ARIES: A Transaction Recovery Method

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(Modified from George Tsiknis' CPSC 304 slides and Ramakrishnan and Gehrke's slides from "Database Management Systems")

Discussion by Sampoorna Biswas

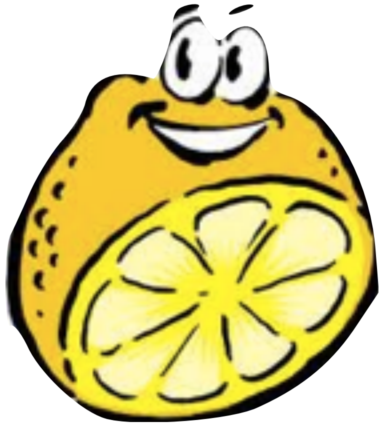
ARIES

What did we read?

- Super long survey paper
- Basically covers all the intricate details of ARIES
- Gives an idea of how complicated it is to implement a system that allows for transaction rollback and recovery

Review: Transactions

- A transaction is a set of read and write operations that are executed as one unit
- One of four states:
  - **Active**: making progress
  - **Failed**: cannot continue due to some type of error
  - **Aborted**: DB had to roll back to a previous save point
  - **Committed**: finished without running into an error



Review: ACID

- **Atomicity**: Either all actions in the transaction occur, or none occur.

- **Consistency**: If each transaction is consistent, and the DB starts in a consistent state, then the DB ends up being consistent.

- **Isolation**: The execution of one transaction is isolated from that of other transactions.

- **Durability**: If a transaction commits, then its effects persist.

Buffer Pool Management

- Data objects are stored on pages in a database (stable storage)
- Whenever an object is modified, the page that it is on needs to be fetched to the memory buffer
  - Page becomes **dirty**
- Save values by writing dirty pages to disk

Buffer Management Policy

- **Steal**: Write pages to disk and take the buffer regardless of transaction state

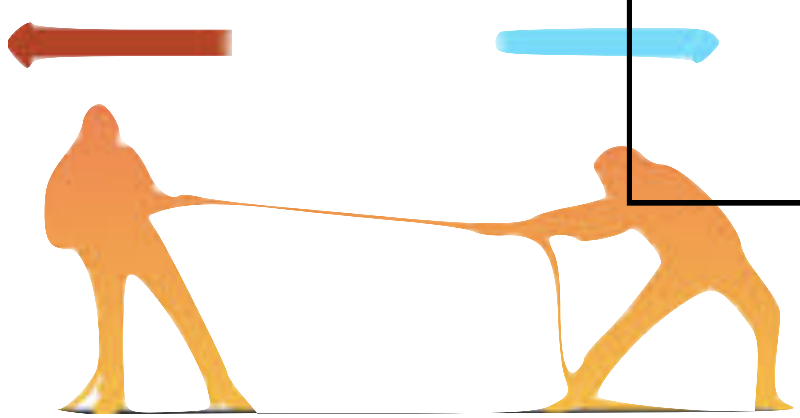
- **No-steal**: Keep a page in memory if it has been updated by an active transaction

- **Force**: Write all the pages modified by a transaction to disk when the transaction commits

- **No-force**: Write pages to disk when buffer space is needed; doesn't care about when a transaction commits

