1, which inserts an entry (V_1, R_1), and subsequently
  - by another transaction T_2, which inserts an entry (V_2, R_2) in the same node, moving the entry (V_1, R_1) even before T_1 completes execution
- At this point, we cannot undo transaction T_1 by replacing the contents of the node with the old value prior to T_1 performing its insert, since that would also undo the insert performed by T_2; transaction T_2 may still commit (or may have already committed)
- Hence, the only way to undo the effect of insertion of (V_1, R_1) is to execute a corresponding delete operation

Recovery with Early Lock Release

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- Support for high-concurrency locking techniques, such as those used for B^+-tree concurrency control, which release locks early
  - Supports "logical undo"
- Recovery based on "repeating history", whereby recovery executes exactly the same actions as normal processing
  - including redo of log records of incomplete transactions, followed by subsequent undo
  - Key benefits
    - supports logical undo
    - easier to understand/show correctness
- Early lock release is important not only for indices, but also for operations on other system data structures that are accessed and updated very frequently like:
  - data structures that track the blocks containing records of a relation
  - the free space in a block
  - the free blocks

Logical Undo Logging

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- Operations like B^+-tree insertions and deletions release locks early
  - They cannot be undone by restoring old values (**physical undo**), since once a lock is released, other transactions may have updated the B^+-tree
  - Instead, insertions (deletions) are undone by executing a deletion (insertion) operation (known as **logical undo**)
- For such operations, undo log records should contain the undo operation to be executed
  - Such logging is called **logical undo logging**, in contrast to **physical undo logging**
    - Operations are called **logical operations**
  - Other examples:
    - delete of tuple, to undo insert of tuple
      - allows early lock release on space allocation information
    - subtract amount deposited, to undo deposit
      - allows early lock release on bank balance

Physical Redo

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- Redo information is logged **physically** (that is, new value for each write) even for operations with logical undo
  - Logical redo is very complicated since database state on disk may not be "operation consistent" when recovery starts
  - Physical redo logging does not conflict with early lock release

Operation Logging: Process

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- When operation starts, log $< T_i, O_j,$ **operation-begin** $>$. Here O_j is a unique identifier of the operation instance
- While the system is executing the operation, it creates update log records in the normal fashion for all updates performed by the operation
  - the usual old-value (*physical undo information*) and new-value (*physical redo information*) is written out as usual for each update performed by the operation;
  - the old-value information is required in case the transaction needs to be rolled back before the operation completes
- When operation completes, $< T_i, O_j,$ **operation-end**$, U >$ is logged, where U contains information needed to perform a logical undo information
  - For example, if the operation inserted an entry in a B^+-tree, the undo information U would indicate that a deletion operation is to be performed, and would identify the B^+-tree and what entry to delete from the tree. This is called **logical logging**
  - In contrast, logging of old-value and new-value information is called **physical logging**, and the corresponding log records are called **physical log records**

Operation Logging (2): Example

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- Insert of (key, record-id) pair (K5, RID7) into index I9

<T1, O1, operation-begin>
....
<T1, X, 10, K5>
<T1, Y, 45, RID7>
} Physical redo of steps in insert
<T1, O1, operation-end, (delete I9, K5, RID7)>

Operation Logging (3)

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- If crash/rollback occurs before operation completes:
  - the **operation-end** log record is not found, and
  - the physical undo information is used to undo operation
- If crash/rollback occurs after the operation completes:
  - the **operation-end** log record is found, and in this case
  - logical undo is performed using U; the physical undo information for the operation is ignored
- *Redo of operation (after crash) still uses physical redo information*

Transaction Rollback with Logical Undo

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Rollback of transaction T_i, scan the log backwards

a) If a log record $< T_i, X, V_1, V_2 >$ is found, perform the undo and log $< T_i, X, V_1 >$

b) If a $< T_i, O_j,$ **operation-end**$, U >$ record is found
- Rollback the operation logically using the undo information U
  - Updates performed during roll back are logged just like during normal operation execution
  - At the end of the operation rollback, instead of logging an **operation-end** record, generate a record $< T_i, O_j,$ **operation-abort** $>$
- Skip all preceding log records for T_i until the record $< T_i, O_j$ **operation-begin**$>$ is found

c) If a redo-only record is found ignore it

d) If a $< T_i, O_j,$ **operation-abort** $>$ record is found: skip all preceding log records for T_i until the record $< T_i, O_j,$ **operation-begin** $>$is found

e) Stop the scan when the record $< T_i,$ **start**$>$ is found

f) Add a $< T_i,$ **abort**$>$ record to the log

Note:
- Cases c) and d) above can occur only if the database crashes while a transaction is being rolled back
- Skipping of log records as in case d) is important to prevent multiple rollback of the same operation

