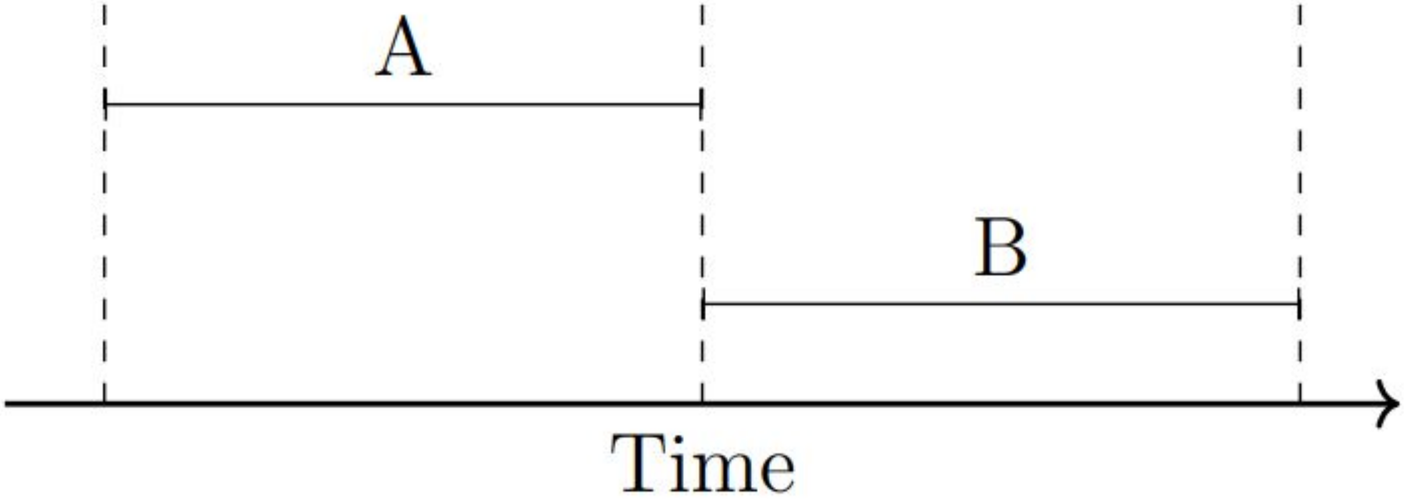
Control de la concurrencia

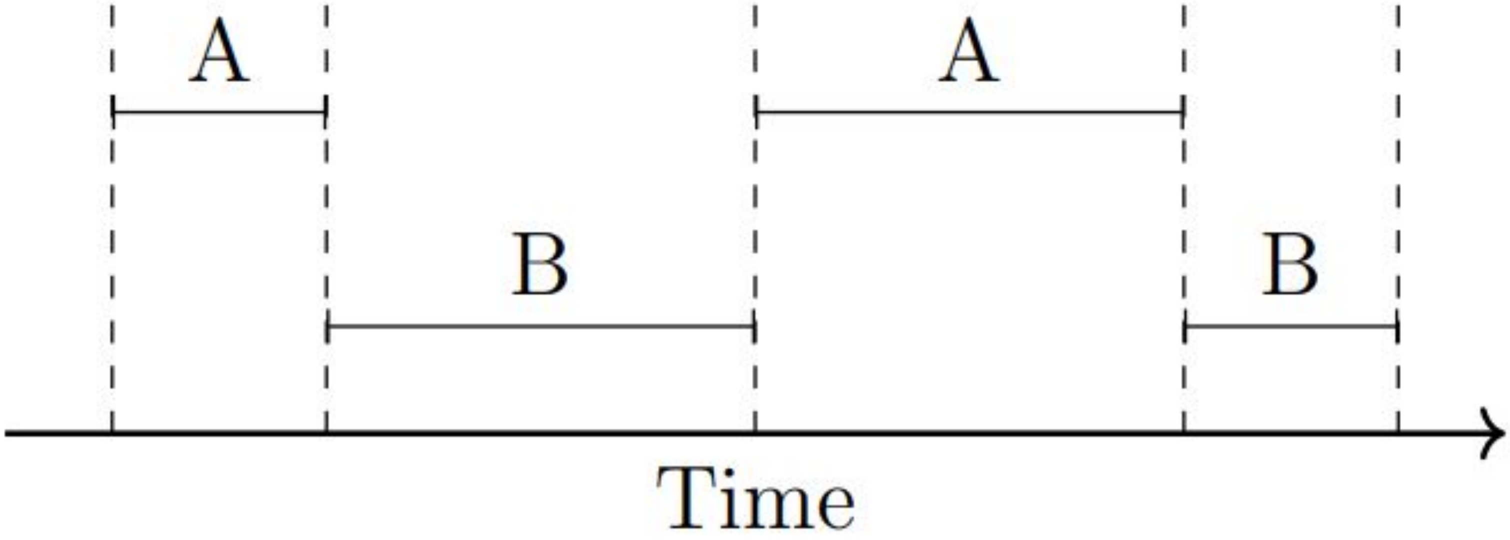
Sivana Hamer - sivana.hamer@ucr.ac.cr
Escuela de Ciencias de la Computación

UNIVERSIDAD DE COSTA RICA

En sistemas mono-usuario, se puede ejecutar todo dentro de un thread serialmente

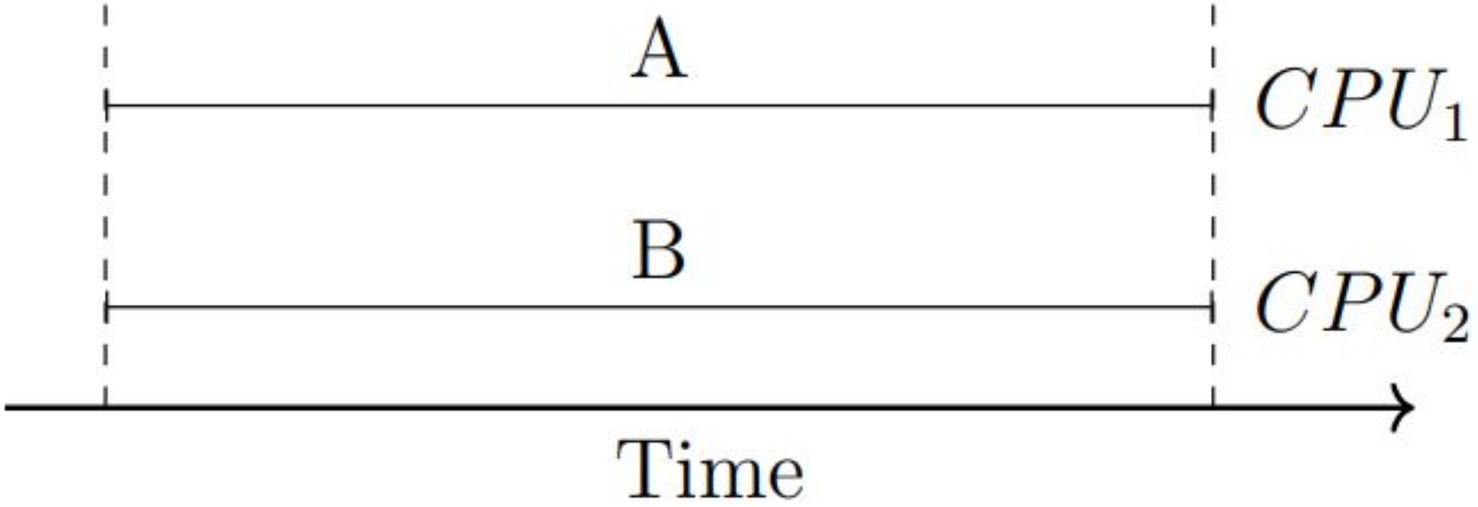


También se puede ejecutar intercaladamente un proceso



(b) Interleaved processing

Se puede procesar totalmente paralelo en varias CPUs



(c) Parallel processing

Un *schedule* es el orden en que se ejecutan las transacciones

T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;

Se puede tener un *schedule serial*

T_1	T_2
	read(A);
	$A := A + 50$;
	write(A);
	commit;
read(A);	
$A := A - 100$;	
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	

Se puede tener un *schedule* equivalente a ejecución serial

T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
read(B);	
$B := B + 100$;	
write(B);	
commit;	

Se puede tener un *schedule* que deja un estado inconsistente

T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	

Con la ejecución concurrente, pueden suceder varios problemas

T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
write(A);	
	write(A);
read(B);	
$A := B + 100$;	
write(B);	

Figure 8: Lost update example

T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
	read(A);
	$A := A + 50$;
	write(A);
read(B);	
ABORT;	

T_1	T_2
read(A)**;**	
$A := A - 50;$	
write(A);	
	read(A);
	$A := A + 50;$
	write(A)**;**
read(A)**;**	
$A := A - 50;$	
write(A);	

Figure 10: Unrepeatable read example

T_1	T_2
read(tA);	
	insert$(a_{n+1}$ **in** $tA)$;
read(tA);	

Figure 11: Phantom read example

La seriabilidad determina si una ejecución concurrente es equivalente a una ejecución serial

T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;

≡

T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
read(B);	
$B := B + 100$;	
write(B);	
commit;	

Existen dos tipos de seriabilidad…

- Basado en conflictos
- Basado en vistas

Se pueden generar conflictos por el mismo ítem de datos cuando…

	Write	**Read**
Write	✓	✓
Read	✓	

If I and J are two consecutive instructions of a schedule S that do not have a conflict, then we can swap the order of I and J to generate a new schedule for S'. S is equivalent to S' as all instructions have the same order except for I and J whose order does not matter. If schedule S can be transformed into a schedule S' by swapping non-conflicting instructions, then S and S' are *conflict equivalent*.

