Optimistic Concurrency Control

April 13, 2017

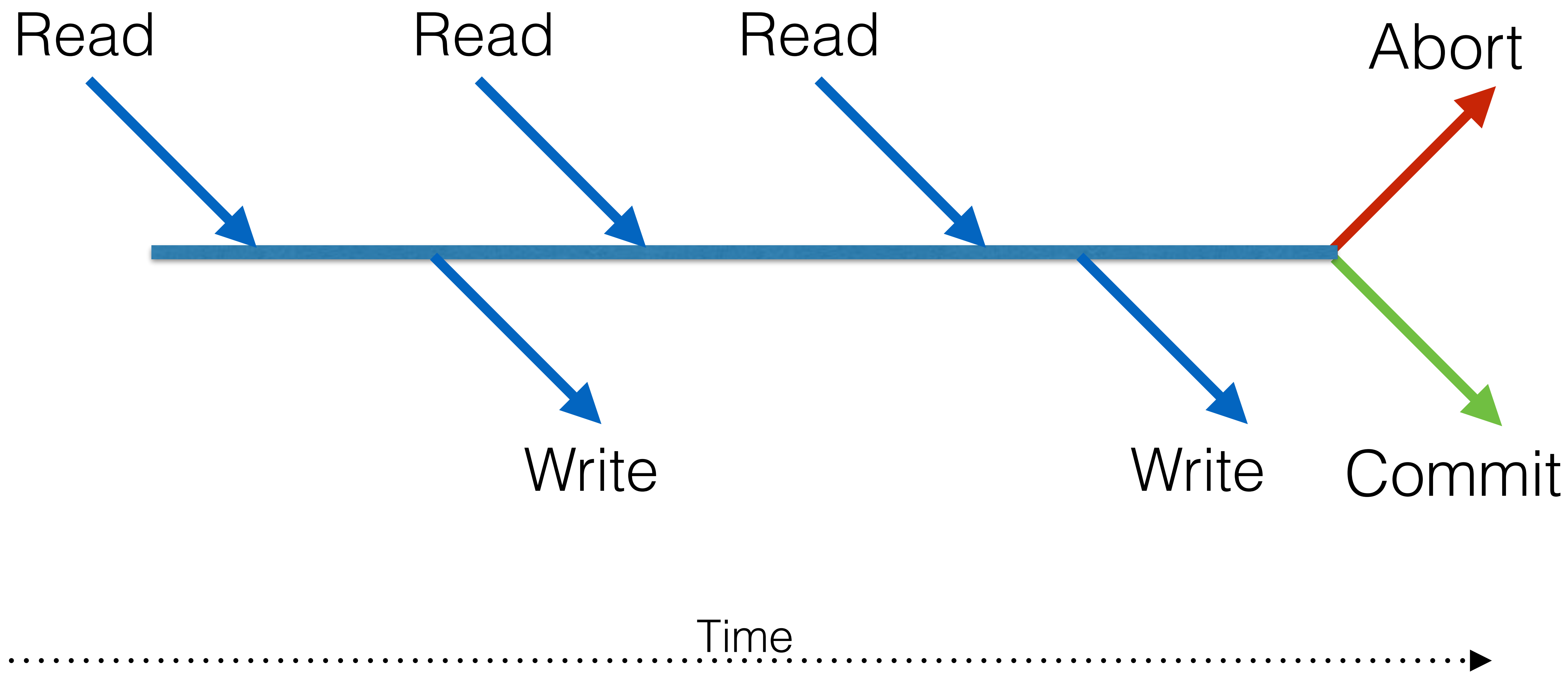
Serializability

Executing transactions serially wastes resources

Interleaving transactions creates correctness errors

Give transactions the *illusion* of isolation

Serializability



The Illusion of Isolation

Preserve order of reads, writes across transactions

The Illusion of Isolation

Option 1: Avoid situations that break the illusion

Locking

Lock an object before reading or writing it

Unlock it after the transaction ends

This is pessimistic!

Locking

Time ↓

T1	T2
W(A)	
W(B)	
	W(A)
	W(B)
COMMIT	COMMIT

Not allowed! T2 has to wait!