Buffer Management Policy

	No Steal	Steal
Force	Trivial for A & D	
No Force		Difficult for A & D



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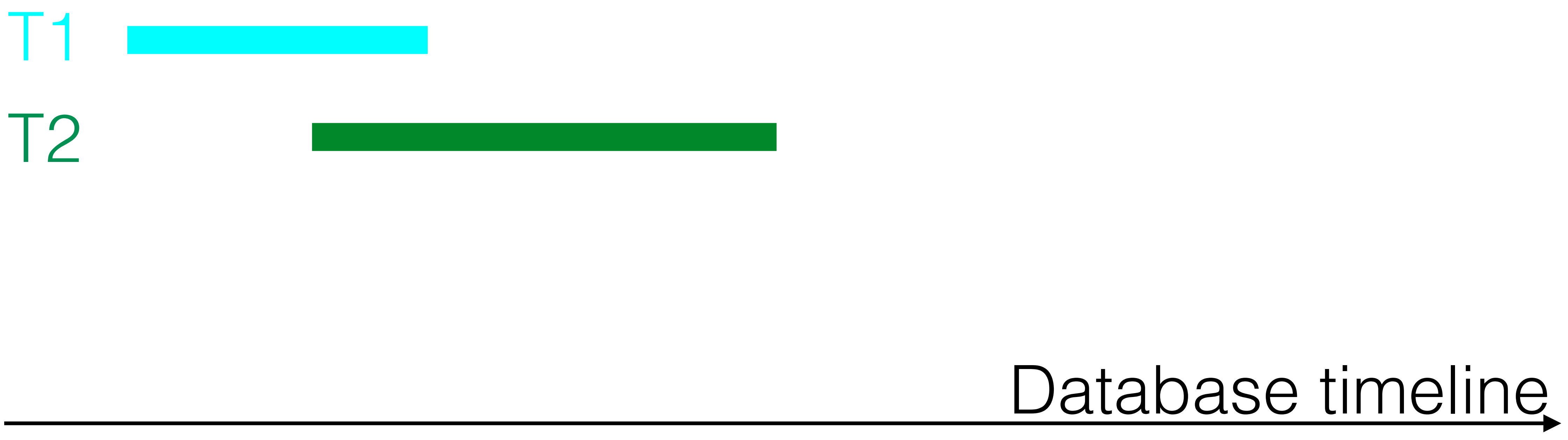

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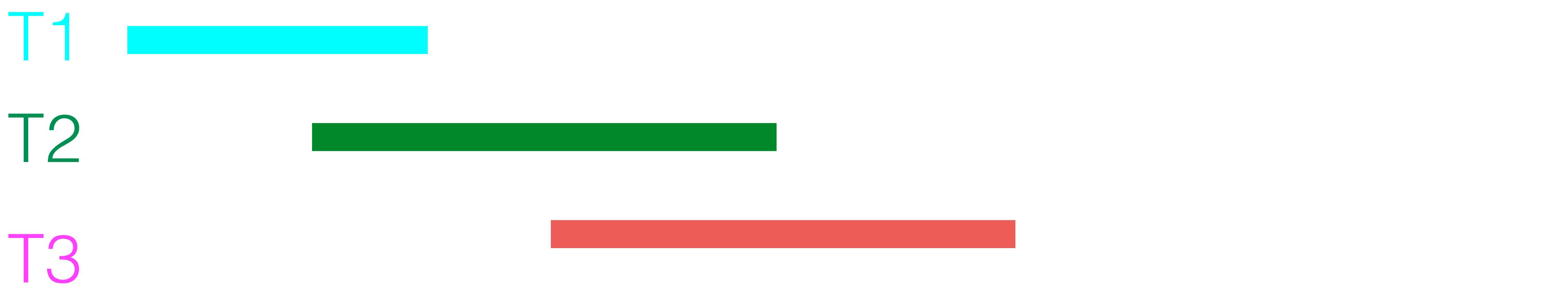

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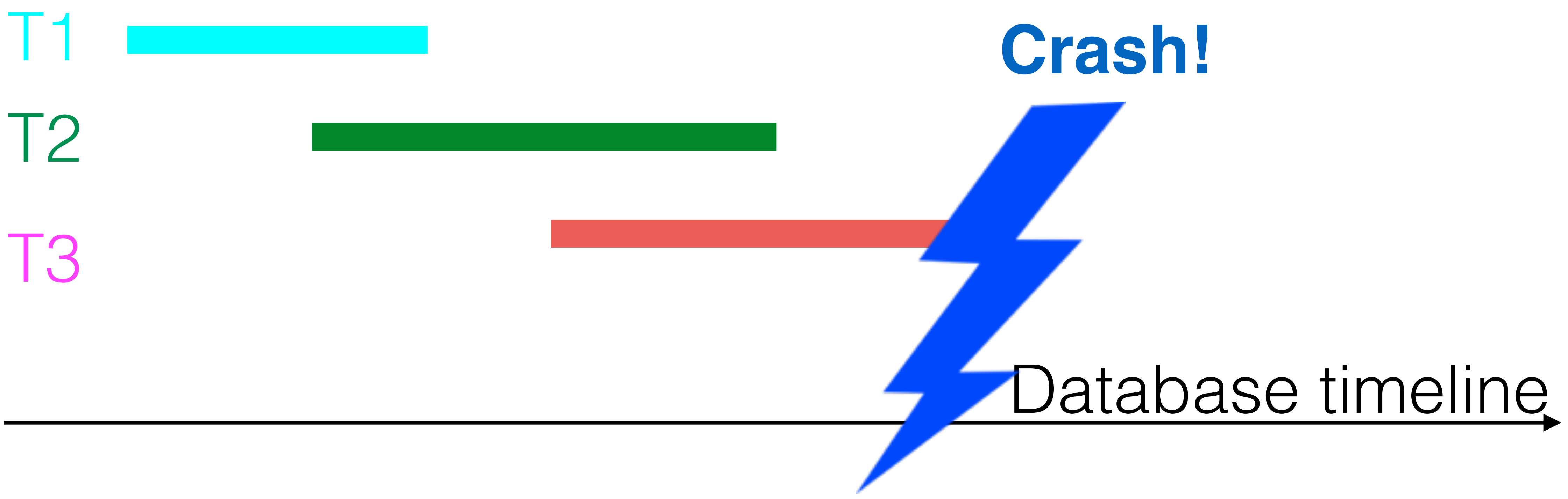