T_1	T_2
read(A);	
write(A);	
	read(A);
	write(A);
read(B);	
write(B);	

(a) Concurrent schedule

T_1	T_2
read(A);	
write(A);	
	read(A);
	write(A);
read(B);	
write(B);	

(a) Concurrent schedule

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
	write(A);
write(B);	

(b) T_1 *read*$(B) \leftrightarrow T_2$ *write*(A)

T_1	T_2
read(A);	
write(A);	
	read(A);
	write(A);
read(B);	
write(B);	

(a) Concurrent schedule

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
	write(A);
write(B);	

(b) T_1 $read(B) \leftrightarrow T_2$ $write(A)$

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
write(B);	
	write(A);

(c) T_1 $write(B) \leftrightarrow T_2$ $write(A)$

T_1	T_2
read(A);	
write(A);	
	read(A);
	write(A);
read(B);	
write(B);	

(a) Concurrent schedule

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
	write(A);
write(B);	

(b) T_1 $read(B) \leftrightarrow T_2$ $write(A)$

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
write(B);	
	write(A);

(c) T_1 $write(B) \leftrightarrow T_2$ $write(A)$

T_1	T_2
read(A);	
write(A);	
read(B);	
	read(A);
write(B);	
	write(A);

(d) T_1 $read(B) \leftrightarrow T_2$ $read(A)$

T_1	T_2
read(A);	
write(A);	
	read(A);
	write(A);
read(B);	
write(B);	

(a) Concurrent schedule

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
	write(A);
write(B);	

(b) T_1 *read*$(B) \leftrightarrow T_2$ *write*(A)

T_1	T_2
read(A);	
write(A);	
	read(A);
read(B);	
write(B);	
	write(A);

(c) T_1 *write*$(B) \leftrightarrow T_2$ *write*(A)

T_1	T_2
read(A);	
write(A);	
read(B);	
	read(A);
write(B);	
	write(A);

(d) T_1 *read*$(B) \leftrightarrow T_2$ *read*(A)

T_1	T_2
read(A);	
write(A);	
read(B);	
write(B);	
	read(A);
	write(A);

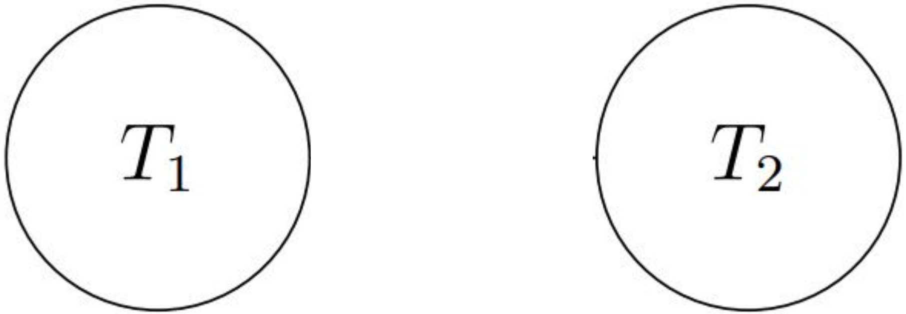
(e) T_1 *read*$(B) \leftrightarrow T_2$ *read*(A)

También se puede generar un gráfico de dependencia con las siguientes condiciones…

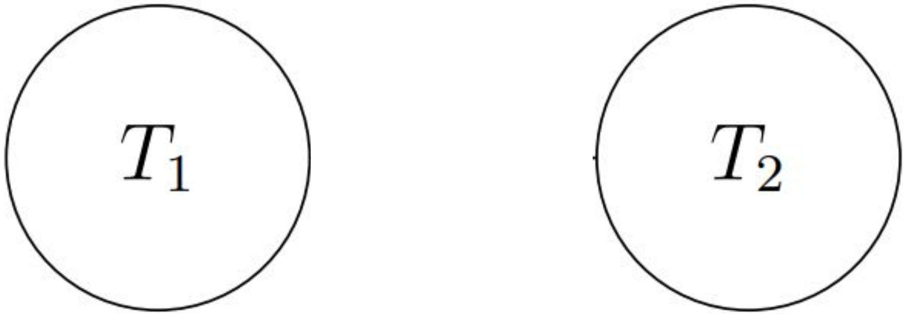
- T_i executes a $write(Q)$ before T_j executes a $read(Q)$.
- T_i executes a $read(Q)$ before T_j executes a $write(Q)$.
- T_i executes a $write(Q)$ before T_j executes a $write(Q)$.

edge T_i to T_j

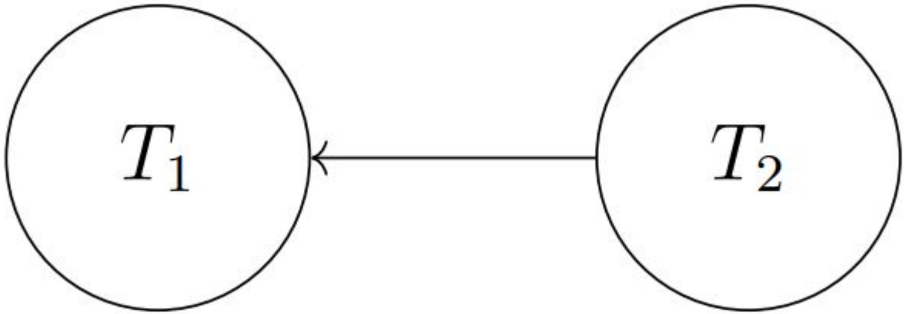
T_1	T_2
read(A);	
$A := A - 100$;	
write(A);	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
read(B);	
$B := B + 100$;	
write(B);	
commit;	



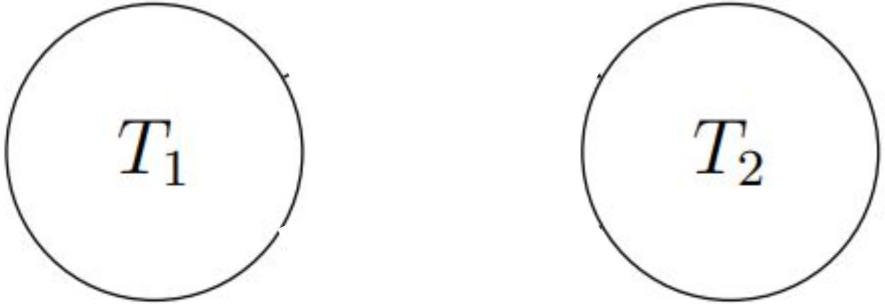
T_1	T_2
read(A);	
$A := A - 100$;	
$\boxed{\text{write}(A);}$	
	$\boxed{\text{read}(A);}$
	$A := A + 50$;
	write(A);
	commit;
read(B);	
$B := B + 100$;	
write(B);	
commit;	



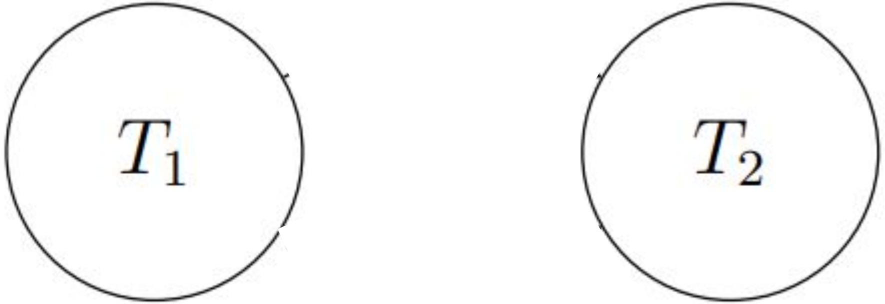
T_1	T_2
read(A);	
$A := A - 100$;	
$\boxed{\text{write}(A);}$	
	$\boxed{\text{read}(A);}$
	$A := A + 50$;
	write(A);
	commit;
read(B);	
$B := B + 100$;	
write(B);	
commit;	



