Transactions, Recovery and Concurrency (II)

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Concurrenc rol

Concurrency Control Methods

- **Locking Mechanism**

The idea of locking some data item X is to:

- give a tran a item X,
- do not restr s.

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This prevents one transaction from changing a data item currently being used in another transaction.

- We will discuss a simple locking scheme which locks individual items, using read and write locks

Locking Rules

- In this schema, every transaction T must obey the following rules.

- 1) If T has only one operation (read/write) manipulating an item X:
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  - obtain a read lo
  - obtain a write l
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  - unlock X when done with it.
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- 2) If T has several operations manipulating X:
  - obtain one proper lock only on X:

    a read lock if all operations on X are reads;

    a write lock if one of these operations on X is a write.
  - unlock X after the last operation on X in T has been executed.

Locking Rules (cont.)

- In this scheme,
  - Several read locks can be issued on the same data item at the same time.

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  - A read lock and a same data item at the same time, neither two

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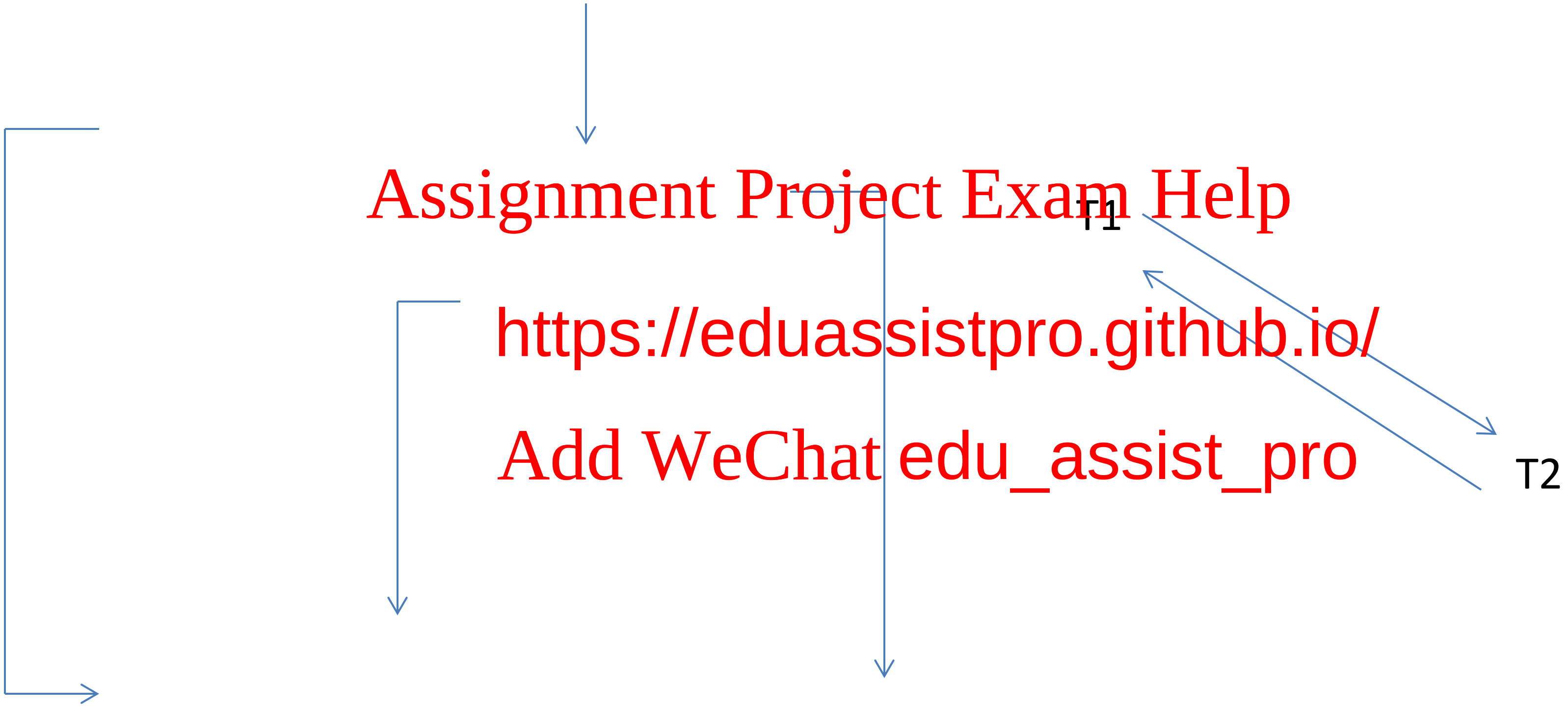
- This still does not guarantee seriali