Locking

- This is <u>expensive</u>! Locking costs are still incurred even if no conflicts ever actually occur!

- This is <u>restrictive</u>! Don’t know in advance what an xact will do, so can’t allow all schedules.

We don’t know what a transaction will do until it does.

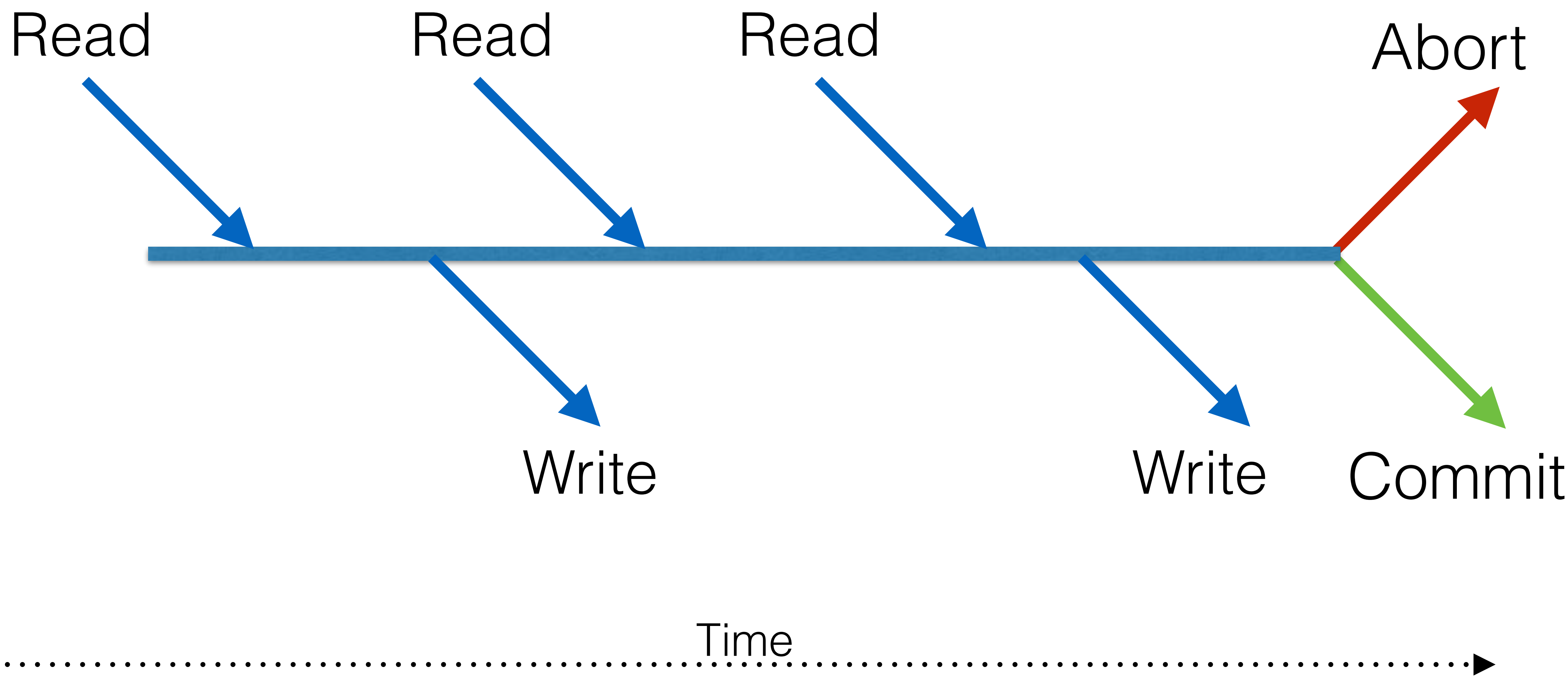
So let the transaction do it.