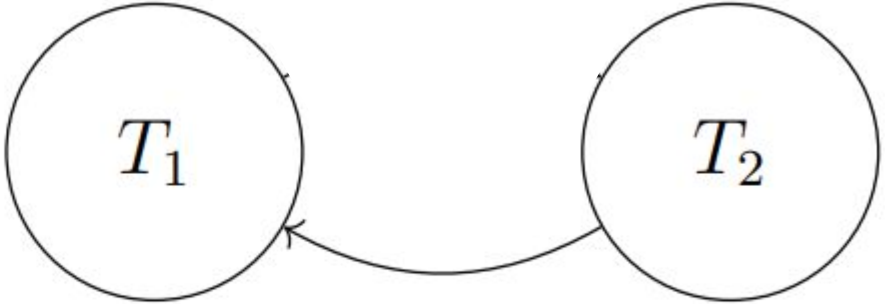
T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



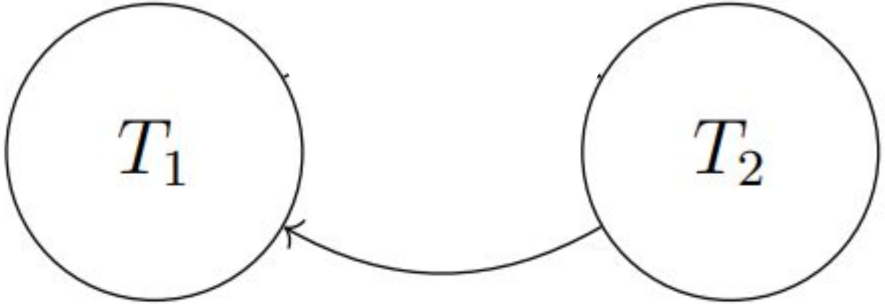
T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	$\boxed{\text{write}(A);}$
	commit;
$\boxed{\text{write}(A);}$	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



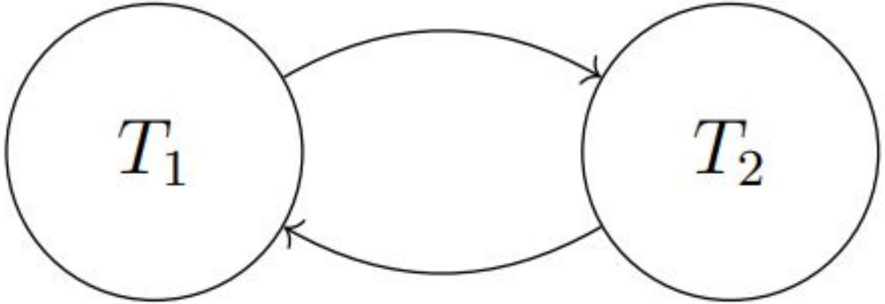
T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	$\boxed{\text{write}(A);}$
	commit;
$\boxed{\text{write}(A);}$	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



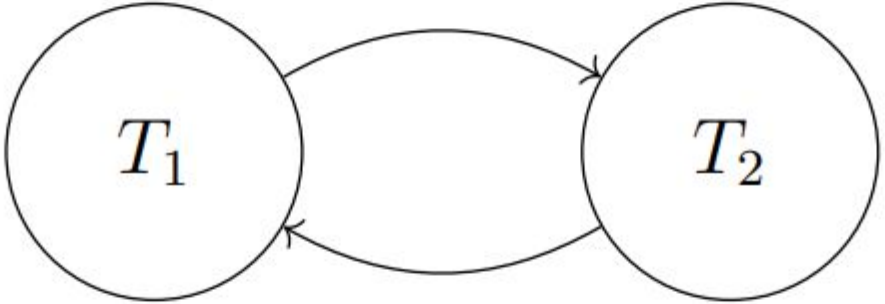
T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



T_1	T_2
read(A);	
$A := A - 100$;	
	read(A);
	$A := A + 50$;
	write(A);
	commit;
write(A);	
read(B);	
$B := B + 100$;	
write(B);	
commit;	



Se **genera un ciclo**, por lo tanto **no es serializable por conflictos**

Existen protocolos para el manejo de la concurrencia

😁

Optimistas

Asume que los conflictos **son pocos** comunes

😥

Pesimistas

Asume que los conflictos **son** comunes

Optimistas

Asume que los conflictos **son pocos** comunes

Pesimistas

Asume que los conflictos **son** comunes

Se basan en candados 🔒

T_1	T_2

X-LOCK(A);
read(A);
write(A);
UNLOCK(A);	

Item	Ti	Tipo

Se basan en candados 🔒

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	

Item	Ti	Tipo

Se basan en candados 🔒

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	

El candado es otorgado

Item	**Ti**	**Tipo**
A	T1	X

Se basan en candados 🔒

T_1	T_2

X-LOCK(A);
read(A);
write(A);
UNLOCK(A);	

Item	**Ti**	**Tipo**
A	T1	X

Se basan en candados 🔒

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	

Item	Ti	Tipo
A	T1	X

Se basan en candados 🔒

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	

Item	Ti	Tipo
A	T1	X

Se basan en candados 🔒

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	Se libera el candado

Item	Ti	Tipo

Hay distintos tipos de candados…

- **Shared lock ($S-LOCK$).** Several transactions can read at the same time, but none can write. This lock can be acquired by multiple transactions at the same time.
- **Exclusive lock ($X-LOCK$).** Only one transaction can both read and write. This lock prevents other transactions acquiring $S-LOCK$ or $X-LOCK$.

	$S-LOCK$	$X-LOCK$
$S-LOCK$	✓	✗
$X-LOCK$	✗	✗

Aún con candados, se pueden generar estados inconsistentes

T_1	T_2
X-LOCK(A);	
read(A);	
write(A);	
UNLOCK(A);	
	X-LOCK(A);
	write(A);
	UNLOCK(A);
S-LOCK(A);	
read(A);	
UNLOCK(A);	

También puede quedar una transacción *starved*, se queda esperando por un recurso

T_1	T_2	T_3	T_4	$\cdots$
S-LOCK(A);				$\cdots$
	X-LOCK(A);			$\cdots$
		S-LOCK(A);		$\cdots$
UNLOCK(A);				$\cdots$
			S-LOCK(A);	$\cdots$
		UNLOCK(A);		$\cdots$

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	Ti	Tipo

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	Ti	Tipo

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A); ← Otorgado	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	**Ti**	**Tipo**
A	T1	X

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	**Ti**	**Tipo**
A	T1	X

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Otorgado

Item	**Ti**	**Tipo**
A	T1	X
B	T2	S

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	Ti	Tipo
A	T1	X
B	T2	S

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	**Ti**	**Tipo**
A	T1	X
B	T2	S

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	**Ti**	**Tipo**
A	T1	X
B	T2	S

Otro problema son los deadlocks, donde las transacciones no pueden avanzar por el orden en que se piden los recursos

T_1	T_2
X-LOCK(A);	
	S-LOCK(B);
	read(B);
	S-LOCK(A);
write(A);	
UNLOCK(B);	

Item	Ti	Tipo
A	T1	X
B	T2	S

En 2PL, se piden los candados en fases

Fase de crecimiento
Se piden los candados

T_1	T_2
X-LOCK(A);	
X-LOCK(B);	
read(A);	
write(A);	
	X-LOCK(A);
UNLOCK(A);	
	read(A);
	write(A);
read(B);	
write(B);	
ABORT;	

Candados shorts
Se liberan al momento que ya no se usa

Fase de contracción
Se liberan los candados

En strict 2PL, se piden los candados en fases

Fase de crecimiento
Se piden los candados

T_1	T_2
X-LOCK(A);	
S-LOCK(B);	
	X-LOCK(A);
read(B);	
UNLOCK(B);	
read(A);	
write(A);	
UNLOCK(A);	
COMMIT;	
	read(A);
	write(A);
	COMMIT;

Candados long
Se liberan al hacer commit o abort

Fase de contracción
Se liberan los candados

	$S - LOCK$	$X - LOCK$
2PL	short	short
Strict 2PL	short	long
Rigorous 2PL	long	long

