



Module 53

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Objectives &
Outline

Transactional
Logging

Hot Backup
Example

Recovery
Algorithm

Data Access

Checkpoint

Redo Phase

Undo Phase

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Module Summary

Database Management Systems

Module 53: Backup & Recovery/3: Recovery/2

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Module Summary

- Failures may be due to variety of sources – each needs a strategy for handling
- A proper mix and management of volatile, non-volatile and stable storage can guarantee recovery from failures and ensure Atomicity, Consistency and Durability
- Log-based recovery is efficient and effective



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Module Summary

- To understand Transactional Logging with Hot Backup
- To focus on concurrent transactions and understand the recovery algorithms



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Module Summary

- Transactional Logging
- Recovery Algorithm



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Module Summary

Transactional Logging



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Module Summary

- In systems where high availability is a requirement **Hot backup** is preferable **wherever possible**
- **Hot backup** refers to keeping a database up and running while the backup is performed concurrently
 - Such a system usually has a module or plug-in that allows the database to be backed up while staying available to end users
 - Databases which stores transactions of **asset management companies, hedge funds, high frequency trading companies** etc. try to implement Hot backups as these data are highly dynamic and the operations run 24x7
 - Real time systems like **sensor and actuator data in embedded devices, satellite transmissions** etc. also use Hot backup



Transactional Logging as Hot Backup

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- In regular database systems, **Hot Backup** is mainly used for *Transaction Log Backup*
- **Cold backup** strategies like **Differential, Incremental** are preferred for *Data backup*
The reason is evident from the disadvantages of Hot backup
- **Transactional Logging** is used in circumstances where a possibly inconsistent backup is taken, but another file generated and backed up (after the database file has been fully backed up) can be used to restore consistency
- The information regarding **data backup versions** while recovery at a **given point** can be inferred from the Transactional Log backup set
- Thus they play a vital role in **database recovery**



Transactional Logging with Recovery: Example

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To understand how **Transactional Logging** works we consider Figure 1 that represents a chunk of a database just before a backup has been started

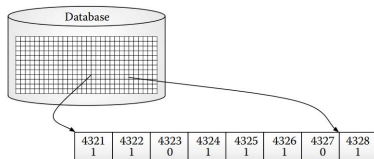


Figure 1: *Database content*

- While the backup is in progress, modifications may continue to occur to the database. For example, a request to modify the data at location “4325” to ‘0’ arrives.
- When a request comes through to modify a part of the DB, the modifications will be written in the **given order compulsorily**
 - 1 Transaction Log
 - 2 Database (itself)

This is depicted in Figure 2

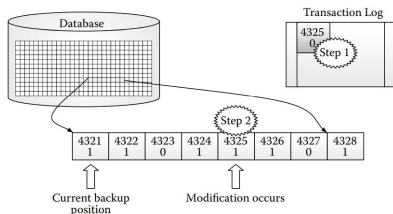


Figure 2: *Changes to a DB during a hot backup*

- If a crash occurs **before writing to the database** then the **inconsistent backed up file is recovered first**, and then the pending **modifications in the transaction log** (backed up*) are applied to **re-establish consistency**

***Note:** *The Transaction Log itself is backed up using Hot Backup the Data is backed up incrementally*



Transactional Logging with Recovery: Example (2)

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Consider in the previous scenario before the occurrence of crash, another request modifies the content of location “4321” to ‘0’. Incidentally **this change gets written in the database itself** (recall: Immediate Modification). This is indicated in Figure 3

