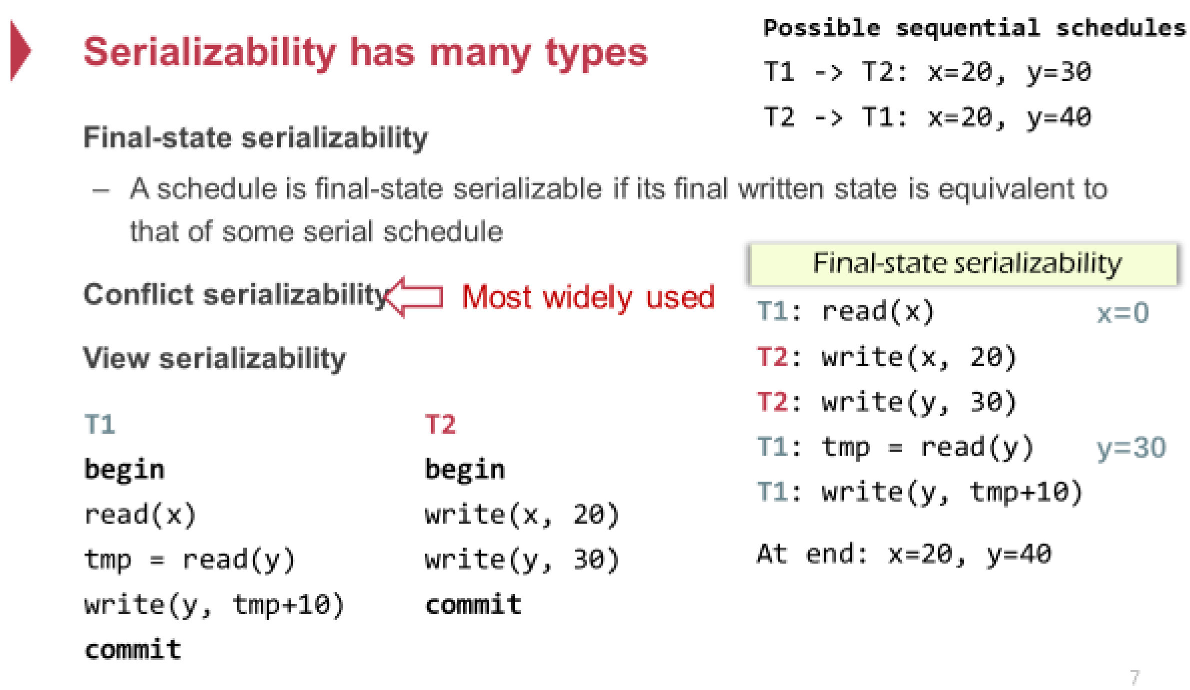
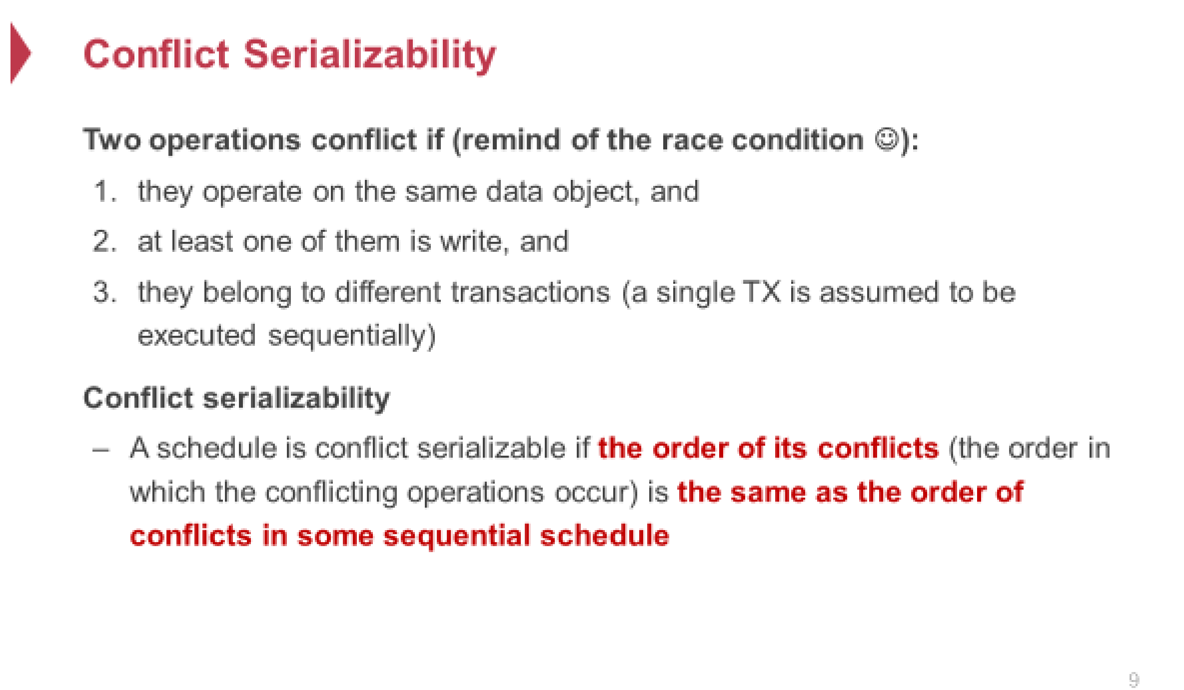
Serializability, OCC&Transaction