Cuando sucede un deadlock, se puede manejar de varias maneras…

Detección y recuperación

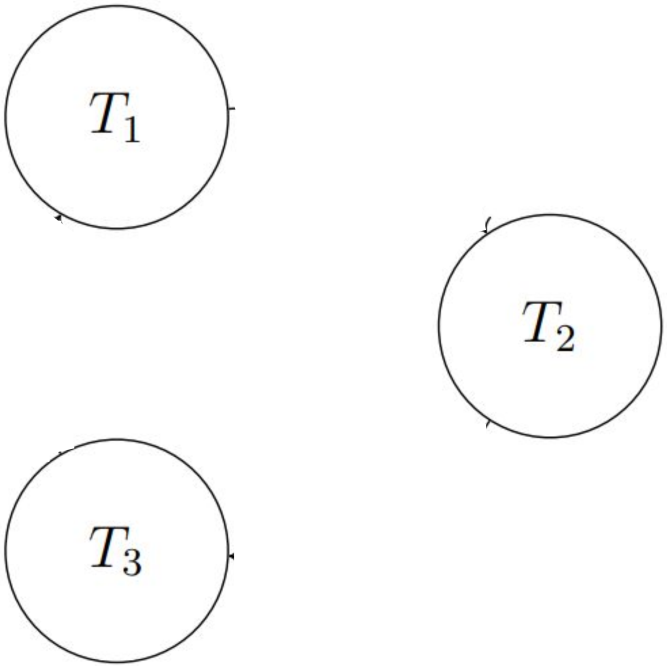
Prevenión

Se puede detectar deadlocks y luego recuperar el sistema a un estado consistente

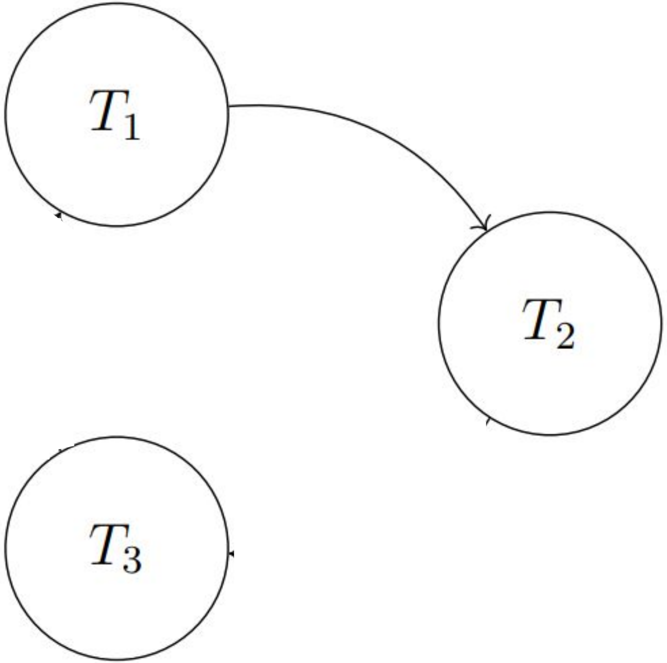
Una manera en que se puede manejar es con wait-for-graphs

Deadlocks can be detected with *waits-for graphs*. Every transaction is a node. An edge is created from T_i to T_j if T_i is waiting for transaction T_j to release a lock. The edge is removed when T_j releases the data item required by T_i. A deadlock exists in the system if, when we check periodically, there is a cycle in the wait-for graph. The deadlock detection algorithm is invoked frequently if many deadlocks occur. Worst case, the algorithm could be invoked every time a lock is not granted immediately.

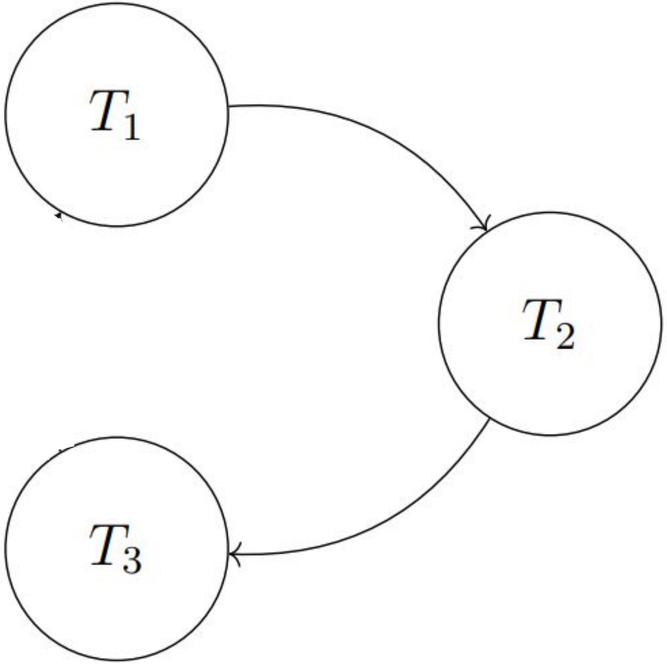
T_1	T_2	T_3
S-LOCK(A);		
	X-LOCK(B);	
		X-LOCK(C);
	S-LOCK(D);	
		S-LOCK(D);
S-LOCK(B);		
	S-LOCK(C);	
		X-LOCK(A);
$\dots$	$\dots$	$\dots$



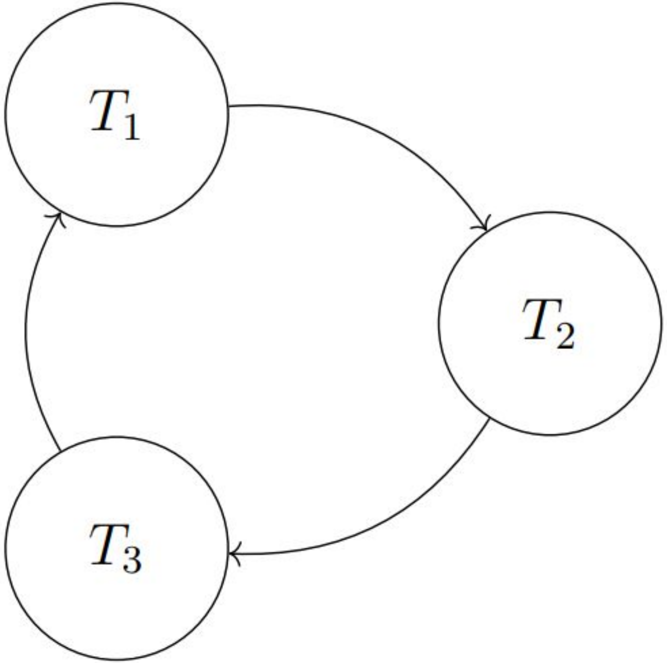
T_1	T_2	T_3
S-LOCK(A);		
	$\boxed{\textbf{X-LOCK(B);}}$	
		X-LOCK(C);
	S-LOCK(D);	
		S-LOCK(D);
$\boxed{\textbf{S-LOCK(B);}}$		
	S-LOCK(C);	
		X-LOCK(A);
...	...	...



T_1	T_2	T_3
S-LOCK(A);		
	X-LOCK(B);	
		$\boxed{\textbf{X-LOCK(C);}}$
	S-LOCK(D);	
		S-LOCK(D);
S-LOCK(B);		
	$\boxed{\textbf{S-LOCK(C);}}$	
		X-LOCK(A);
...	...	...



T_1	T_2	T_3
S-LOCK(A);		
	X-LOCK(B);	
		X-LOCK(C);
	S-LOCK(D);	
		S-LOCK(D);
S-LOCK(B);		
	S-LOCK(C);	
		X-LOCK(A);
...	...	...



Basado en la detección, se selecciona una víctima para hacerle rollback

En la prevención de deadlocks, se asegura que no se entra en un estado de deadlock

Hay protocolos que realizan roll back para salir del deadlock

- **Wait-die ("Old waits for young"):** If the requesting transaction has a higher priority than the holding transaction, it waits. Otherwise, it is aborted. The older transaction is allowed to *wait* for a younger transaction. The younger transaction *dies* (aborts) if it requests the lock held by an older transaction.
- **Wound-wait ("Young waits for old"):** If the requesting transaction has a higher priority than the holding transaction, the holding transaction aborts and rolls back (wounds). Otherwise, it waits. The younger transaction is allowed to *wait* for an older transaction. The older transaction *wounds* (abort) the younger transaction holding the lock.