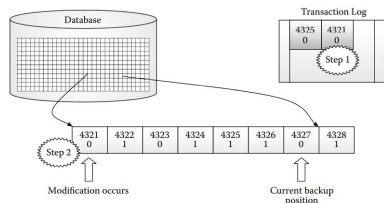


Figure 3: *Applying Tr. logs during recovery*

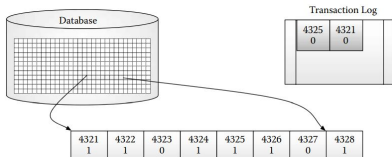


Figure 4: *Recovered DB files and Tr. logs*

- Figure 3 is the state of the database after which the system crashes. Note that this part has already been backed up, and hence, the backup is inconsistent with the database.
- Recovery Phase:
 - Data recovery is done from the last data back up set (Figure 1)
 - Log recovery is done from the Transaction Log backup set. It will be same as the current transaction log because of Hot backup
 - Figure 4 shows the recovered database and log
- The recovered database is inconsistent. To re-establish consistency all transaction logs generated between the start of the backup and the end of the backup must be **replayed**

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- When using transactional logging we distinguish between *recover* and *restore*:
 - Recover**: retrieve from the backup media the database files and transaction logs, and
 - Restore**: reapply database consistency based on the transaction logs
- For our restore process, we recover inconsistent database files and completed transaction logs. The recovered files will resemble the configuration shown in Figure 4
- The final database state after replaying log on the recovered database is displayed in Figure 5
- The state of database is consistent**

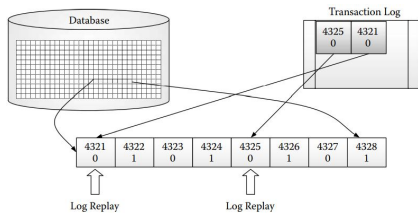


Figure: 5: *Database restore process via log replay*

- Note that an unnecessary log replay is shown occurring for block 4325. Whether such replays will occur is dependent on the database being used. For instance, a database vendor might choose to replay all logs because it would be faster than first determining whether a particular logged activity needs to be replayed
- Once all transaction logs have been replayed, the database is said to have been restored, that is, it is at a point where it can now be opened for user access



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Recovery Schemes

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Module Summary

- **So far:**
 - We covered key concepts
 - We assumed serial execution of transactions
- **Now:**
 - We discuss concurrency control issues
 - We present the components of the basic recovery algorithm



Concurrency Control and Recovery

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Module Summary

- With concurrent transactions, all transactions share a single disk buffer and a single log
 - A buffer block can have data items updated by one or more transactions
- We assume that *if a transaction T_i has modified an item, no other transaction can modify the same item until T_i has committed or aborted*
 - That is, the updates of uncommitted transactions should not be visible to other transactions
 - ▷ Otherwise how do we perform undo if T_1 updates A, then T_2 updates A and commits, and finally T_1 has to abort?
 - Can be ensured by obtaining exclusive locks on updated items and holding the locks till end of transaction (strict two-phase locking)
- Log records of different transactions may be interspersed in the log



Example of Data Access with Serial Transaction

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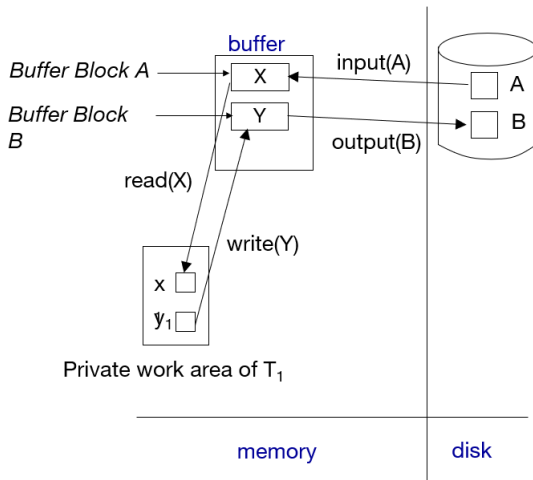
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Example of Data Access with Concurrent Transactions