(Then check if it broke anything later)

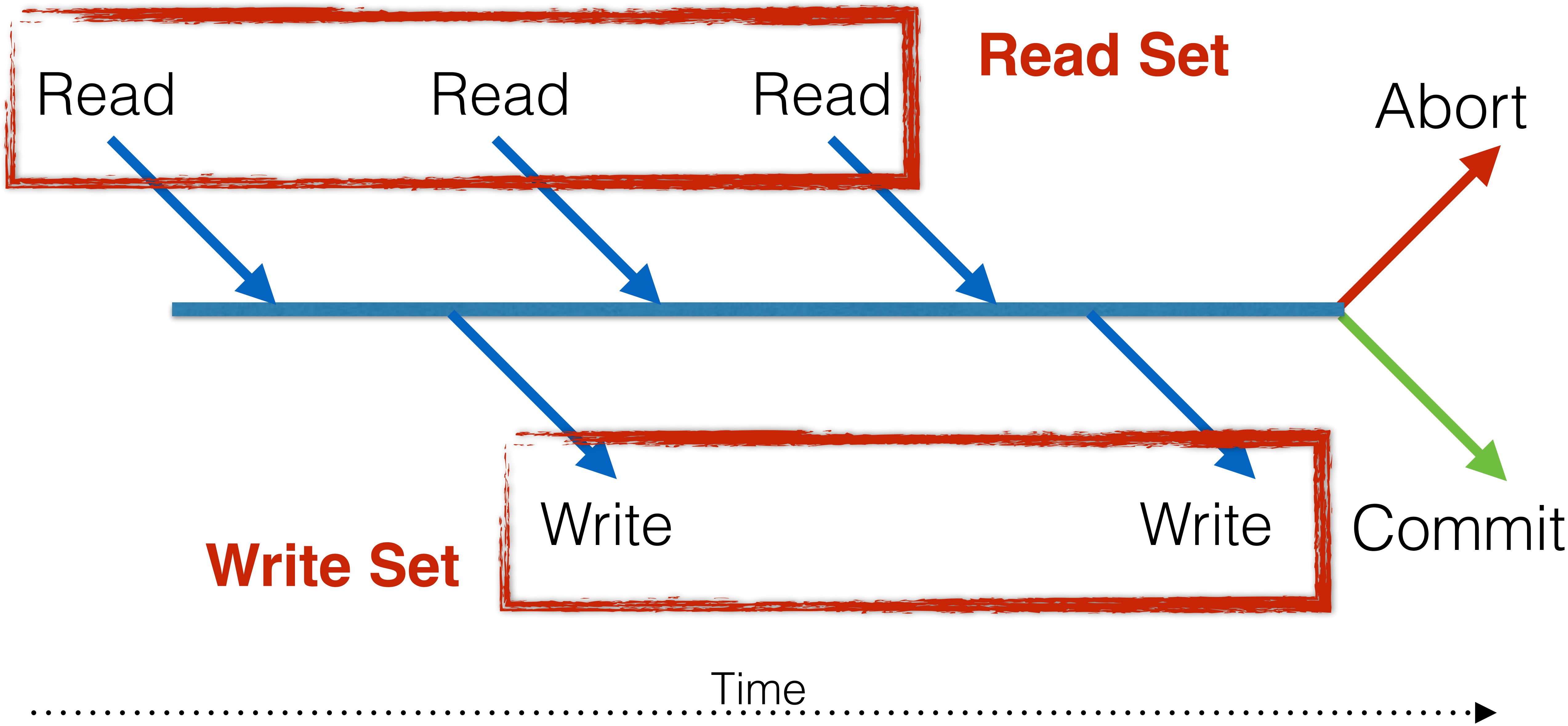
Optimistic CC

- **Read Phase**: Transaction executes on a private copy of all accessed objects.
- **Validate Phase**: Check for conflicts.
- **Write Phase**: Make the transaction's changes to updated objects public.

Read Phase



Read Phase


Read
Read
Read
Read Set
Abort
Write
Write
Commit
Write Set
Time

Read Phase

ReadSet(T_i): Set of objects read by T_i.

WriteSet(T_i): Set of objects written by T_i.