En *wait-die* T1 espera que T2 libere el candado

T_1	T_2
BEGIN	
	BEGIN
	X-LOCK(A);
X-LOCK(A);	

$$T_1 < T_2$$

En *wound-wait* T2 aborta y T1 obtiene el candado

T_1	T_2
BEGIN	
	BEGIN
	X-LOCK(A);
X-LOCK(A);	

$$T_1 < T_2$$

En *wait-die* T2 pide el candado y como lo tiene T1, T2 muere

T_1	T_2
BEGIN	
X-LOCK(A);	
	BEGIN
	X-LOCK(A);

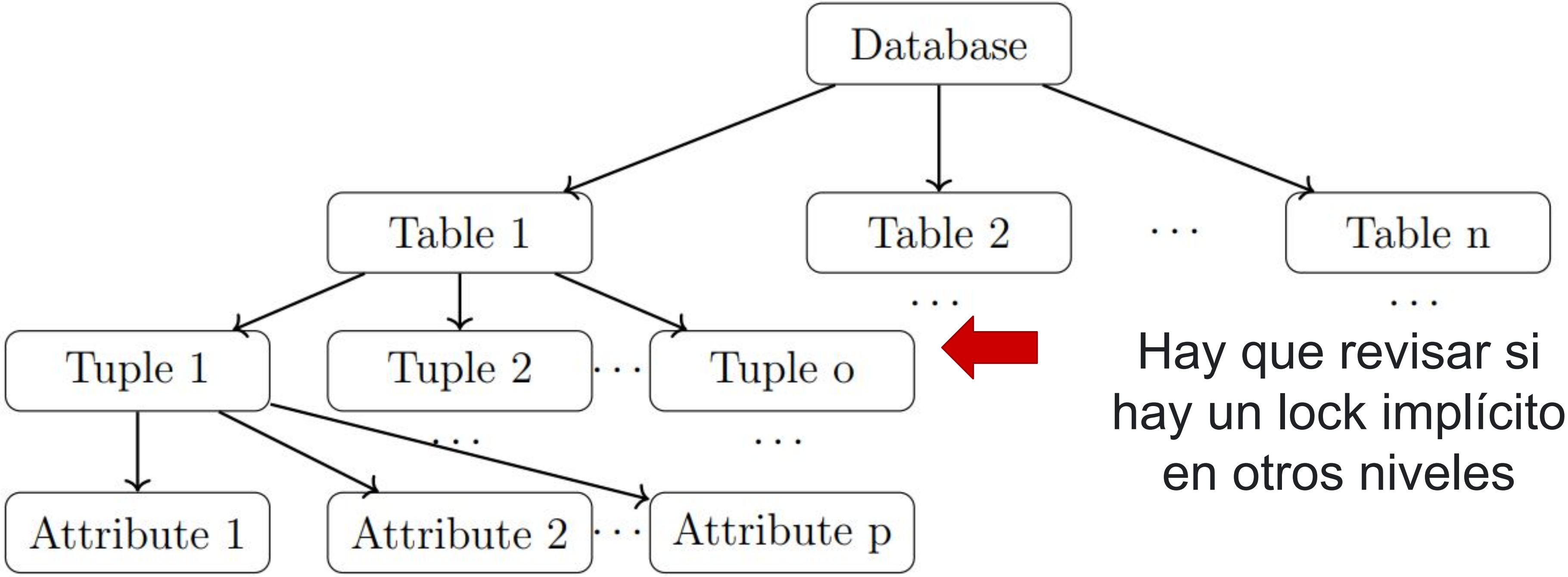
$$T_1 < T_2$$

En *wound-wait* T2 espera que T1 libere el candado

T_1	T_2
BEGIN	
X-LOCK(A);	
	
	BEGIN
	X-LOCK(A);

$$T_1 < T_2$$

En vez de pedir un candado por elemento, se puede pedir items de granularidad más gruesa con granularidad múltiple

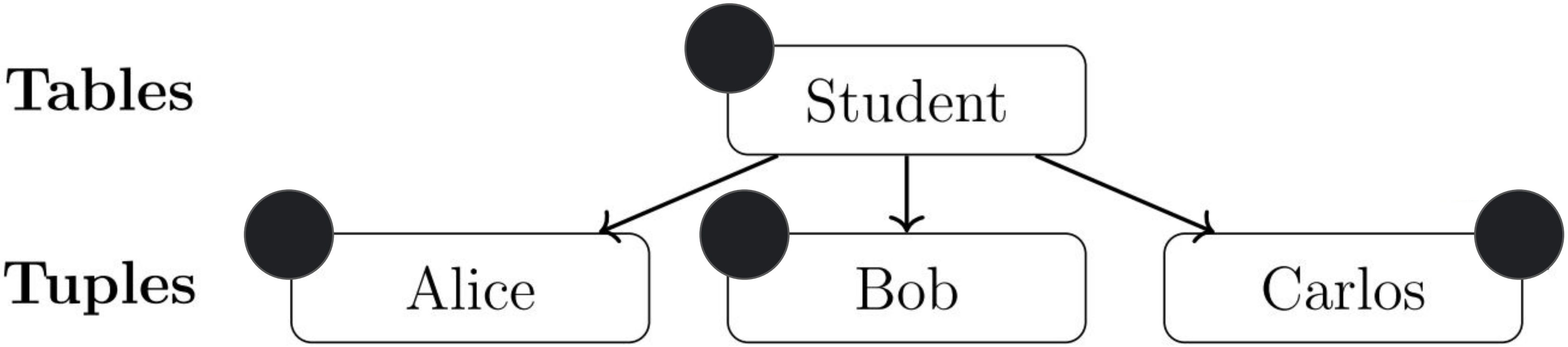


Hay que revisar si hay un lock implícito en otros niveles

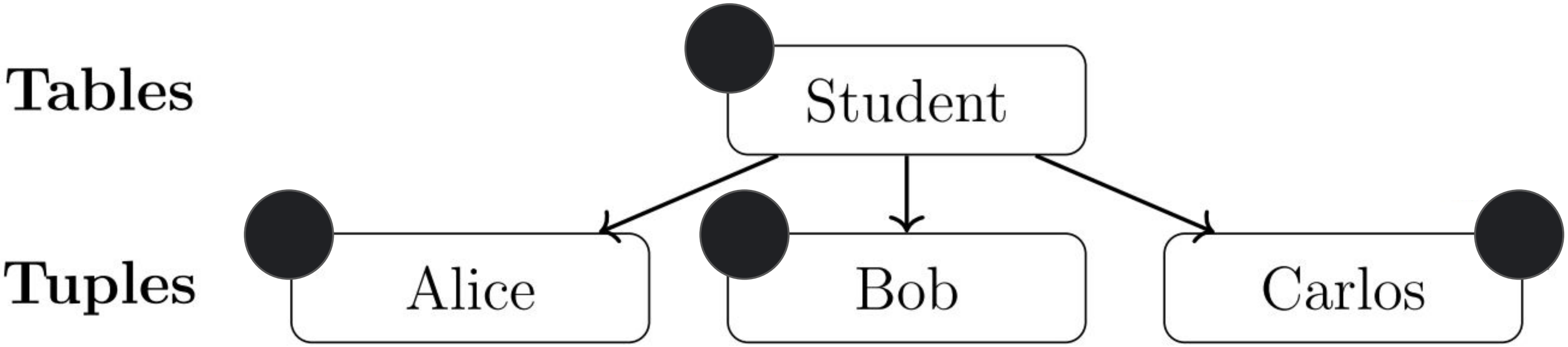
Por lo tanto, se pueden utilizar nodos de intención para no revisar niveles inferiores

- **Intention-shared (IS) mode:** Indicares that the descendants have explicit shared-mode locks.
- **Intention-exclusive (IX) mode:** Indicates that the descendants have explicit exclusive-mode or shared-mode locks.
- **Shared and intention-exclusive (SIX) mode:** The node is explicitly locked in shared-mode, with the descendants explicitly locked in exclusive-mode.

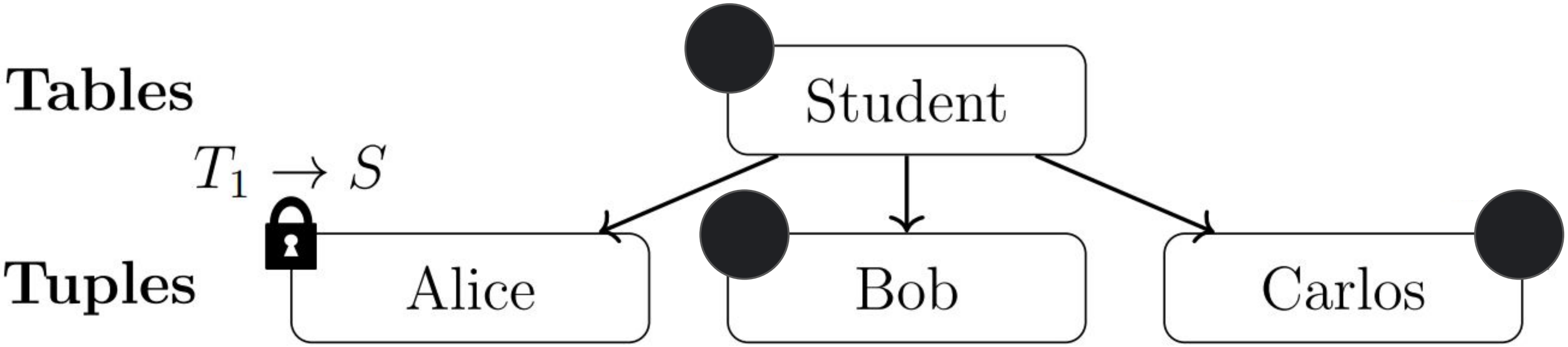
	IS	IX	S	SIX	X
IS	✓	✓	✓	✓	✗
IX	✓	✓	✗	✗	✗
S	✓	✗	✓	✗	✗
SIX	✓	✗	✗	✗	✗
X	✗	✗	✗	✗	✗


Tables
Tuples
Student
Alice
Bob
Carlos

Suppose that transaction T_1 wants to read the data for Alice.

