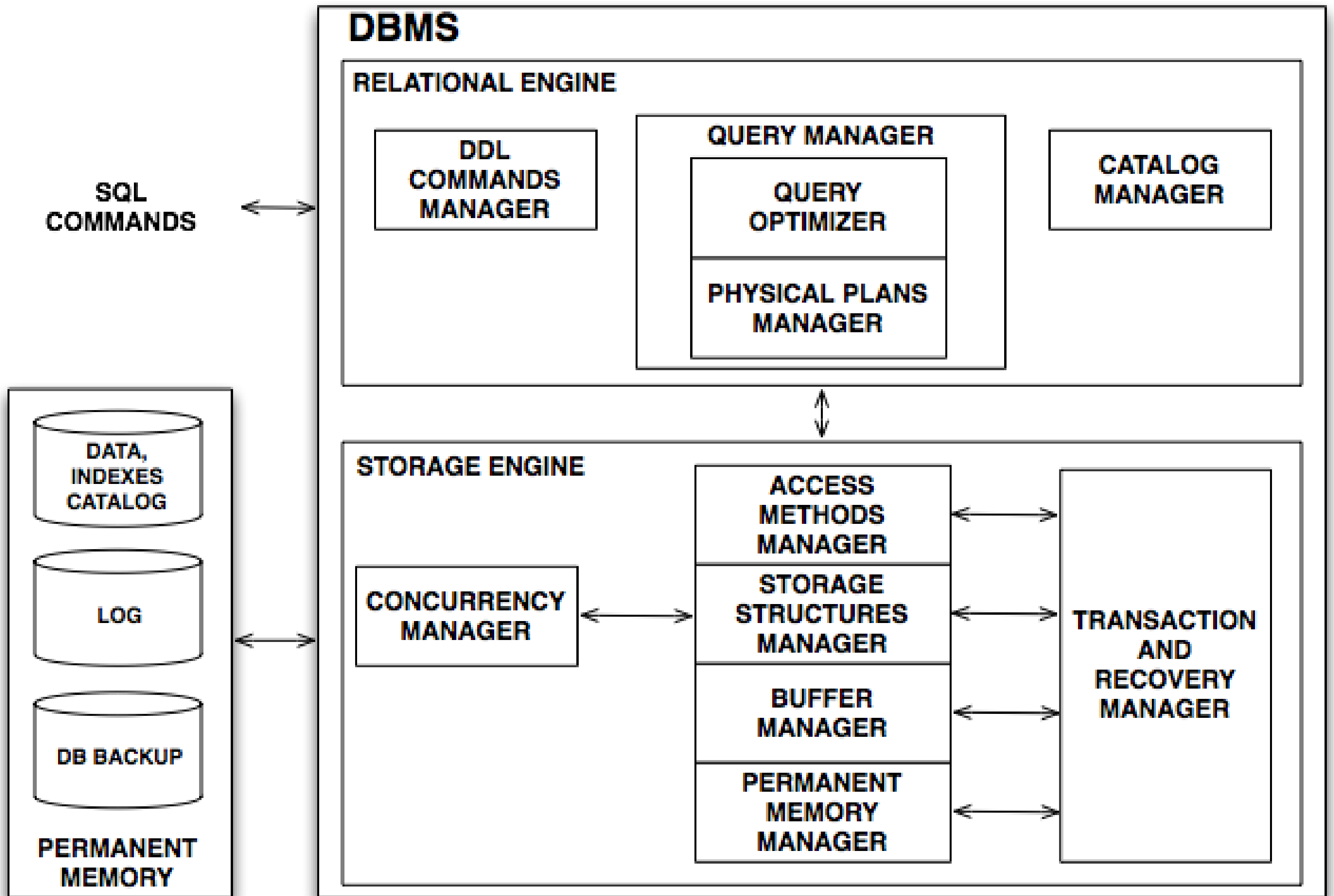
DBMS ARCHITECTURE



Transactions

- A transaction: a sequence of one or more SQL operations (interactive or embedded):
  - declared by the programmer to constitute a unit
  - treated by the DBMS as one unit