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Two Phase Locking (2PL)

- To guarantee serializability, transactions must also obey the *two-phase locking protocol*:

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  - *Growing Phase* t be obtained before any locks are releas

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  - *Shrinking Phase*: gradually release a lock is released no new locks may be requested).

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Two Phase Locking (2PL) (Cont.)

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- Locking thus provides a solution to the problem of correctness of schedules.

Two phase locking ensures conflict serializability

Deadlock

- A problem that arises with locking is **deadlock**.
- Deadlock occurs when two transactions are each waiting for a lock on an item held by the other.

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Deadlock Check

- Create the *wait-for graph* for currently active transactions:
  - create a vertex for each transaction; and
  - an arc from T_i to T_j if T_i is waiting for an item locked by T_j.

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- If the graph has https://eduassistpro.github.io/ occurred.

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Several methods to deal with deadlocks

- *deadlock detection*
  - periodically check for deadlocks, abort and rollback some transactions (restart them later). This is a good choice if transactions pendent.

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Several methods to deal with deadlocks (Cont.)

- *deadlock prevention* - Assign priorities based on timestamps. Assume Ti wants a lock that Tj holds. Two policies are possible:

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  - Wait-Die: If Ti Tj; otherwise Ti aborts

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  - Wound-wait: If Ti has higher prior otherwise Ti waits

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- If a transaction re-starts, make sure it has its original timestamp

Timestamp ordering

- The idea here is:

  – to assign each transaction a timestamp (e.g. start time of transaction), and

  – to ensure that the schedule used is xecuting the transactions in timestamp order.

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- Each data item, X, is assigned
  - a read timestamp, *read_TS*(X) - the latest timestamp of a transaction that read X, and
  - a write timesta estamp of a transaction that write X.

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- These are used in read and write operations as follows. Suppose the transaction timestamp is T.

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- **Thomas' write rule:**

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T_1	T_2	T_3
read (x)		
	read (y)	
	write (y)	
read (z)		
		read (z)
Write (z)		

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r_TS (x) = 0 → 1
w_TS(x) = 0
r_TS (y) = 0 → 2
w_TS(y) = 0 → 2
r_TS (z) = 0 → 1 → 3
w_TS(z) = 0 → 3

- Some problems:
  - Cyclic restart: There is no deadlock, but a kind of livelock can occur - some transactions may be constantly aborted and restarted.

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  - Cascading roll led back, so are any transactions w transactions which read a value written by the can be avoided by not allowing transactions to read valu ncommitted transactions (make them wait).

Multiple-Granularity Locks

- Hard to decide what granularity to lock (tuples vs. pages vs. tables).
- Shouldn't
- Data “cont

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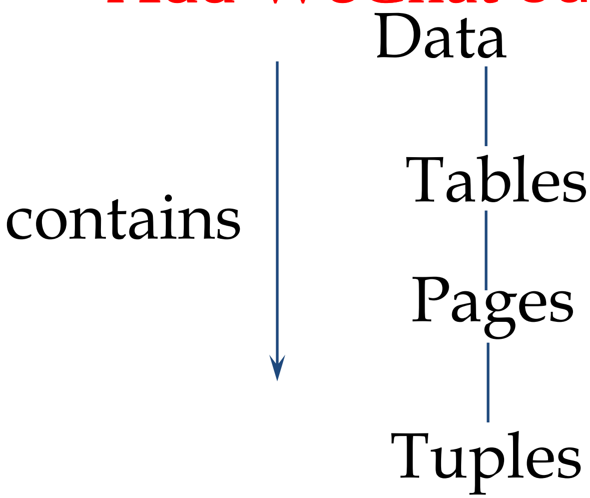

Solution: New Lock Modes, Protocol

- Allow Xacts to lock at each level, but with a special protocol using new “intention” locks:

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- Before locki
must set “int
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its ancestors.
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- For unlock, go from specifi
general (i.e., bottom-up).
- SIX mode: Like S & IX at the same time.