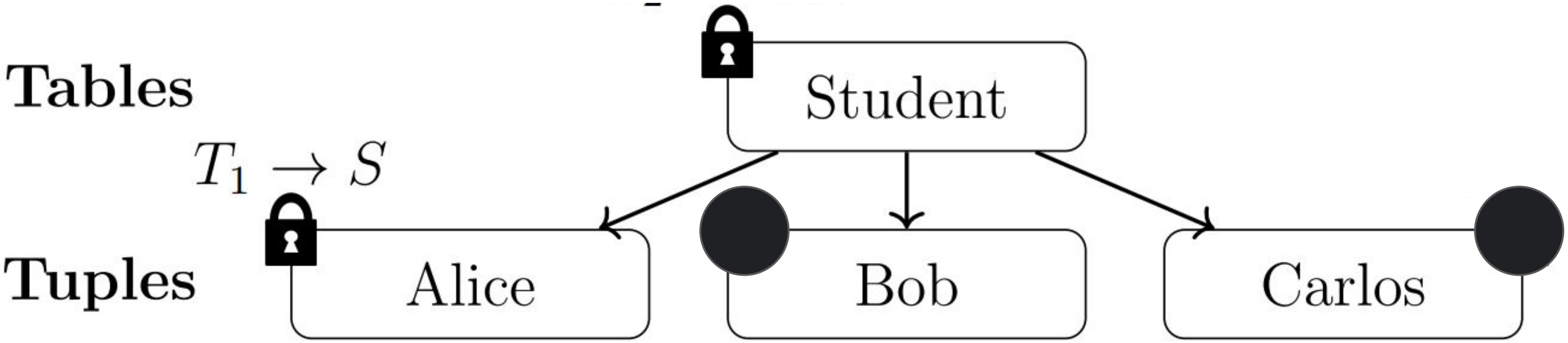


Suppose that transaction T_1 wants to read the data for Alice.

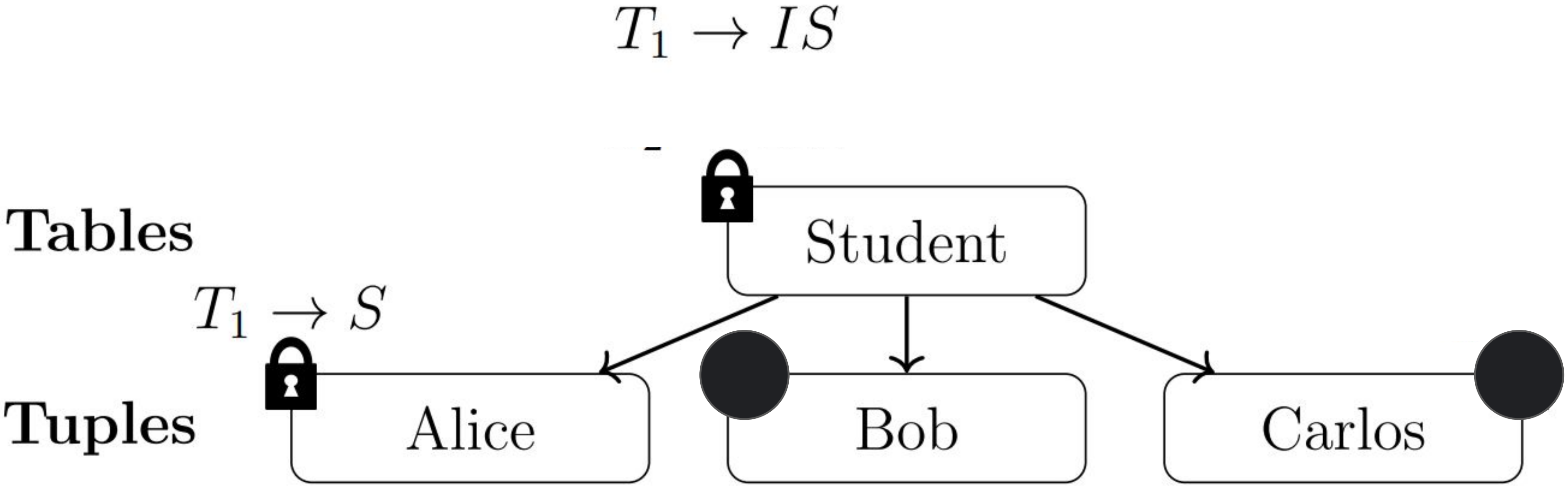


Suppose that transaction T_1 wants to read the data for Alice.

$$T_1 \rightarrow IS$$

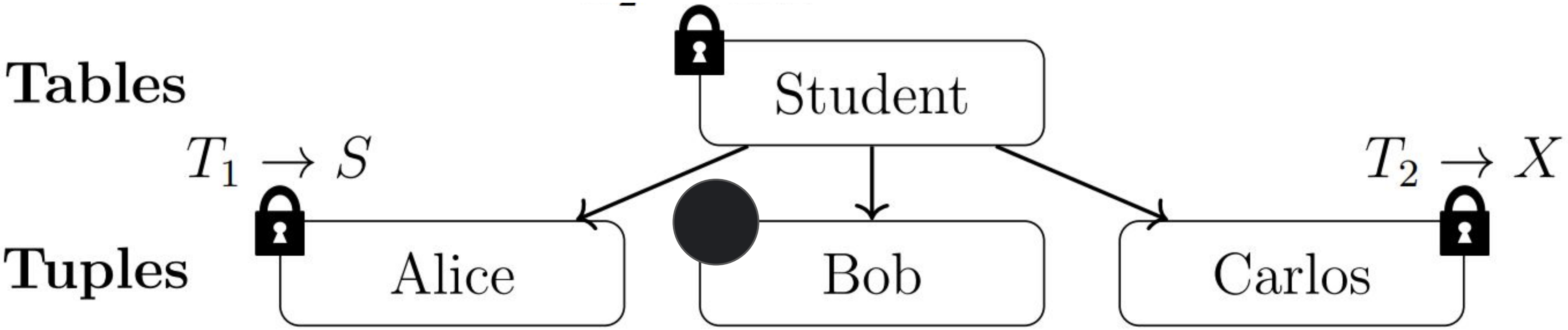


Now, let us assume that transaction T_2 wants to update Carlos's record.

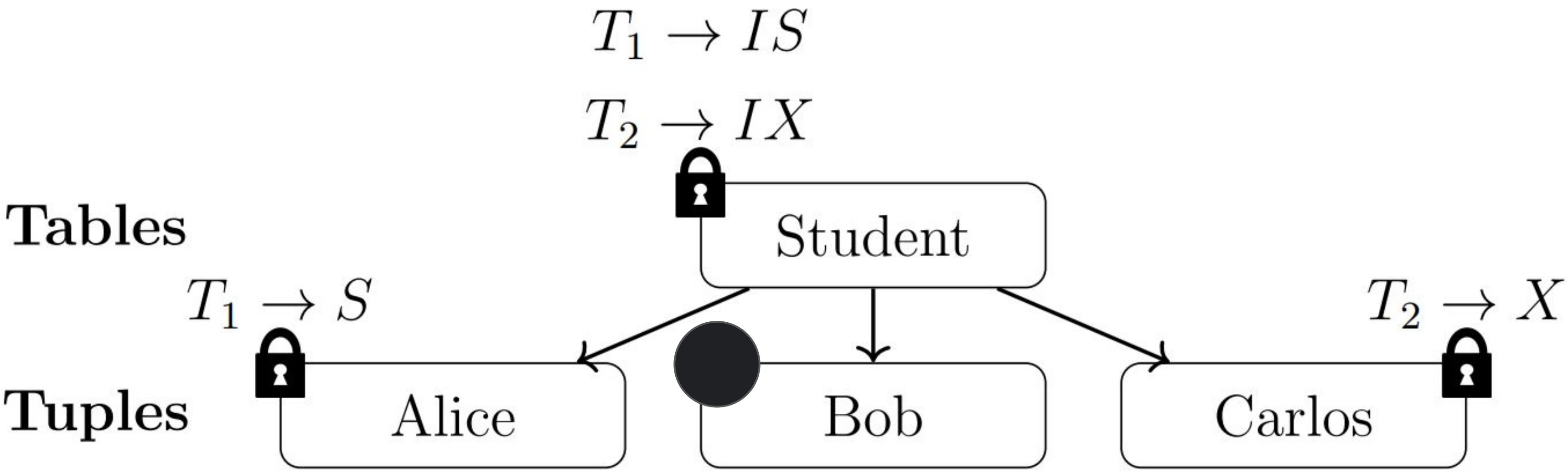


Now, let us assume that transaction T_2 wants to update Carlos's record.