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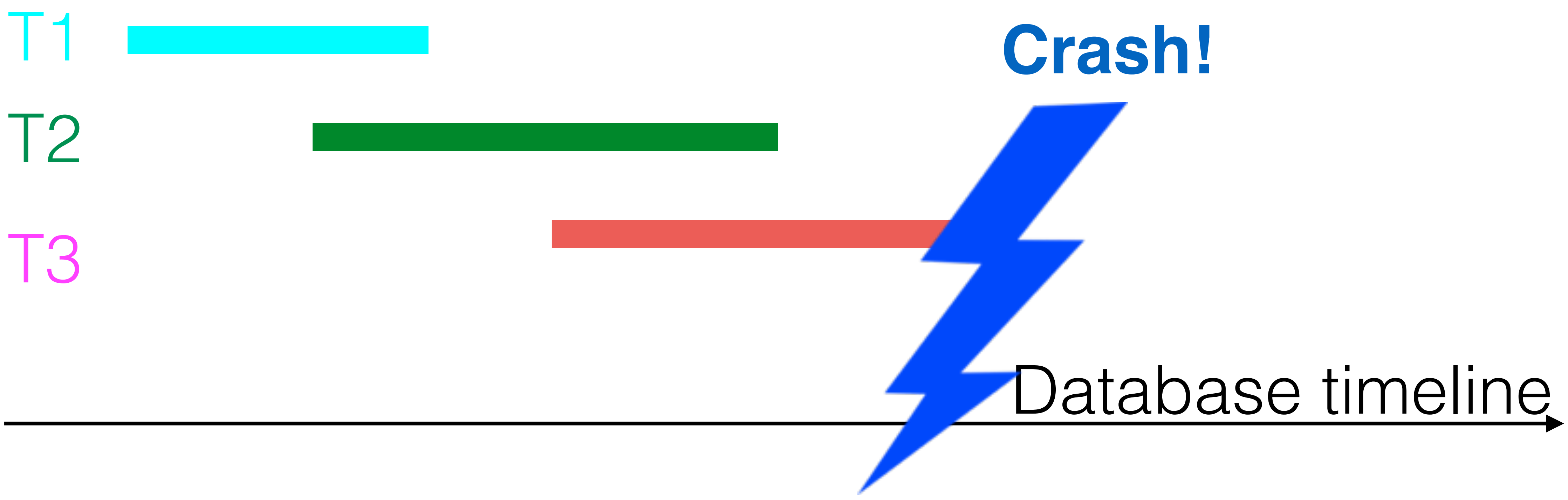


