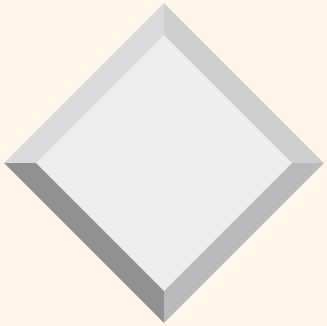
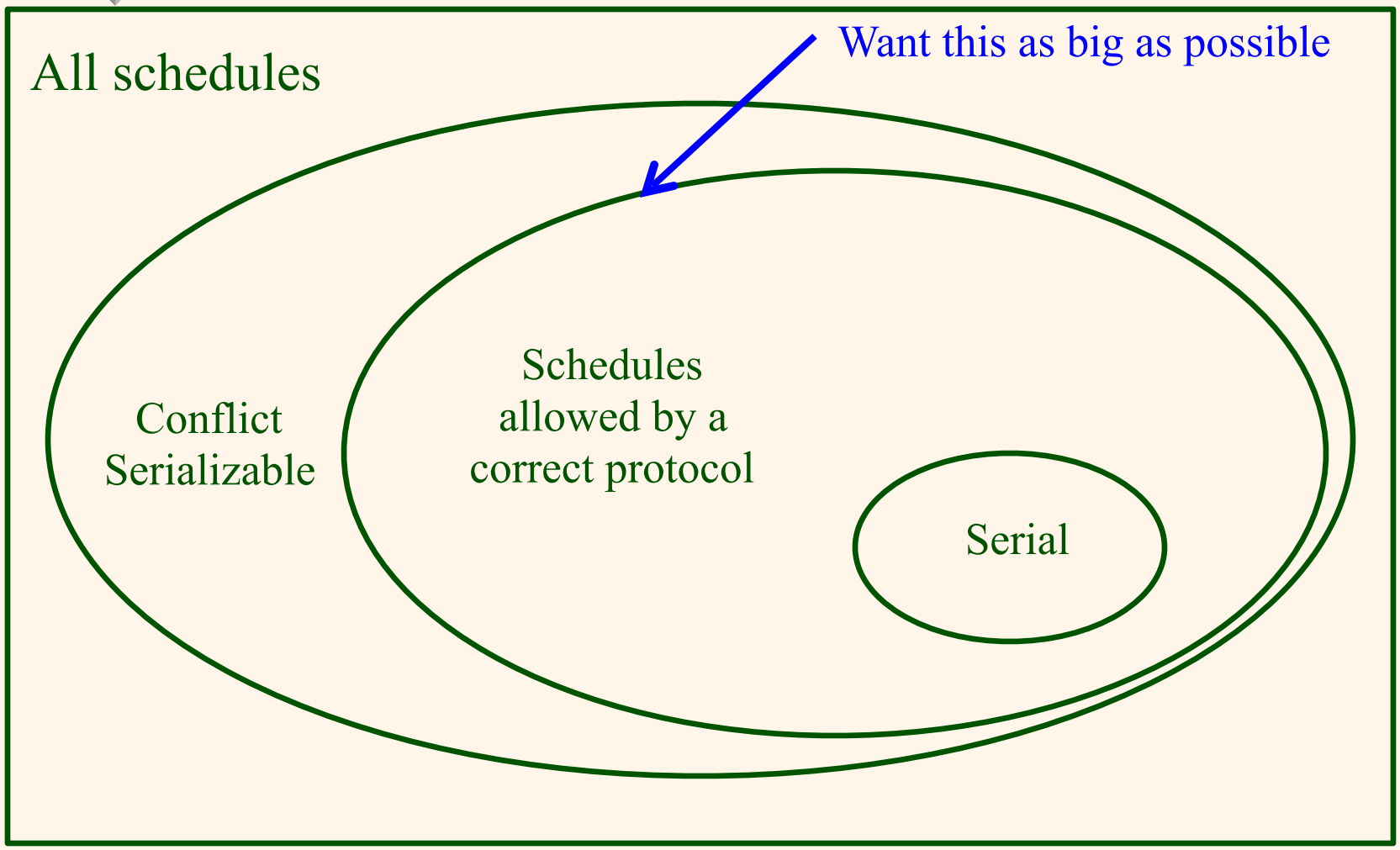


Concurrency Control - Two-Phase Locking

Last time

- Conflict serializability
- Protocols to enforce it

Big Picture


All schedules
Want this as big as possible
Conflict Serializable
Schedules allowed by a correct protocol
Serial