Serializability

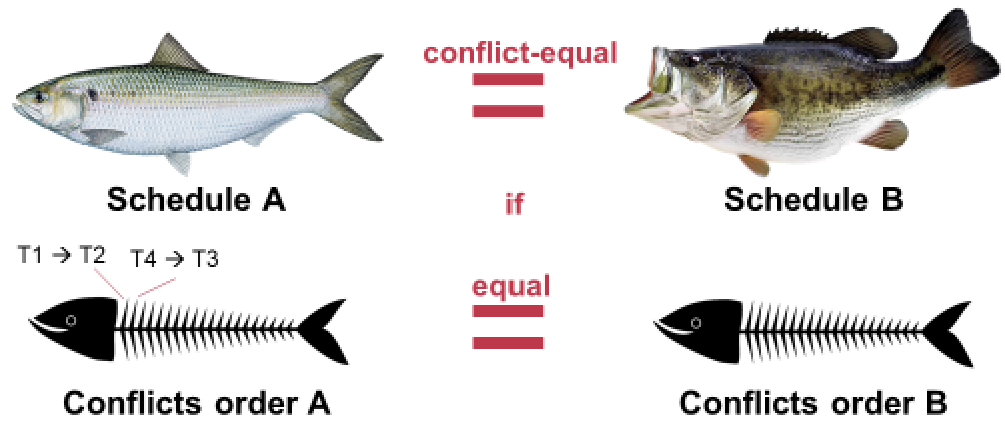


final state serializabliity 只要结果正确即可，但并不serializable T1,T2交替执行，任何一个线性执行是不会有这样的情况。



conflict 可以证明符合serializability

Conflict Equivalence



If conflicts-order-A equals to conflicts-order-B, then schedule-A conflict-equals to schedule-B

构建conflict graph来判断是否一样

怎么构建？如下：

Use Conflict Graph to determine the sequential schedule

Conflict Graph

– Nodes are transactions, edges are **directed**

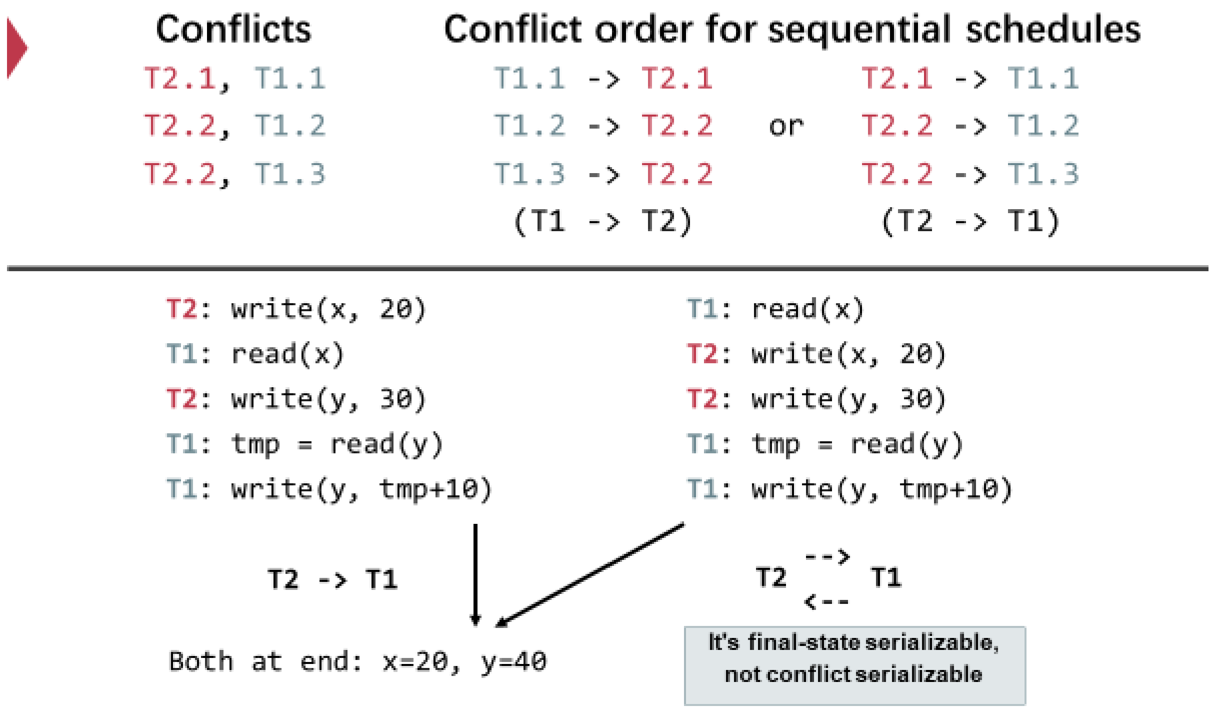
– Edge between T_i and T_j if and only if:

1. T_i and T_j have a conflict between them, and
2. the first step in the conflict occurs in T_i

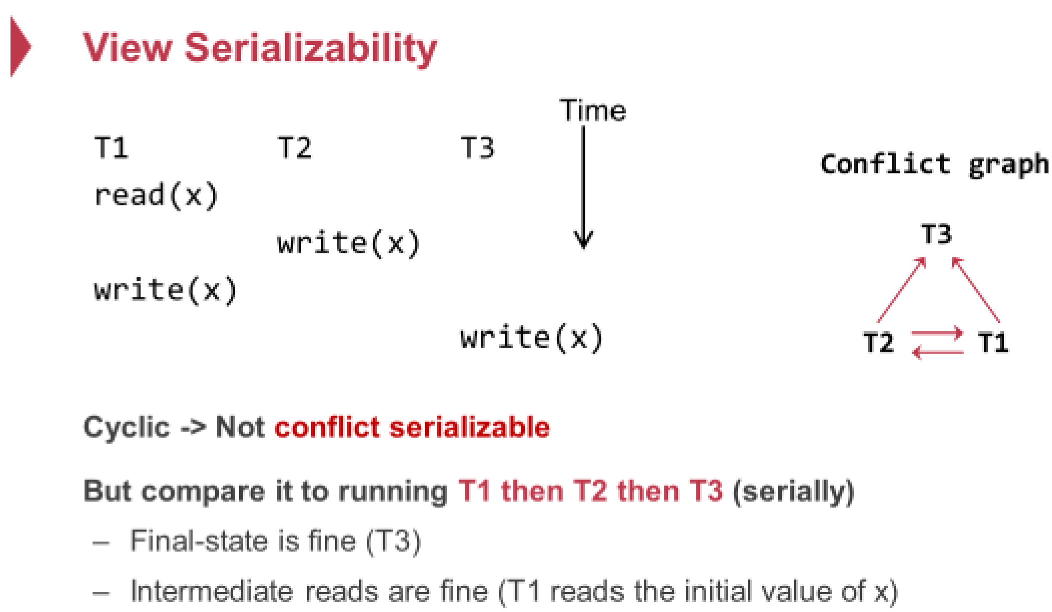
A schedule is conflict serializable if and only if:

– It has an **acyclic** conflict graph

例子：



无环一定是serializable，但有环不一定不是serializable：



先是T1->T2，再是T2->T1，再是T1,T2->T3，存在环

但这个结果和线性跑T1 T2 T3结果是一致的。因为最终结果只用考虑T3写的值就够了。初始状态只用考虑T1读的是初始状态。

因此使用conflict graph是一个充分条件，并不是必要条件，因此需要对这个条件进行放松，即view serializability

View Serializability

Informal definition

– *A schedule is view serializable if the final written state as well as intermediate reads are the same as in some serial schedule*

Formally, for those interested

– Two schedules **S** and **S'** are **view equivalent** if:

- If T_i in S reads an initial value for X, so does T_i in S'
- If T_i in S reads the value written by T_j in S for some X, so does T_i in S'
- If T_i in S does the final write to X, so does T_i in S'

A schedule is **view serializable** if it is **view equivalent** to some serial schedule

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总结

Question

Why conflict serializability, given that it seems too strict?

Why not focus on view serializability? (Allow more interleaving, & is still correct)

Final-state Serializability	$\supset$	**View Serializability**	$\supset$	**Conflict Serializability**
Care the final state only		Care the final state as well as intermediate read		Care the final state as well as all the **data dependency**