Transactions

- A transaction is a sequence of operations on the database and on temporary data, with the following properties:
  - Atomicity: Only successful transactions change the state of the database
  - Isolation: Transactions behave as if they were executed in isolation from each other
  - Durability: If the DBMS crashes after a transaction commits, all effects of the transaction must remain in the database

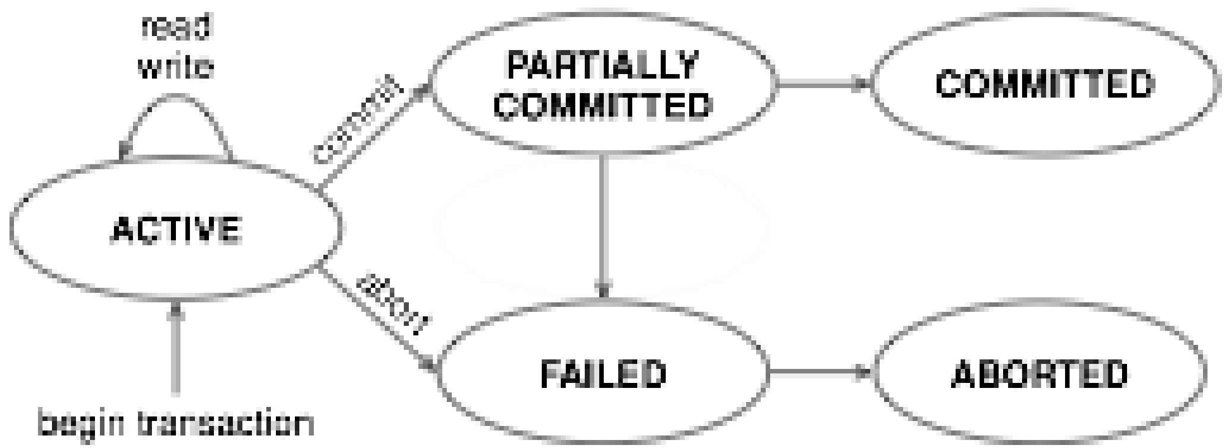
Transaction management

- Transaction properties:
  - Atomicity, Consistency, Isolation, Durability - ACID
  - The Recovery Manager guarantees Atomicity & Durability.
  - Isolation: Concurrency Control Manager
  - Consistency:
    - Integrity constraints
    - Code correctness
    - Combined with Atomicity, Isolation, Durability
- Isolation and Serializability

Transactions for the DBMS

- For the DBMS, a transaction T makes read/write operations on the database
- To read a page $r_i[x]$ it is first brought into the buffer from the disk, if it is not already in the buffer pool
- To write a page $w_i[x]$ an in-memory copy of the page is first modified and is later written to disk, only when the buffer manager decides to do it
- This has to be made compatible with Atomicity and Durability

Lifecycle of a transaction



- Read/Write and Commit are execute by the system when required by the transaction
- The rollback (abort) transition is executed under request or by the system

Kinds of failure

- Transaction failure is an interruption of a transaction which only affects the state of the transaction
- System failure is a failure of the system (either the DBMS or the computer) which may have affected the content of main memory – persistent store is safe
- Media failure (aka *disaster*) also affects persistent store

Protection from failures

- DB backup.
- Log file (for simplicity assume not buffered):
  - (**begin**, T)
  - (**commit**, T)
  - (**abort**, T)
  - For each write: (**write**, T, P, BeforeImage, AfterImage)
- LSN
- Recovery: re-execute log operations on the DB backup (details later)