Locking-Based Protocols

- First family of protocols – based on idea of locks
- Before any read or write, a transaction must request a lock on an object
  - A "permission to operate" on this object
- Locks are managed centrally by the DBMS lock manager

Locking-Based Protocols

- Locks can last only as long as a single operation (short locks)
  - Good idea to use those anyway – prevent two transactions from writing to the same object literally at the same time
- But can also allow transactions to hold on to them for longer

A simple locking scheme

- Before execution, each transaction locks entire database
- After it commits, releases lock for next transaction

Locking objects

- For greater concurrency, allow locks on individual DB objects
- Locking scheme #2:
  - Transaction comes into system
  - Requests locks on all objects it needs to access
  - When obtains locks, proceeds
  - On commit, releases all locks
- Why is this better already?
  - And does it still enforce conflict serializability?

Another refinement

- If a transaction T has a lock on A, no-one else can operate on A until it finishes
- But suppose T is only reading A
  - And T' also only wants to read A
  - Can't we allow them both in?
- Realistic scenario: in a lot of DB workloads, reads much more frequent than writes...

Kinds of locks

- Idea: refine locks into two kinds:
  - read locks – can be shared
  - write locks – must be exclusive
- Transaction explicitly asks system for either read or write lock
  - When can system grant a read lock?
  - When can system grant a write lock?

Locking Scheme #3

- Allows us to have a new locking scheme:
  - Transaction requests read/write locks on all the objects it will need to access
    - If needs to both read and write to object, must request write lock
  - Waits until it has all of them
  - Runs
  - On commit, releases all locks
- Does it still guarantee conflict serializability?

More refinements

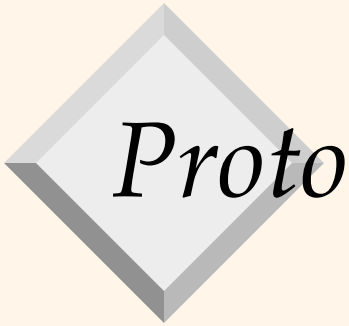
- Can we allow transactions to release some locks before commit?
  - If transaction is done with the object, should be fine
  - Problem: some dirty reads now possible
  - W1(A) R2(A) Abort1
  - Need to abort 2 as well
  - A cascading abort
- But would guarantee conflict serializability
  - Just not the ACA or strictness properties we discussed

More refinements

- Can we allow transactions to acquire locks "as needed" rather than all at once?
  - Yes, but deadlock can happen!
  - Transactions 1 and 2 both need write locks on A and B
  - Transaction 1 gets lock on A
  - Transaction 2 gets lock on B
  - Neither can proceed!
  - Need some deadlock handling algorithm
- But would still be correct (guarantee conflict serializability)

More refinements

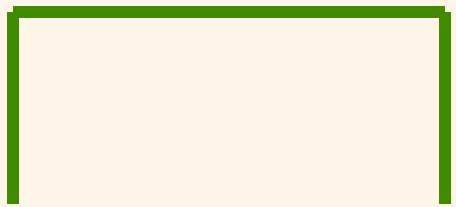
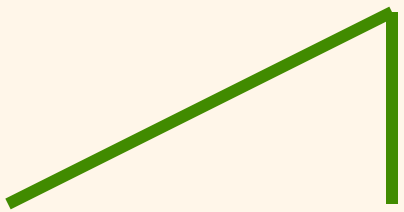
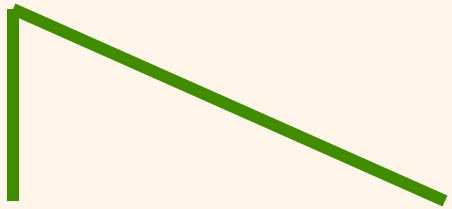
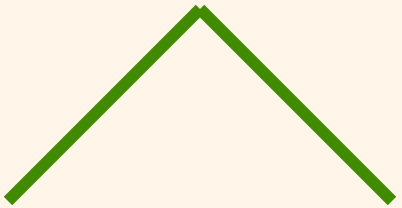
- Can even do both:
  - acquire locks as needed
  - release when no longer needed
- But to guarantee conflict-serializability, need to have two separate phases:
  - Phase 1: only acquire locks
  - Phase 2: only release locks
- Two-phase locking (2PL)



