Transactional Memory: Myths and Limits

R. Guerraoui, EPFL


Lausanne
Vevey
Villeneuve
Nyon
Genève

This tutorial is about

Principles of transactional memory

Transactional memory

1. Why do we care?
2. What should we expect?
3. What might we expect?

Transactional memory

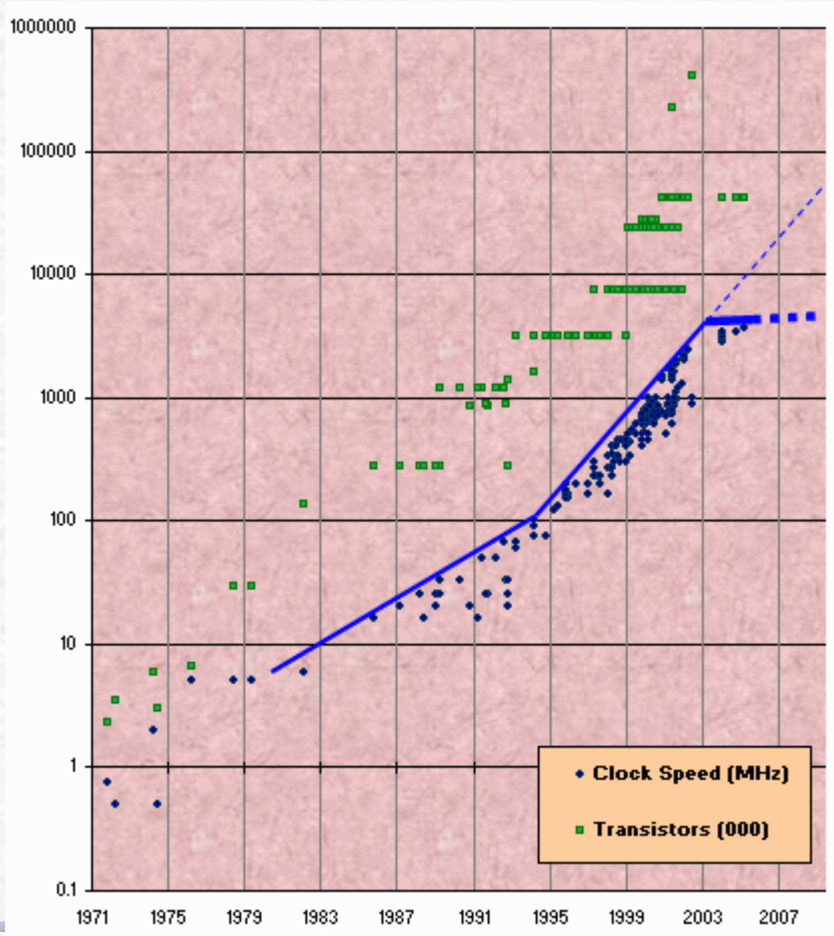
1. Why do we care?

From the New York Times San Francisco, May 7, 2004

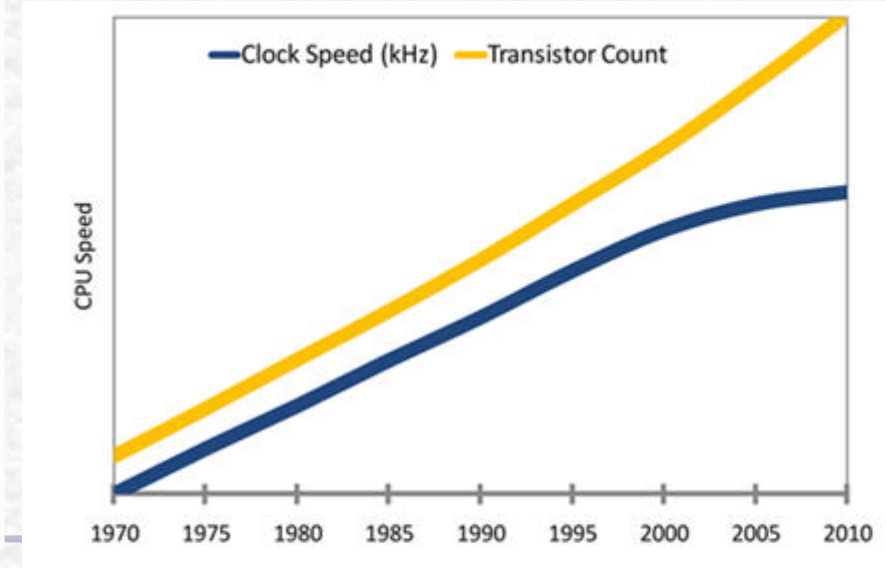
Intel announces a drastic change in its business strategy:

« Multicore is THE way to boost performance »

Moore's Law and CPU speed



- Transistor count still rising according to Moore's Law
- Clock speed flattening



Multicores

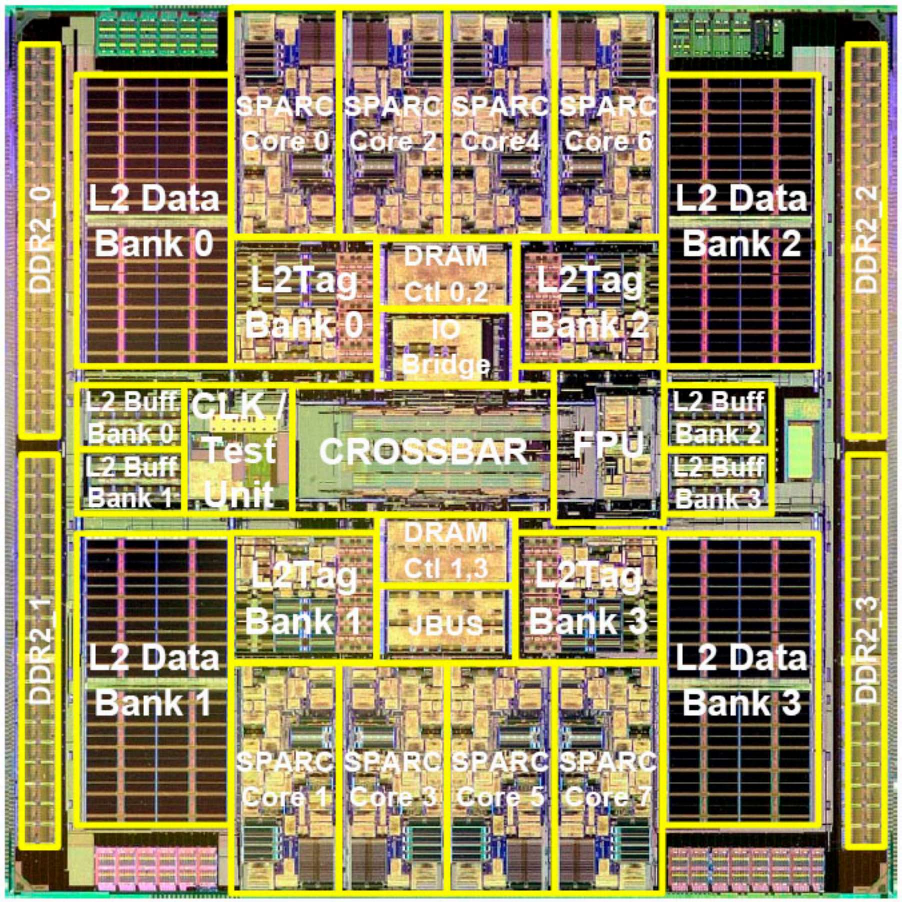
- Multicores are the only way to increase performance
- Indeed single-thread performance doesn’t improve…

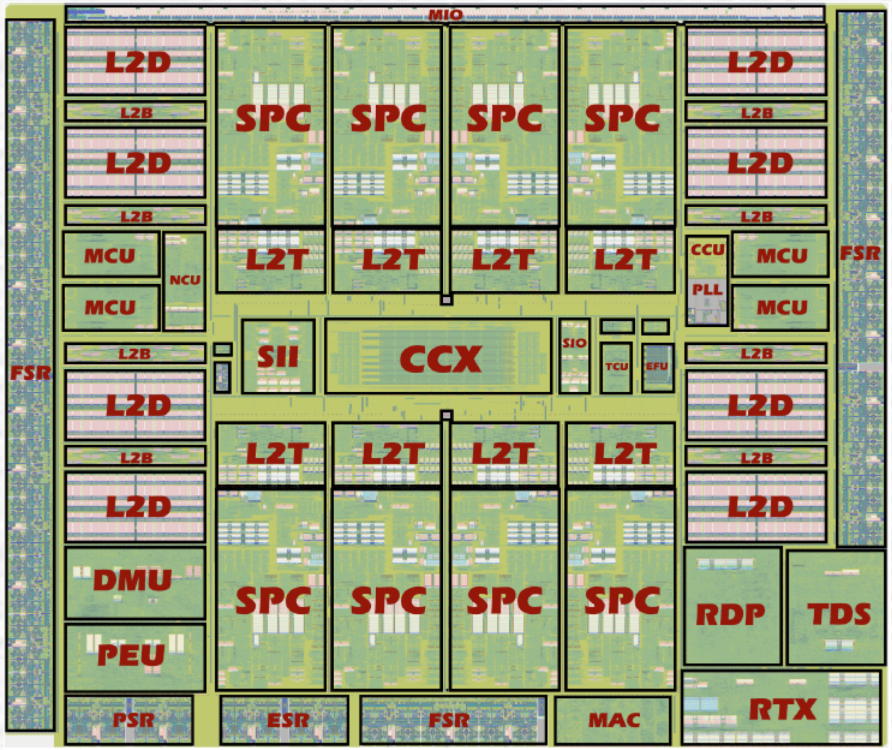
  … but we can put more cores on a chip

Multicores everywhere

- **Dual-core** commonplace in laptops
- **Quad-core** in desktops
- **Dual quad-core** in servers
- All major chip manufacturers produce multicore CPUs
  - **SUN Niagara** (8 cores, 32 concurrent threads)
  - **Intel Xeon** (4 cores)
  - **AMD Opteron** (4 cores)
  - …

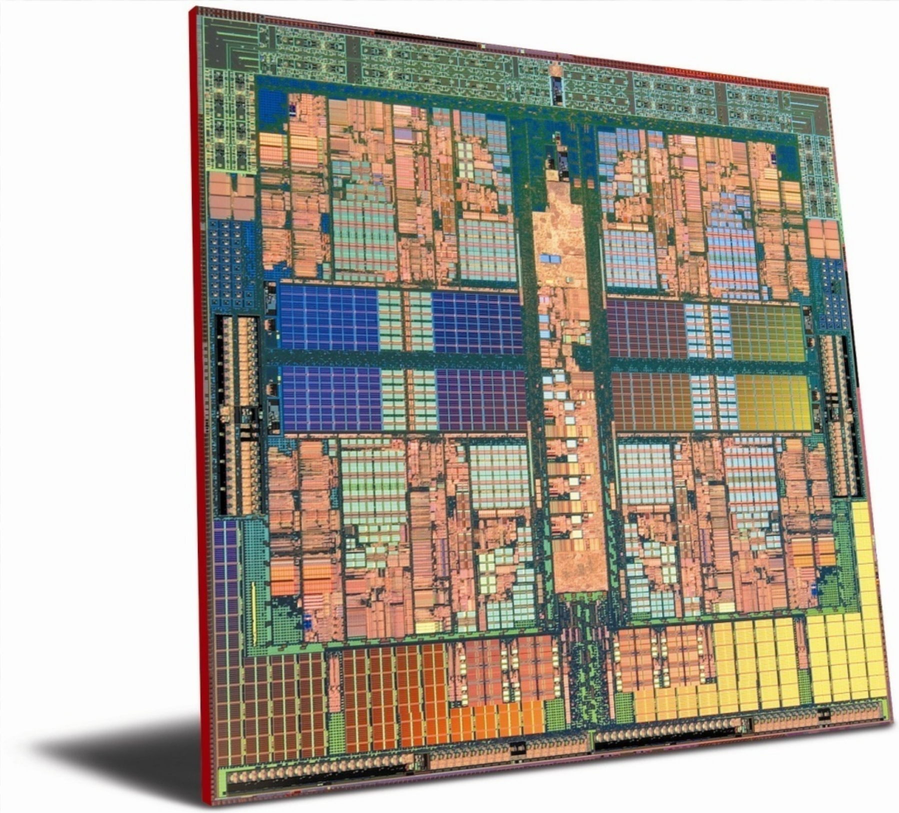
SUN's Niagara CPU2 (8 cores)

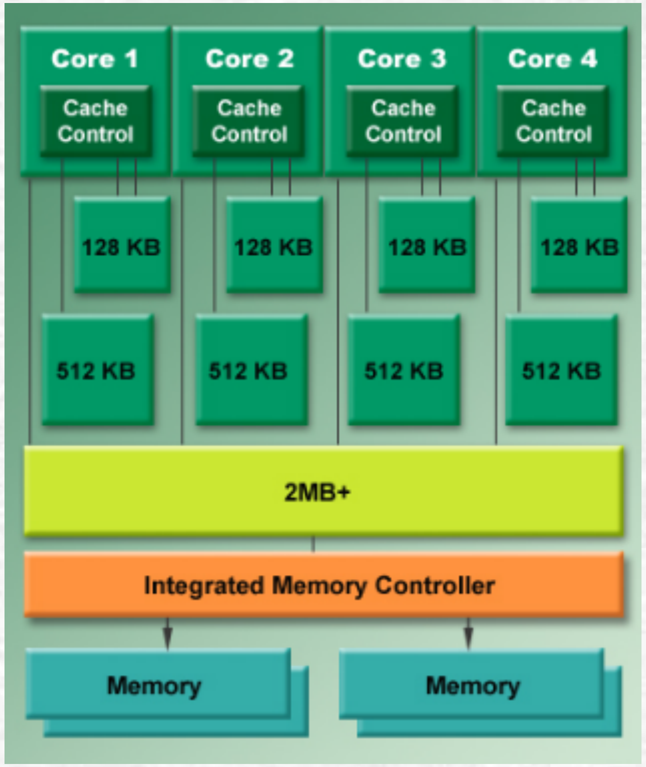




CCX – Crosssbar
CCU – Clock control
DMU/PEU – PCI Express
EFU – Efuse for redundancy
ESR – Ethernet SERDES
FSR – FBD SERDES
L2B – L2 write-back buffers
L2D – L2 data arrays
L2T – L2 tag arrays
MCU – Memory controller
MIO – Miscellaneous I/O
PSR – PCI Express SERDES
RDP/TDS/RTX/MAC – Ethernet
SII/SIO – I/O data path to and from memory
SPC – SPARC cores
TCU – Test and control unit

AMD Opteron (4 cores)





L1 cache

L2 cache

L3 cache (shared)

Basically

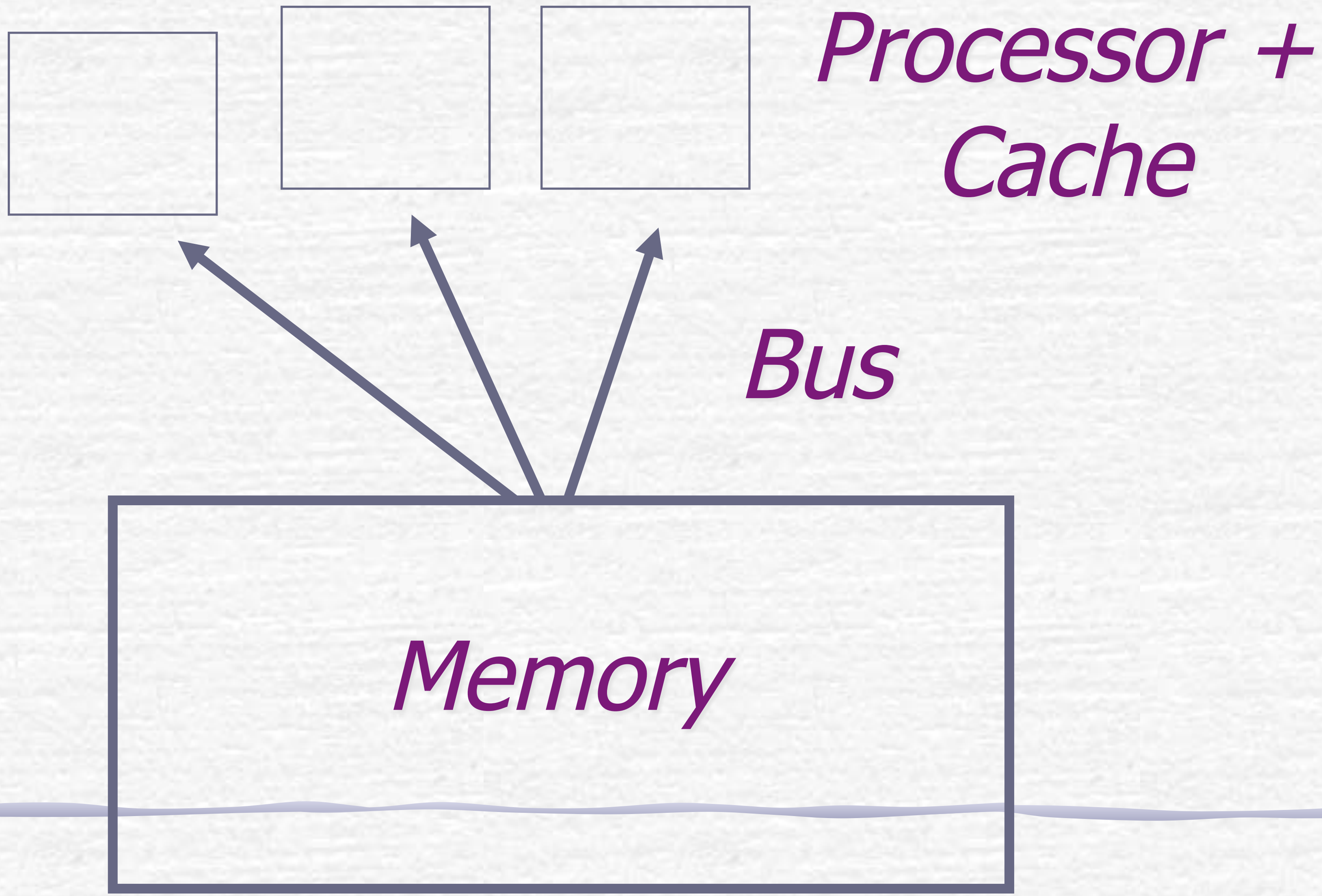
- Two fundamental components that *fall apart*: ***processors*** and ***memory***

- The Interconnect links the processors with the memory:
- - *SMP* (symmetric): bus (a tiny Ethernet)
- - *NUMA* (network): point-to-point network

Cycles

- The basic unit of time is the cycle: time to execute an instruction
- This changes with technology but the ***relative*** cost of instructions (local vs memory) does not

Simple view



Hardware synchronization objects

- The basic unit of communication is the *read* and *write* to the memory (through the cache)
- More sophisticated objects are sometimes provided: *C&S*, *T&S*, *LL/SC*

