Recovery Theory

Storage Types

- *Volatile* storage
  - main memory, which does not survive crashes.
- *Non-volatile* storage
  - tape, disk, which survive crashes.
- *Stable* storage
  - information in stable storage is "never" lost.
  - There is no such physical medium; it is an approximation that is implemented.

Failure Types

- *Program Failures*
  - logical errors, bad input, unavailable data, user cancellation
  - resource limits
- *System Failures*
  - computer hardware malfunction, power failures
  - bugs in O.S, operator error
- *Media Failures*
  - disk head crash, data transfer error,
  - disk controller failure
- *Unrecoverable errors*
  - failure to make archive dumps
  - destruction of archives

Theory of Recovery

The goals of the recovery system are:

- When a transaction *T* ***commits***
  - Make the updates permanent in the database so that they can survive subsequent failures.
- When a transaction *T* ***aborts***
  - Obliterate any updates on data items by aborted transactions in the database.
  - Obliterate the effects of *T* on other transactions; i.e., transactions that read data items updated by *T*.
- When the system ***crashes*** after a system or media failure
  - Bring the database to its most recent consistent state.

Recovery Actions

- Recovery protocols implement two actions:
  - *Undo* action: required for atomicity.
    Undoes all updates on the stable storage by an uncommitted transaction.
  - *Redo* action: required for durability
    Redoes the update (on the stable storage) of committed transaction.

Recovering from Failures

- *Program Failures* — *Transaction Undo*
  - *Removes all the updates of the aborted transaction*
  - *Does not affect any other transaction*
- *System Failures* — *Global Undo*
  Partial Redo
  - *Effects of committed transactions are reflected in the database*
- *Media Failures* — *Global Redo*

Cascading Aborts

- Consider the execution:
  $w_1(x)\ r_2(x)$
  - If T_1 aborts, T_2 must also abort.
  - T_2 has an ***abort dependency*** on T_1.
- In general, any transaction that reads data items updated (written) by a transaction that aborts must also be aborted.
- What will happen if T_2 is committed before T_1 is aborted?
  $w_1(x)\ r_2(x)\ c_2\ \alpha_1$

  The system cannot abort T_2 without violating the semantics of commit operations.

Recoverable Executions (RC)

- To prevent unrecoverable situations the TM must keep full track of read/write operations and delay commit requests of transactions.
- Definition:
  A transaction T_m ***reads*** x from transaction T_n in an execution if
  1. T_m reads x after T_n has written into it
  2. T_n does not abort before T_m reads x and
  3. $\forall\ T_k$: $w_{Tk}(x)$ occurred between $w_{Tn}(x)$ and $r_{Tm}(x)$, α_{Tk} precedes $r_{Tm}(x)$.

Recoverable Executions (RC) …

- Definition:

  An execution is *recoverable* (**RC**) if for every transaction T_n commits, T_n 's commit follows the commitment of every transaction T_m from which T_n reads.

- **RULE 0:**

  Delay the commit of a transaction that reads uncommitted data.

Effects of Cascading Aborts

- Significant bookkeeping of who updated what and who read what is required.
- Transactions may be forced to abort because some other transaction happened to abort and all the effects of the aborted transaction need to be undone (isolation ?).
- Significant amount of computation may be lost due to cascading aborts.
- In practice, most DBMS are designed to avoid cascading aborts.

Avoiding Cascading Aborts (ACA)

- Definition:

  An execution avoids cascading aborts (ACA) if whenever a transaction T_n reads data updated by T_m , T_m has already committed.

- That is it ensures that every transaction reads only those values there were written by committed transactions.
- This means the DBMS must delay each *r(x)* until all transactions that previously issued a *w(x)* have either *aborted* or *committed*.
- **RULE 1:** Do not permit reading of uncommitted data.
  - Note rule 1 is stronger than Rule 0 (the necessary condition for recoverability).

Undoing Writes

Assume

- Database = { x, y } with initial values x = 1, y = 0
- Transactions:

  T1: write(x, 2); write(y, 3); abort

  T2: write(x, 8); write(y, 9); abort

An interleaved execution

T1	T2	before image of
	write(x, 8)	x = 1
	write(y, 9)	y = 0
write(x, 2)		x = 8
	abort	
write(y, 3)		y = 0
abort		

- when T2 aborts
  - x = before image of $w_2(x, 8)$ => x = 1
  - y = before image of $w_2(y, 9)$ => y = 0
- when T1 aborts
  - x = before image of $w_1(x, 2)$ => x = 8
  - y = before image of $w_1(y, 3)$ => y = 0

The Lost Update Problem

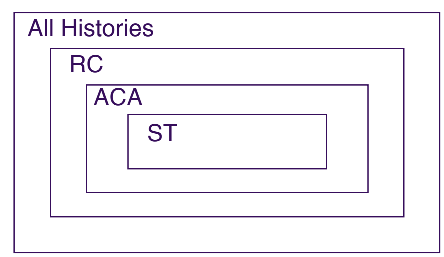
Assume
  Database = { x, y }
    initially x = 1, y = 0
  Transactions:
    T1: write(x, 2); write(y, 3); abort
    T2: write(x, 8); write(y, 9); commit
Consider the following execution
    $w_1(x, 2); w_2(x, 8); w_2(y, 9); c_2; w_1(y, 3); \alpha_1$
  What is the state of the database after this execution ?

Strict Executions

- To solve the undoing writes problem, we must delay the execution of a write(x, val) operation until the transaction that has previously written x terminates, i.e., commits or aborts.
- Definition:
  An execution is strict (ST) if it avoids cascading aborts and overwriting of uncommitted data; i.e., it is ACA and RC.
- That is, a transaction T_n can read or write a data item updated (written) by T_m only after T_m commits or aborts.
- **RULE 2:** Do not permit overwriting of uncommitted data.

Recovery Correctness Criteria

RC $\supset$ ACA $\supset$ ST



Reliability and Serializability