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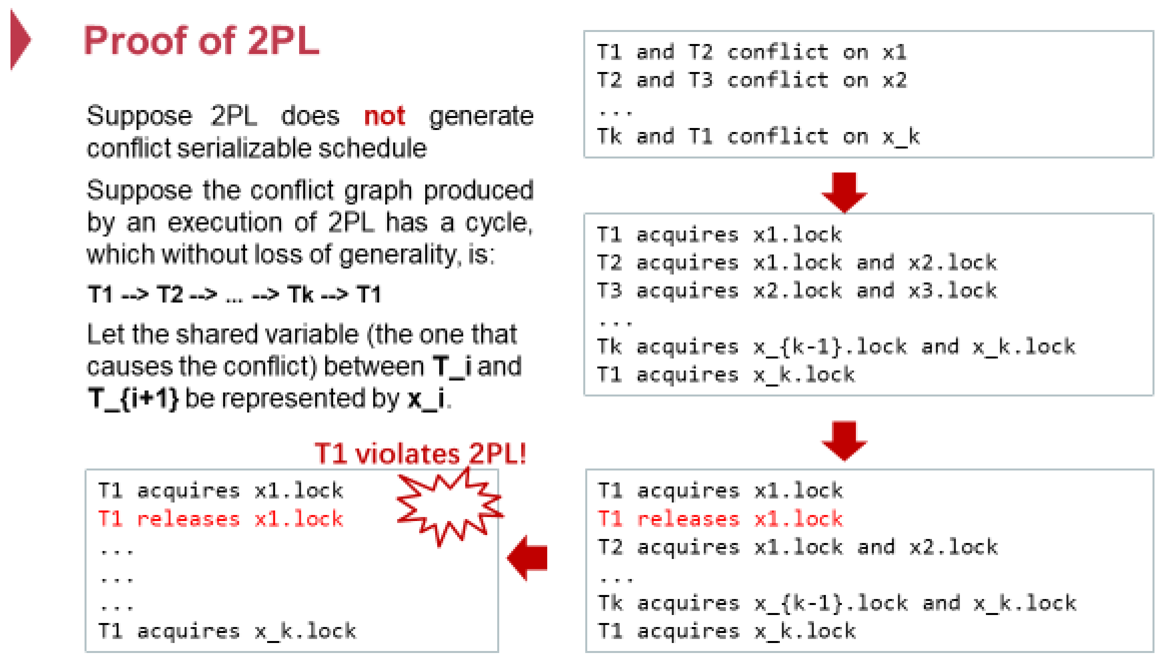
final state没有考虑过程中读的问题。view虽然好，但非常难判断，是np难问题。conflict很好判断，虽然很严格，但其实用的最多的还是conflict，并且conflict可以实现，比如2PL。

目前数据库中的serializability就是指conflict

2PL即conflict serializability：

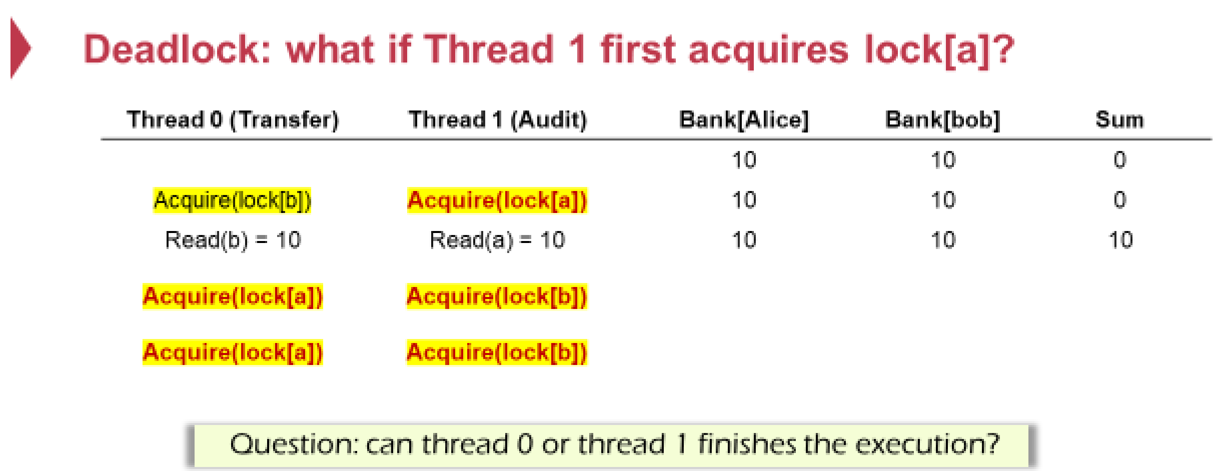


即证无环。用反证法，若有环T1,T2,...,Tn,T1 ，然后可以把这些conflict通过锁展开。如T2要拿T1的锁，T3要拿T2的锁... 而T1必须要release，T2才能拿到锁，而T1最后还需要拿Tn的锁，不符合2PL的定义（2PL拿完锁后就不能放锁）因此矛盾

但2PL不一定能全部保证serializability。比如一个list，中间有两个元素，两个元素自己拿锁修改，但list并没有锁，现在依然可以在list后面插入元素。但真实场景往往不会考虑这种麻烦。

Deadlock

例子：



Thread 0 (Transfer)	Thread 1 (Audit)	Bank[Alice]	Bank[bob]	Sum
		10	10	0
Acquire(lock[b])	Acquire(lock[a])	10	10	0
Read(b) = 10	Read(a) = 10	10	10	10
Acquire(lock[a])	Acquire(lock[b])			
Acquire(lock[a])	Acquire(lock[b])			

Methods for resolving the deadlock

1. Acquire locks in a pre-defined order Prevention

– Not support general TX: TX must know the read/write sets before execution

2. Detect deadlock by calculating the conflict graph Detection

– If there is a cycle, then there must be a deadlock

– Abort one TX to break the cycle

– High cost for detection

3. Using heuristics (e.g., timestamp) to pre-abort the TXs Retry

– May have false positive, or live locks

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1. 拿锁顺序如果是一样，则不会出现死锁问题。但不一定所有transaction都可以满足这个条件
2. 拿锁的时候可以把等待的环给拿出来，然后abort一个transaction。但开销太大，要去构建一个环
3. 用时间来判断是否死锁，若超时则直接abort。但可能会出现误判。

拿锁是一种悲观的判断，那么也有乐观的控制方法

Optimistic concurrency control

Executing TXs optimistically w/o acquiring the lock

Checks the results of TX before it commits

– If violate serializability, then **aborts & retries**

First proposed in 1981, widely used today

HEKATON Microsoft SQL Server　App Engine　CouchDB

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先不拿锁，如果满足，则继续，如果不满足则直接abort

OCC Executes a Transaction in 3 Phases

Phase 1: Concurrent local processing

- Reads data into a read set
- Buffers writes into a write set

Phase 2: Validation serializability in critical section

- Validates whether serializability is guaranteed:
- Has any data in the read set been modified?