The free ride is over

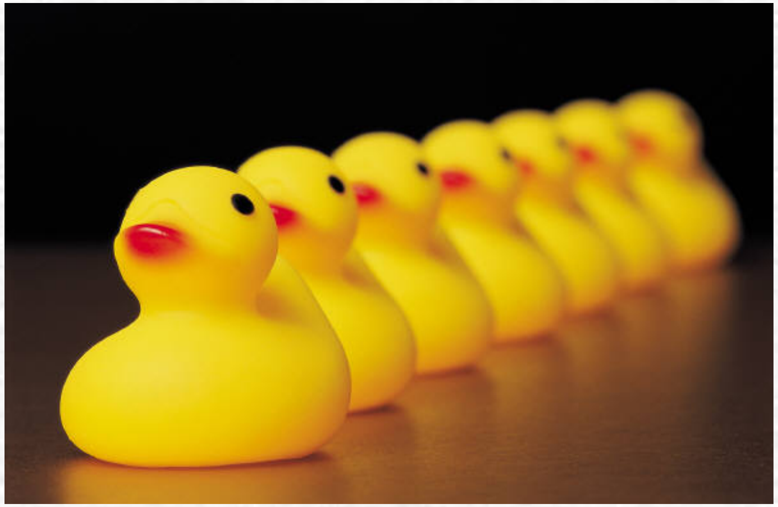
The free ride is over

- Cannot rely on CPUs getting faster
- Utilizing more than one CPU core requires thread-level parallelism (TLP)

Every one will need to fork threads

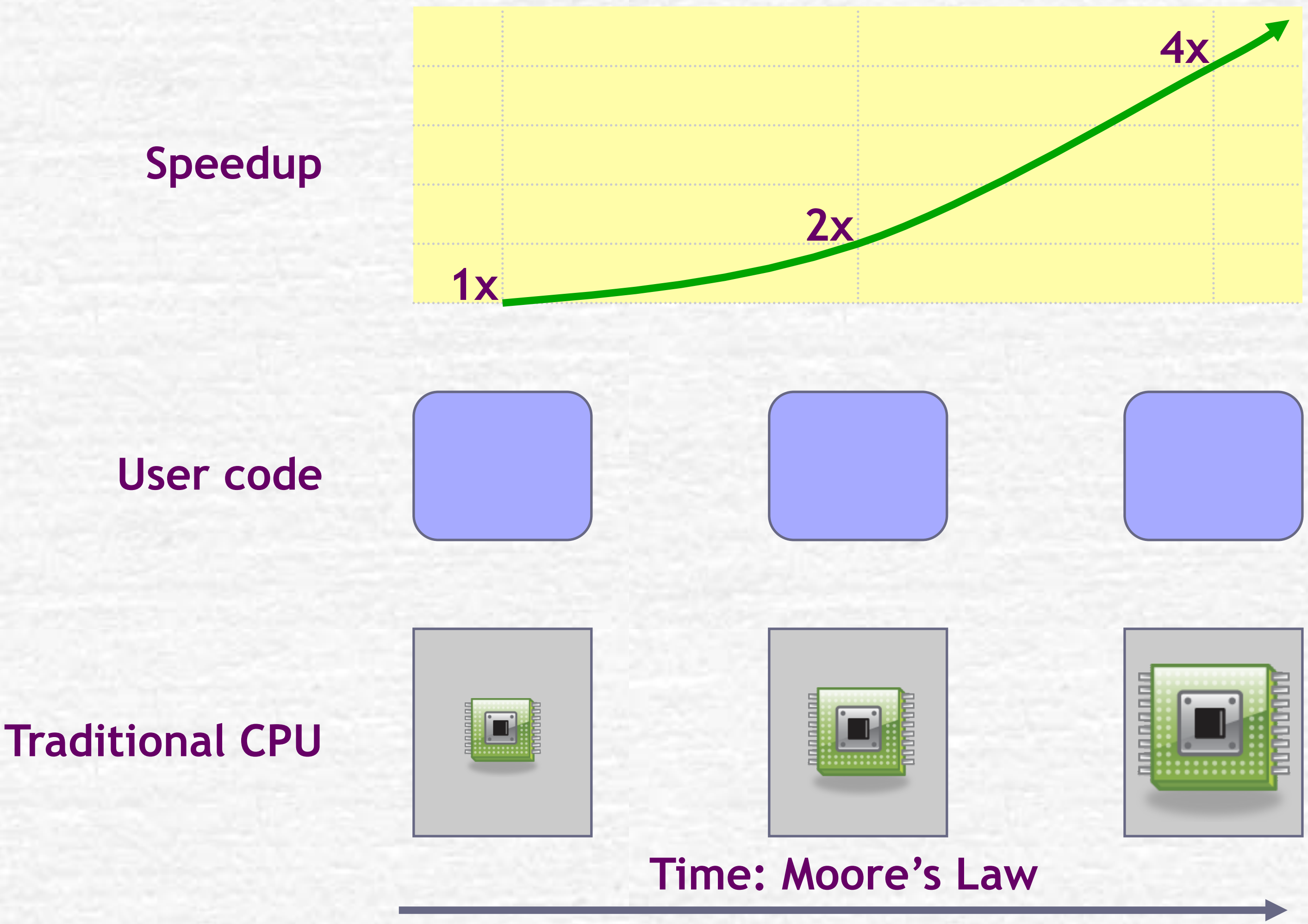
Travailler plus pour gagner plus

Forking threads is easy

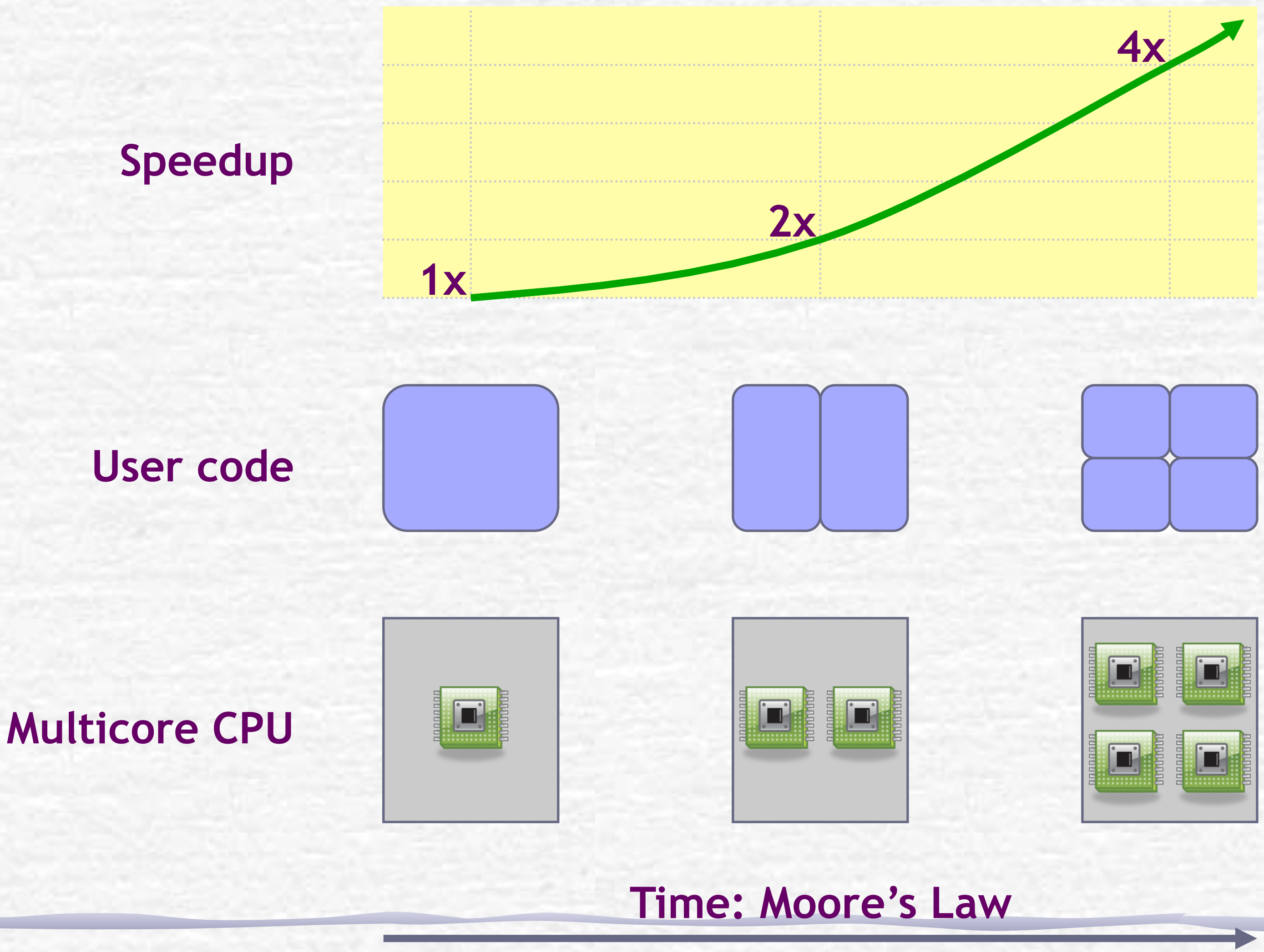


Handling their conflicts is hard

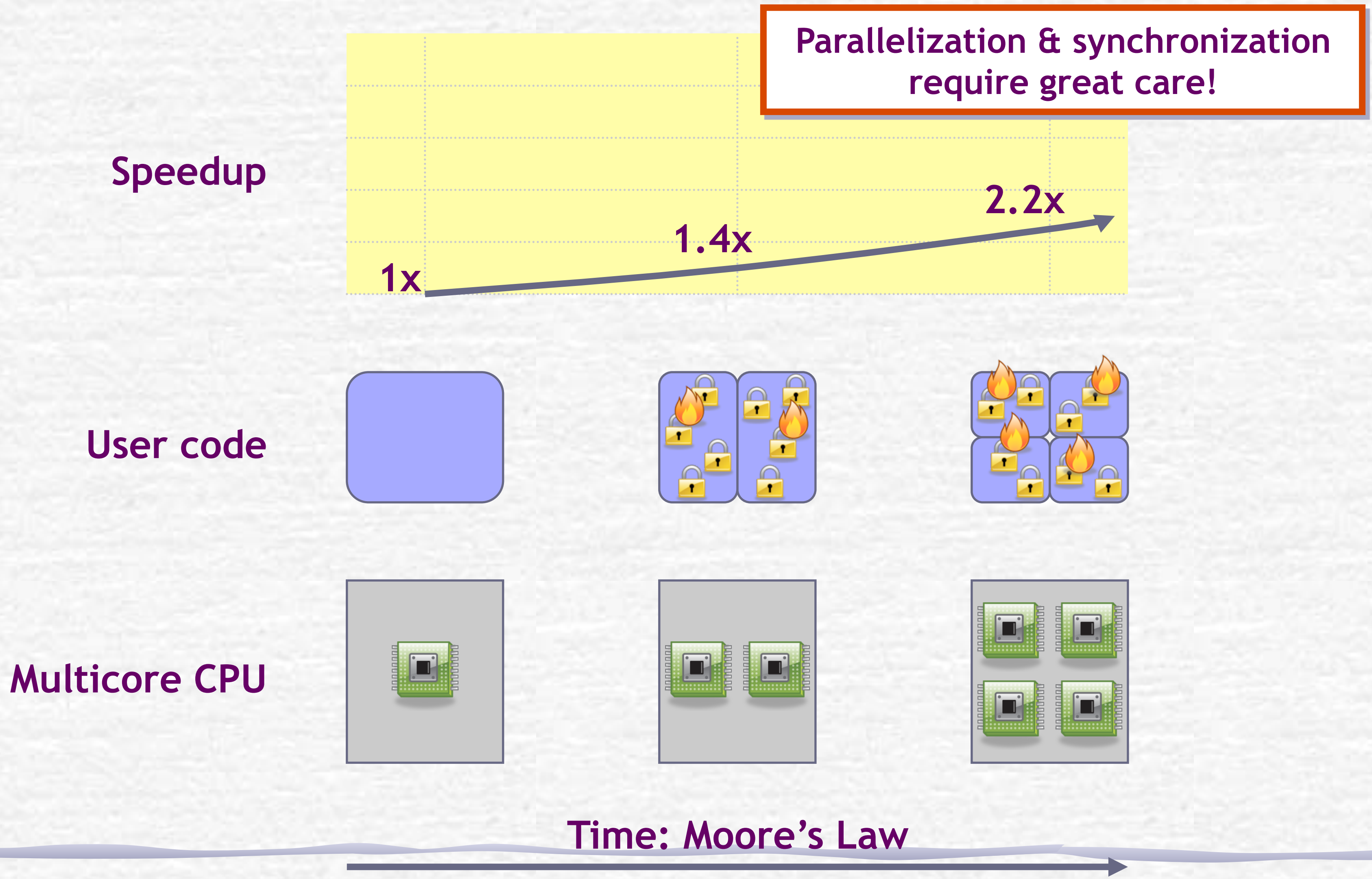
Traditional scaling



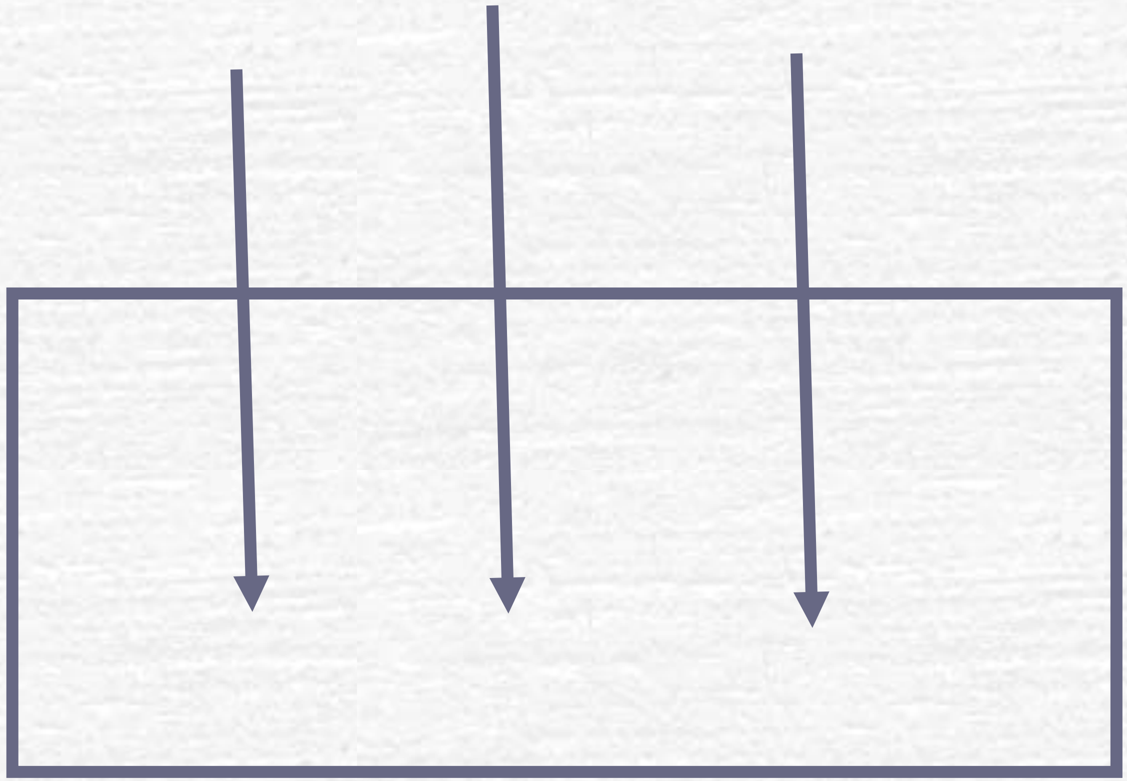
Ideal multicore scaling



Real-world scaling



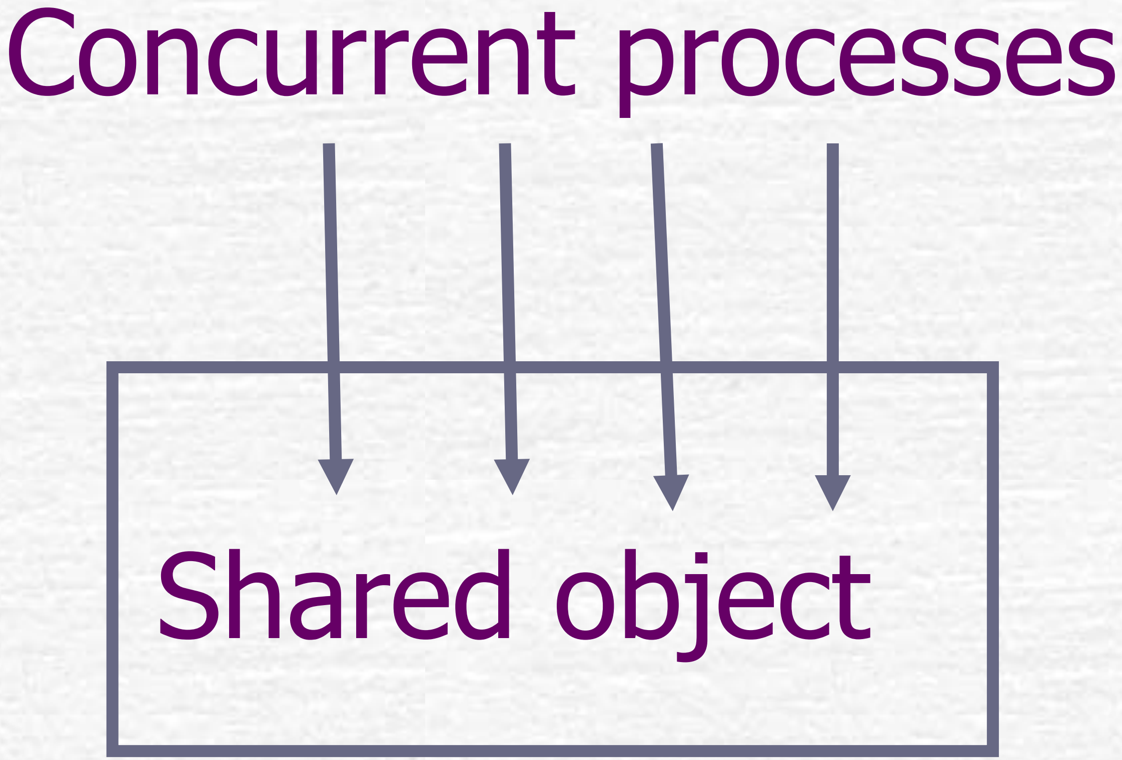
The problem
Sharing



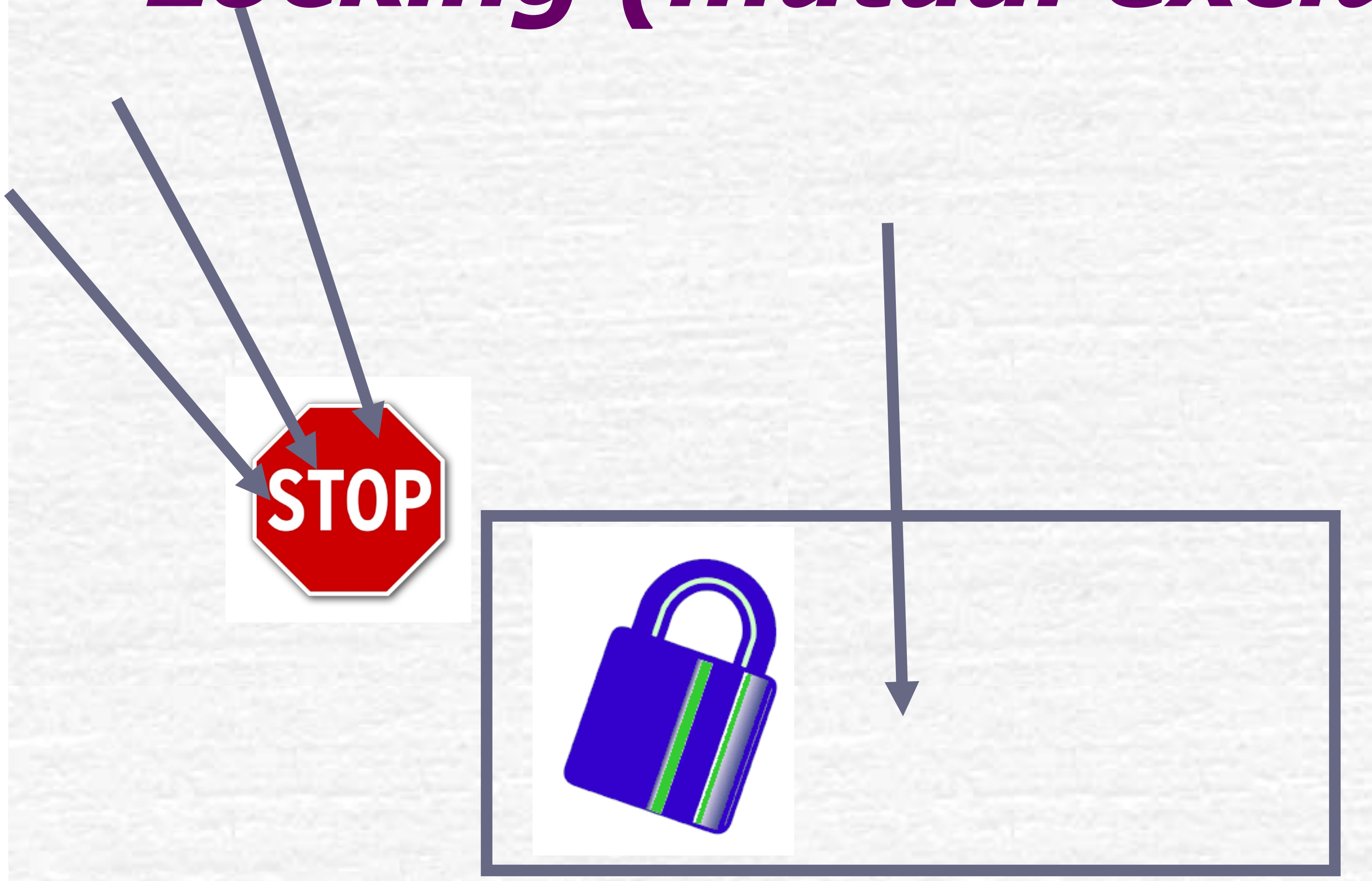
Counter

```
public class Counter

private long value;

public Counter(int i) { value = i;}

public long getAndIncrement()
{
return value++;
}
```

How to synchronize?