Validation Phase

Pick a serial order for the transactions
(e.g., assign id #s or timestamps)

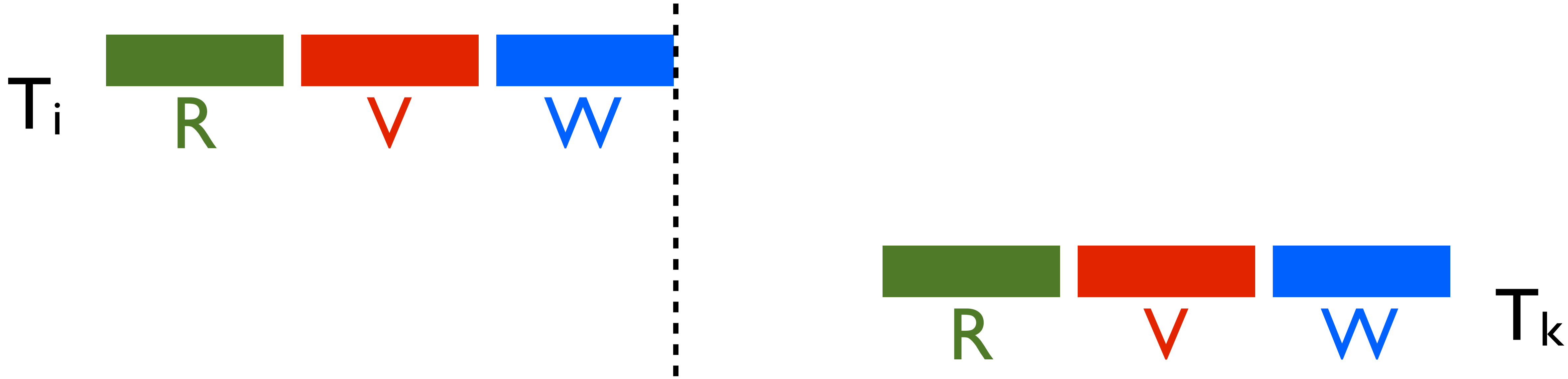
When should we assign Transaction IDs? (Why?)

Validation Phase

What tests are needed?

Simple Test

For all i and k for which i < k,
check that Ti completes before Tk begins.

