Introduction to Database Systems CSE 444

Lectures 11-12
Transactions: Recovery (Aries)

Readings

- Material in today's lecture NOT in the book
- Instead, read Sections 1, 2.2, and 3.2 of: Michael J. Franklin. Concurrency Control and Recovery. The Handbook of Computer Science and Engineering, A. Tucker, ed., CRC Press, Boca Raton, 1997.

Transaction Management

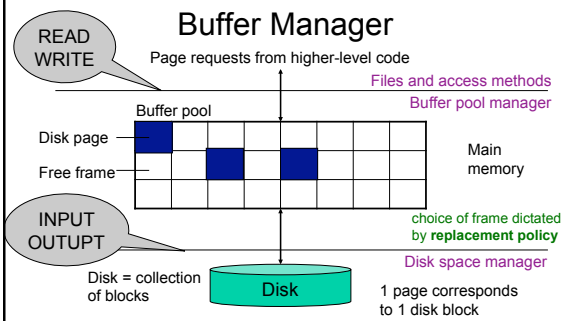
Two parts:

- Recovery from crashes: ACID
- Concurrency control: ACID

Both operate on the buffer pool

Our current focus: recovery

Buffer Manager



- Data must be in RAM for DBMS to operate on it!
- Buffer pool = table of <frame#, pageid> pairs

Buffer Manager Policies

- **STEAL or NO-STEAL**
  - Can an update made by an uncommitted transaction overwrite the most recent committed value of a data item on disk?
- **FORCE or NO-FORCE**
  - Should all updates of a transaction be forced to disk before the transaction commits?
- Easiest for recovery: NO-STEAL/FORCE
- Highest performance: STEAL/NO-FORCE

Comparison Undo/Redo

- Undo logging:
  - OUTPUT must be done early
  - If <COMMIT T> is seen, T definitely has written all its data to disk (hence, don't need to redo) – inefficient

  Steal/Force
- Redo logging
  - OUTPUT must be done late
  - If <COMMIT T> is not seen, T definitely has not written any of its data to disk (hence there is not dirty data on disk, no need to undo) – inflexible

  No-Steal/No-Force
- Would like more flexibility on when to OUTPUT: undo/redo logging (next)

  Steal/No-Force

Aries Recovery Algorithm

- An UNDO/REDO log with lots of clever details

Write-Ahead Log

- Enables the use of STEAL and NO-FORCE
- **Log: append-only file containing log records**
- For every update, commit, or abort operation
  - Write physical, logical, or physiological log record (more later)
  - Note: multiple transactions run concurrently, log records are interleaved
- After a system crash, use log to:
  - Redo some transaction that did commit
  - Undo other transactions that didn't commit

Write-Ahead Log

- All log records pertaining to a page are written to disk before the page is overwritten on disk
- All log records for transaction are written to disk before the transaction is considered committed
  - Why is this faster than FORCE policy?
- **Committed transaction**: transactions whose commit log record has been written to disk

Granularity in ARIES

- Page-oriented logging for REDO (element=one page)
- Logical logging for UNDO (element=one record)
- Result: logs logical operations within a page
- This is called *physiological logging*
- Why this choice?
  - Must do page-oriented REDO since cannot guarantee that db is in an action-consistent state after crash
  - Must do logical undo because ARIES will only undo loser transactions (this also facilitates ROLLBACKs)

ARIES Method

Recovery from a system crash is done in 3 passes:

1. **Analysis pass**
   - Figure out what was going on at time of crash
   - List of dirty pages and active transactions
2. **Redo pass (repeating history principle)**
   - Redo all operations, even for transactions that will not commit
   - Get back to state at the moment of the crash
3. **Undo pass**
   - Remove effects of all uncommitted transactions
   - Log changes during undo in case of another crash during undo

ARIES Method Illustration

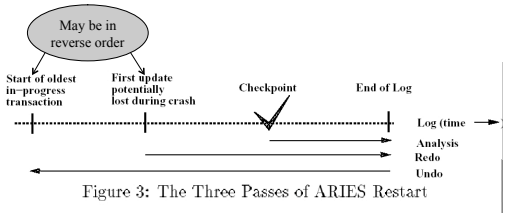


Figure 3: The Three Passes of ARIES Restart

[Franklin97]