Locking (mutual exclusion)



Locked object

Locking with compare&swap()

- A *Compare&Swap* object maintains a value x, init to ⊥, and y;

- It provides one operation: *c&s(v,w);*

  ✓ Sequential spec:

  - c&s(old,new)

    {y := x; if x = old then x := new; return(y)}

Locking with compare&swap()

```
lock() {
repeat until
unlocked = this.c&s(unlocked,locked)
}

unlock() {
        this.c&s(locked,unlocked)
    }
```

Locking with compare&swap()

```
lock() {
while (true)
 {
 repeat until (unlocked = this.getState());
 if unlocked = (this.c&s()) return(true);
 }
}

unlock() {
        this.setState(0);
    }
```

Explicit use of a lock

```
Lock l = ...;
    l.lock();
    try {
// access the resource protected by this lock
    } finally {
        l.unlock();
    }
```

Implicit use of a lock

```
public class SynchronizedCounter {
    private int c = 0;
    public synchronized void increment() {
        c++;
    }
    public synchronized void getAndincrement()  {
        c++; return c;
    }
    public synchronized int value() {
        return c;
    }
}
```

Locking is the current state of concurrency affairs

The use of locks is dangerous

- 50% of the bugs reported in Java come from the mis-use of « synchronized »

Coarse grained locks => slow

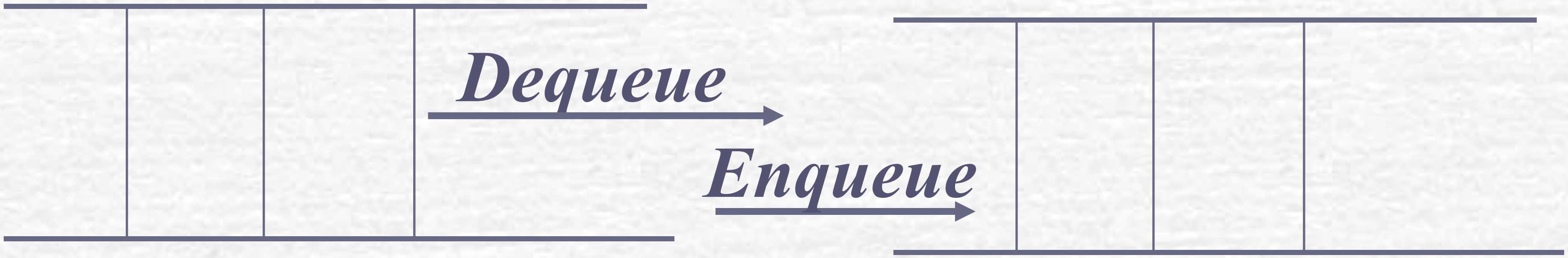
Fine grained locks => errors

Double-ended queue

Fine-grained locking

- It took two years for the Java Standards Committee to approve (in Java 5) a fine-grained locking-based implementation of a hash-table

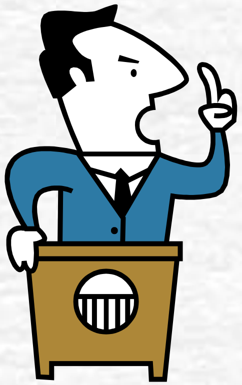
Locks do not compose



Lock-free computing?

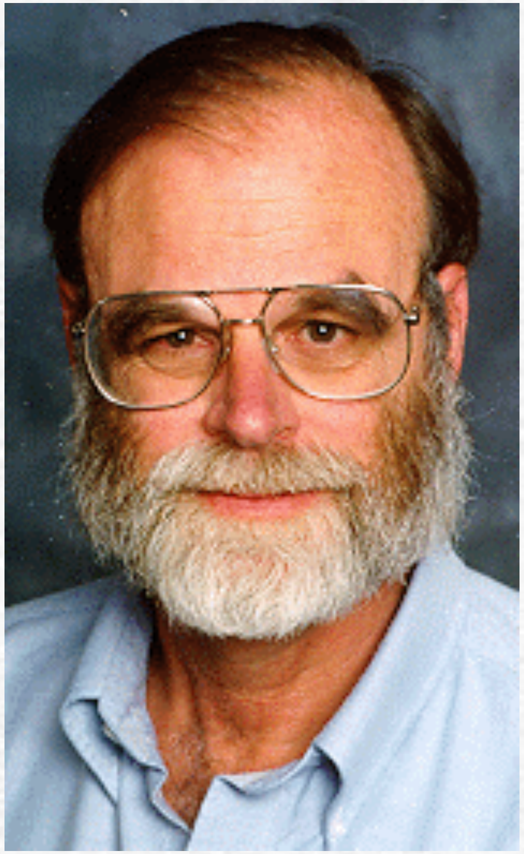
Every lock-free data structure
$\Rightarrow$ podc/spaa/disc

Wanted



A concurrency control abstraction that is simple and efficient

Transactions



Historical perspective

- Eswaran et al (CACM'76) Databases
- Papadimitriou (JACM'79) Theory
- Liskov/Sheifler (TOPLAS'82) Language
- Knight (ICFP'86) Architecture
- Herlihy/Moss (ISCA'93) Hardware
- Shavit/Touitou (PODC'95) Software
- Herlihy et al (PODC'03) Software - Dynamic

- Now: DISC/PODC/POPL/PLDI/ECOOP/OOPSLA-SPLASH/CAV…Transact

Back to the undergraduate level

- accessing object 1;
- accessing object 2;

Back to the undergraduate level

atomic {

- accessing object 1;
- accessing object 2;

}

```
class Queue {
  QNode head;
  QNode tail;
  public enq(Object x) {
    atomic {
      QNode q = new QNode(x);
      q.next = head;
      head = q;
    }
  }
  ... }
```

Simple example
(consistency invariant)

$$0 < x < y$$

Simple example (transaction)

- T: x := x+1 ; y:= y+1

The illusion of a critical section

atomic {

- accessing object 1;
- accessing object 2;

}

How to provide that illusion?

Software (STM) or Hardware (HTM)?

The garbage-collection analogy

- In the early times, the programmers had to take care of allocating and de-allocating memory
- The GC gives the illusion of infinite memory
- A hardware support was initially expected, but now software solutions are very effective

Program

Transactional Memory

Hardware

Behind the scenes

Two-phase locking (2PL)

- To ***write*** O, T requires a ***lock*** on O;
T ***waits*** if some T' acquired a ***lock*** on O

- To ***read*** O, T requires a ***lock*** on O;
T ***waits*** if some T' acquired a ***lock*** on O

- Before committing, T ***releases*** all its locks

Two-phase locking (2PL)

- To ***write*** O, T wait to for a ***lock*** on O;
- To ***read*** O, T waits to for a ***lock*** on O;
- Before committing, T ***releases*** all its locks

Two-phase locking (more details)

- Every object O, with state s(O) (a ***register***), is protected by a lock l(O) (a **c&s**)

- Every transaction has local variables wSet and wLog

- Initially: l(O) = unlocked, wSet = wLog = empty

Two-phase locking

```
Upon op = read() or write(v) on object O
if O outside wSet then
   wait until unlocked= l(O).c&s(unlocked,locked)
wSet = wSet U O
wLog = wLog U S(O).read()
if op = read() then return S(O).read()
S(O).write(v)
return ok
```

Two-phase locking (cont'd)

Upon ***commit()***

cleanup()

return ok

Upon ***abort()***

rollback()

cleanup()

return ok

Two-phase locking (cont'd)

Upon ***rollback()***

for all O in wSet do S(O).write(wLog(O))

wLog = empty

Upon ***cleanup()***

for all O in wSet do l(O).c&s(locked,unlocked)

wSet = empty

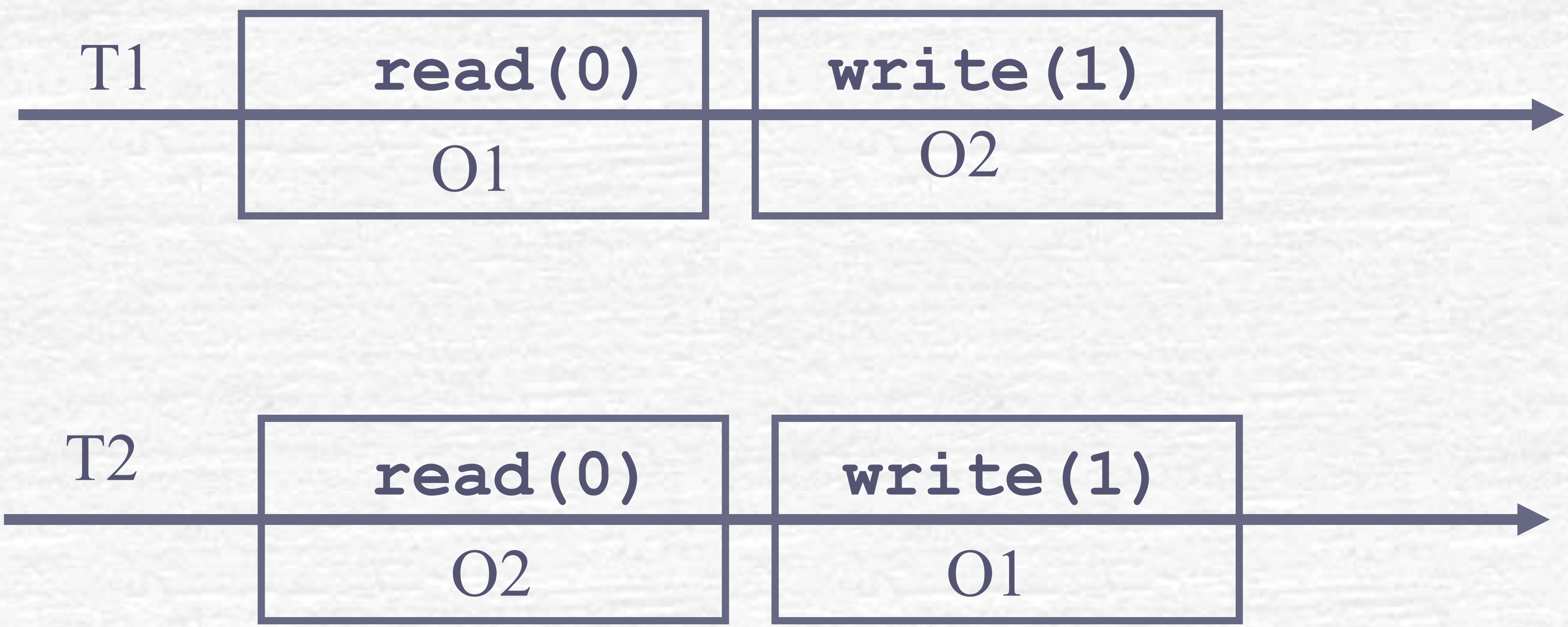
Why two phases? (what if?)

- To ***write*** or ***read*** O, T requires a ***lock*** on O;
T ***waits*** if some T' acquired a ***lock*** on O

-

- T ***releases*** the lock on O when it is done with O

Why two phases?



No STM implements 2PL

All implement a variant of it

Two-phase locking (read-write lock)

- To ***write*** O, T requires a ***write-lock*** on O;
T ***waits*** if some T’ acquired a ***lock*** on O

- To ***read*** O, T requires a ***read-lock*** on O;
T ***waits*** if some T’ acquired a ***write-lock*** on O

- Before committing, T ***releases*** all its locks

Two-phase locking
- better dead than wait -

- To ***write*** O, T requires a ***write-lock*** on O;
- T ***aborts*** if some T' acquired a ***lock*** on O

- To ***read*** O, T requires a ***read-lock*** on O;
- T ***aborts*** if some T' acquired a ***lock*** on O

- Before committing, T releases all its locks

Two-phase locking
- better kill than wait -

- To ***write*** O, T requires a ***write-lock on*** O;
T ***aborts T'*** if some T' acquired a ***lock*** on O

- To ***read*** O, T requires a ***read-lock*** on O;
T ***waits*** if some T' acquired a ***write-lock*** on O

- Before committing, T releases all its locks
- A transaction that is aborted restarts again

Visible Read
(SXM; RSTM)

- ***Write is mega killer***: to write an object, a transaction aborts any live one which has read or written the object
- ***Read is visible***: when a transaction reads an object, it says so

Visible Read

- A visible read invalidates cache lines
- This reduces the throughput of read-dominated workloads, by inducing a lot of traffic on the bus

Two-phase locking
- invisible reads – DSTM -

- To ***write*** O, T requires a ***write-lock on*** O;

T aborts T’ if some T’ acquired a ***write-lock*** on O

- To ***read*** O, T checks if ***all objects read remain valid*** - else T aborts

- Before committing, T checks if ***all objects read remain valid*** and releases all its locks

Invisible reads (more details)

- Every object O, with state s(O) (register), is protected by a lock l(O) (c&s)

- Every transaction maintains, besides wSet and wLog:

- - a local variable rset(O) for every object

Invisible reads

Upon ***write(v)*** on object O

if O outside wSet then

wait until unlocked= l(O).c&s(unlocked,locked)

wSet = wSet U O

wLog = wLog U S(O).read()

(*,ts) = S(O).read()

S(O).write(v,ts)

return ok

Invisible reads

Upon ***read()*** on object O

(v,ts) = S(O).read()

if O in wSet then return v

if l(O) = locked or not validate() then abort()

if rset(O) = 0 then rset(O) = ts

return v

Invisible reads

Upon ***validate()***

for all O s.t rset(O) > 0 do

 (v,ts) = S(O).read()

 if ts not rset(O) or

    (O outside wset and l(O) = locked)

then return false

else return true

Invisible reads

Upon ***commit()***

```
s := validate()
for all O in wset do
 (v,ts) = S(O).read()
S(O).write(v,ts+1)
cleanup()
if s then commit() else abort()
```

Invisible reads

Upon ***rollback()***
for all O in wSet do S(O).write(wLog(O))
wLog = empty

Upon ***cleanup()***
for all O in wset do l(O).c&s(locked,unlocked)
wset = empty
rset(O) = 0 for all O

DSTM

- ***Killer write*** (ownership)
- ***Careful read*** (validation)

Performance figures look good

- *"It is better for Intel to get involved in this [**Transactional Memory**] now so when we get to the point of having …tons… of cores we will have the answers"*
- ***Justin Rattner, Intel Chief Technology Officer***

- *"…we need to explore new techniques like **transactional memory** that will allow us to get the full benefit of all those transistors and map that into higher and higher performance."*
    - ***Bill Gates, Businessman***

- *"...manual synchronization is intractable... **transactions** are the only plausible solution...."*
  - ***Tim Sweeney, Epic Games***

The TM Topic is VERY HOT

- Sun, Intel, AMD, IBM, MSR, …
- Fortress (Sun); X10 (IBM); Chapel (Cray)

All set?

Hmmm….