Transaction Rollback with Logical Undo

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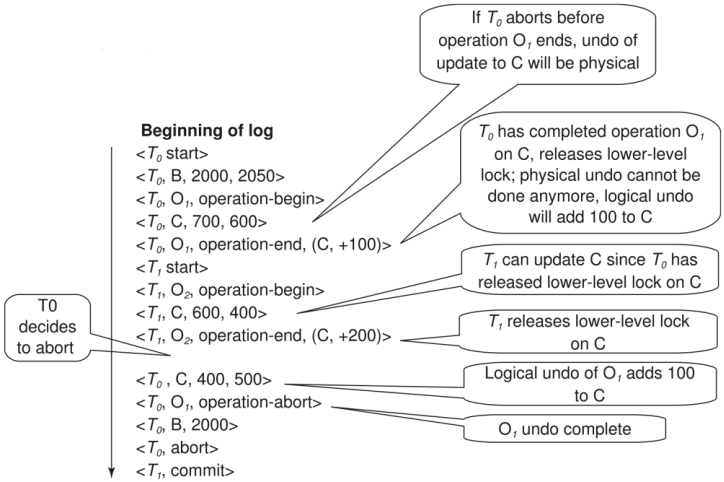

Failure Recovery with Logical Undo

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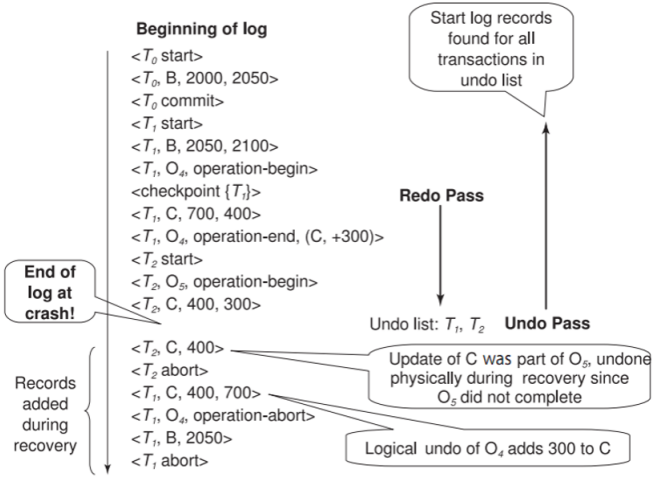

Transaction Rollback: Another Example

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- Example with a complete and an incomplete operation

$< T1, start >$
$< T1, O1,$ operation-begin$>$
...
$< T1, X, 10, K5 >$
$< T1, Y, 45, RID7 >$
$< T1, O1,$ operation-end, (delete $I9, K5, RID7$) $>$
$< T1, O2,$ operation-begin$>$
$< T1, Z, 45, 70 >$
← T1 Rollback begins here
$< T1, Z, 45 >$ ← Redo-only log record during physical undo (of incomplete O2)
$< T1, Y, \ldots, \ldots >$ ← Normal redo records for logical undo of O1
...
$< T1, O1,$ operation-abort$>$ ← What if crash occurred immediately after this?
$< T1, abort >$

Recovery Algorithm with Logical Undo

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Basically same as earlier algorithm, except for changes described earlier for transaction rollback

- (**Redo phase**): Scan log forward from last $<$ **checkpoint** $L>$ record till end of log
  - **Repeat history** by physically redoing all updates of all transactions,
  - Create an undo-list during the scan as follows
    - *undo-list* is set to L initially
    - Whenever $<T_i$ **start**$>$ is found T_i is added to undo-list
    - Whenever $<T_i$ **commit**$>$ or $<T_i$ **abort**$>$ is found, T_i is deleted from *undo-list*
  - This brings database to state as of crash, with committed as well as uncommitted transactions having been redone
  - Now *undo-list* contains transactions that are **incomplete**, that is, have neither committed nor been fully rolled back

Recovery Algorithm with Logical Undo (2)

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Recovery from system crash (cont.)

- (**Undo phase**): Scan log backwards, performing undo on log records of transactions found in *undo-list*
  - Log records of transactions being rolled back are processed as described earlier, as they are found
    - Single shared scan for all transactions being undone
  - When $< T_i$ **start**$>$ is found for a transaction T_i in undo-list, write a $< T_i$ **abort**$>$ log record.
  - Stop scan when $< T_i$ **start**$>$ records have been found for all T_i in *undo-list*
- This undoes the effects of incomplete transactions (those with neither **commit** nor **abort** log records). Recovery is now complete.

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Module Summary

Deciding factors for having a Backup & Recovery setup.

- **Data Importance**
  - How important is the information in your database for your company? For business-critical data you will create a plan that involves making extra copies of your database over the same period and ensuring that the copies can be easily restored when required
- **Frequency of Change**
  - How often does your database get updated? For instance, if critical data is modified daily then you should make a daily backup schedule.
- **Speed**
  - How much time do you need to back up or recover your files? Recovery speed is an important factor that determines the maximum possible time period that could be spent on database backup and recovery.

Source: *http://www.centriqs.com/database/database-backup-and-recovery.php*

Plan for Backup and Recover (2)

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Module Summary

- **Equipment**
  - Do you have necessary equipment to make backups? To perform timely backups and recoveries, you need to have proper software and hardware resources.
- **Employees**
  - Who will be responsible for implementing your database backup and recovery plan? Ideally, one person should be appointed for controlling and supervising the plan, and several IT specialists (e.g. system administrators) should be responsible for performing the actual backup and recovery of data.
- **Storing**
  - Where do you plan to store database duplicates? In case of Online/Offsite storage you can recover your systems in case of a natural disaster. Storing backups on-site is essential to quick restore. But onsite storage has capacity bottlenecks and high maintenance costs.

Source: *http://www.centriqs.com/database/database-backup-and-recovery.php*

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- Recovery based on operation logging supplements log-based recovery
- Planning for Backup

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