	--	IS	IX	S	X
	√	√	√	√	√
IS	√	√	√	√	
IX	√	√	√		
S	√	√		√	
X	√				

Multiple Granularity Lock Protocol

- Each Xact starts from the root of the hierarchy.
- To get S or X lock on a node, must hold IS or IX on parent node.
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  - What if X t? S on parent?
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- To get X or IX or SIX on a nod IX or SIX on parent node.
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- Must release locks in bottom-up order.

Protocol is correct in that it is equivalent to directly setting locks at the leaf levels of the hierarchy.

Examples

- T1 scans R, and updates a few tuples:
  - T1 gets an SIX lock on R, then repeatedly gets an S lock on tuples of R, and occasionally upgrades to X on the tuples.
- T2 uses an index to
  - T2 gets an IS lock on R, and repeatedly gets an S lock on R.
- T3 reads all of R:
  - T3 gets an S lock on R.
  - OR, T3 could behave like T2; can use lock escalation to decide which.

	--	IS	IX	S	X
--	√	√	√	√	√
IS	√	√	√	√	
IX	√	√	√		
S	√	√		√	
X	√				

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Dynamic Databases

Sailors (*sid*: integer, *sname*: string, *rating*: integer, *age*: real)
Reserves (*sid*: integer, *bid*: integer, *day*: dates, *rname*: string)

- If we relax the assumption that the DB is a fixed collection of objects, even Strict 2PL will not assure serializability:
  - T1 locks all pages containing sailor records with *rating* = 1, say, *age* = 71).
  - Next, T2 i = 1, *age* = 96.
  - T2 also deletes oldest sail ng = 2 (and, say, *age* = 80), and commits.
  - T1 now locks all pages containing sailor records with *rating* = 2, and finds oldest (say, *age* = 63).
- No consistent DB state; however T1 "correctly" gets through!

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The Problem

- T1 implicitly assumes that it has locked the set of all sailor records with *rating* = 1.
  - Assumption only holds if no sailor records are added while T1 is executing!
  - Need so rce this assumption. (Index lo predicate locking.)
- Example shows that conflict serializability guarantees serializability only if the set of objects is fixed!

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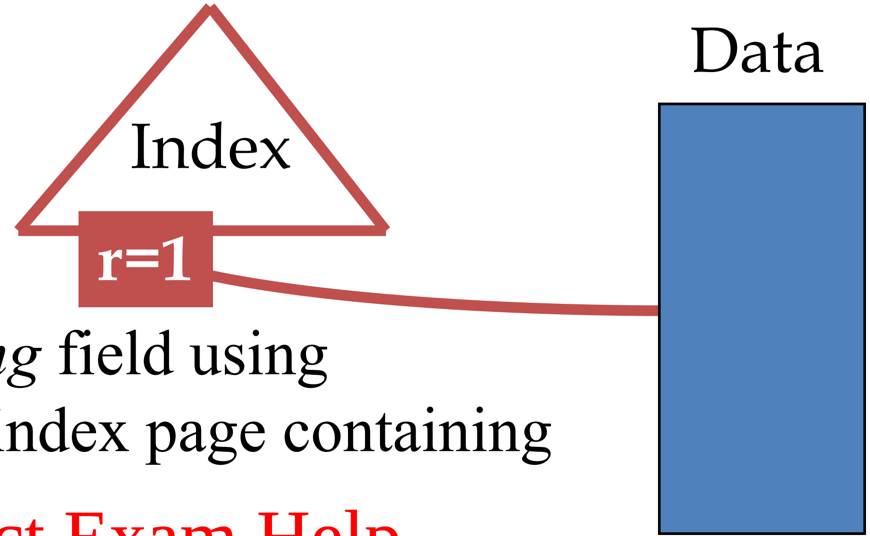
Index Locking



- If there is a dense index on the *rating* field using Alternative (2), T1 should lock the index page containing the data entries with *rating* = 1.