Faster recovery through Checkpoint

- Commit consistent CKP:
  - Do not accept new transactions
  - Wait until all transactions finish
  - Flush all buffer “dirty” pages to disk
  - Write CKP record to the log file
- Buffer consistent CKP - V1:
  - Do not accept new transactions
  - Suspend active transactions
  - Flush all buffer “dirty” pages to disk.
  - Write CKP record (with list of active T ids) to the log fil

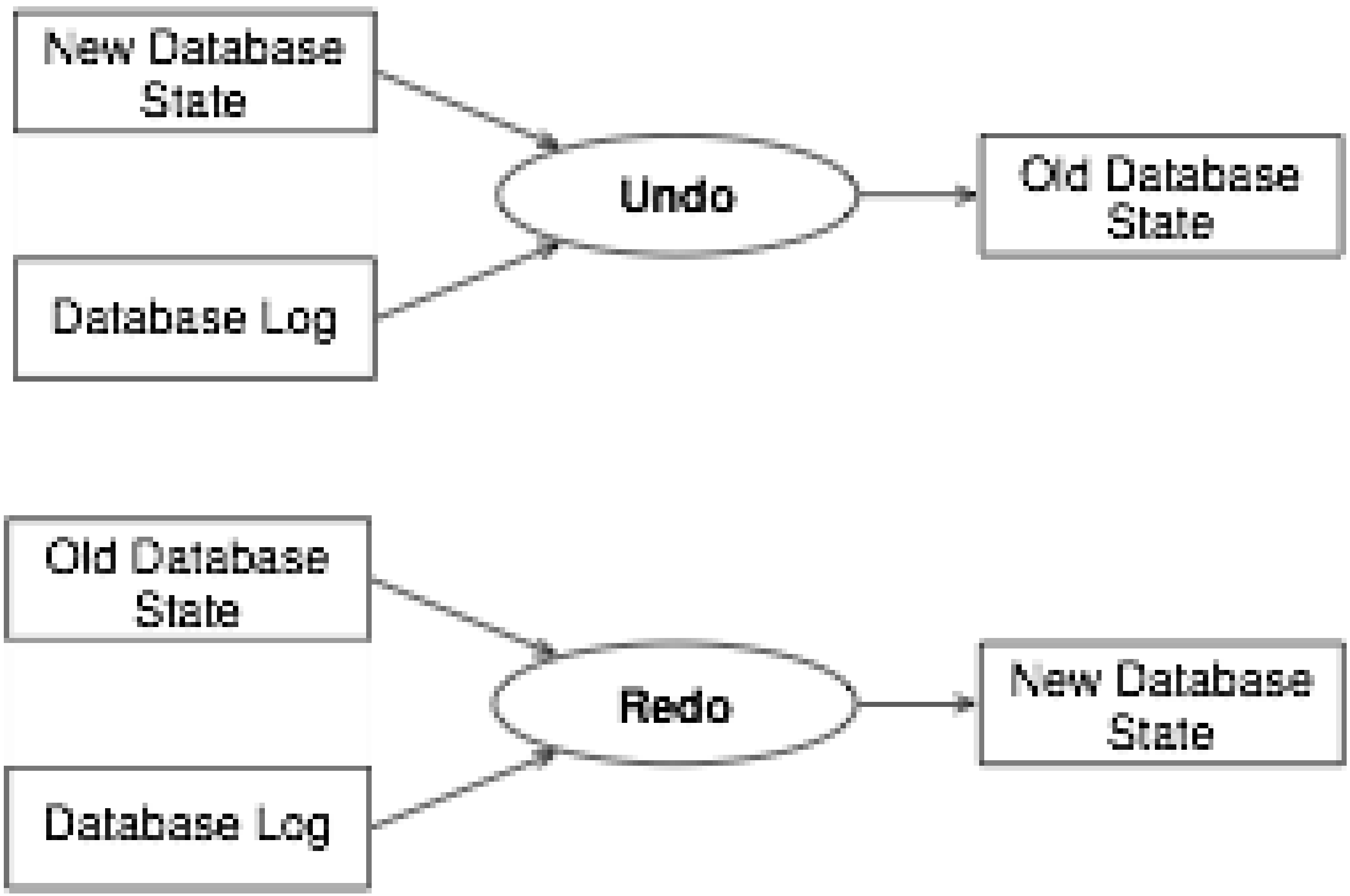
Faster recovery through Checkpoint

- No stop checkpoint:
  - Write begin-CKP record (with list of active T ids) to the log file
  - Start a new thread that scans the buffer and flush buffer "dirty" pages to disk in parallel with the standard transactions – guaranteeing that all pages that were dirty at begin-CKP time are flushed before end of CKP