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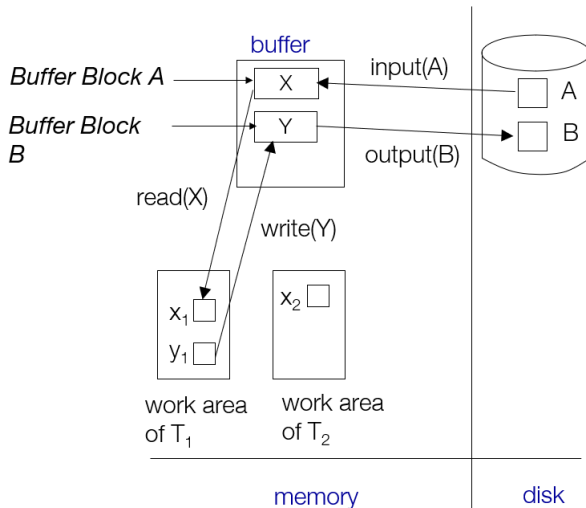
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Recovery Algorithm

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Module Summary

- **Logging** (during normal operation):
 - $\langle T_i \text{ start} \rangle$ at transaction start
 - $\langle T_i, X_j, V_1, V_2 \rangle$ for each update, and
 - $\langle T_i \text{ commit} \rangle$ at transaction end



Recovery Algorithm (2)

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- **Transaction rollback (during normal operation)**

- Let T_i be the transaction to be rolled back
- Scan log backwards from the end, and for each log record of T_i of the form $\langle T_i, X_j, V_1, V_2 \rangle$
 - ▷ perform the undo by writing V_1 to X_j ,
 - ▷ write a log record $\langle T_i, X_j, V_1 \rangle$

... such log records are called **Compensation Log Records (CLR)**
- Once the record $\langle T_i \text{ start} \rangle$ is found stop the scan and write the log record $\langle T_i \text{ abort} \rangle$



Recovery Algorithm (3): Checkpoints Recap

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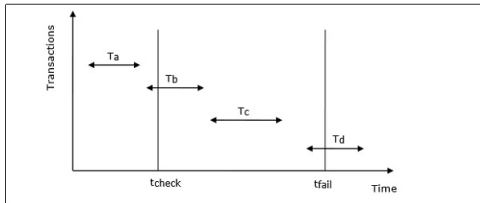
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- Let the time of checkpointing is t_{check} and the time of system crash is t_{fail}
- Let there be four transactions T_a , T_b , T_c and T_d such that:
 - T_a commits before checkpoint
 - T_b starts before checkpoint and commits before system crash
 - T_c starts after checkpoint and commits before system crash
 - T_d starts after checkpoint and was active at the time of system crash



- The actions that are taken by the recovery manager are:
 - Nothing is done with T_a
 - Transaction redo is performed for T_b and T_c
 - Transaction undo is performed for T_d



Recovery Algorithm (4): Checkpoints Recap

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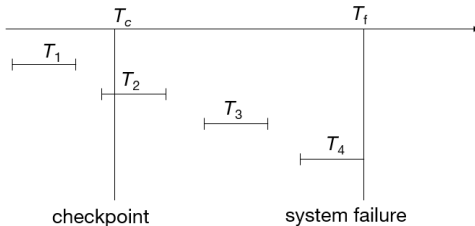
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Module Summary



- Any transactions that committed before the last checkpoint should be ignored
 - T_1 can be ignored (updates already output to disk due to checkpoint)
- Any transactions that committed since the last checkpoint need to be redone
 - T_2 and T_3 redone
- Any transaction that was running at the time of failure needs to be undone and restarted
 - T_4 undone



Recovery Algorithm (5): Redo-Undo Phases

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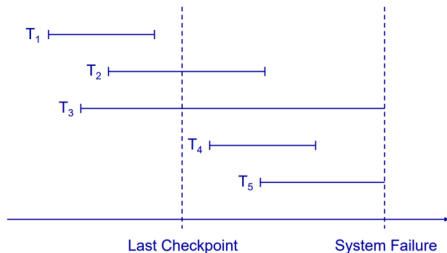
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Module Summary