ARIES Data Structures

- Active Transactions Table
  - Lists all running transactions (active transactions)
  - For each txn: lastLSN = most recent update by transaction
- Dirty Page Table
  - Lists all dirty pages
  - For each dirty page: recoveryLSN (recLSN)= first LSN that caused page to become dirty
- Write Ahead Log contains log records
  - LSN, prevLSN = previous LSN for same transaction
  - other attributes

ARIES Data Structures

Dirty pages

pageID	recLSN
P5	102
P6	103
P7	101

Log

LSN	prevLSN	transID	pageID	Log entry
101	-	T100	P7	
102	-	T200	P5	
103	102	T200	P6	
104	101	T100	P5	

Active transactions

transID	lastLSN
T100	104
T200	103

Buffer Pool

P5 PageLSN=104	P6 PageLSN=103	P7 PageLSN=101

The LSN

- Each log entry receives a unique *Log Sequence Number*, LSN
  - The LSN is written in the log entry
  - Entries belonging to the same transaction are chained in the log via **prevLSN**
  - LSN's help us find the end of a circular log file:

After crash, log file = (22, 23, 24, 25, 26, 18, 19, 20, 21)
Where is the end of the log ? 18

ARIES Method Details

- Steps under normal operations
  - Add log record
  - Update transactions table
  - Update dirty page table
  - Update pageLSN

ARIES Method

- More details and long example on the board
- Please TAKE NOTES!

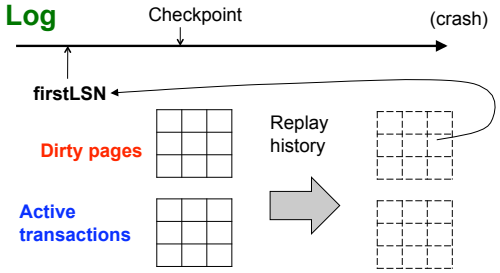
Checkpoints

- Write into the log
  - Entire active transactions table
  - Entire dirty page table
- Very fast ! No waiting, no END CKPT
- But, effectiveness is limited by dirty pages
  - There is a background process that periodically sends dirty pages to disk

1. Analysis Phase

- Goal
  - Determine point in log where to start REDO
  - Determine set of dirty pages when crashed
    - Conservative estimate of dirty pages
  - Identify active transactions when crashed
- Approach
  - Rebuild active transactions table and dirty pages table
  - Reprocess the log from the beginning (or checkpoint)
    - Only update the two data structures
  - Compute: **firstLSN** = smallest of all recoveryLSN

1. Analysis Phase



2. Redo Phase

Main principle: replay history

- Process Log forward, starting from **firstLSN**
- Read every log record, sequentially
- Redo actions are not recorded in the log
- Needs the Dirty Page Table

2. Redo Phase: Details

For each Log entry record LSN

- If affected page is not in Dirty Page Table then **do not update**
- If recoveryLSN > LSN, then **no update**
- Read page from disk;
  If **pageLSN** > LSN, then **no update**
- Otherwise perform update

3. Undo Phase

Main principle: "logical" undo

- Start from the end of the log, move backwards
- Read only affected log entries
- Undo actions *are* written in the Log as special entries: CLR (Compensating Log Records)
- CLRs are redone, but never undone

3. Undo Phase: Details

- "Loser transactions" = uncommitted transactions in Active Transactions Table
- **ToUndo** = set of lastLSN of loser transactions
- While **ToUndo** not empty:
  - Choose most recent (largest) LSN in **ToUndo**
  - If LSN = regular record: undo; write a CLR where CLR.undoNextLSN = LSN.prevLSN; if LSN.prevLSN not null, insert in **ToUndo** otherwise, write <END TRANSACTION> in log
  - If LSN = CLR record: (don't undo !)
    if CLR.**undoNextLSN** not null, insert in **ToUndo**
    otherwise, write <END TRANSACTION> in log

Handling Crashes during Undo

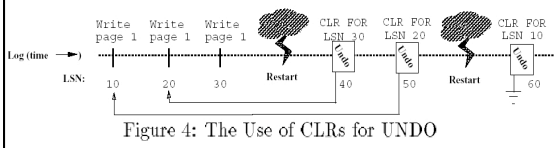


Figure 4: The Use of CLRs for UNDO

[Figure 4 from Franklin97]