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  - If there are no 1, T1 must lock the index

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    ta entry *would* be, if it existed!

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- If there is no suitable index, T1 must lock all pages, and lock the file/table to prevent new pages from being added, to ensure that no new records with *rating* = 1 are added.

Predicate Locking

- Grant lock on all records that satisfy some logical predicate, e.g. *age > 2*salary*.

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- Index lockin f predicate locking for orts efficient implementation of the p ock.

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- What is the predicate in the sailor example?
- In general, predicate locking has a lot of locking overhead.

Locking in B+ Trees

- How can we efficiently lock a particular leaf node?
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  - Btw, don't confuse this with multiple granularity locking!
- One solution https://eduassistpro.github.io/ cture, just lock pages while traversing th Add WeChat edu_assist_pro owing 2PL.
- This has terrible performance!
  - Root node (and many higher level nodes) become bottlenecks because every tree access begins at the root.

Two Useful Observations

- Higher levels of the tree only direct searches for leaf pages.
- For inserts, a node on a path from root to modified leaf must be l course), only if a split can pr e modified leaf. (Similar point holds es.)
- We can exploit these observations to design efficient locking protocols that guarantee serializability *even though they violate 2PL.*

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A Simple Tree Locking Algorithm

- Search: Start at root and go down; repeatedly, S lock child then unlock parent.
- Insert/Delete: Start at root and go down, obtaining X locks as needed. O if it is safe:
  - If child i s on ancestors.
- Safe node: Node such that c ot propagate up beyond this node.
  - Inserts: Node is not full.
  - Deletes: Node is not half-empty.

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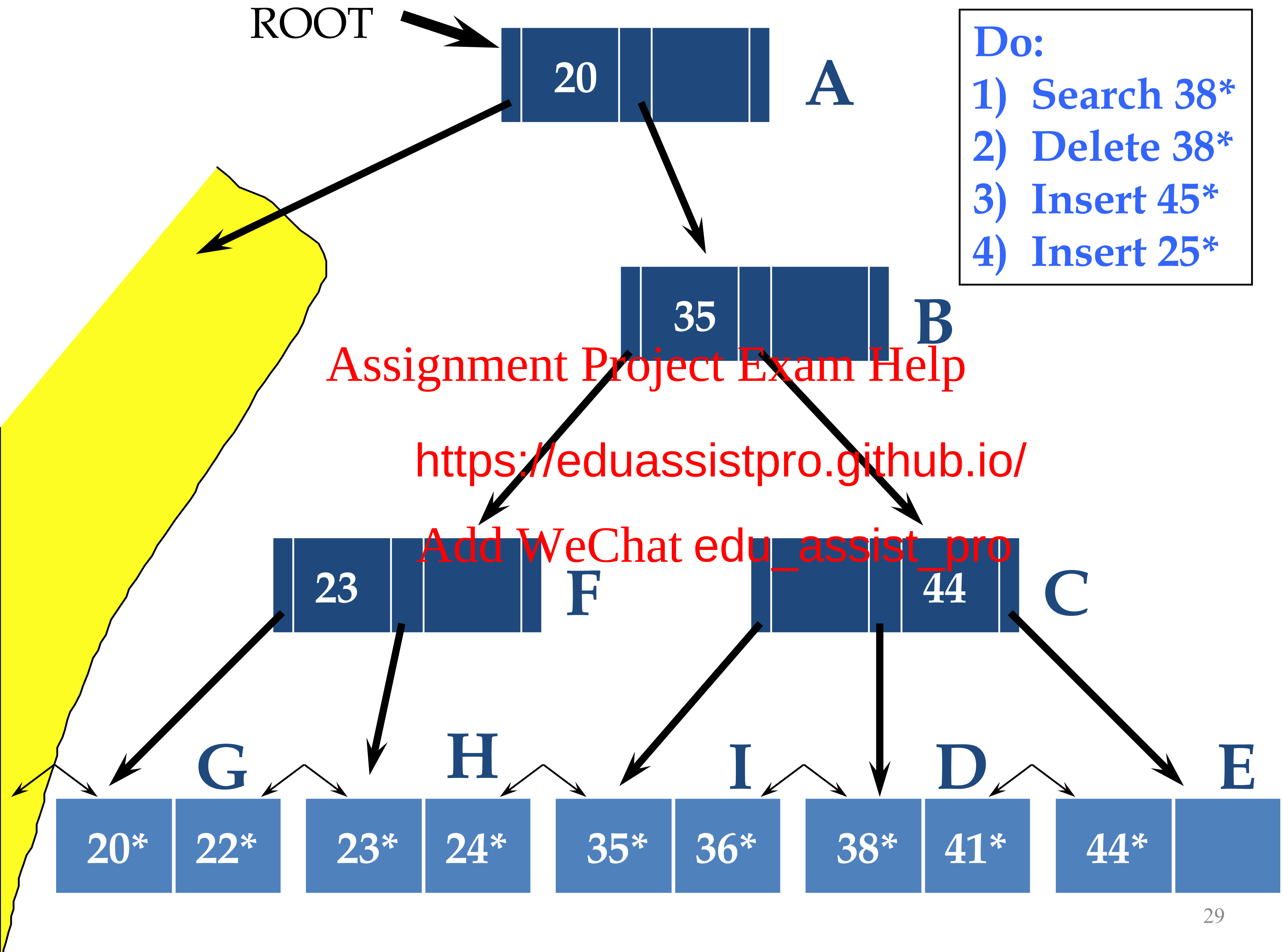