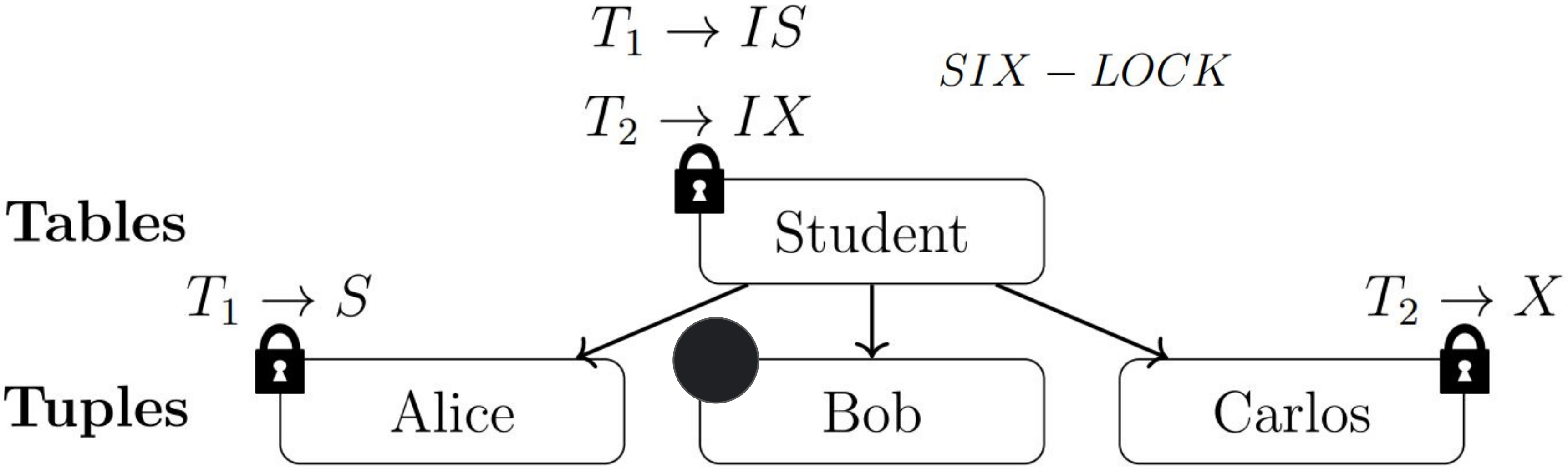
$$T_1 \to IS$$



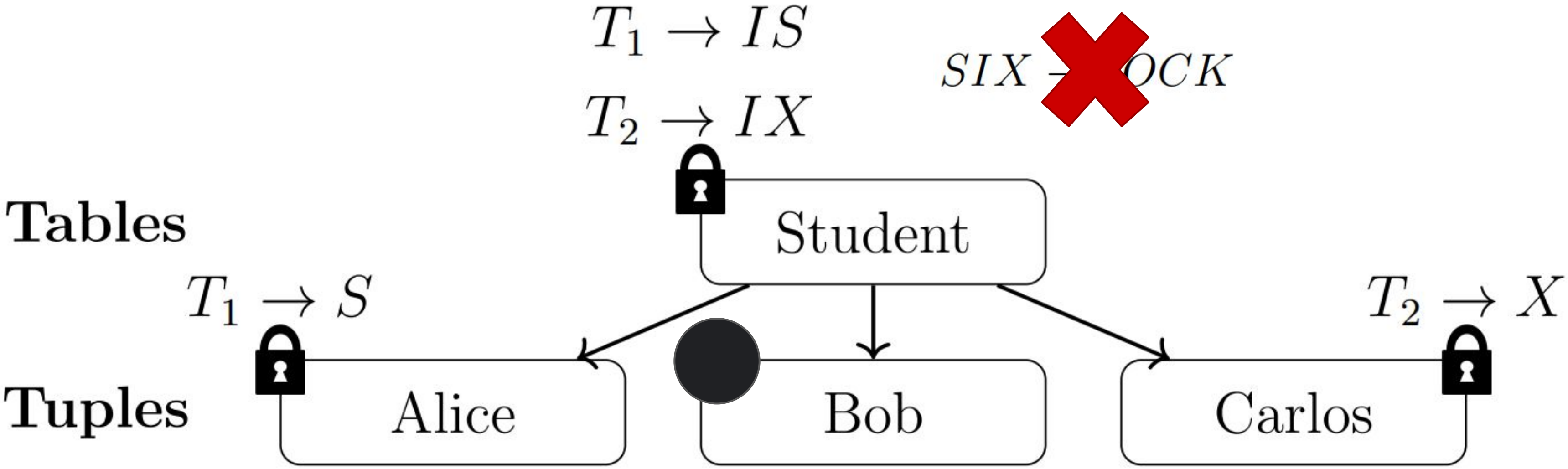
Finally, let's assume that transaction T_3 scans wants to scan the student table to update some student records.



Finally, let's assume that transaction T_3 scans wants to scan the student table to update some student records.



Finally, let's assume that transaction T_3 scans wants to scan the student table to update some student records.



😁

Optimistas

Asume que los conflictos **son pocos** comunes

😥

Pesimistas

Asume que los conflictos **son** comunes

Se puede manejar concurrencia utilizando estampillas de tiempo de las transacciones

- **Read operations.**
  - If $TS(T_i) < W-TS(Q)$, a future transaction has written to data item Q before T_i violating the $TS(T_i) < TS(T_j)$ property. Therefore, T_i is aborted and restarted with a new timestamp value.
  - Else, $TS(T_i) \geq W-TS(Q)$ the order $TS(T_i) < TS(T_j)$ is preserved and the $read(Q)$ instruction is executed. The DBMS also updates $R-TS(Q) = max(R-TS(Q), TS(T_i))$.
- **Write operations.**
  - If $TS(T_i) < R-TS(Q)$ or $TS(T_i) < W-TS(Q)$, a future transaction has read or written to data item Q before T_i violating the $TS(T_i) < TS(T_j)$ property. Therefore, T_i is aborted and restarted with a new timestamp value.
  - Else, $TS(T_i) \geq R-TS(Q)$ and $TS(T_i) \geq W-TS(Q)$ the order of execution is ensured and the $write(Q)$ instruction is executed. The DBMS also updates $W-TS(Q) = TS(T_i)$.