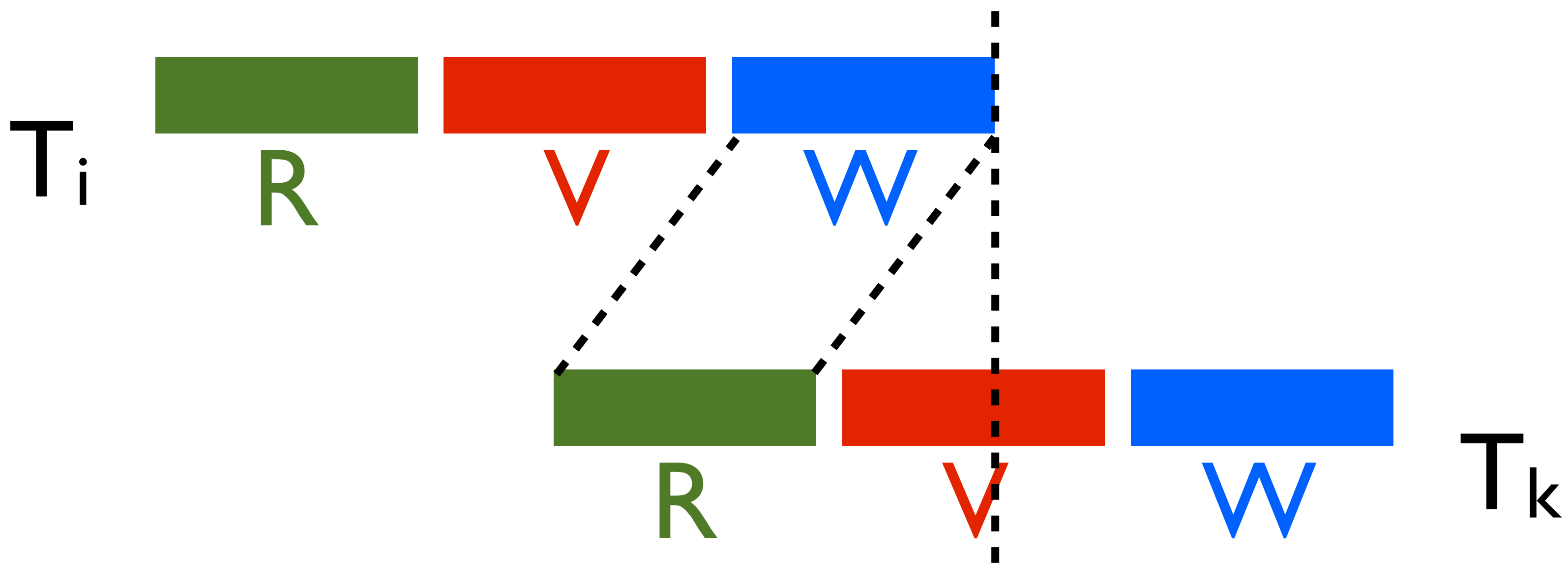


Is this sufficient?

Is this efficient?

Test 2

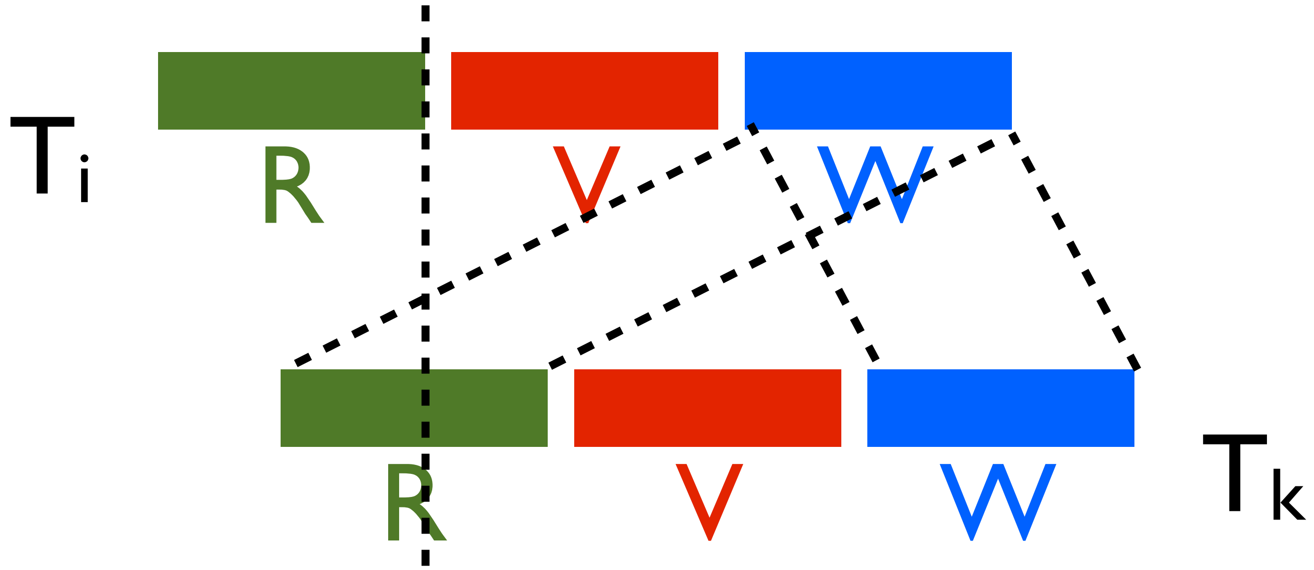
For all i and k for which i < k,
check that Ti completes before Tk begins its write phase
AND WriteSet(Ti) ∩ ReadSet(Tk) is empty



How do these two conditions help?

Test 3

For all i and k for which i < k,
check that Ti completes its read phase first
AND WriteSet(Ti) ∩ ReadSet(Tk) is empty
AND WriteSet(Ti) ∩ WriteSet(Tk) is empty



How do these three conditions help?

Which test (or tests) should we use?

Hint: How would you implement each test?