  - Write end-CKP record to the log file
- Guarantee:
  - For any end-CKP in the log, every update performed before the corresponding begin-CKP is on disk

ARIES algorithm checkpoint

- Rather then flushing the pages, it stores the information that is needed, at restart time, to know which operations have to be redone, i.e.:
  - for each dirty page:
    - Its address
    - The LSN of the first record that made page dirty
  - For each transaction:
    - Status, and last LSN if active
- Fuzzy checkpoint: empty <begin chkpoint> and, later, the actual checkpoint information record
- ARIES redoes everything and then undoes

Undo, Redo algorithms



Recovery algorithms

- The methods for transactions management differ for the use of the undo and redo algorithms to recover a database after a failure, e.g. how write operations on the DB and commits are managed.
  - Undo–Redo: Steal Policy (a new T may steal the buffer), NoForce Policy (write of buffer is not forced)
  - Undo–NoRedo: Steal, ***Force***
  - NoUndo–Redo: ***NoSteal (Pin)***, NoForce
  - NoUndo–NoRedo: ***NoSteal (Pin)***, ***Force***
- Hyp: a write to the log is forced to the permanent memory

Undo - NoUndo

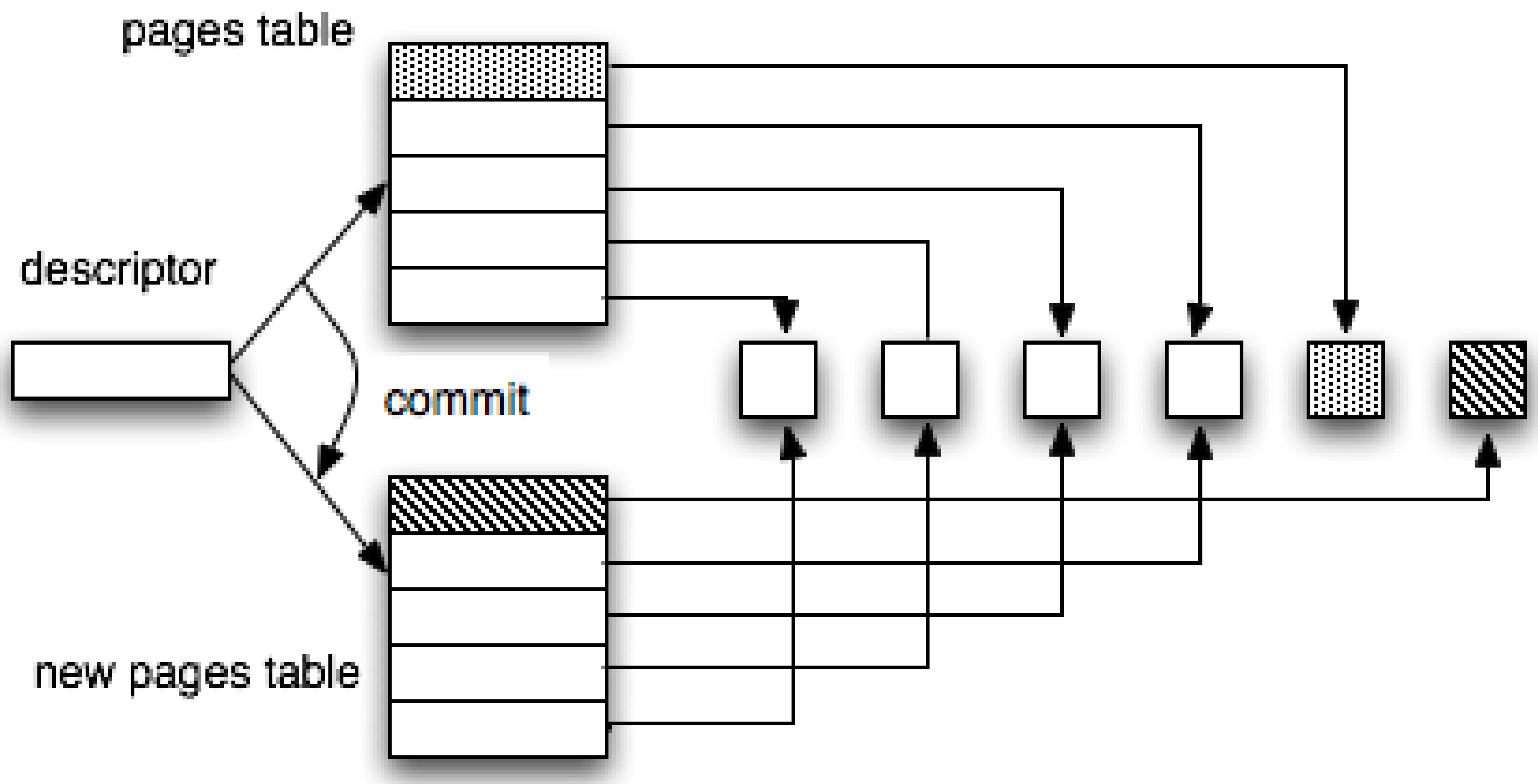
- Constraints on write:
  - NoUndo:
    - Deferred updates
  - Undo:
    - Free update (or *immediate* update or *buffer stealing*):
    - Rule for undoing updates: Log Ahead Rule or Write Ahead Log: save the before images before writing