Tests

- ***Micro-Benchmarks***
  - Linked-lists; red-black trees, etc.
  - Consider specific loads: typically focus on read-only transactions

Challenging TMs STMBench7 (GKV'07)

- ***Large data structure***: challenge memory overhead
- ***Short and long operations***: kills non-linear algorithms
- ***Complex access patterns***

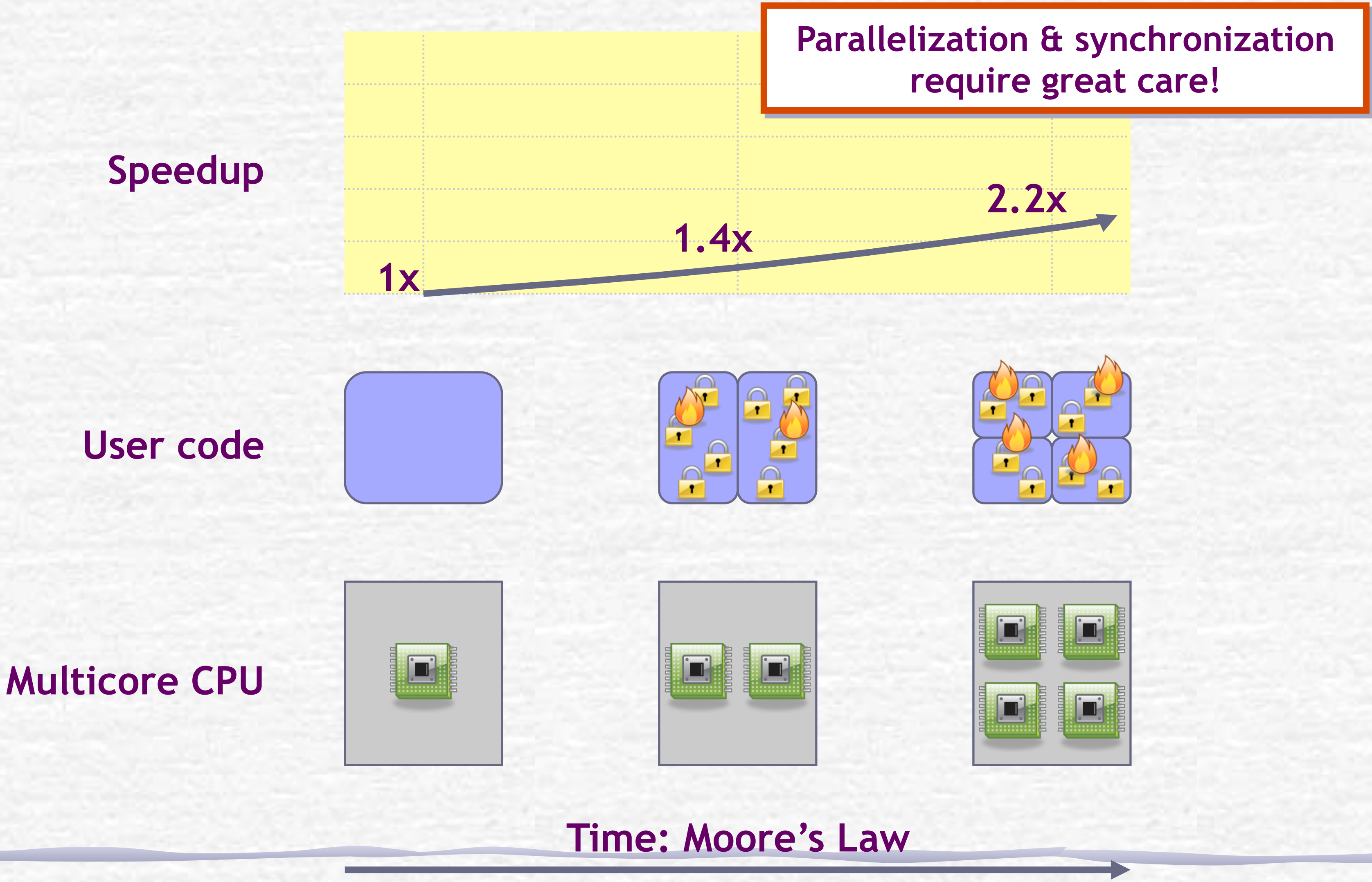
STMBench7

- Performance figures were not that good
- All TMs eventually collapsed because of memory usage (except X)

A new generation

- SwissTM,
- TL2,
- TinySTM,...

Real-world scaling

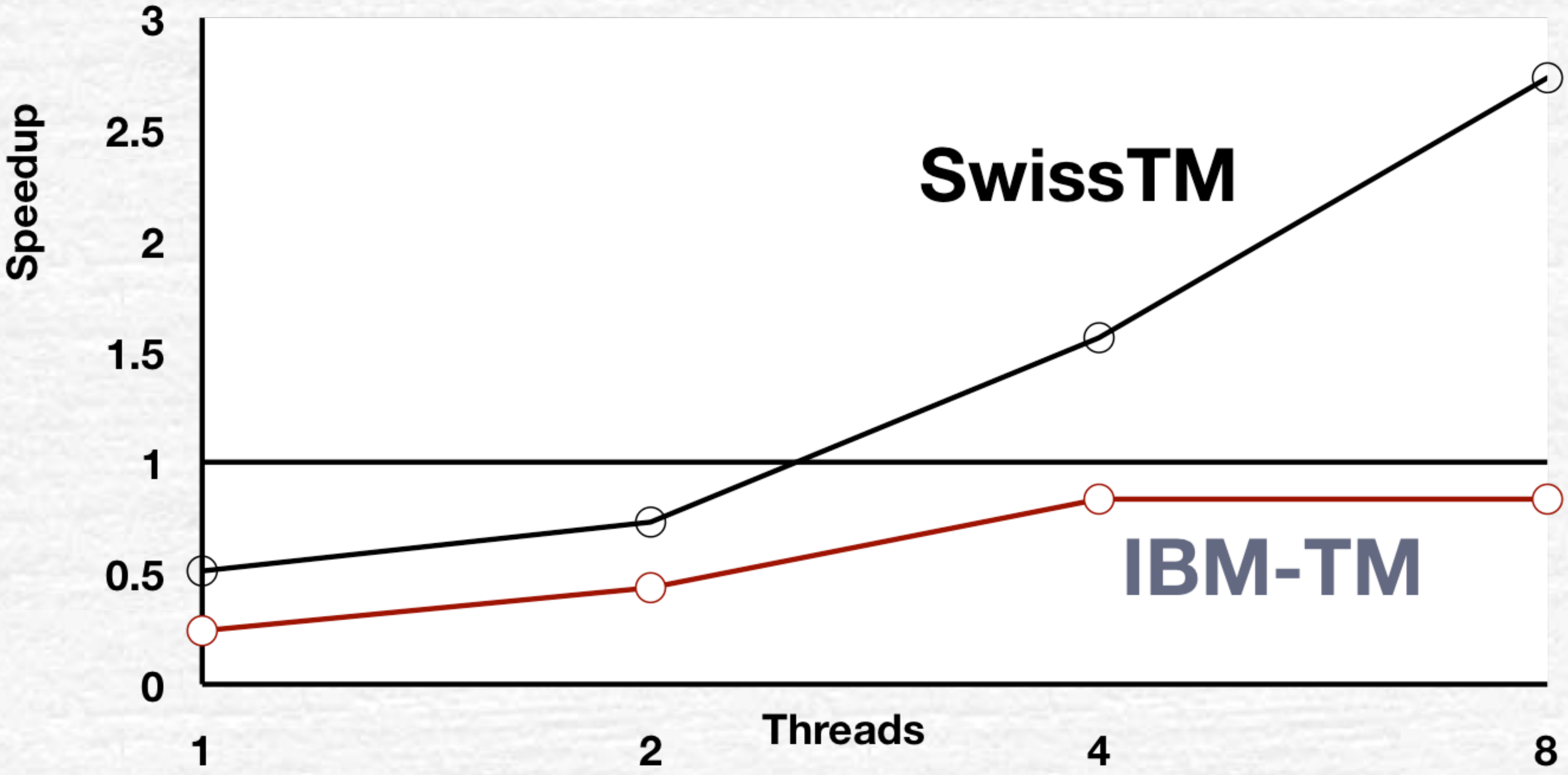


Software Transactional Memory: Why is it only a Research Toy (CACM 2009)

C. Cascaval, C. Blundell, M. Michael,
H. Cain, P. Wu, S. Chiras, S. Chatterjee

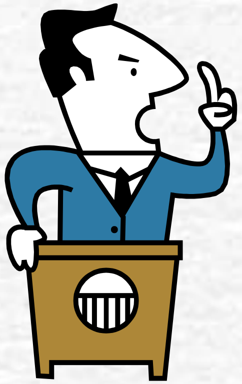
Why STM can be more than a Research Toy (CACM 2010)

A. Dragojević, P. Felber, V. Gramoli, R. Guerraoui



Speedup
3
2.5
2
1.5
1
0.5
0
SwissTM
IBM-TM
Threads
1
2
4
8

Wanted



Some principles

Transactional memory

1. Why do we care?

Simplicity

2. What should we expect?

What safety property?

3. What might we expect?

Transactional memory

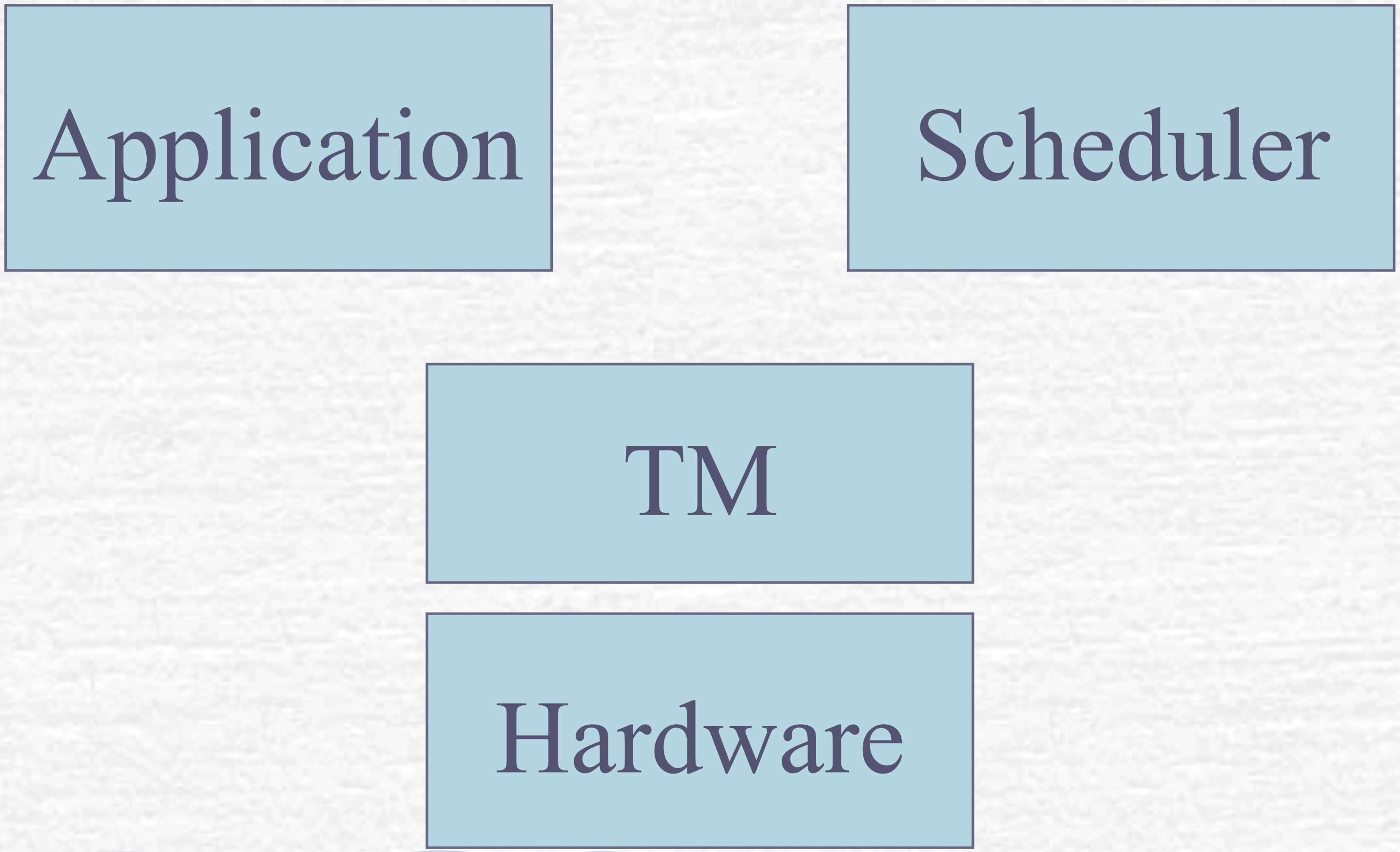
Safety of a TM

Let's recall the old good atomicity property

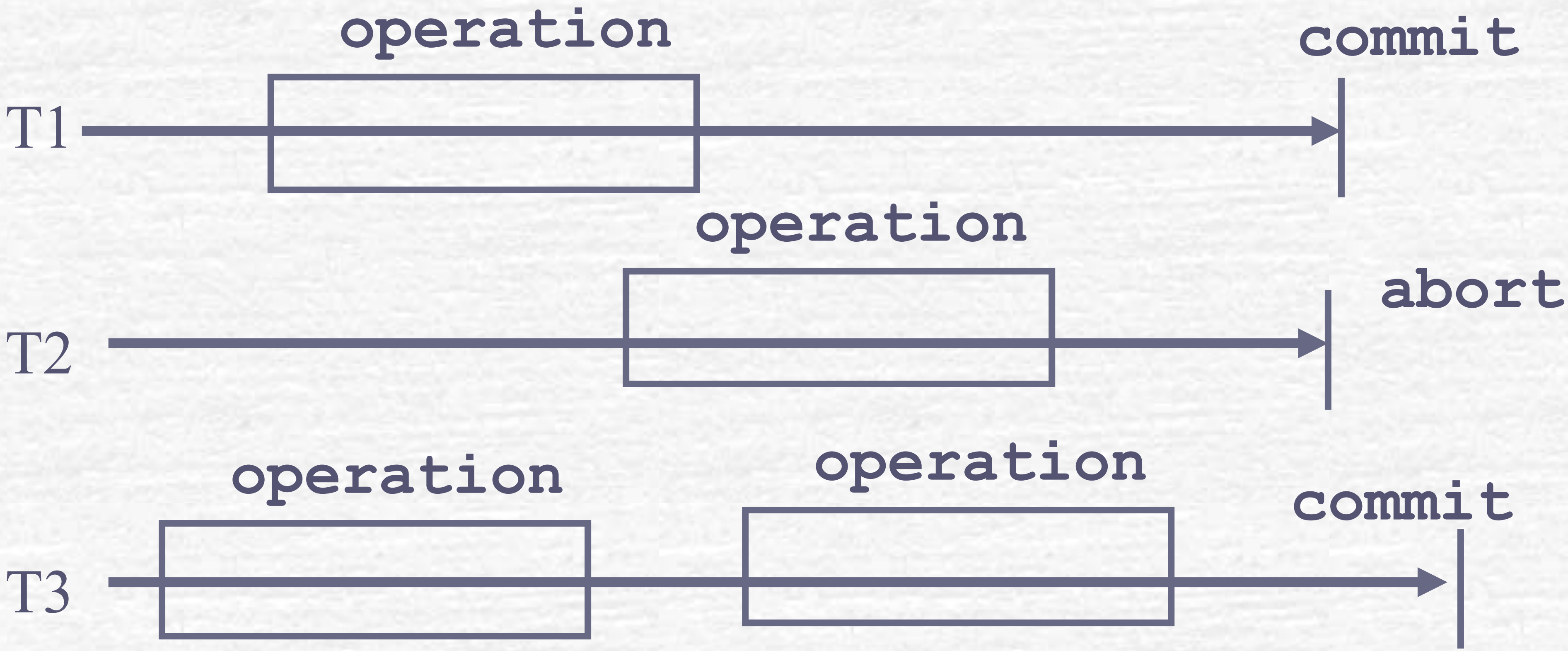
Gray,Papadimitriou,Weihl,..

Transactions and objects

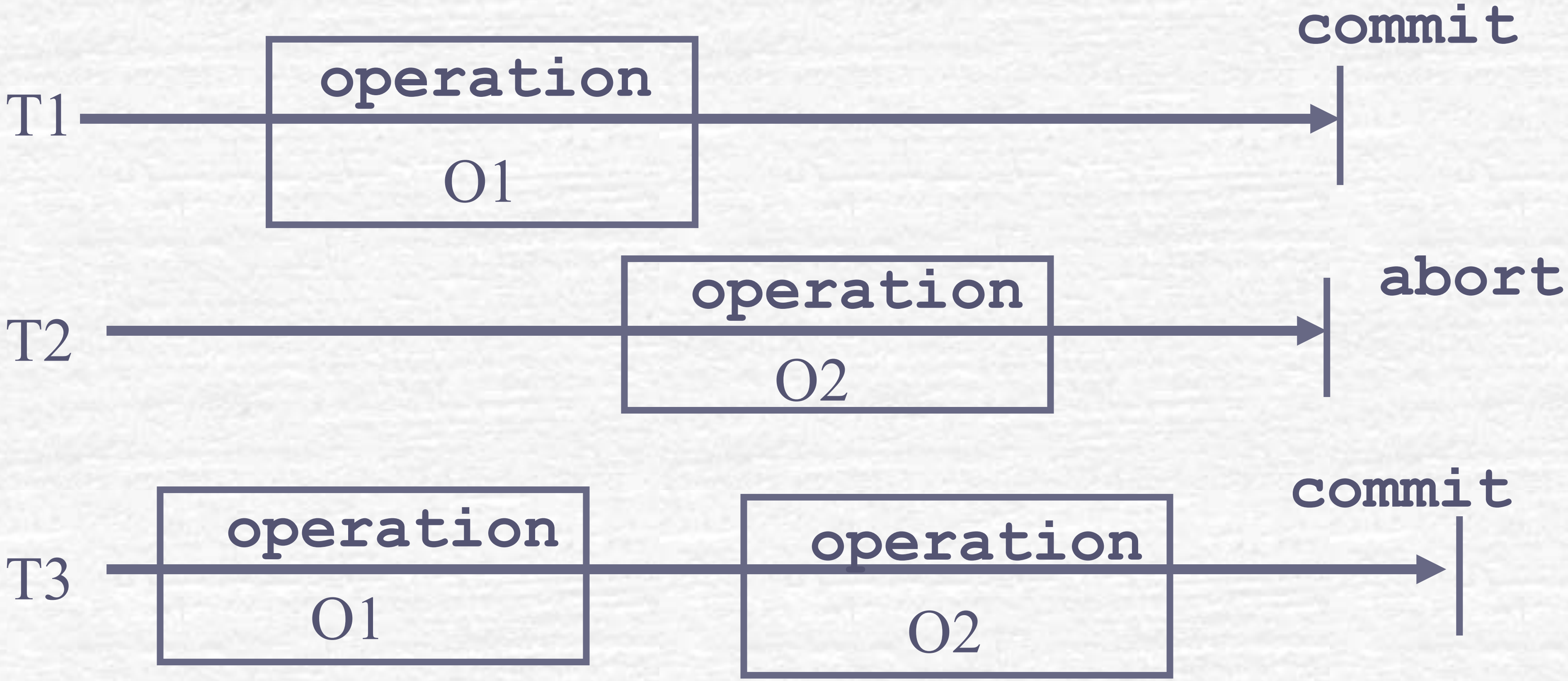
- ***Transactions*** invoke operations on shared ***objects***
- Every operation ***invocation*** is expected to return a ***reply***
- Every transaction is expected either to ***abort*** or ***commit***


Application
Scheduler
TM
Hardware

Transactions and objects



Transactions and objects



Transactions

- Transactions are ***sequential*** units of computations
- Transactions are ***asynchronous***