Phase 3: Commit the results in critical section or abort

- Aborts: aborts the transaction if validation fails
- Commits: installs the write set and commits the transaction

1. 把读写都放入一个缓存集合
2. 验证是否序列化
3. 成功则提交，失败则abort重新来一次

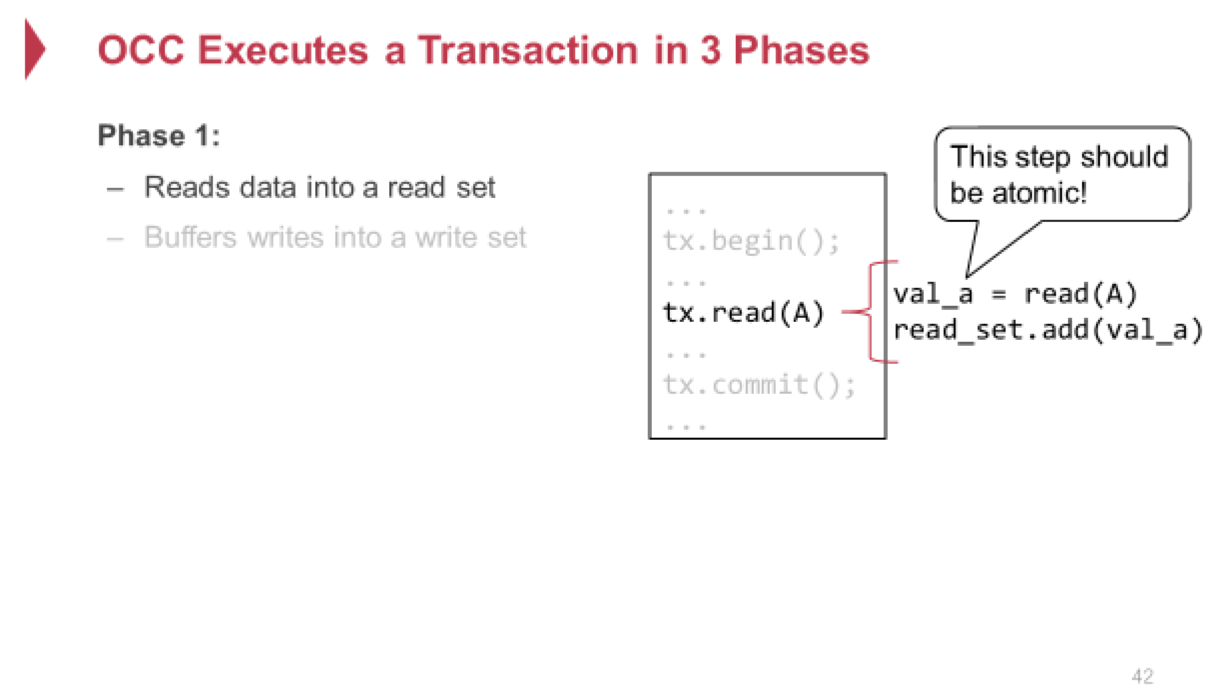
OCC Executes a Transaction in 3 Phases

Before phase one, TX needs to allocate the execution context

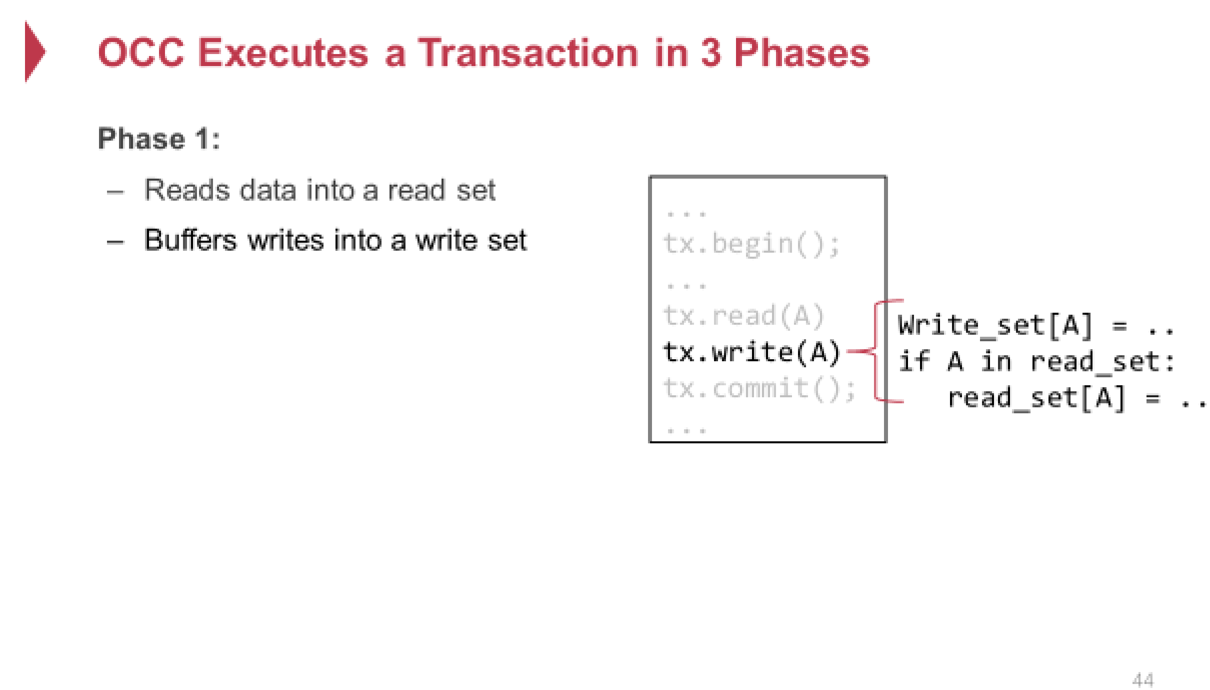
- Read-set & write set

```
...
tx.begin();      Init read_set
                 Init write_set
...
tx.read(A)
...
tx.commit();
...
```


先初始化read/write set



直接读，放入读集合。若后面直接接了一个相同的read（可重复读）则直接到set中去寻找，不然可能被改动。



在write中，同时需要去改变read set。

OCC Executes a Transaction in 3 Phases

Phase 2:

- Validates whether serializability is guaranteed:
- Has any data in the read set been modified?

```
...
tx.begin();
...
tx.read(A)
...
tx.commit();
...
```

```
for d in read_set:
    if d has changed:
        abort()
```

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OCC Executes a Transaction in 3 Phases

Phase 3:

- Aborts: aborts the transaction if validation fails
- Commits: installs the write set and commits the transaction

```
...
tx.begin();
...
tx.read(A)
...
tx.commit();
...
```

```
for d in read-set:
    if d has changed:
        abort()
for d in write_set:
    write(d)
```

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phase2，phase3如上

OCC Executes a Transaction in 3 Phases

Phase 3:

- Aborts: aborts the transaction if validation fails
- Commits: installs the write set and commits the transaction

Phase 2 & 3 should execute in a critical section

- Otherwise, what if a value has changed during validation?

```
...
tx.begin();
...
tx.read(A)
...