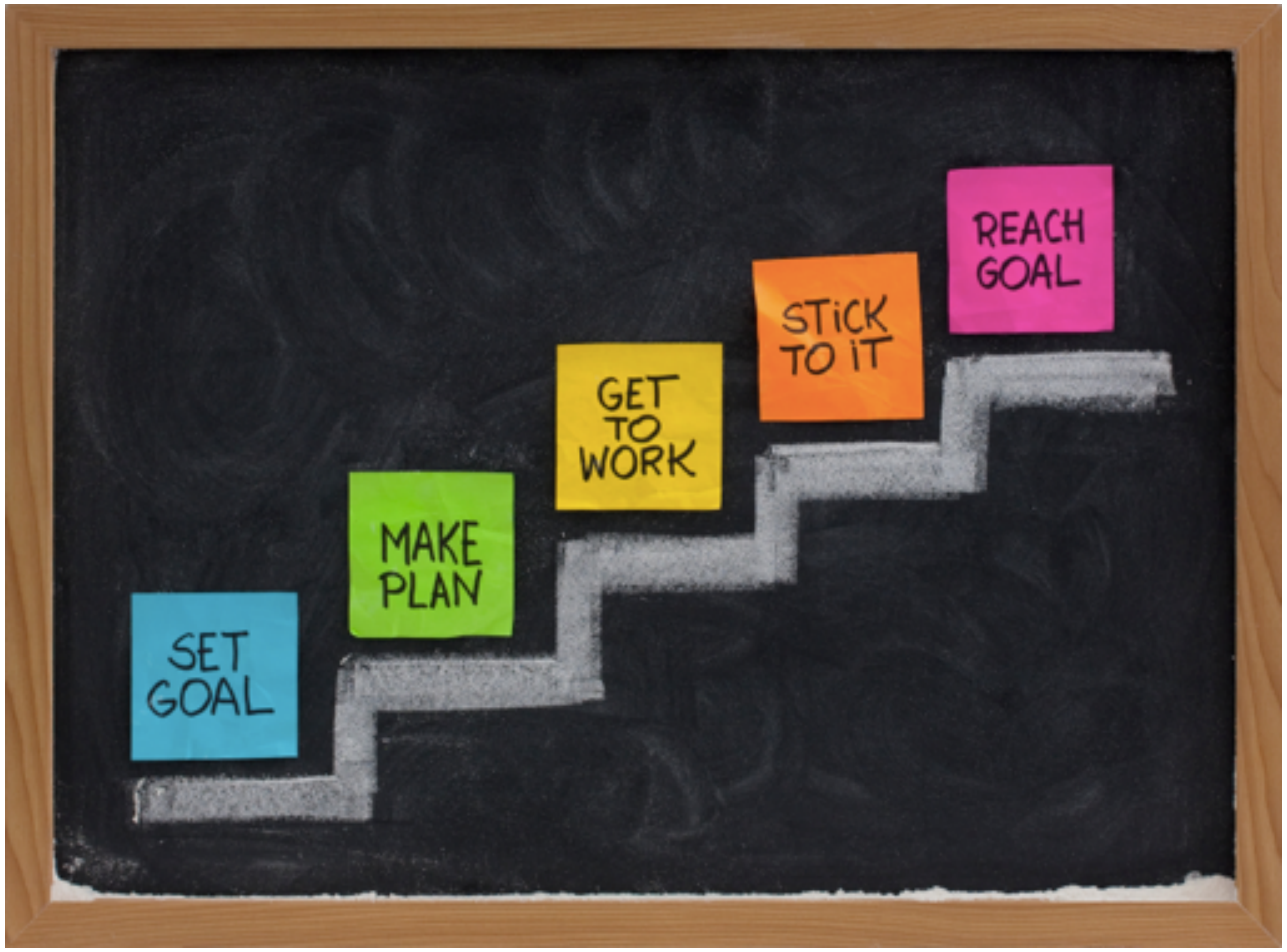
What do we want the state of the server to look like after restart?

ARIES

- Algorithm for Recovery and Isolation Exploiting Semantics
- Algorithm used for database recovery after a database crash
- Created based on nine goals

ARIES Goals

- Simplicity
- Operation Logging
- Flexible storage management
- Partial rollbacks
- Flexible buffer management
- Recovery independence
- Logical undo
- Parallelism and fast recovery
- Minimal overhead



Discussion Question

- **Small groups!**
  - Five minutes group discussion

- Each group randomly picks a piece of paper with ONE Goal on it.
- 1-2 sentences on the ONE Goal your group picks and its challenge
- Vote for the 2 most and 2 least important goals
- Pick one of your votes explain why you voted it as such **OR** add and justify one more goal you think that is important but not listed here.

ARIES: Logging

- Uses a log to keep track of all database changes
  - Record the old and new values of an item for undo/redo purposes
- **WAL** = Write Ahead Logging
  - Forces the writing out of a log record before the corresponding data page gets to disk.
  - Must write all log records for a transaction before commit.