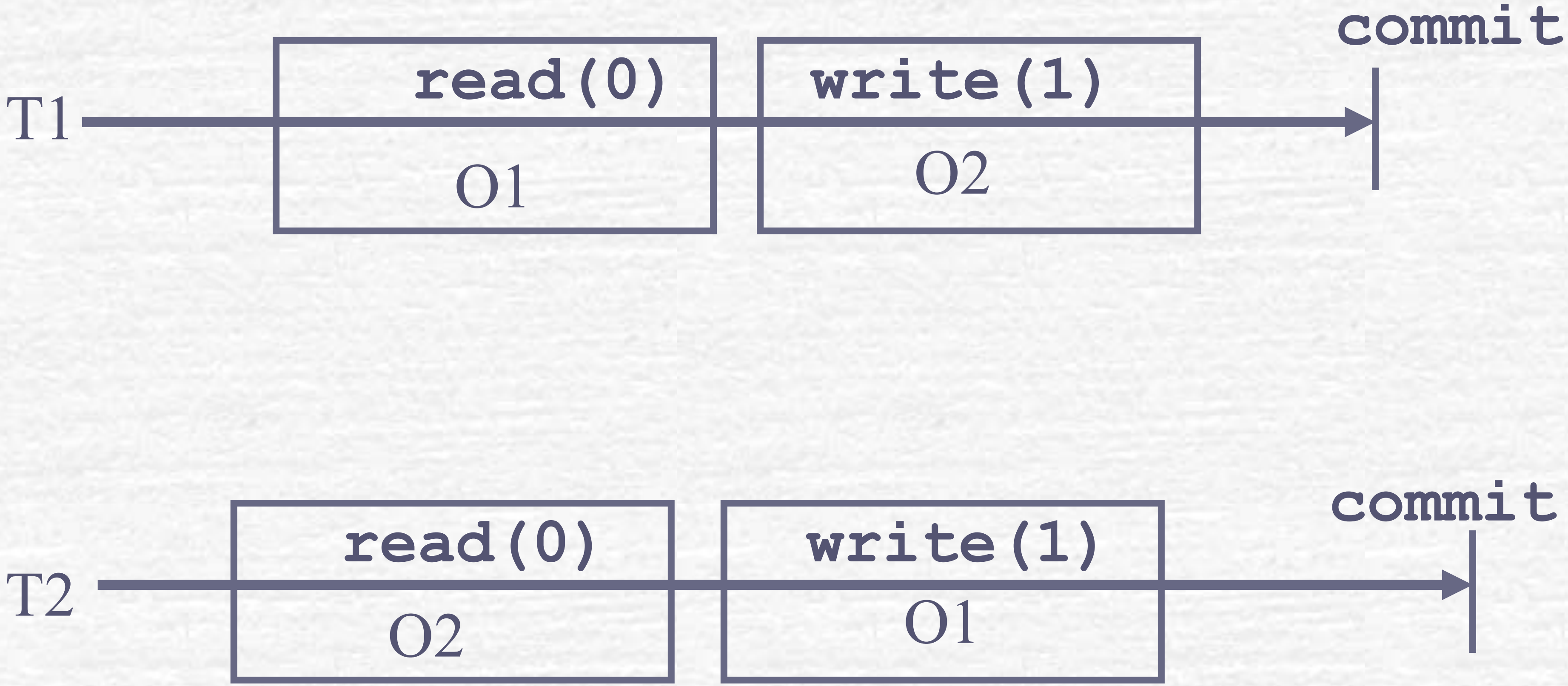
(pre-emption, page faults, crashes)

Histories

- The execution of a set of transactions on a set of objects is modeled by a ***history***
- A history is a ***total order*** of operation, commit and abort events
  - H = (S,<)

The history depicts what the user sees

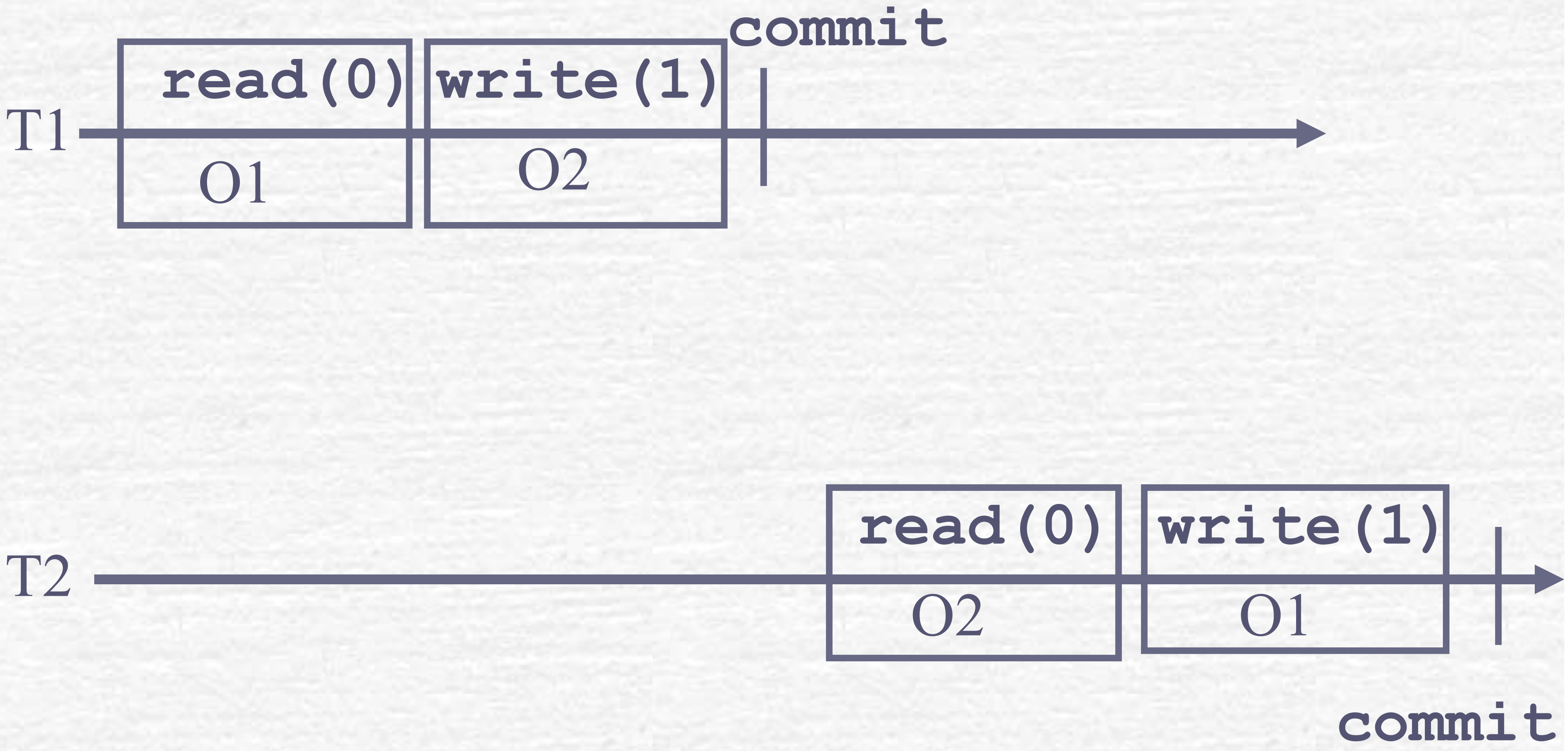
History H1



Histories

- Two ***transactions*** are ***sequential*** (in a history) if one invokes its first operation after the other one commits or aborts; they are ***concurrent*** otherwise
- A ***history*** is ***sequential*** if it has only sequential transactions; it is ***concurrent*** otherwise
- Two histories are ***equivalent*** if they have the ***same*** transactions

Sequential history H2 <=> H1



The old theory (Pap 79)

A history is **atomic** *if its restriction to* **committed** *transactions is* **serializable**

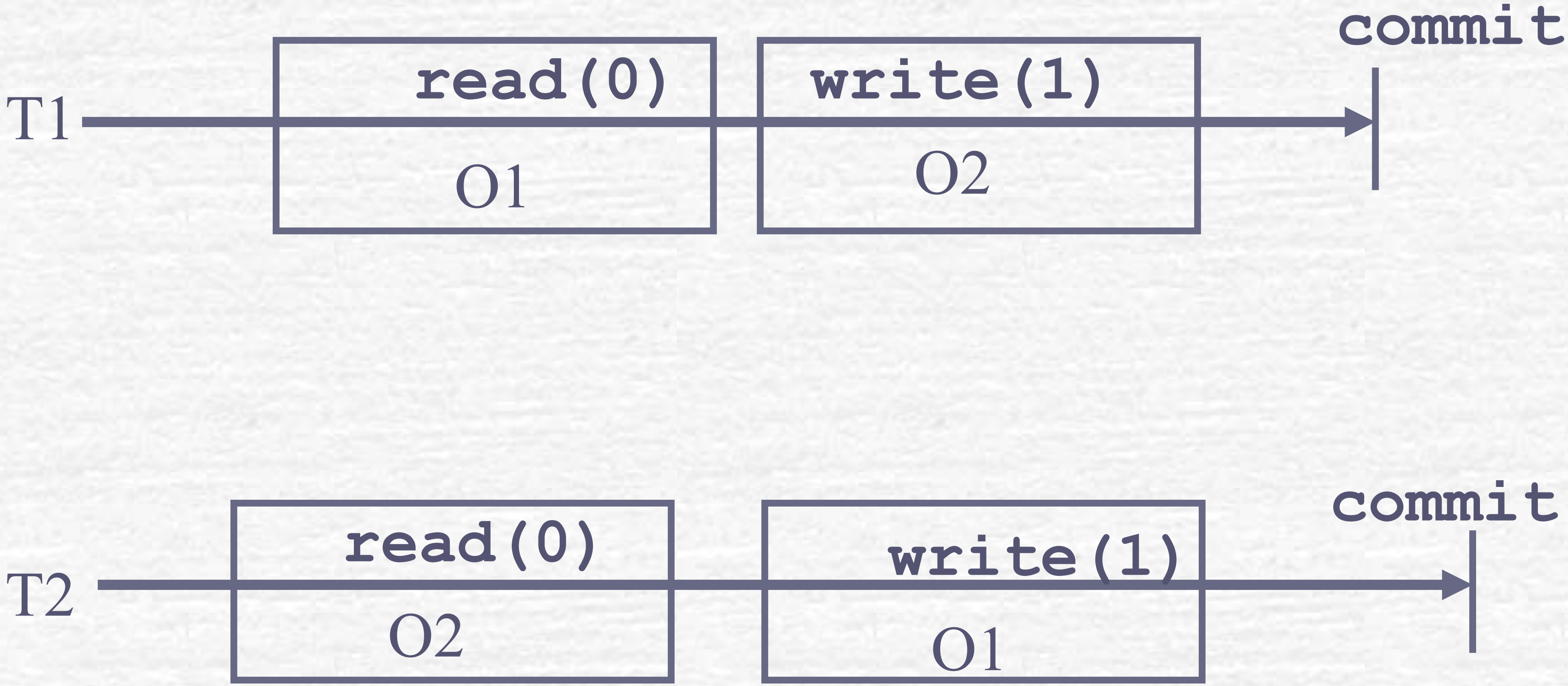
A history H of ***committed*** transactions is ***serializable*** if there is a history S(H) that is

(1) equivalent to H

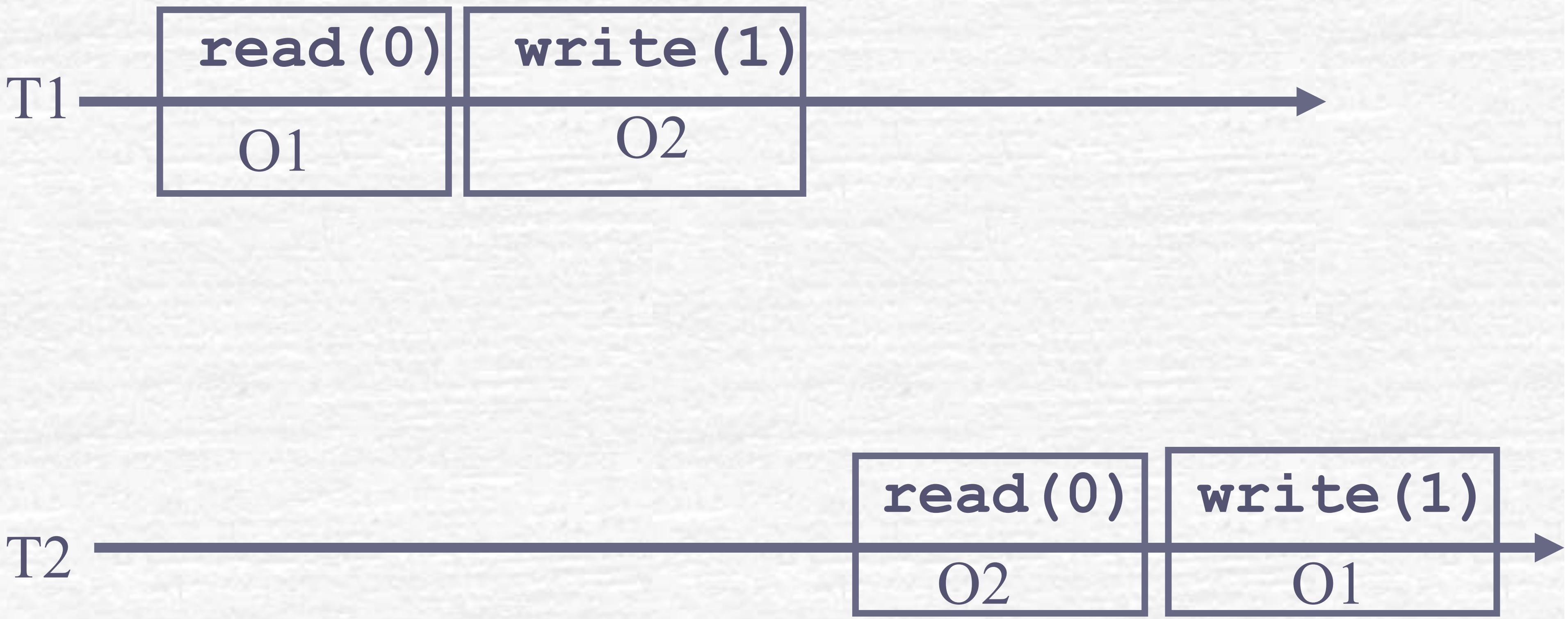
(2) sequential

(3) has every ***read returns the last value written***

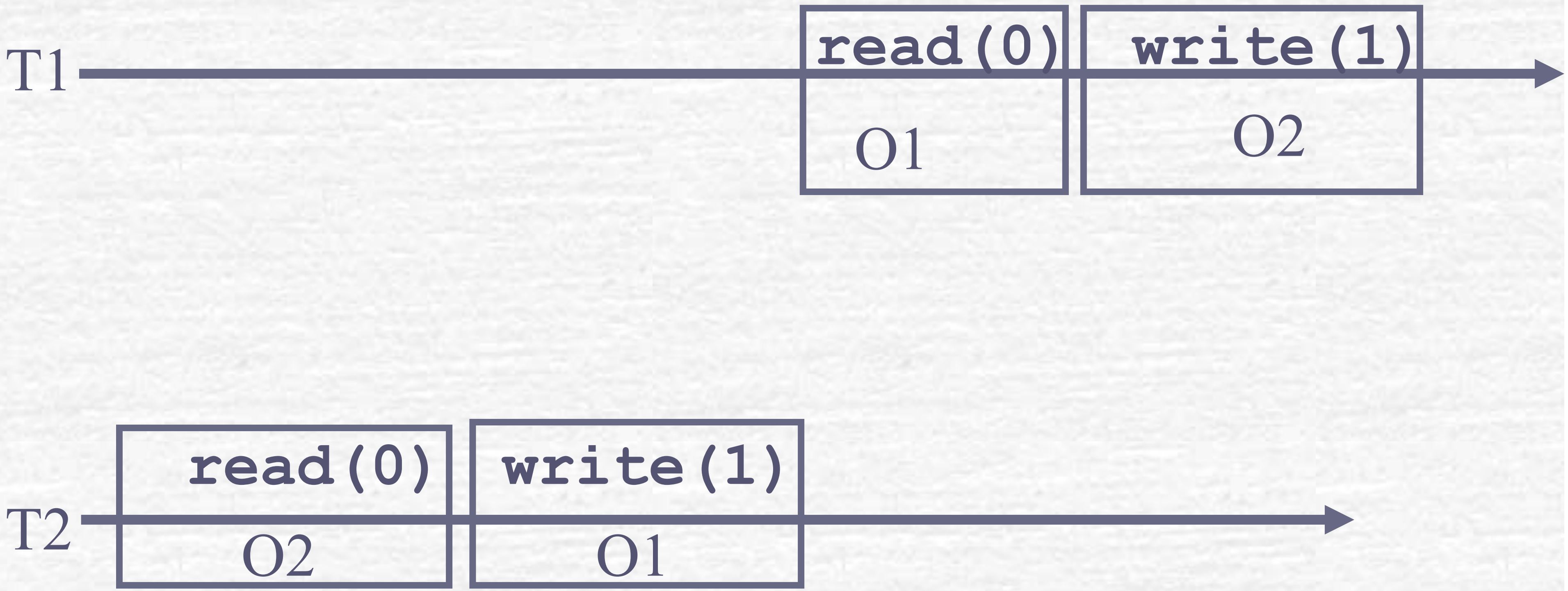
Atomic history?



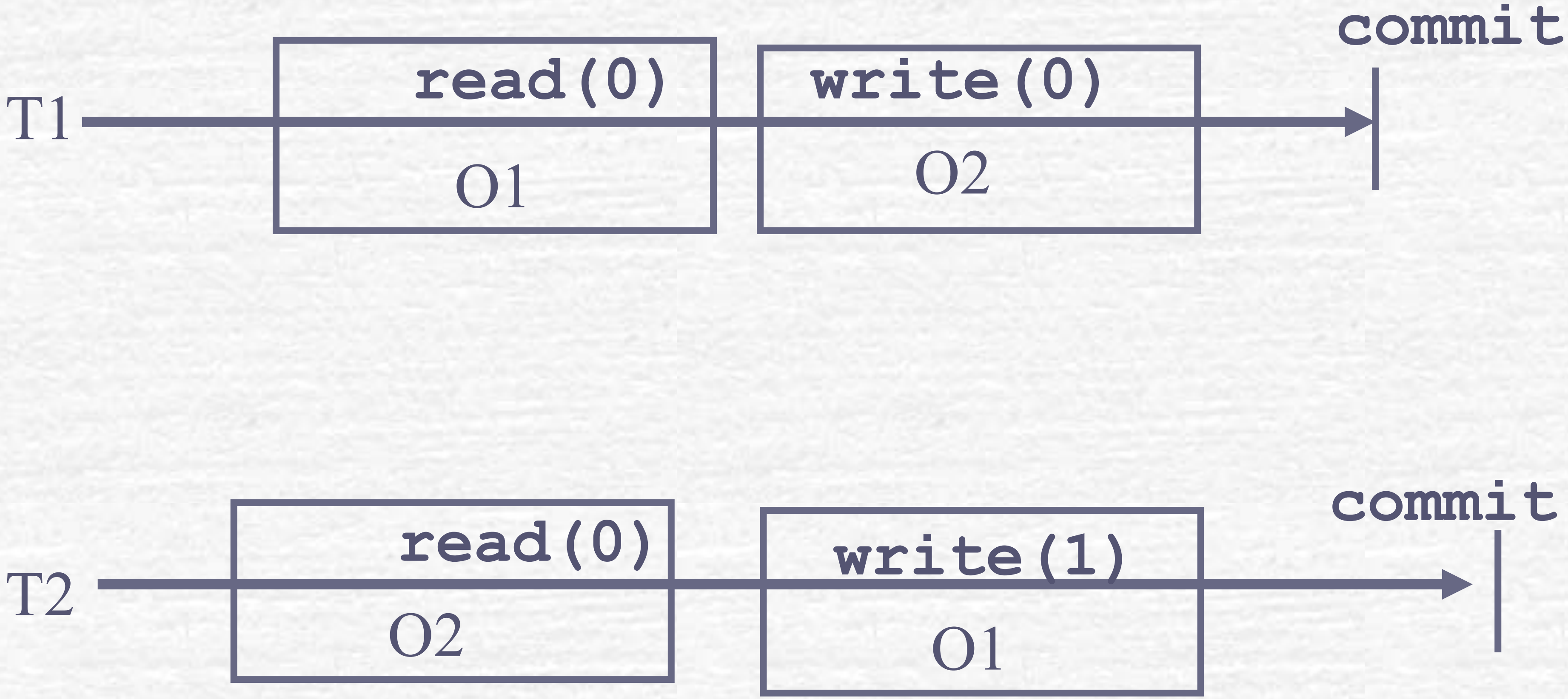
Sequential history?