Do:
1) Search 38*
2) Delete 38*
3) Insert 45*
4) Insert 25*

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A Better Tree Locking Algorithm (See Bayer-Schkolnick paper)

- Search: As before.
- Insert/Delete:

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  - Set lock leaf, and set X lock on l

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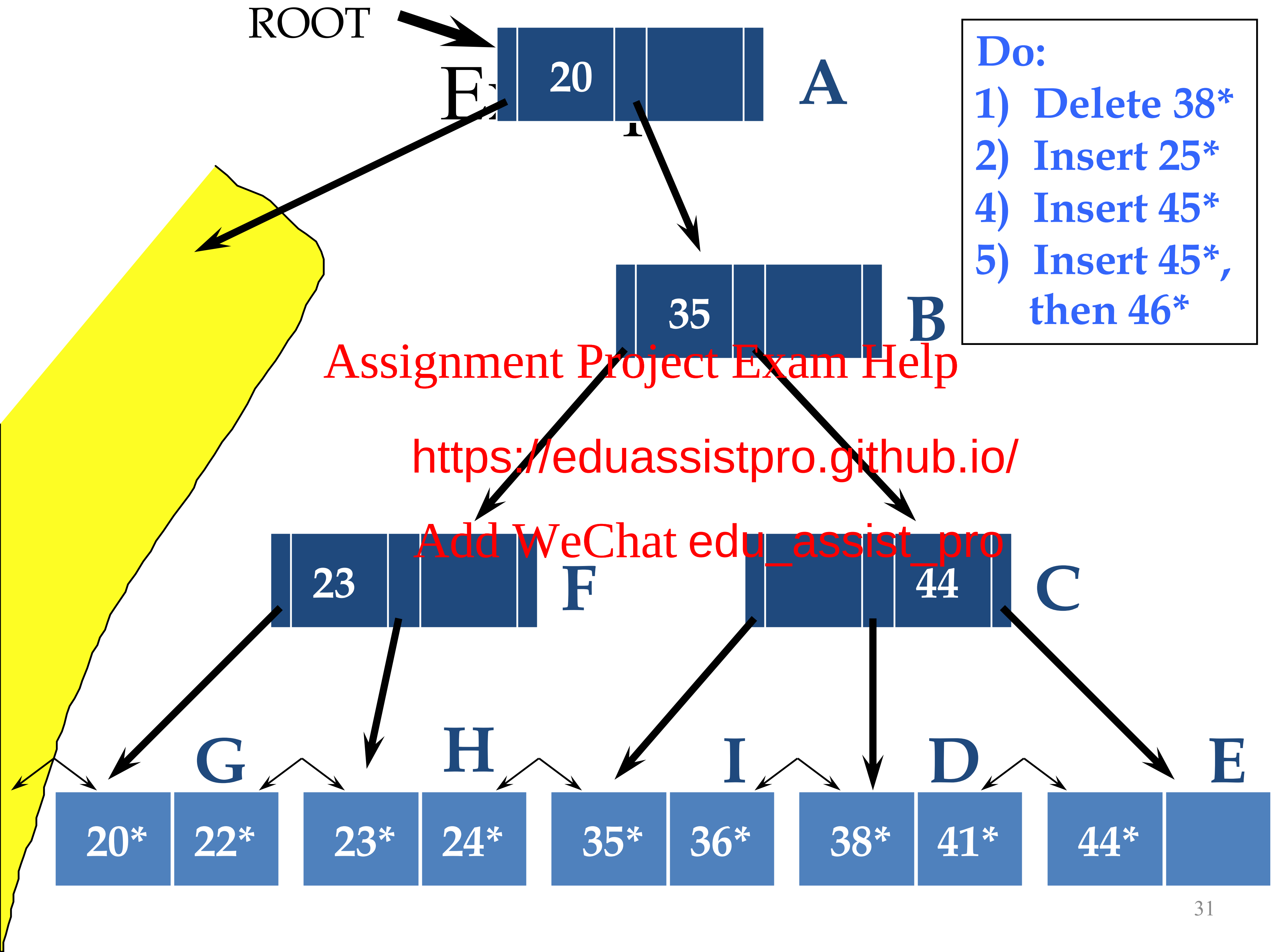
  - If leaf is not safe, rele s, and restart Xact using previous Insert/Delete protocol.
- Gambles that only leaf node will be modified; if not, S locks set on the first pass to leaf are wasteful. In practice, better than previous alg.



Do:

1) Delete 38*
2) Insert 25*
4) Insert 45*
5) Insert 45*, then 46*