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  - Must write all log records for a transaction before commit. **=> durability**

ARIES: Logging

- Each log has a unique number, a **log sequence number (LSN)**
  - LSN always increases

- Each data page has a **pageLSN** that records the last LSN number that modified it

ARIES: Logging

- There are different types of logs possible:
  - Update: created during page modification
  - Commit: log forcibly written to stable storage
  - Abort
  - End: created for both aborted and committed transactions
  - Compensation Log Records (CLRs): used during undos

ARIES: Logging

- Different types of log records can hold differing amounts of information:
    - prevLSN
    - transID
    - type
    - pageID
    - length
    - offset
    - before-image
    - after-image
    - undoNextLSN

Update records only

CLR records only

ARIES: Logging

- The **transaction table** stores all active transactions
    - Contains transID, state, LastLSN, UndoNxtLSN
- Transactions removed from table when the transaction has ended

ARIES: Logging

- The **dirty pages table** stores information about dirty buffer pages
  - Each table entry has PageID and RecLSN
    - RecLSN is the LSN of the action that first made the page dirty

ARIES: Checkpoint

- Helps us not have to rollback super far if the system crashes
- Write to the log:
  - begin_checkpoint record
  - end_checkpoint record: stores the current transaction table and dirty page table
- ARIES stores the LSN of the checkpoint record in a safe place **=> fuzzy checkpoint**

ARIES: Crash Recovery

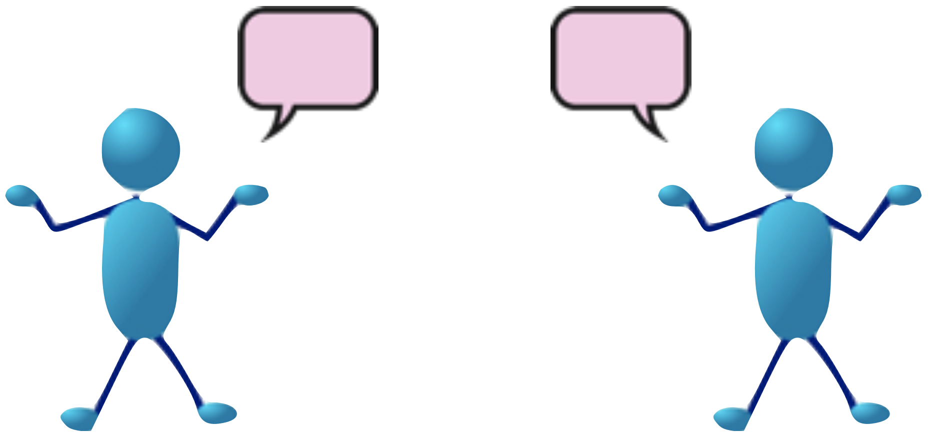
- Three phases:
  - **Analysis**: examine the transactions that have occurred between the crash point and the last check point
  - **Redo**: redo all actions from RecLSN onward
  - **Undo**: undo the effects of the failed transactions from end to first LSN of oldest transaction active at crash time

ARIES: Analysis

- **Goal**: figure out where Redo needs to start at,and what transactions need to be rolled back
- Use the last end_checkpoint record to reconstruct the transaction table and the dirty page table
- Starting from end_checkpoint, update the transaction table and dirty page table according to what the log lists
    - Results in knowing what the smallest LSN in the dirty page table is (i.e., where Redo starts)

Discussion Question

- If you were designing a transaction processing system, would you do a checkpoint after the analysis phase? Why or why not?