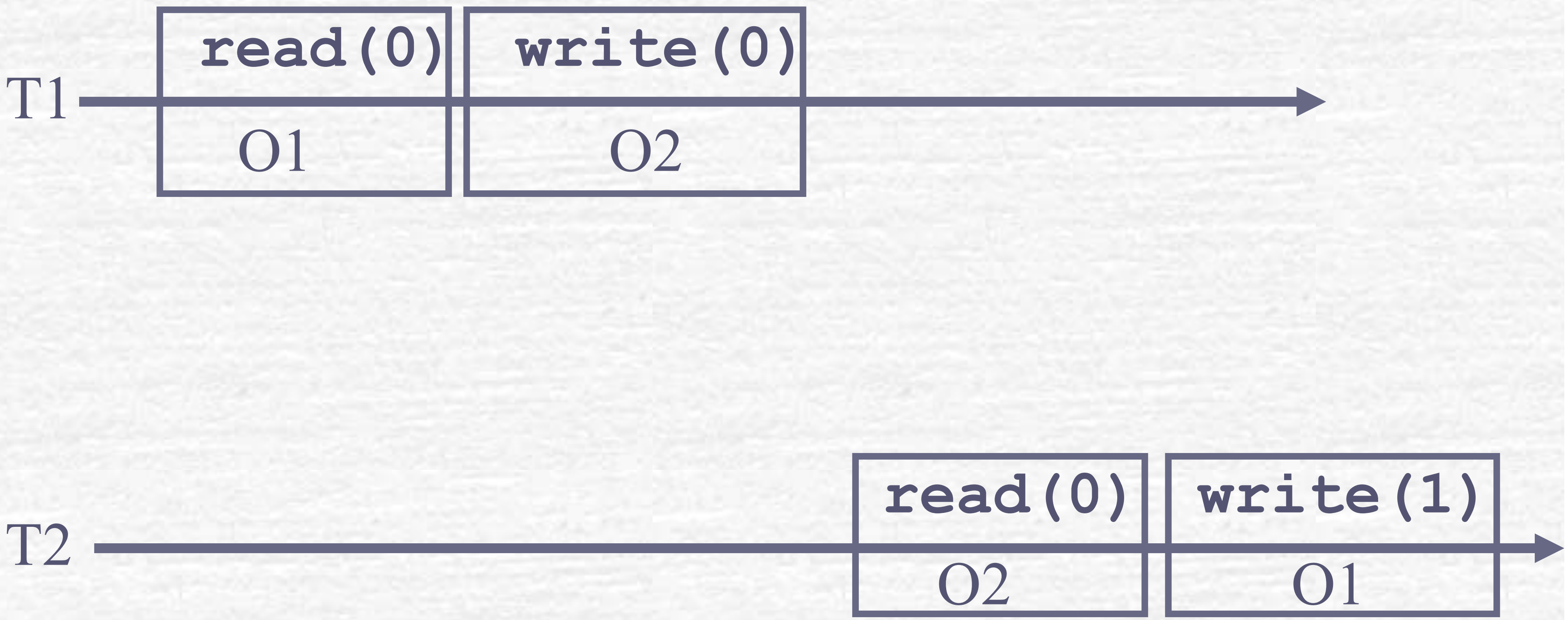
Sequential history?



Atomic history?



Sequential history



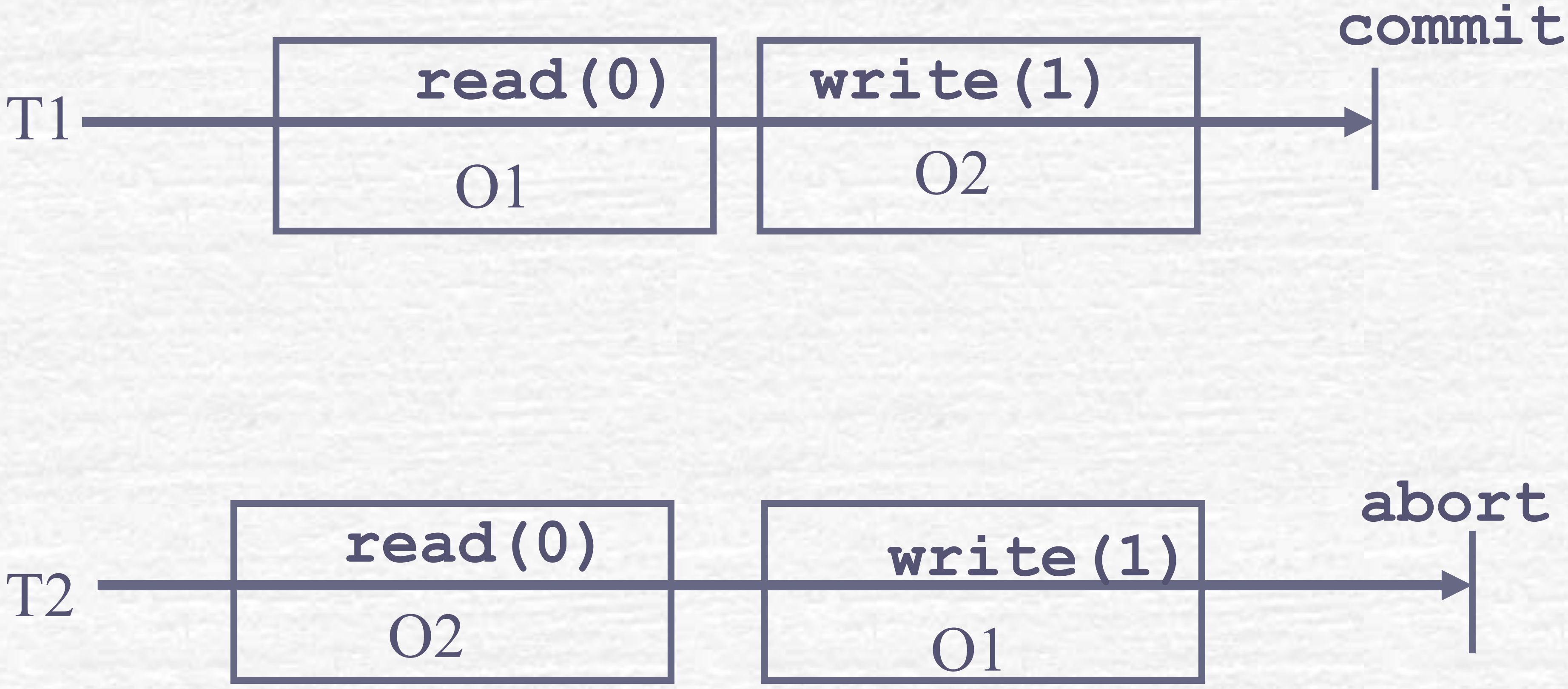
A history H of ***committed*** transactions is serializable if there is a history S(H) that is

(1) equivalent to H

(2) sequential

(3) has every read returns the last value written

Atomic history



A history H of committed transactions is serializable if there is a history S(H) that is

(1) equivalent to H

(2) sequential

(3) has every ***read return the last value written***

There is more to shared objects than ***read/write registers,*** e.g., ***queues***, ***compare&swap***, ***counters***, etc

All these objects have a ***sequential specification (Weihl)***

Sequential specification of a register

- Sequential specification
  - ***read()***
    - return(x)
  - ***write(v)***
    - x <- v;
    - return(ok)

Queue

- A ***queue*** has two operations: ***enqueue ()*** and ***dequeue()***
- A ***queue internally*** maintains a list *x* which exports operation *appends()* to put an item at the end of the list and *remove ()* to remove an element from the head of the list

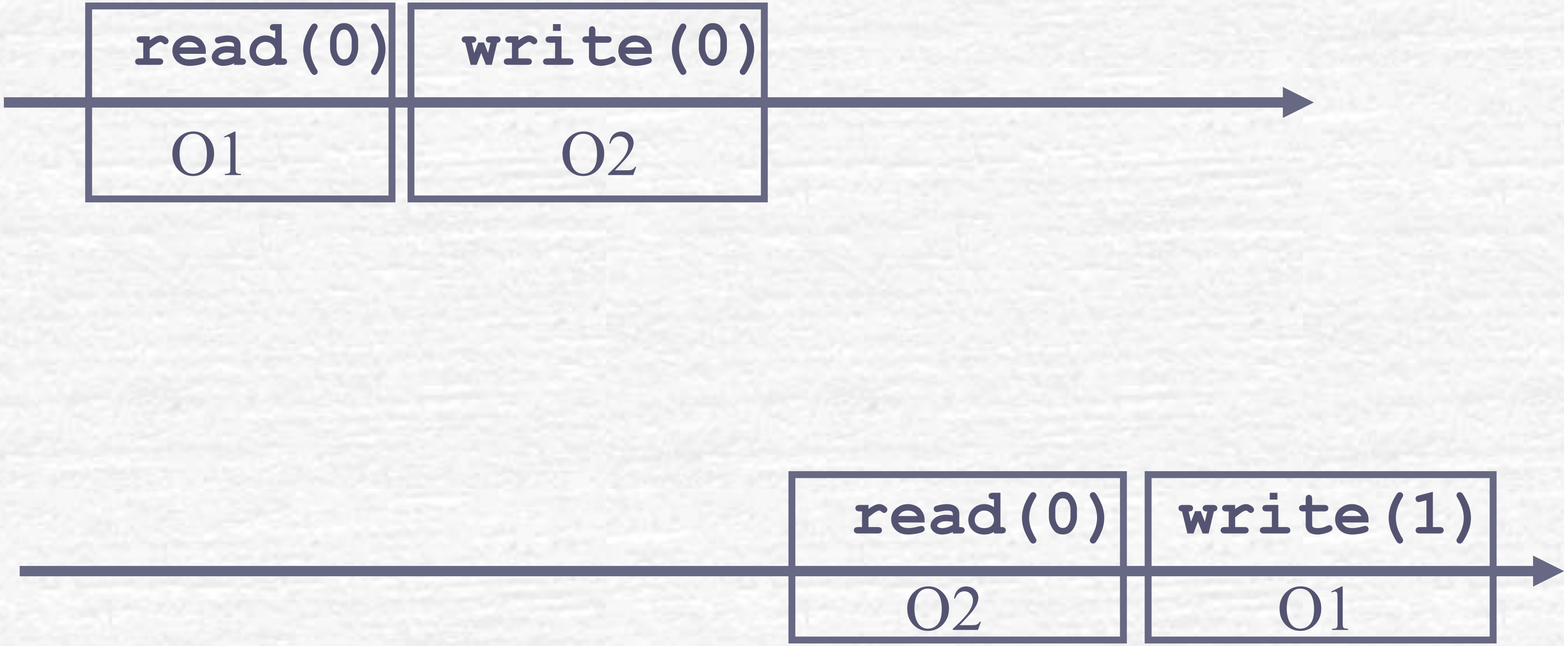
Sequential specification

- ***dequeue()***
  - if(x=0) then return(nil);
  - else return(x.remove())
- ***enqueue(v)***
  - x.append(v);
  - return(ok)

Legal history

A sequential history is ***legal*** if each restriction to an object belongs to its ***sequential specification***

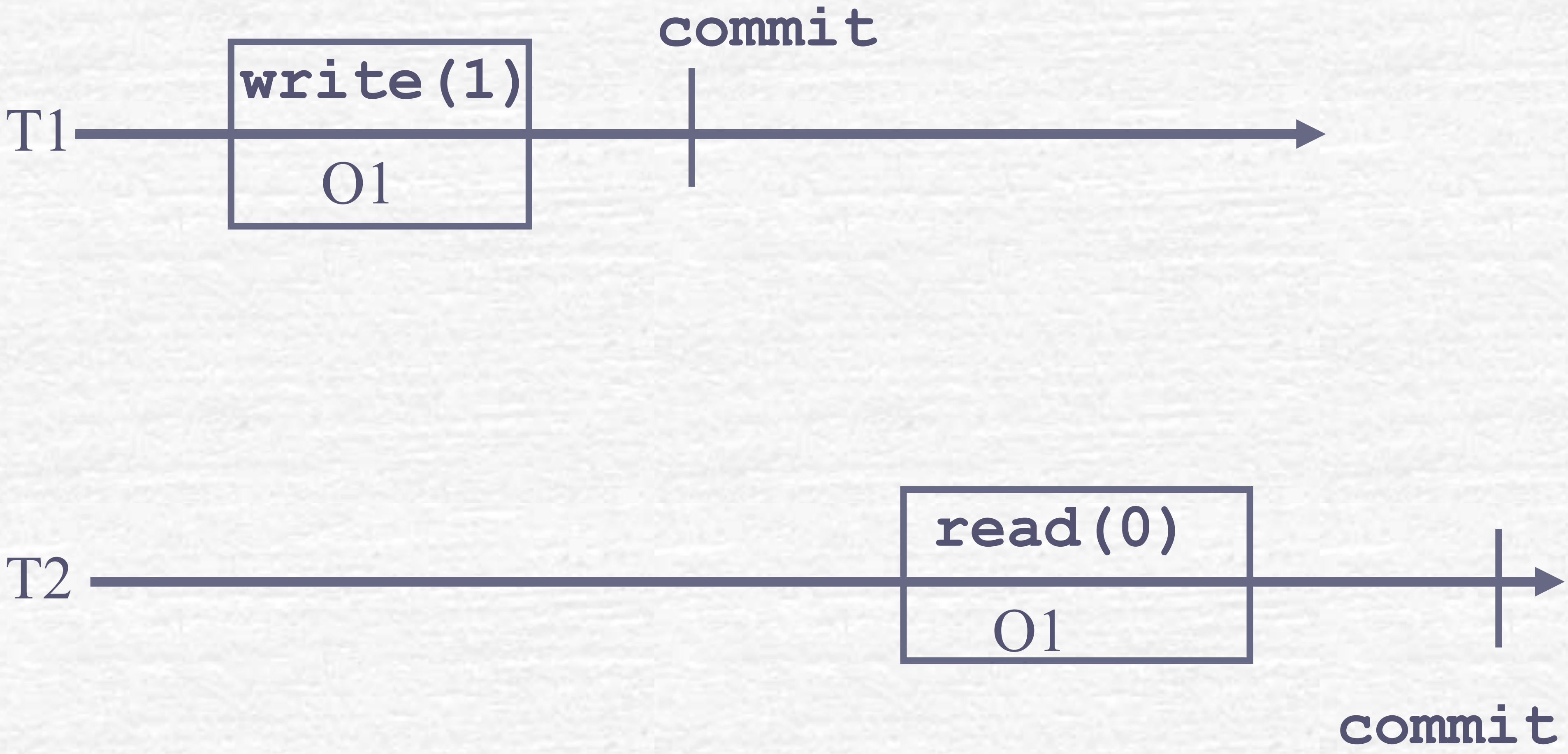
Legal history



Legal history

A history H of committed transactions is serializable if there is a history S(H) that is
(1) equivalent to H
(2) sequential
(3) legal

Real-time



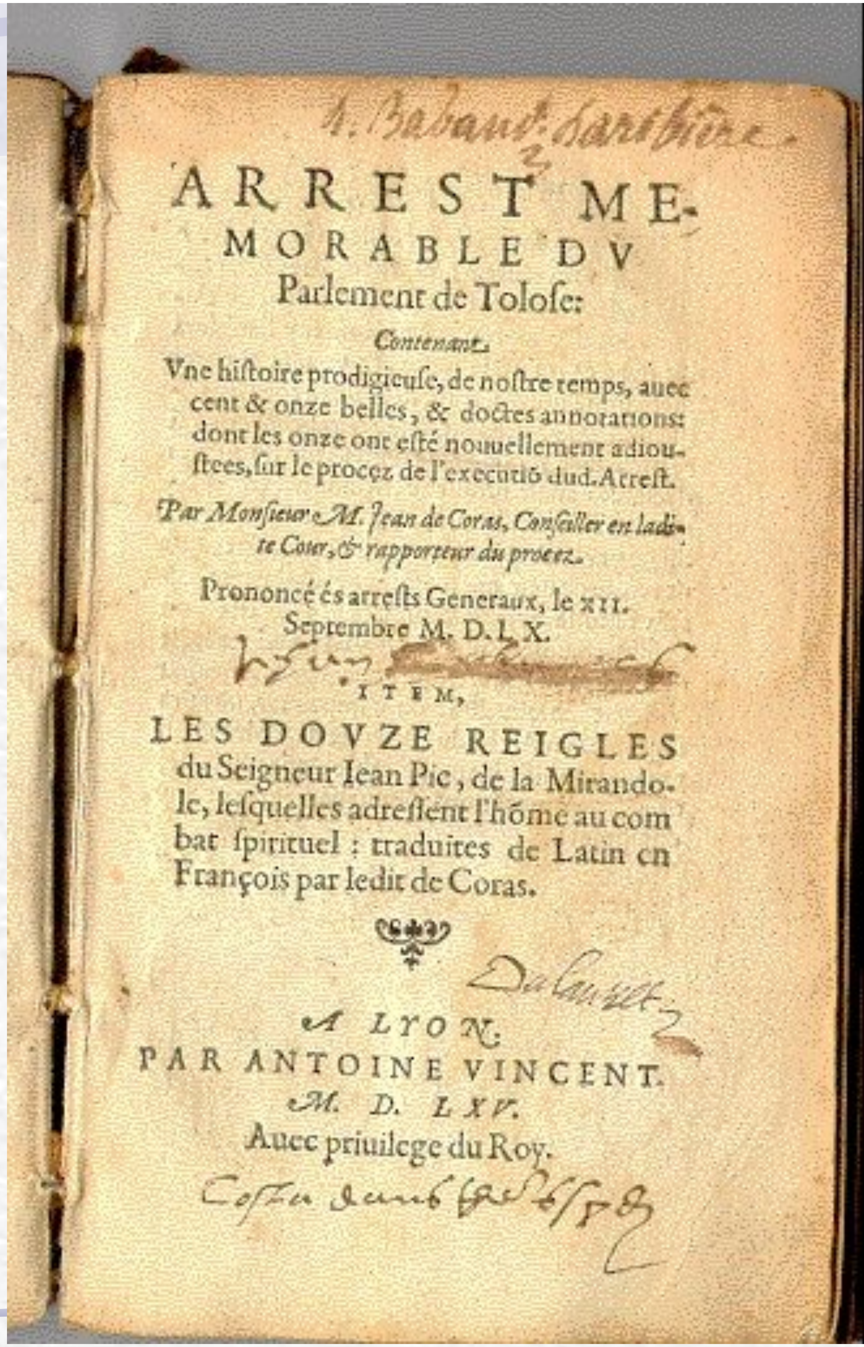
Histories

- Two histories are ***equivalent*** if they have the ***same*** transactions
- Two histories are ***strictly equivalent*** if they have the same transactions in the same order

Atomicity

A history H of committed transactions is strictly serializable if there is a history S(H) that is
(1) ***strictly equivalent to H***
(2) sequential
(3) legal

Is classical atomicity enough?



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Parlement de Tolose:

Contenant

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A LYON.
PAR ANTOINE VINCENT.
M. D. LXV.
Auec priuilege du Roy.