Validation

- Assigning the transaction ID, validation, and the parts of the write phase are a critical section.
  - Nothing else can go on concurrently.
  - The validation phase can be long; This is bad.
- **Optimization**: Read-only transactions that don't need a critical section (no write phase).

Optimistic CC Overheads

- Each operation must be recorded in the readset/writeset (sets are expensive to allocate/destroy)
- Must test for conflicts during validation stage
- Must make validated writes “public”.
  - Critical section reduces concurrency.
  - Can lead to reduced object clustering.
- Optimistic CC must **restart** failed transactions.

Timestamp CC

- Give each object a read timestamp (RTS) and a write timestamp (WTS)
- Give each transaction a timestamp (TS) at the start.
- Use RTS/WTS to track previous operations on the object.
  - Compare with TS to ensure ordering is preserved.

Timestamp CC

- When T_i reads from object O:
  - If WTS(O) > TS(T_i), T_i is reading from a ‘later’ version.
    - Abort Ti and restart with a new timestamp.
  - If WTS(O) < TS(T_i), T_i’s read is safe.
    - Set RTS(O) to MAX(RTS(O), TS(T_i))

Timestamp CC

- When T_i writes to object O:
    - If RTS(O) > TS(T_i), T_i would cause a dirty read.
        - Abort T_i and restart it.
    - If WTS(O) > TS(T_i), T_i would overwrite a ‘later’ value.
        - Don’t need to restart, just ignore the write.
    - Otherwise, allow the write and update WTS(O).

Problem: Recoverability

Time	T1	T2
↓	`W(A)`	
		`R(A)`
		`W(B)`
		`COMMIT`

What happens if T1 aborts (or the system crashes)?