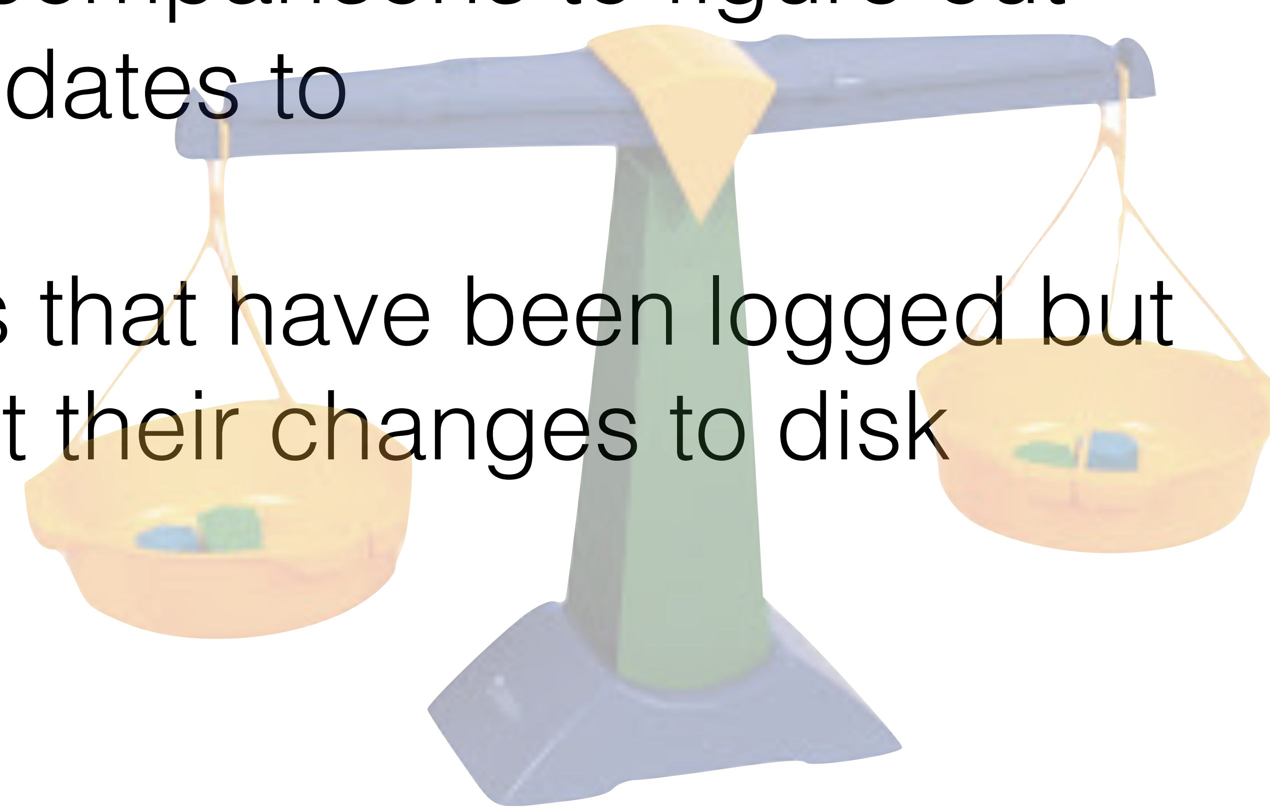


ARIES: Redo

- **Goal**: Repeat history to **reconstruct database state that was present during crash time**

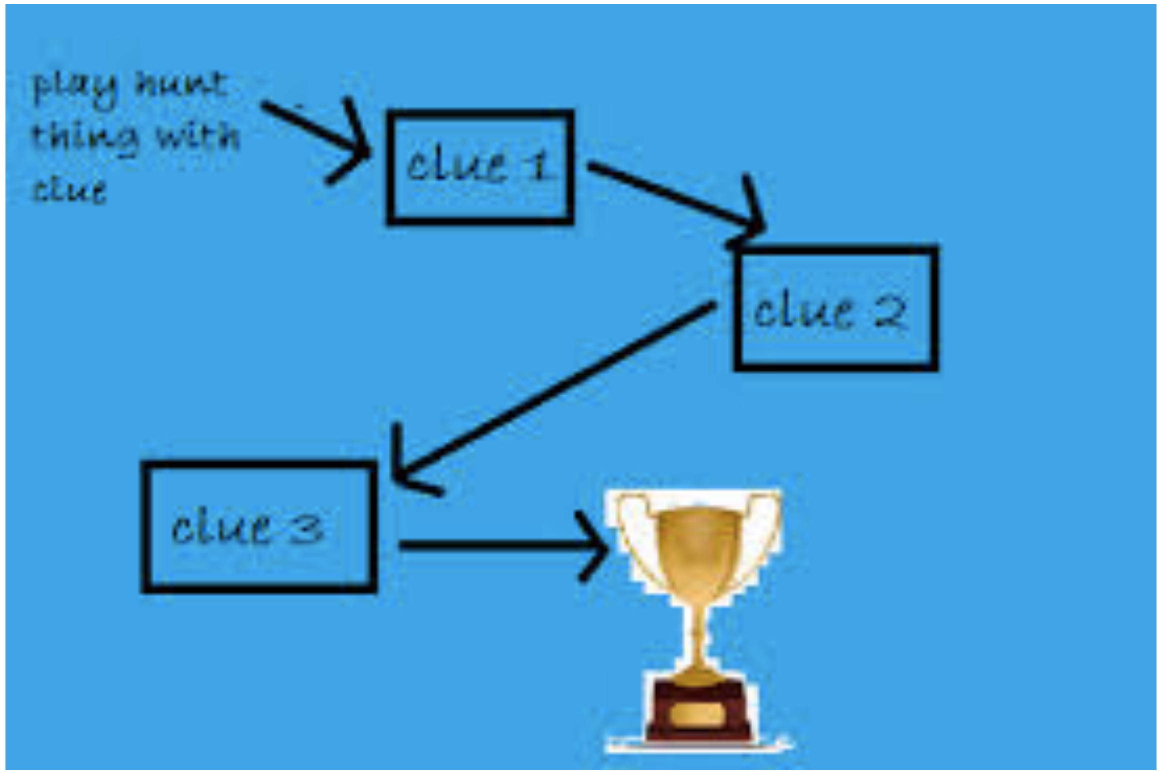
- Uses LSN and recLSN comparisons to figure out which pages to redo updates to