Redo - NoRedo

- Constraint on commit:
  - NoRedo:
    - Deferred commit: all modified pages have to be flushed before commit: force writes
  - Redo:
    - No constraints on commit, immediate commit: commit now, flush when you like (NoForce)
    - Rule for redoing: Save the after images before committing

Shadow Pages: No-undo and No-redo

NoUndo NoRedo: needs the ability to write many pages atomically – shadow pages



Choice among the different solutions

- Undo – Redo is the best one

Example of undo-redo implementation

- **beginTransaction**()
  - T := newTransactionIde();
    Log.append(begin, T);
    return(T).
- **write**(T, P, V)
  - Buffer.getAndPinPage(P);
    BI := page P; AI := V;
    Log.append(Write, T, P, BI, AI);
    Buffer.updatePage(P, V);
    Buffer.unpinPage(P).

Implementation

- **commit**(T)
  - Log.append(commit, T)
- **abort**(T)
  - Log.append(abort, T);
    for each (write, T, P, BI, AI) $\in$Log with
    do Buffer.undoPage(P, BI)

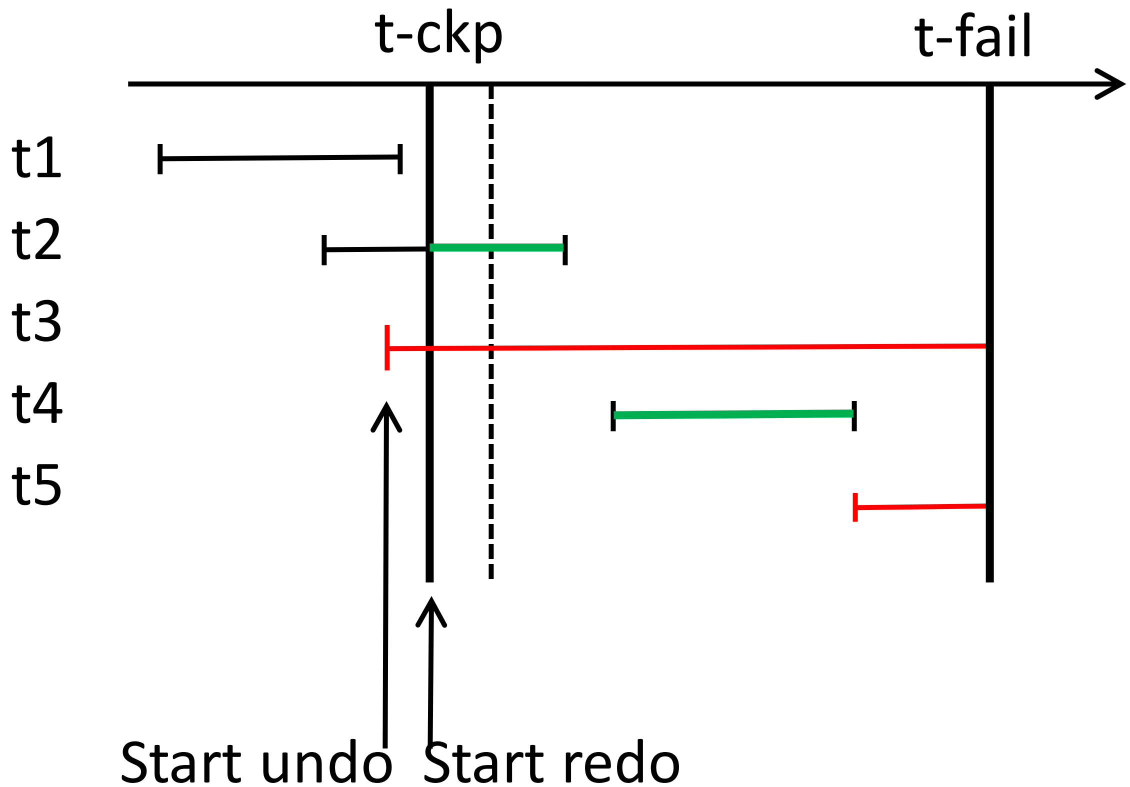
Restart

- **restart**()
  - **for each** (**begin**, T)$\in$Log
    do if (**commit**, T)$\notin$Log
        then add(T,listUndo);
    for each (write, T, P, BI, AI)$\in$Log
    order by LSN
    do if T$\in$listUndo **then** Buffer.undoPage(P, AI)
                                    else Buffer.redoPage(P, BI)

Recovery (undo-redo)

- Transction failure:
  - Undo(T)
- System failure
  - Undo/redo
- Media failure
  - Use the DB backup and redo committed transactions

Restart



Restart with CKP

- Restart:
  - ckp=**false**; toUndo=toRedo=**{}**;

```
for backward r in log                          -- rollback
until (ckp and empty(toUndo)) {
  if r = (commit,T)   then toRedo+={T};
  elsif r = (write,T,x,bi,ai) and not (T in toRedo)
                      then {toUndo+={T}; undo(x,bi)}
  elsif r = (begin,T)   then toUndo-={T}
  elsif r = (b-ckp,TList) then {ckp=true;
                                toUndo+=TList-toRedo}
}
rollForward(toRedo);
```

RollForward

- RollForward(toRedo):
  - **for** r **in** log **starting from last begin-ckp**
    until (**empty**(toRedo)) {
    if r = (**commit**,T) **then** toRedo-={T};
    elsif r = (write,T,x,bi,ai) **and** (T **in** toRedo)
    then {redo(x,ai)}
    }

Buffer and Log

- Where is restart executed – log or persistent store?
- What happens if there is a failure during restart?

Common optimizations

- Log granularity is at record (or field) level, not at page level
- Log is buffered
- Pages contain the LSN of the last operation executed
- Undo actions are logged
- Each log entry has the LSN of the previous log entry of the same transaction