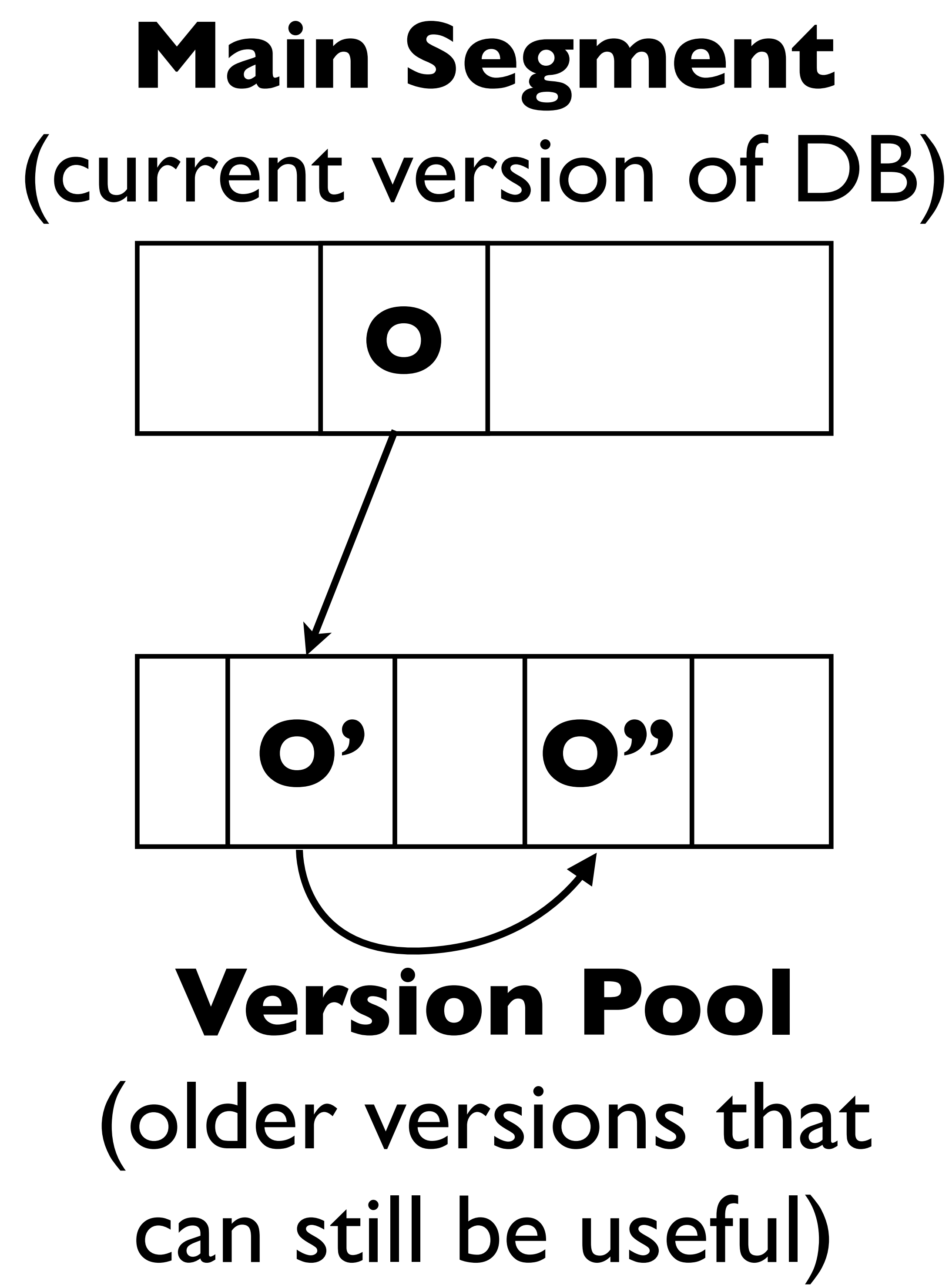
Timestamp CC and Recoverability

- Buffer all writes until a writer commits.
  - But update WTS(O) when the write to O is **allowed**.
- Block readers of O until the last writer of O commits.
- Similar to writers holding X locks until commit, but not quite 2PL.

Can we avoid read after write conflicts?

Multiversion TS CC

- Let writers make a “new” copy, while readers use an appropriate “old” copy.
- Readers are **always** allowed to proceed.
- … but may need to be blocked until a writer commits.

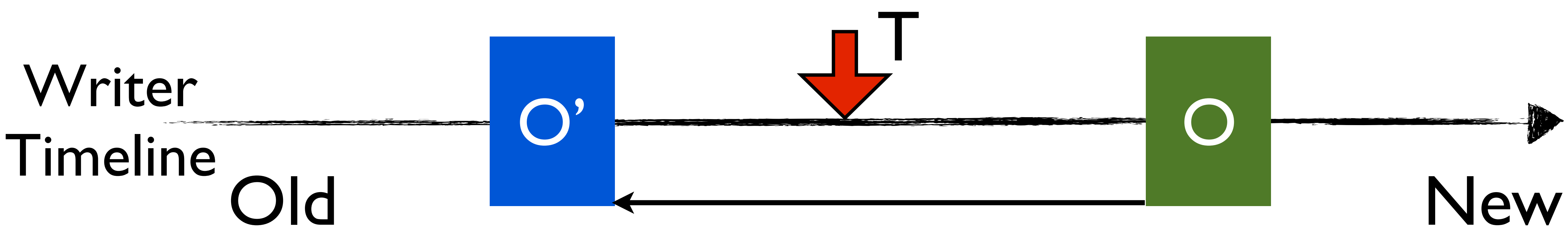


Multiversion TS CC

- Each version of an object has:
  - The writing transaction's TS as its WTS.
  - The highest transaction TS that read it as its RTS.
- Versions are chained backwards in a linked list.
  - We can discard versions that are too old to be "of interest".
- Each transaction classifies itself as a reader or writer for each object that it interacts with.

Reader Transactions

- Find the newest version with WTS < TS(T)
  - Start with the latest, and chain backward.
- Assuming that some version exists for all TS, reader xacts are never restarted!
  - … but may block until the writer commits.



Writer Transactions

- Find the newest version V s.t. WTS < TS(T)
- If RTS(V) < TS(T) make a copy of V with a pointer to V with WTS = RTS = TS(T).
    - The write is buffered until commit, but other transactions can see TS values.
- Otherwise reject the write (and restart)