  - Reapplies all updates that have been logged but did not manage to get their changes to disk before crash



ARIES: Undo

- **Goal**: Undo effects of failed transactions
- **Loser transactions**: transactions active at crash
- Need to undo all loser transactions in reverse order
- Follow the lastLSN of each loser transaction until all effects of the transaction have been undone



Crash Recovery Example

LSN	Log
00, 05	begin_checkpoint, end_checkpoint
10	update: T1 writes P5
20	update: T2 writes P3
30	T1 abort

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LSN	Log
00, 05	begin_checkpoint, end_checkpoint
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Analysis and Redo phase get us here

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Undo phase

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40, 45	CLR: Undo T1 LSN 10 T1 End
50	update: T3 writes P1
60	update: T2 writes P5
	CRASH, RESTART
70	CLR: Undo T2 LSN 60

UndoNext LSN = 20

Undo phase

Crash Recovery Example

LSN	Log
00, 05	begin_checkpoint, end_checkpoint
10	update: T1 writes P5
20	update: T2 writes P3
30	T1 abort
40, 45	CLR: Undo T1 LSN 10 T1 End
50	update: T3 writes P1
60	update: T2 writes P5
	CRASH, RESTART
70	CLR: Undo T2 LSN 60
80, 85	CLR: Undo T3 LSN 50 T3 End

UndoNext LSN = 20

Undo phase

Crash Recovery Example

LSN	Log
00, 05	begin_checkpoint, end_checkpoint
10	update: T1 writes P5
20	update: T2 writes P3
30	T1 abort
40, 45	CLR: Undo T1 LSN 10 T1 End
50	update: T3 writes P1
60	update: T2 writes P5
	CRASH, RESTART
70	CLR: Undo T2 LSN 60
80, 85	CLR: Undo T3 LSN 50 T3 End
90	CLR: Undo T2 LSN 20 T2 End

UndoNext LSN = 20

Undo phase

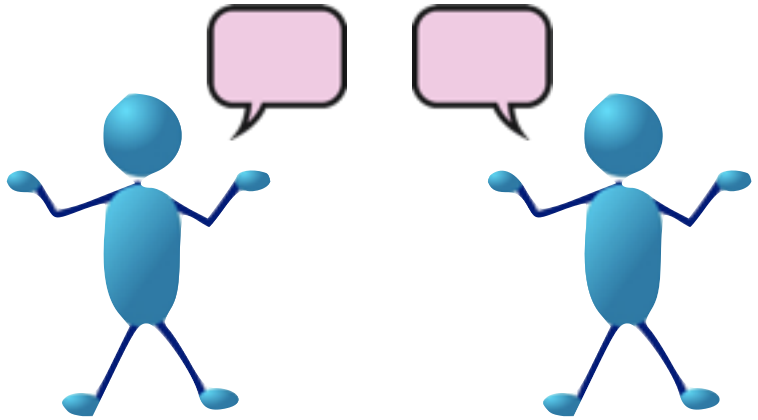
Selective Redo

- Redo phases are different from system to system (e.g., System R and DB2 use different redo phases)
- Selective redo is the idea of only redoing non-loser transactions
  - Can lead to trouble because we must log undos (for media recovery), but then we would attempt to redo the undo

Discussion Question

- If you are designing a system for transaction processing:
  - Would you redo “loser” transactions?
  - Would you use selective redo?
  - Would you do a checkpoint after the analysis phase?

Why or why not?



Summary

- ARIES is a database recovery algorithm
- Uses logs to identify what has happened
- Three phases: analysis, redo, and undo
- Different systems have different redo phases