tx.commit();
...
```

Critical section

```
for d in read_set:
    if d has changed:
        abort()
for d in write_set:
    write(d)
```

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验证和写入必须要原子操作

How to implement the critical section for phase 2 & 3?

Global lock may satisfy

- The phase 2 & 3 are typically short
  - No TX logic is executed, only the validation

```
def validate_and_commit() // phase 2 & 3
    global_lock.lock()
    for d in read-set:
        if d has changed:
            abort()
    for d in write-set:
        write(d)
    global_lock.unlock()
```

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最简单方式：直接拿全局锁

效果比2PL好，因为phase1可以直接并发执行

同样可以加更加细粒度的锁

How to implement the critical section for phase 2 & 3?

Using two-phase locking

- Allow more concurrency
- What about the problem of deadlock?

```
def validate_and_commit() // phase 2 & 3
    for d in read-set:
        d.lock()
        if d has changed:
           abort() // abort will release all the held lock
    for d in write-set:
        d.lock()
        write(d)
    // release the locks
    ...
```

在这里可以很好解决死锁问题。可以直接按照顺序拿锁

How to implement the critical section for phase 2 & 3?

Using two-phase locking

- Allow more concurrency
- Use sort to avoid deadlock; b king overhead as 2PL

Question: do we need to lock the read-set?

```
def validate_and_commit() // phase 2 & 3
    for d in sorted(read-set + write-set):
        d.lock()
    for d in read-set:
        if d has changed:
           abort()
    for d in write-set:
        write(d)
    // release the locks
    ...
```

但如果read和write都要拿锁，其实和2PL的效率是一样的。其实可以直接不拿read的锁

How to implement the critical section for phase 2 & 3?