- **Recovery from failure:** Two phases
 - **Redo phase:** Replay updates of all transactions, whether they committed, aborted, or are incomplete
 - **Undo phase:** Undo phase: Undo all incomplete transactions



Requirement:

- Transactions of type T_1 need no recovery
- Transactions of type T_2 or T_4 need to be re-done
- Transactions of type T_3 or T_5 need to be undone and restarted

Strategy:

- Ignore T_1
- Redo T_2 , T_3 , T_4 and T_5
- Undo T_3 and T_5



Recovery Algorithm (6): Redo Phase

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Module Summary

- Find last **< checkpoint L >** record, and set undo-list to L
- Scan forward from above **< checkpoint L >** record
 - Whenever a record $\langle T_i, X_j, V_1, V_2 \rangle$ is found, redo it by writing V_2 to X_j
 - Whenever a log record $\langle T_i \text{ start} \rangle$ is found, add T_i to undo-list
 - Whenever a log record $\langle T_i \text{ commit} \rangle$ or $\langle T_i \text{ abort} \rangle$ is found, remove T_i from undo-list
- Steps for the REDO operation are:
 - If the transaction has done INSERT, the recovery manager generates an insert from the log
 - If the transaction has done DELETE, the recovery manager generates a delete from the log
 - If the transaction has done UPDATE, the recovery manager generates an update from the log.

Source: *Distributed DBMS - Database Recovery*



Recovery Algorithm (7): Undo Phase

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Module Summary

- Scan log backwards from end
 - Whenever a log record $\langle T_i, X_j, V_1, V_2 \rangle$ is found where T_i is in undo-list perform same actions as for transaction rollback:
 - ▷ Perform undo by writing V_1 to X_j
 - ▷ Write a log record $\langle T_i, X_j, V_1 \rangle$
 - Whenever a log record $\langle T_i \text{ start} \rangle$ is found where T_i is in undo-list
 - ▷ Write a log record $\langle T_i \text{ abort} \rangle$
 - ▷ Remove T_i from undo-list
 - Stop when undo-list is empty
That is, $\langle T_i \text{ start} \rangle$ has been found for every transaction in undo-list
- Steps for the UNDO operation are:
 - If the faulty transaction has done INSERT, the recovery manager deletes the data item(s) inserted
 - If the faulty transaction has done DELETE, the recovery manager inserts the deleted data item(s) from the log
 - If the faulty transaction has done UPDATE, the recovery manager eliminates the value by writing the before-update value from the log
- After undo phase completes, normal transaction processing can commence

Source: *Distributed DBMS - Database Recovery*



Recovery Algorithm (8): Example

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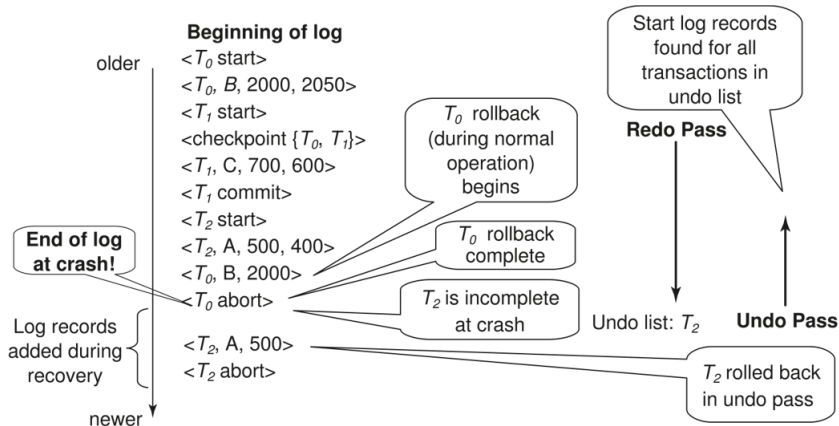
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Module Summary

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

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