DSTM

- To ***write*** O, T requires a ***write-lock on*** O;

T aborts T' if some T' acquired a write-lock on O

- To ***read*** O, T checks if all objects read remain valid - else abort

- At commit time, T checks if all objects read remain valid and releases all its locks

DSTM

- ***Killer write*** (ownership)
- ***Careful read*** (validation)

More efficient algorithm

Apologizing versus asking permission

- ***Killer write***
- ***Optimistic read***
  - validity check only at commit time

Example

Invariant: $0 < x < y$

Initially: $x := 1; y := 2$

Division by zero

- T1: x := x+1 ; y:= y+1
- T2: z := 1 / (y - x)

Infinite loop

- T1: x := 3; y:= 6
- T2: a := y; b:= x;

  repeat b:= b + 1 until a = b

The old theory restricts committed transactions

We need a theory that restricts ***ALL*** transactions: this is what critical sections give us

Requirement: every operation sees a consistent state

How can we capture that precisely?

Histories

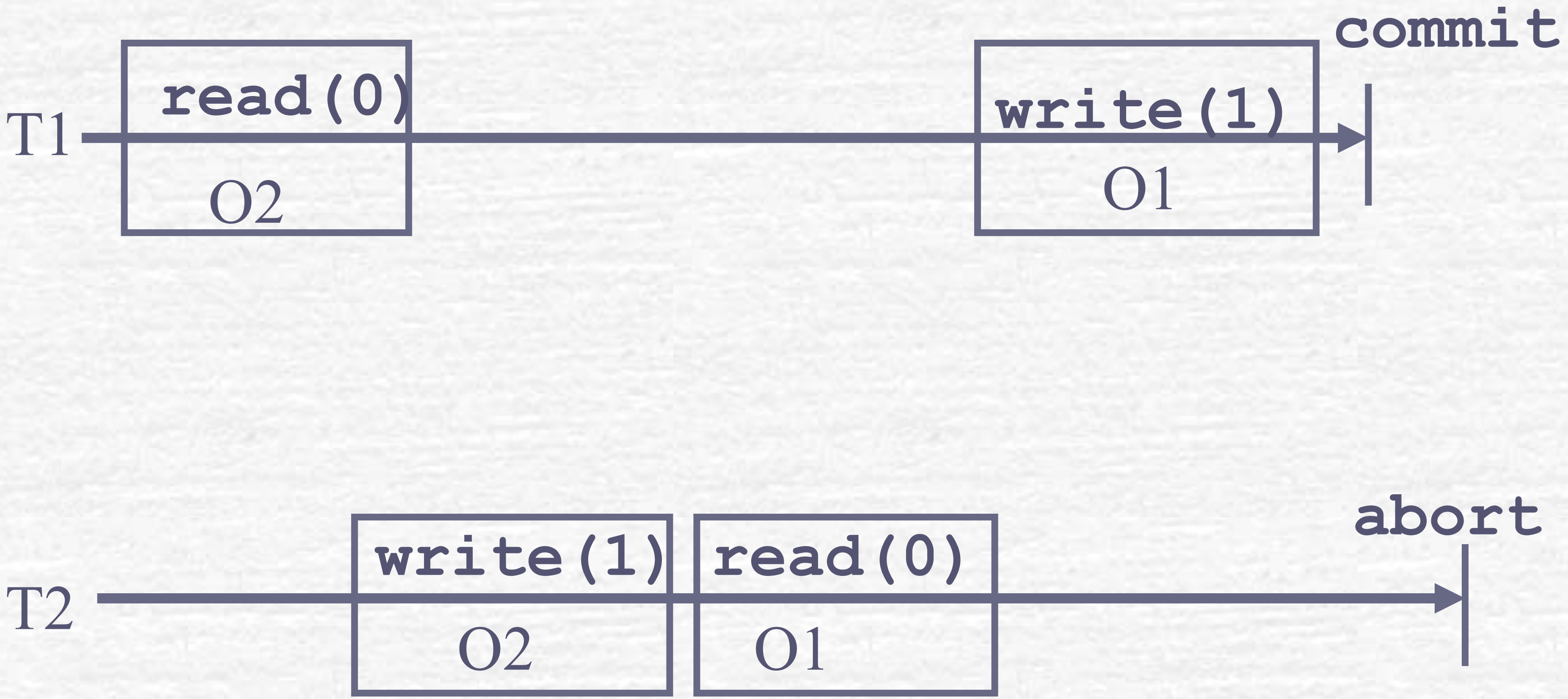
- Let H be any history (made of commited, aborted and pending transactions)

- ***Complete(H)*** is the history made of all transactions of H by removing all pending and aborted ones, except the last one, completed with a commit event

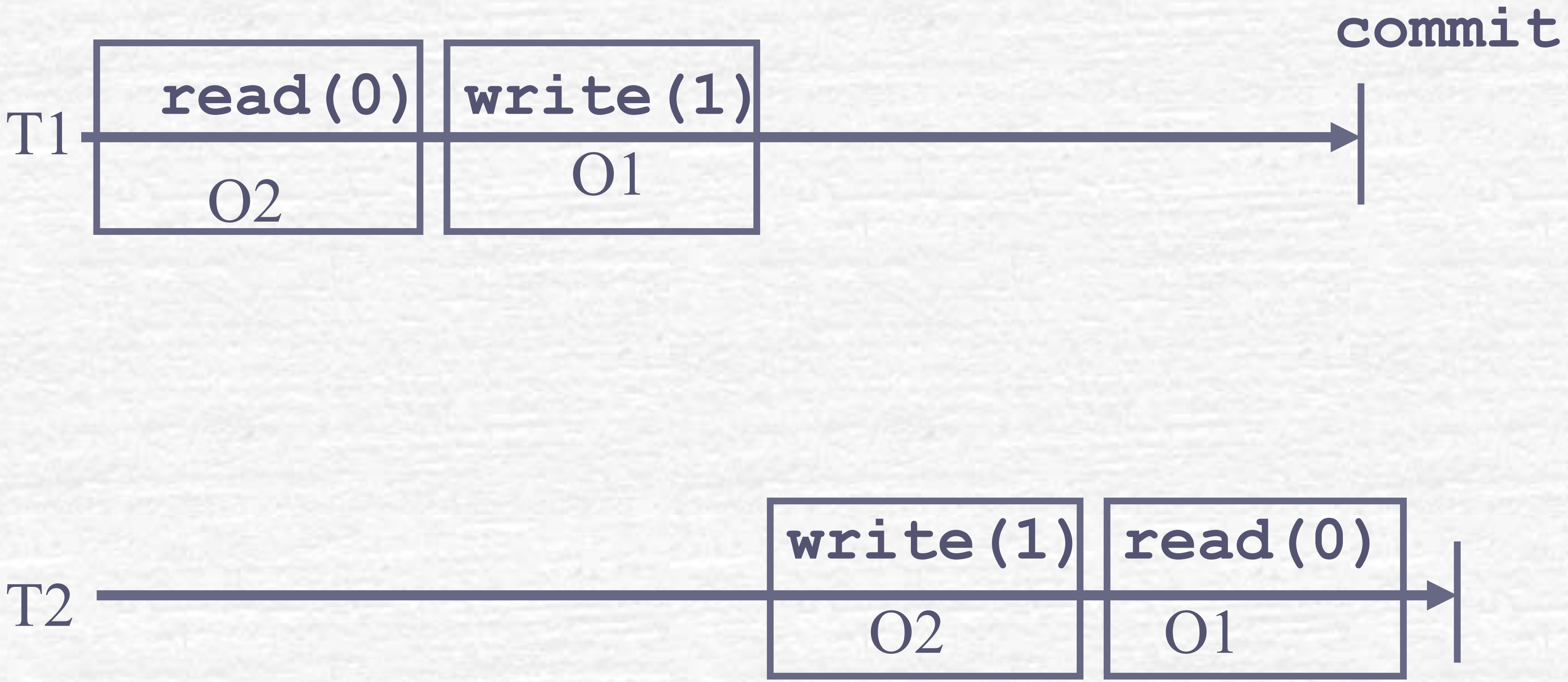
Opacity (GK'08)

A history H is opaque if every prefix H' of H has a complete(H') which is strictly serialisable

Opacity?



Illegal



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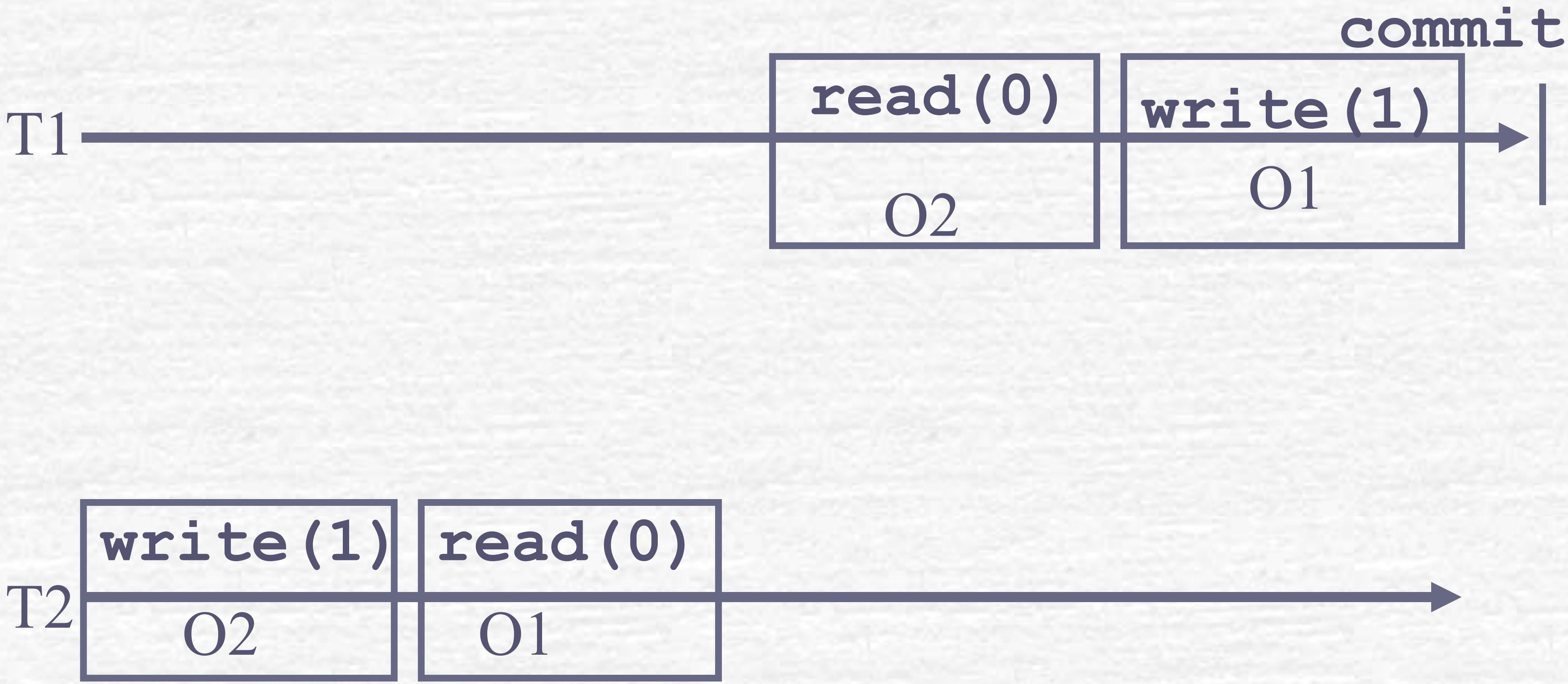
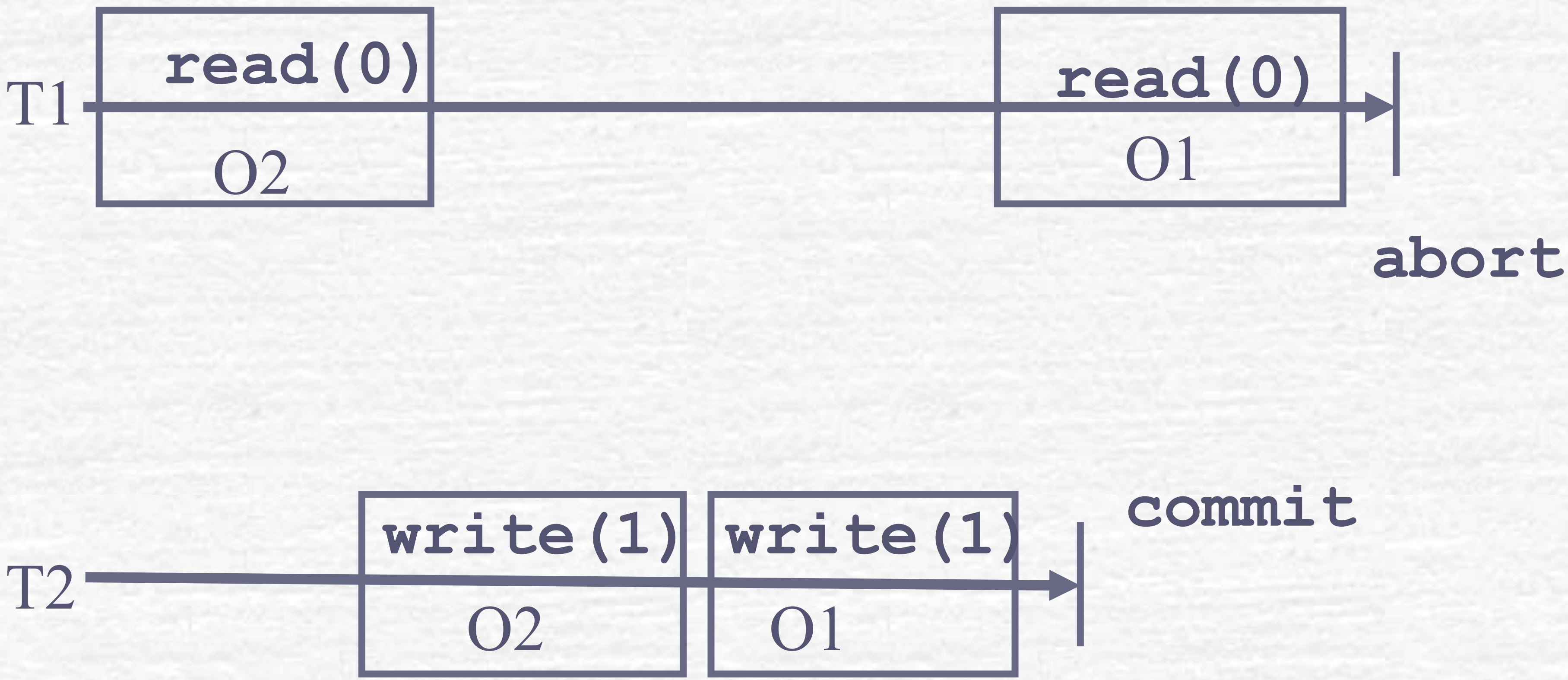
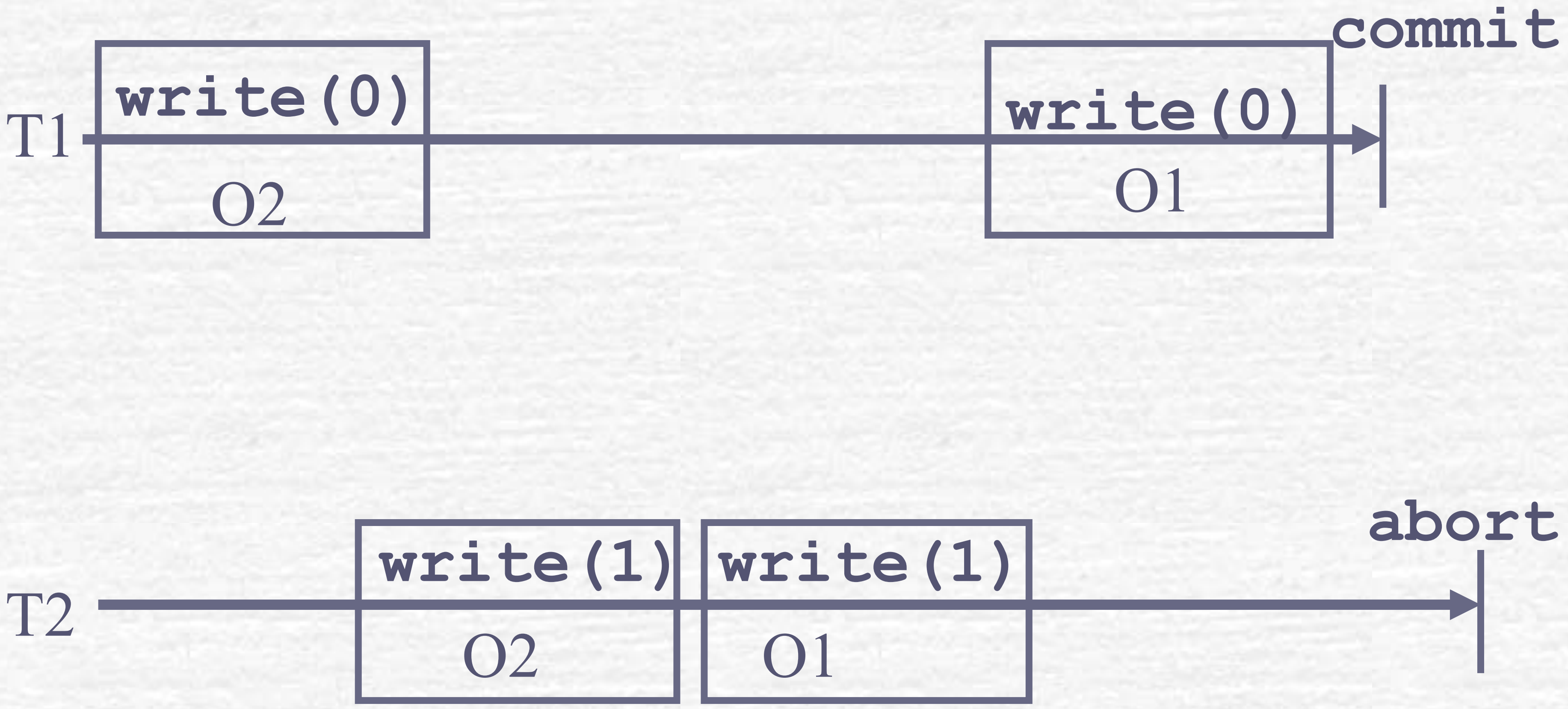


Recoverable (no dirty reads)



Opacity < rigorous scheduling



Most TMs ensure Opacity

Simple algorithm (DSTM)

- ***Killer write*** (ownership)
- ***Careful read*** (validation)

Visible Read (SXM; RSTM)

- ***Write is super killer***: to write an object, a transaction aborts any live one which has read or written the object
- ***Visible but not so careful read***: when a transaction reads an object, it says so