Observation (for the read-set):

- If the validation passes, then it ”appears“ that a lock is held during
- Question: is the following implementation correct?

```
def validate_and_commit() // phase 2 & 3
    for d in sorted(write-set):
        d.lock()
    for d in read-set:
        if d has changed:
           abort()
    for d in write-set:
        write(d)
    // release the locks
    ...
```

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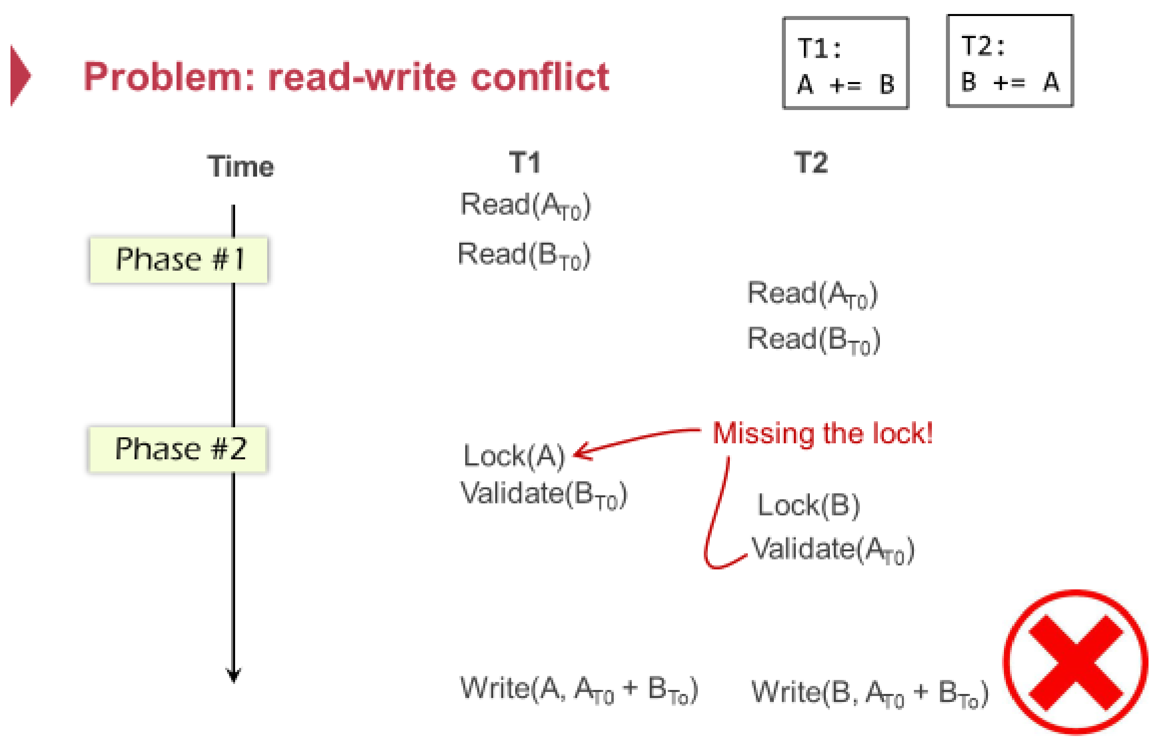
但这个依然有问题。如果d不在这里被拿了锁，而在其他地方被上锁，那么读d时可能不是最新的结果。如下：



OCC advantage

OCC Advantages

Phase 1: Concurrent local processing

- Reads data into a read set
- Buffers writes into a write set

Phase 2: Validation in critical section

- Validates whether serializability is guaranteed:
- Has any data in the read set been modified?

Phase 3: Commit the results in critical section or abort

- Aborts: aborts the transaction if validation fails
- Commits: installs the write set and commits the transaction

Needs synchronization (e.g., with lock), but usually very short at low contention

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OCC Advantages

Use reads more than writes (for each read-only data access)

- OCC (in the optimal case, i.e., no abort)
  - 1 read to read the data value
  - 1 read to validate whether the value has been changed or not (as well as locked)
- 2PL
  - 1 operation to acquire the lock (typically an atomic CAS)
  - 1 read to read the data value
  - 1 write to release the lock
    - A single CPU write is atomic, no need to do the atomic CAS