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Even Better Algorithm

- Search: As before.
- Insert/Delete:
  - Use original Insert/Delete protocol, but set IX locks ins odes.
  - Once leaf is locked, co locks to X locks top-down: i.e., st node nearest to root. (Top-down reduces chances of deadlock.)

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(Contrast use of IX locks here with their use in multiple-granularity locking.)

Hybrid Algorithm

- The likelihood that we really need an X lock decreases as we move up the tree.

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- Hybrid appr

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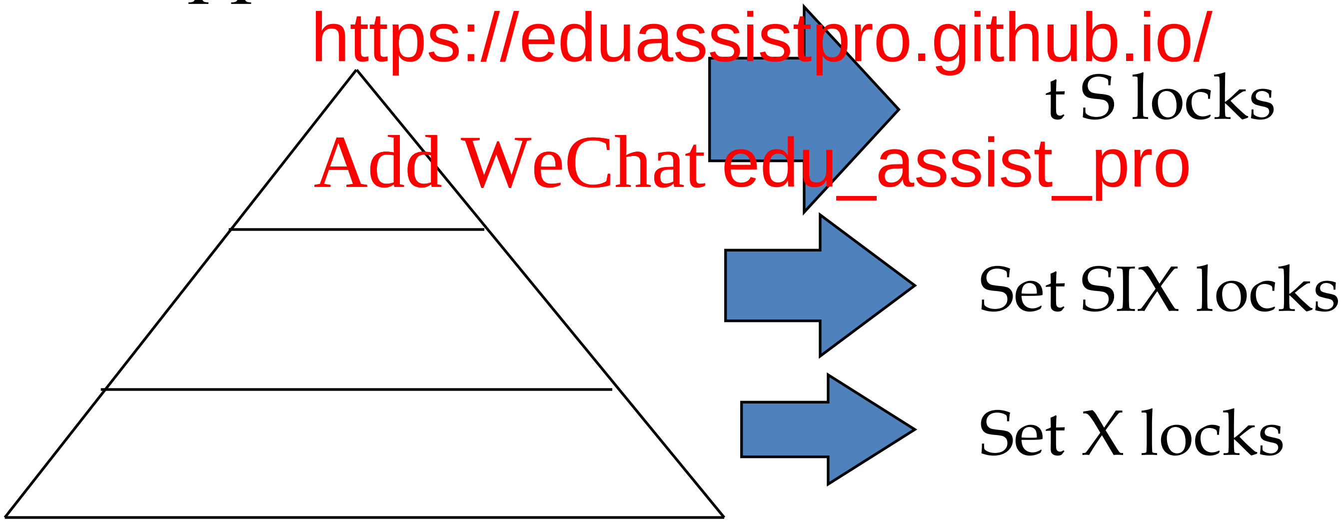