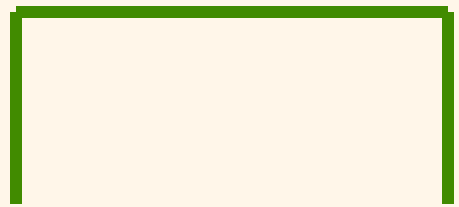
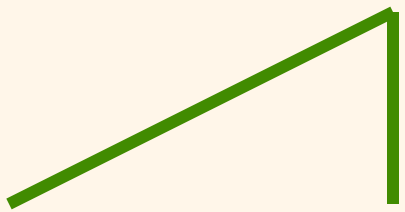
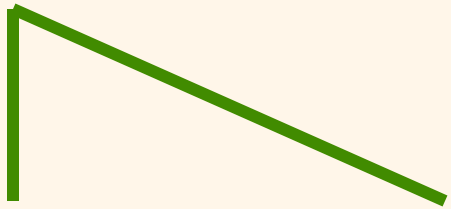
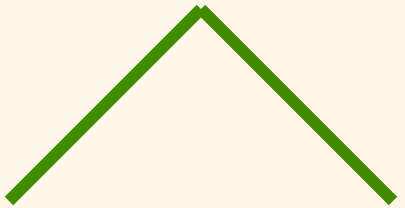
Protocols

- Each transaction locks entire DB
- Each transaction only locks objects it needs
- Each transaction specifies whether it needs read or write locks
- Transaction can release locks before commit if it's done
  - Problem: cascading aborts
- Transaction can acquire locks as needed
  - Problem: deadlocks

Locking options

Acquire / Release	At the start	As needed
Upon Commit		
Early		

2PL variants

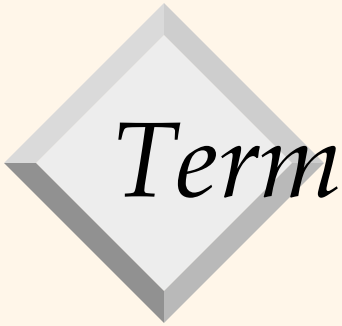
Strict \ Conservative	Yes	No
Yes		
No		

Pros and cons

- Conservative (get all locks at start)
  - + : no deadlocks
  - - : need to know all objects up front
  - - : less concurrency
- Strict (hold locks until commit)
  - +: no cascading aborts
  - - : less concurrency

Summary of Alternatives

- Conservative Strict 2PL
  - No deadlocks, no cascading aborts, no need to know when to release locks
  - But need to know objects a priori
- Conservative 2PL
  - No deadlocks, more concurrency than Conservative Strict 2PL
  - But need to know objects a priori, when to release locks, cascading aborts
- Strict 2PL
  - No cascading aborts, no need to know objects a priori or when to release locks, more concurrency than Conservative Strict 2PL
  - But deadlocks
- "Plain" 2PL (non-Strict, non-Conservative)
  - Most concurrency, no need to know object a priori
  - But need to know when to release locks, cascading aborts, deadlocks



Terminology warning

- 2PL (Two Phase Locking) may refer to:
  - The whole family of techniques, OR
  - The non-Strict, non-Conservative variant (I will sometimes call this plain 2PL to disambiguate)

Let's prove that 2PL is OK!

- Let's prove that (non-strict, non-conservative) 2PL enforces conflict serializability
- To show: suppose system uses 2PL and produces some schedule
  - The conflict graph for this schedule must be acyclic
- (See Bernstein's textbook, Section 3.3.)

Warm-up: enhancing schedules with lock requests

- Given a schedule, suppose it was executed in a system running 2PL (don't know if it was Strict/Conservative)
- Think about possible places where lock and unlock could have happened
- E.g. W1(A)W1(B)
  - All possible places to put lock/unlock requests under 2PL?

A useful observation

- Under 2PL, a transaction cannot issue a release lock request *followed by* an acquire lock request (by definition of 2PL)

Now back to our proof

- By contradiction: suppose we have a schedule produced in a system using 2PL
- And the schedule is not conflict serializable
- What does that mean?

A useful lemma

- Consider the conflict graph for our schedule. If there is a directed path from i to j, then i releases some lock before j acquires some lock
  - not necessarily on same object
- Let's prove that!
- Use induction on path length and our previous observation

A useful lemma

- Consider the conflict graph for our schedule. If there is a directed path from i to j, then i releases some lock before j acquires some lock
  - not necessarily on same object
- Suppose now the graph has a cycle; how does it relate to the above?
- And to 2PL?