Locking is costly especially compared to reads

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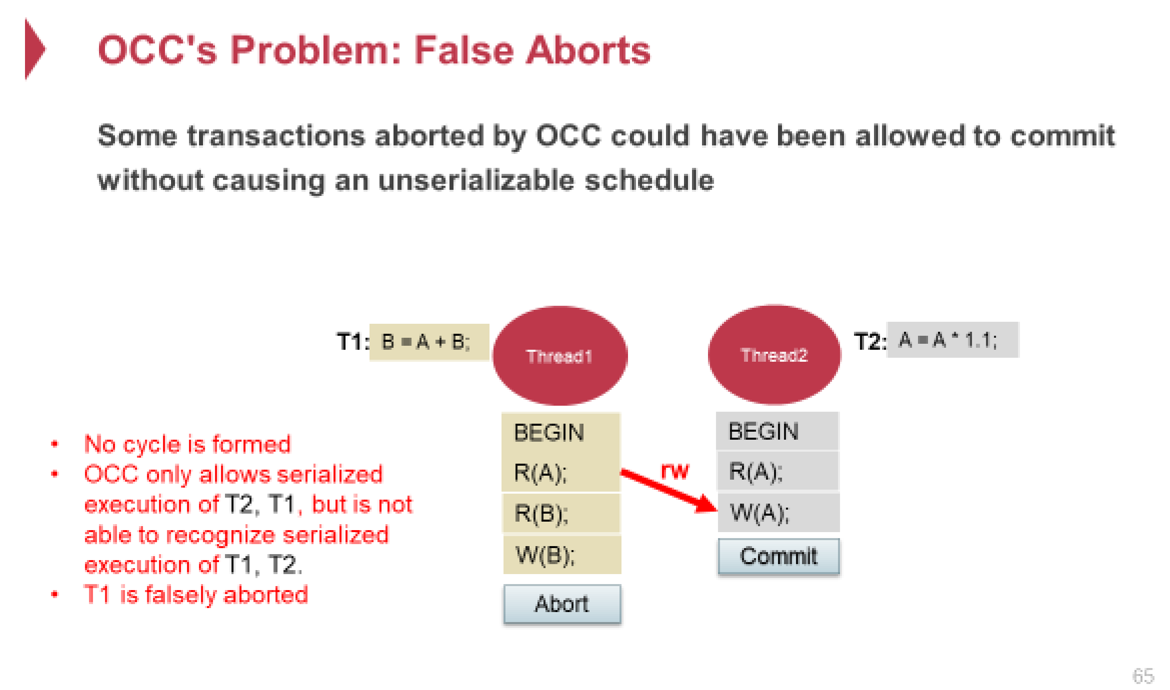
OCC problem

OCC中可能会出现误判的情况

首先是误以为出现矛盾的误判，如下

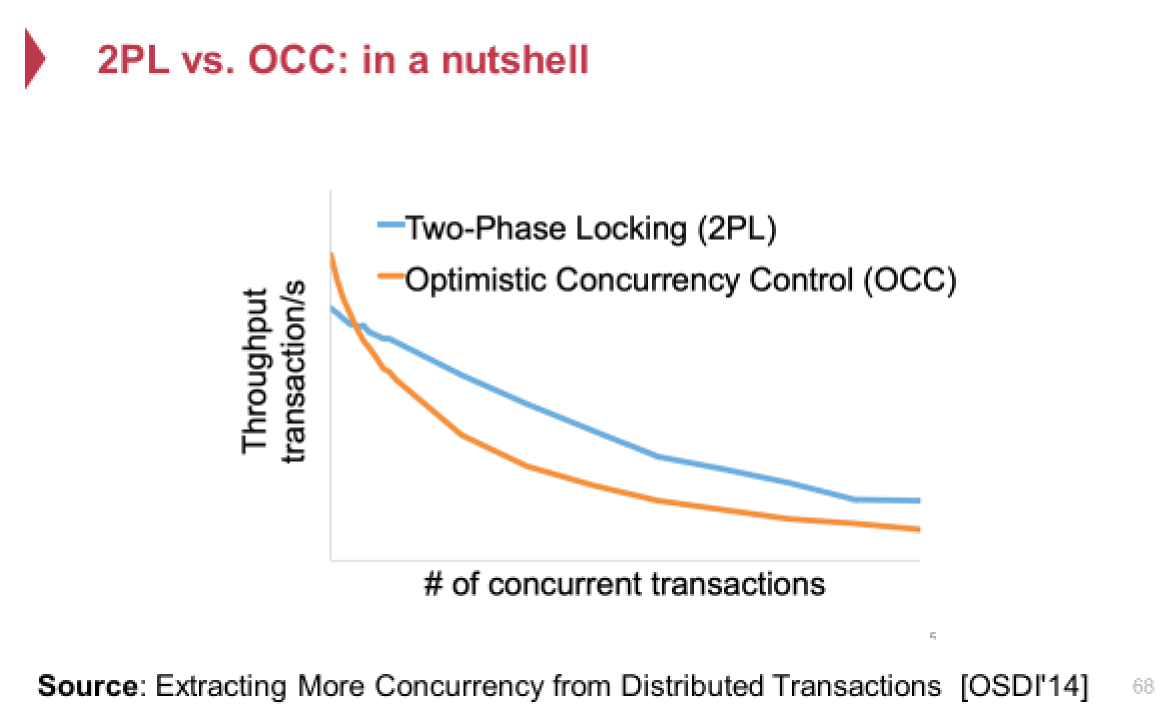


在这个情境中，两个事务实际上并没有冲突。尽管T1读取了A的值，但它并没有修改A；而T2只修改了A的值，没有读取或修改B的值。

但是，当T2先于T1提交时，OCC可能会认为T1读取的A的值已经过时，因为T2已经修改了A的值。因此，T1可能会被中止，即使它和T2实际上是可以并发执行的，不会导致任何数据不一致。

同时，OCC在执行一个耗时很长的操作时，非常容易出现错误。

2PL v.s. OCC



可以看出，在小数量事务时OCC快于2PL，但随着事务变多，OCC效率不如2PL

Lock preliminary

Lock是由计算机原子操作实现的，而lock的原子性操作往往比其余正常操作更加费时，不仅本身操作时间长，还需要阻隔其余cpu的管线。因此使用lock会降低性能