Multiversioning

- Similar to the timestamp ordering approach; but is allowed to access “old” versions of a table.

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- A history of the ersions) of each item is kept.

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- When the value of an item is needed, the system chooses a **proper** version of the item that maintains serializability.

- This results in fewer aborted transactions at the cost of greater complexity to maintain more versions of each item.

- We will look at a scheme, several versions $X_1, \ldots, X_k$ of each data item are kept. For each X_i we also keep

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  – *read* $TS(X_i)$ - a

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  – *write* $TS(X_i)$ - as for timestamp or

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- Read and write are done as follows for a transaction *P* with timestamp T.

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- *Note:* Cascading rollback and cyclic restart problems can still occur, but should be reduced.

- However, there is an increased overhead in maintaining multiple versions of items.

Optimistic scheduling

- In two-phase locking, timestamp ordering, and multiversioning concurrency control techniques, a certain degree of checking is done **before** a database operation can be executed.

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- The idea here is t https://eduassistpro.github.io/ est!

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- No checking is done while the tran cuting.

- The protocol has three phases.

  – *read phase* - A transaction can read data items from the database into local variables. However, updates are applied only to local copies of the data items kept in the transaction workspace.

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  – *validation pha* hat serializability is not violated,

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  – *write phase* -if validation succeeds, updates are applied and the transaction is committed. Otherwise, the updates are discarded and the transaction is restarted.

- A scheme uses timestamps and keeps each transaction's
  - read-set - the set of items read by the transaction,
  - write-set - the set of items written by the transaction.

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- During validation, we check that t does not interfere with any transaction that is committed or currently validating.

- Each transaction T is assigned 3 timestamps:

  Start(T), *Validation*(T), *Finish*(T).

- To pass the validation test for T, one of the following must be true:

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  – 1. *Finish*(S) $<$

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  – 2. for S s.t. *Start*(T) $<$ *Finish*(S), t

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    a) write set of S is disjoint from the nd

    b) *Finish*(S) $<$ *Validation*(T).

- Optimistic control is a good option if there is not much interaction between transactions.

- **Note:** Our earlier treatment of recovery methods largely ignored concurr

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2PL vs. TSO vs. MV vs. OP

- A Comparison among two-phase locking (2PL), timestamp ordering (TSO), multiversioning (MV), optimistic (OP) concurrency control techniques.

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- MV should provi https://eduassistpro.github.io/ egree (in average). However, we nee ach data item.

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- 2PL can offer the second greatest concurrency degree (in average); but will result in deadlocks. To resolve the deadlocks, either
  - need additional computation to detect deadlocks and to resolve the deadlocks, or
  - reduce the concurrency degree to prevent deadlocks by adding other restrictions.

2PL vs. TSO vs. MV vs. OP (cont.)

- If most transactions are very short, we can use 2PL + deadlock detection and resolution.

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- TSO has a less co f 2PL if a proper deadlock resoluti oes not cause deadlocks. Other art and cascading rollback, will appear in TSO.

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- If there are not much interaction between transactions, OP is a very good choice. Otherwise, OP is a bad choice.