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	0
B	0	0

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	0
B	0	0

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$\boxed{TS(T_1) = 1}$$

$$TS(T_2) = 2$$

$$TS(T_1) \geq W - TS(B) = 1 \geq 0$$

	W-TS	**R-TS**
A	0	0
B	$\boxed{0}$	0

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$\boxed{TS(T_1) = 1}$

$TS(T_2) = 2$

$$R-TS(B) = max(R-TS(B), TS(T_1)) = max(0,1)$$

	W-TS	R-TS
A	0	0
B	0	$\boxed{1}$

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	0
B	0	1

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$TS(T_1) = 1$

$\boxed{TS(T_2) = 2}$

$TS(T_2) \geq W-TS(B) = 2 \geq 0.$

	W-TS	R-TS
A	0	0
B	0	1

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$TS(T_1) = 1$

$\boxed{TS(T_2) = 2}$

$R - TS(B) = max(R - TS(B), TS(T_2)) = max(1, 2)$

	W-TS	R-TS
A	0	0
B	0	$\boxed{2}$

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	0
B	0	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$

$$\boxed{TS(T_2) = 2}$$

$$TS(T_2) \geq W-TS(B) = 2 \geq 0$$

$$R-TS(B) = 2 \geq 2$$

	W-TS	R-TS
A	0	0
B	0	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$TS(T_1) = 1$

$\boxed{TS(T_2) = 2}$

$W - TS(B) = TS(T_2) = 2$

	W-TS	R-TS
A	0	0
B	$\boxed{2}$	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	0
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$\boxed{TS(T_1) = 1}$

$TS(T_2) = 2$

$$TS(T_1) \geq W-TS(A) = 1 \geq 0$$

	W-TS	R-TS
A	$\boxed{0}$	0
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$\boxed{TS(T_1) = 1}$

$TS(T_2) = 2$

$$R - TS(A) = max(R - TS(A), TS(T_1)) = max(0, 1)$$

	W-TS	R-TS
A	0	$\boxed{1}$
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	1
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$TS(T_1) = 1$

$\boxed{TS(T_2) = 2}$

$$TS(T_2) \geq W-TS(A) = 2 \geq 0$$

	W-TS	R-TS
A	0	1
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$

$$\boxed{TS(T_2) = 2}$$

$$R-TS(A) = max(R-TS(A), TS(T_2)) = max(1,2)$$

	W-TS	R-TS
A	0	$\boxed{2}$
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	2
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$\boxed{TS(T_1) = 1}$$
$$TS(T_2) = 2$$

$$TS(T_1) \geq W-TS(A) = 1 \geq 0$$

	W-TS	R-TS
A	0	2
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$\boxed{TS(T_1) = 1}$$

$$TS(T_2) = 2$$

$$R-TS(A) = max(R-TS(A), TS(T_1)) = max(2, 1)$$

	W-TS	R-TS
A	0	2
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$
$$TS(T_2) = 2$$

	W-TS	R-TS
A	0	2
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

$$TS(T_1) = 1$$

$$\boxed{TS(T_2) = 2}$$

$$TS(T_2) \geq W-TS(A) = 2 \geq 0$$

$$TS(T_2) \geq R-TS(a) = 2 \geq 2,$$

	W-TS	R-TS
A	0	2
B	2	2

T_1	T_2
read(B);	
	read(B);
	write(B);
read(A);	
	read(A);
read(A);	
	write(A);

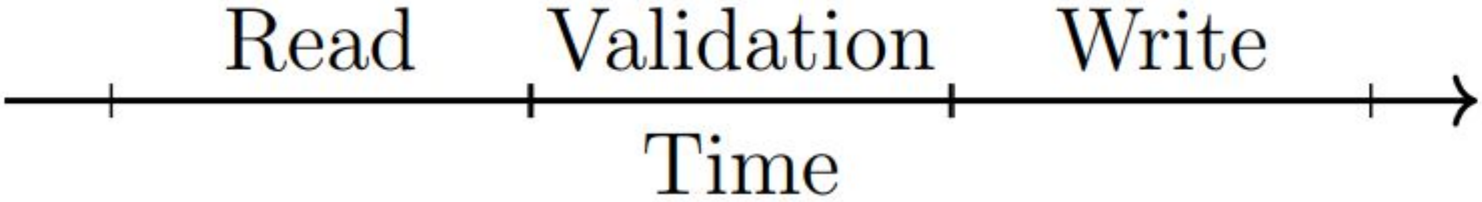
$TS(T_1) = 1$

$\boxed{TS(T_2) = 2}$

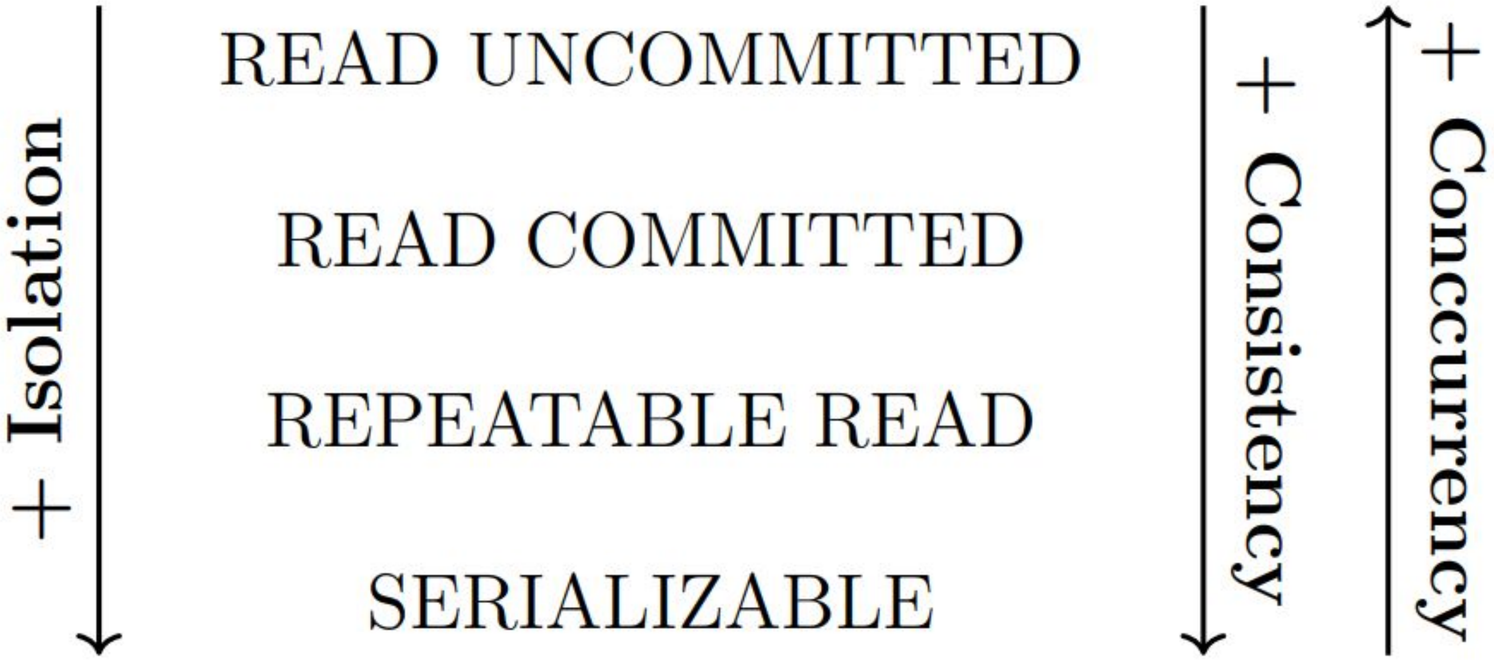
$W - TS(A) = TS(T_2) = 2.$

	W-TS	R-TS
A	2	2
B	2	2

Validación optimista se enfoca en realizar validación solo cuando se hacen escrituras



Los niveles de aislamiento el grado de concurrencia que se requiere



Los problemas que pueden ocurrir dependiendo el nivel de aislamiento son…

	Lost update	Dirty read	Unrepeatable read	Phantom read
READ UNCOMMITTED	✗	?	?	?
READ COMMITTED	✗	✗	?	?
REPEATABLE READ	✗	✗	✗	?
SERIALIZABLE	✗	✗	✗	✗

	$S - LOCK$		$X - LOCK$
	data-item	condition	
READ UNCOMMITTED	None	None	Long
READ COMMITTED	Short	Short	Long
REPEATABLE READ	Long	Short	Long
SERIALIZABLE	Long	Long	Long

SQL

Copy

```
USE AdventureWorks2012;
GO
SET TRANSACTION ISOLATION LEVEL REPEATABLE READ;
GO
BEGIN TRANSACTION;
GO
SELECT *
    FROM HumanResources.EmployeePayHistory;
GO
SELECT *
    FROM HumanResources.Department;
GO
COMMIT TRANSACTION;
GO
```

Referencias

- R. Elmasri and S. Navathe, Fundamentals of database systems, 7th ed. Pearson, 2016, chapters 20 and 21.
- A. Crotty and M. Li. Lectures #15 to #18. [Online]. Available: https://15445.courses.cs.cmu. edu/fall2021/schedule.html
- A. Silberschatz, H. F. Korth, and S. Sudarshan, Database System Concepts, 7th ed. New York, NY: McGraw-Hill, 2020, chapters 17 and 18.
- H. Berenson, “A Critique of ANSI SQL Isolation Levels,” p. 10.
- H. T. Kung and J. T. Robinson, “On Optimistic Methods for Concurrency Control,” ACM Transactions on Database Systems, vol. 6, no. 2, p. 14.
- Microsoft. (2022). SET TRANSACTION ISOLATION LEVEL (Transact-SQL). Recuperado de: https://docs.microsoft.com/en-us/sql/t-sql/statements/set-transaction-isolation-level-transact-sql?view=sql-server-ver16