Visible Read

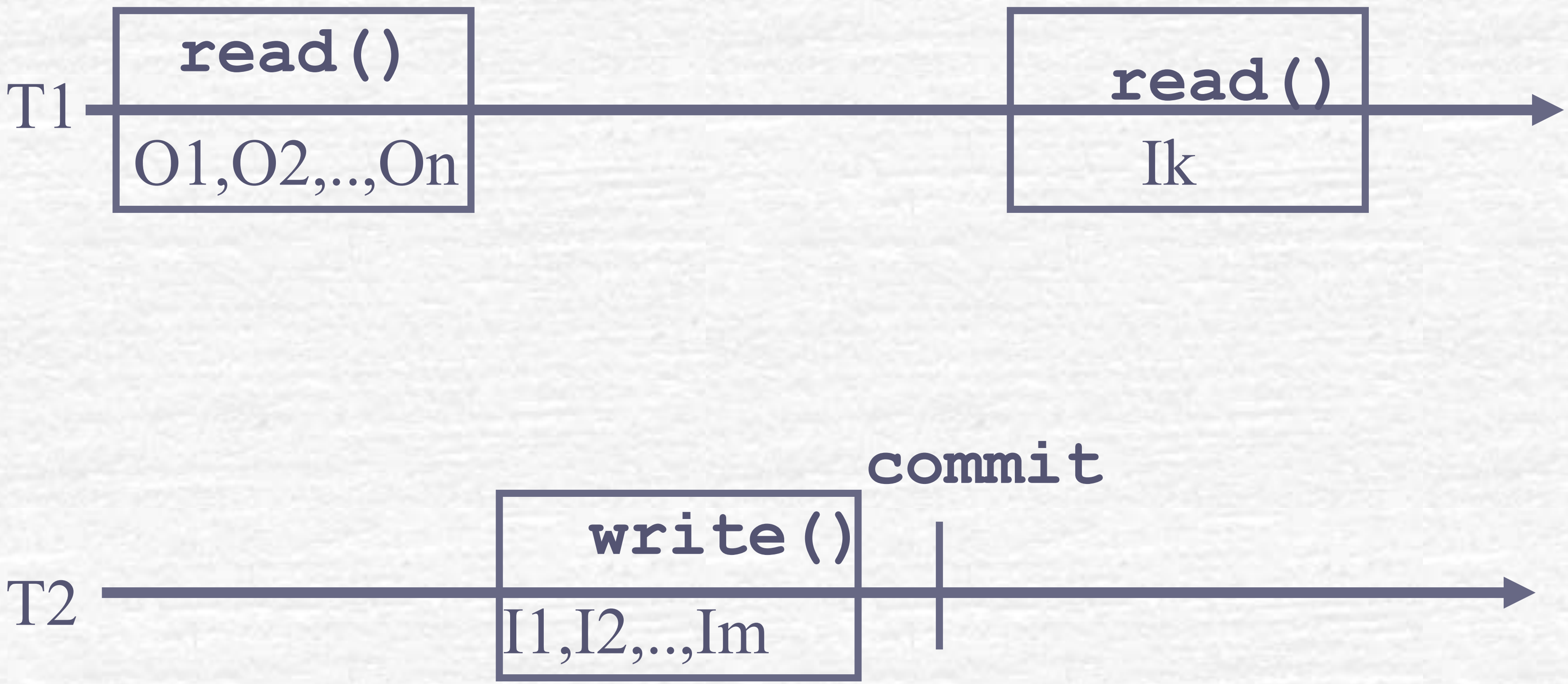
- A visible read invalidates cache lines
- For read-dominated workloads, this means a lot of traffic on the bus between processors
- This would reduce the throughput

Theorem (GK'08)

The read is either
visible or ***careful***

NB. Modulo a weak progress property and the assumption of a single version system

Intuition of the proof

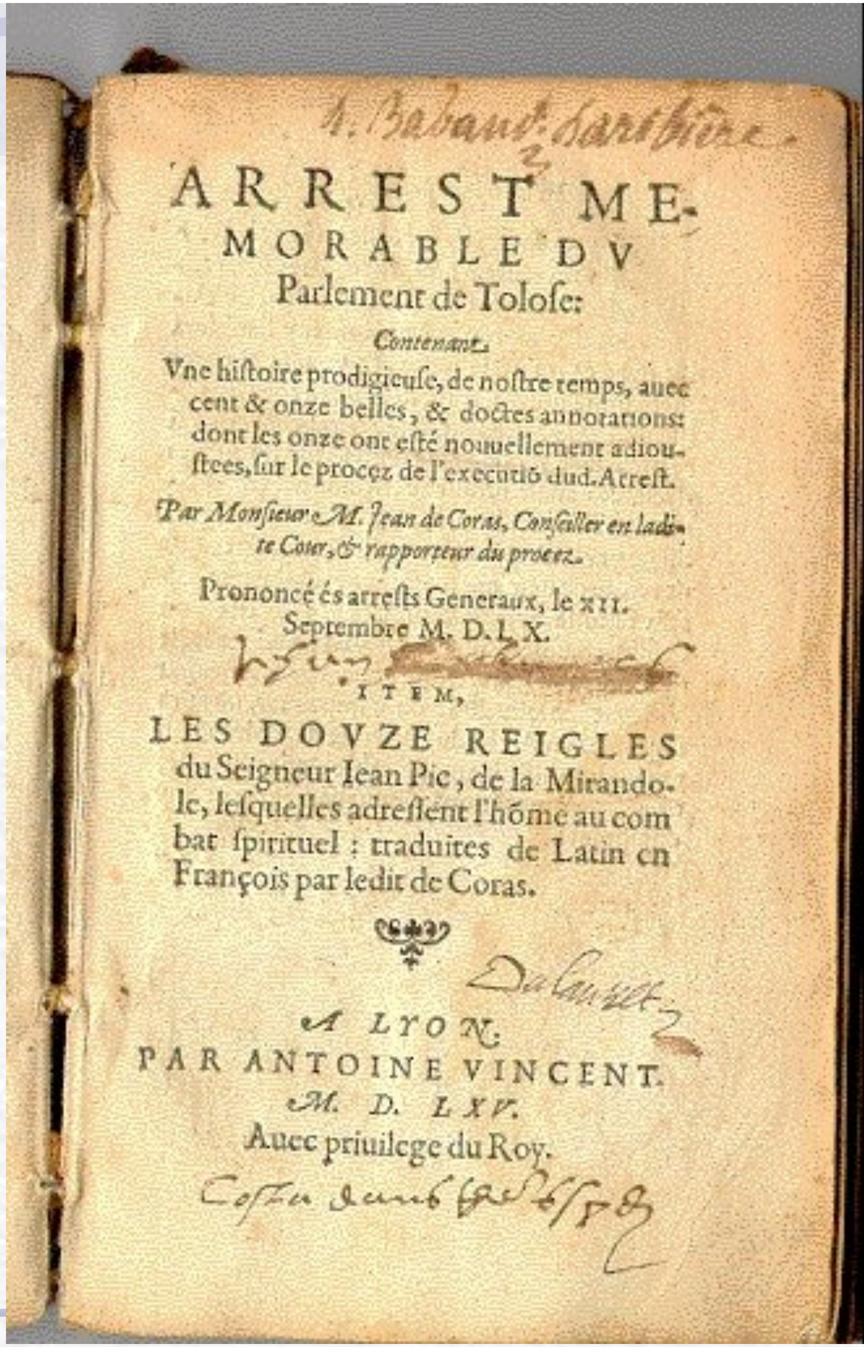


Read invisibility

- The fact that the read is invisible means T1 cannot inform T2, which would in turn abort T1 if it accessed similar objects (SXM, RSTM)

The theorem does not hold for classical atomicity

i.e., the theorem does not hold for ***database transactions***



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How can we verify the opacity of a TM?

- Check that the conflict graph is ***acyclic***
  - Number of nodes is unbounded
  - NP-Complete problem

Reduce the verification space

- ***Uniform*** system
  - All transactions are treated equally
  - All variables are treated equally

TM verification theorem (GHS'08)

- A TM either violates opacity with ***2 transactions and 3 variables*** or satisfies it with ***any*** number of variables and transactions

Reference implementation

- A finite-state transition system (12.500 states) generates all opaque histories for 2 transactions and 3 variables
- A TM is correct if its histories could be generated by the reference implementation
- Simulation relation between the TM (e.g., TL2 4500 states) and the reference implementation

Examples

- It takes 15mn to check the correctness of TL2 and DSTM
- Reverse two lines in TL2: bug found in 10mn - a history not permitted by the reference implementation

Transactional memory

1. Why do we care?

Simplicity

2. What should we expect?

Opacity

3. What might we expect?

What progress?

What might we expect?

Program
T1/T2/../Tn

Block **Abort**

TM

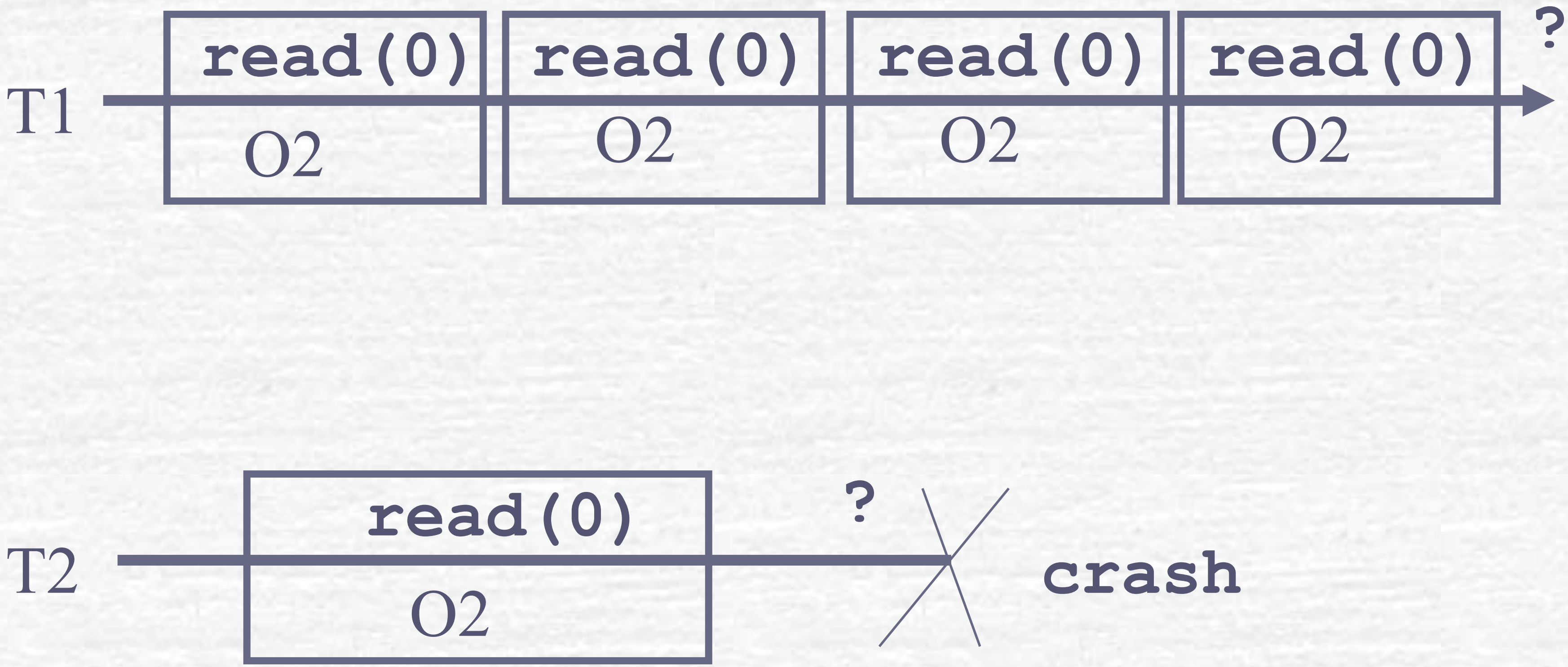
We want progress

- Operations return
- Transactions commit

Nevertheless

- We cannot require from a TM that it commits transactions:
  - from a ***dead*** process; i.e., a dead transaction
  - that infinitely ***loop***

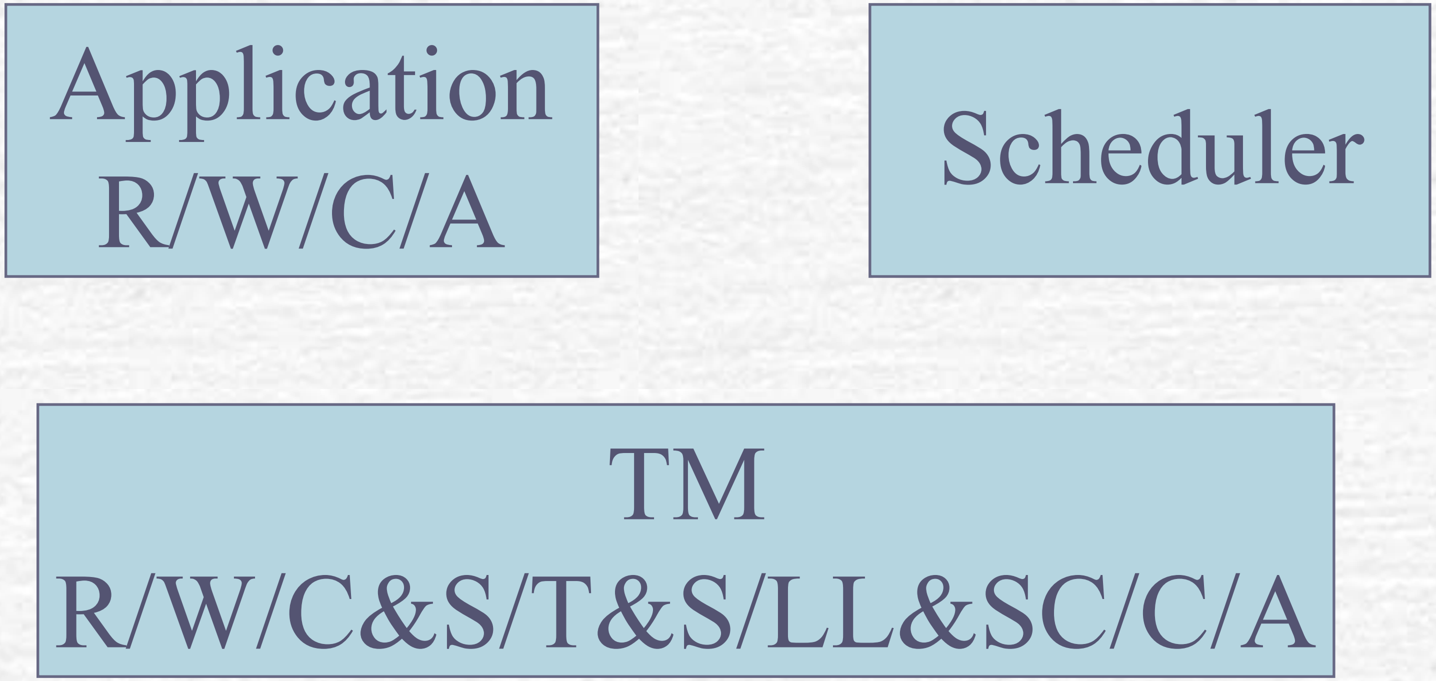
Progress?



Progress

- We can only hope progress for ***correct*** transactions
- But what is a ***correct*** transaction exactly?

Correctness depends on the scheduler and the application



History

- A history (as seen by the user) does not say what the ***scheduler*** does
- We need a ***refined*** notion of history

Low-level history

- A low-level history depicts the events of the ***implementation***
- It is also a ***total order*** of invocation, reply, and termination events
  - H = (S,<)

Low-level history

- The invocations and replies include also ***low-level*** objects used in the implementation
- The low-level history is a ***refinement*** of the high-level one (seen by the user)

Low-level history

- ***Well-formed*** (low-level) history:
  - Every transaction that aborts is immediately repeated until it commits, i.e., :

Every process executes:

T1:op1; T1.op2; ..; T1:Commit?; T1:Abort; T1:op1;.. …

Low-level history

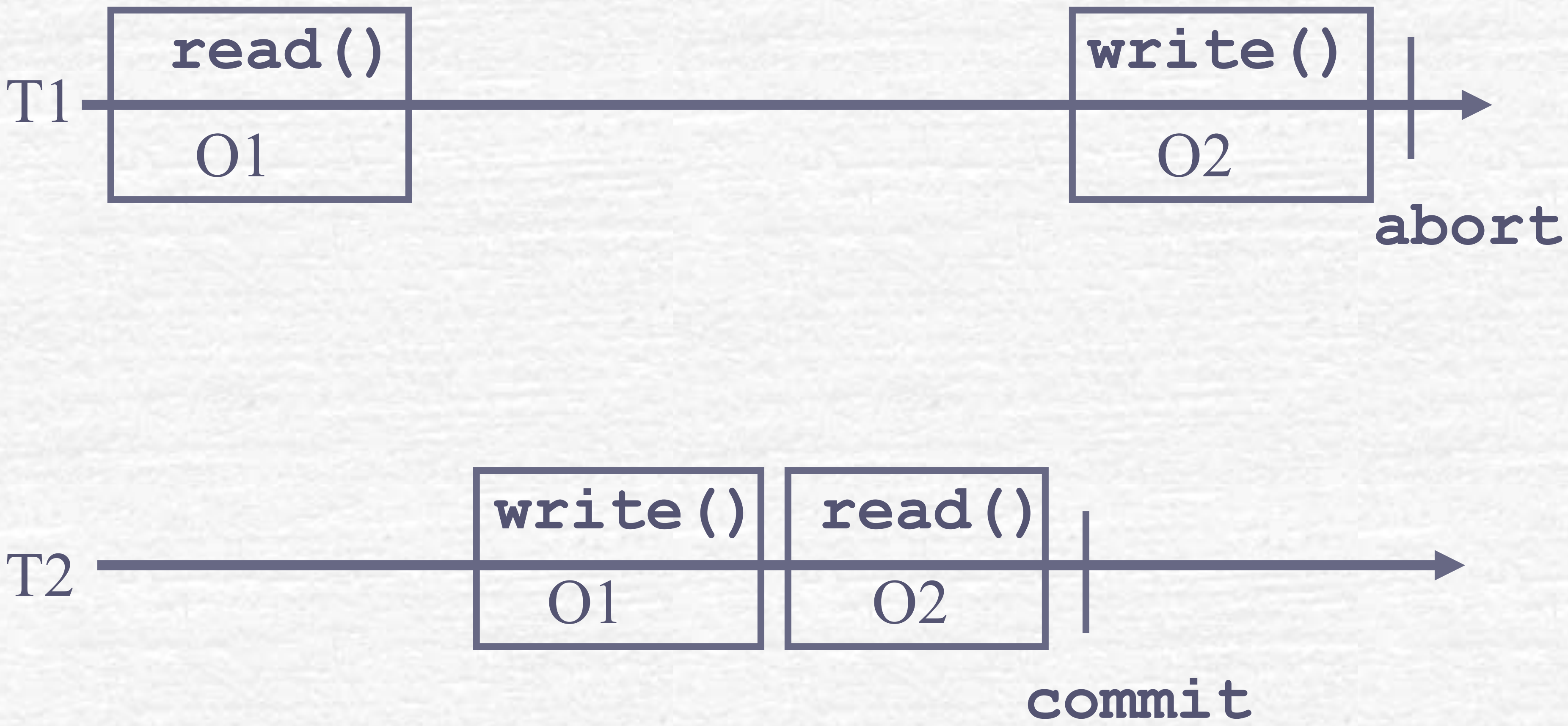
- A transaction T is ***correct*** if
  - (a) ***commit*** is invoked after a finite number of invocation/reply events of T and
  - (b) either T ***commits*** or T performs an infinite number of (low-level) steps

- (a) depends on the ***application***
- (b) depends on the ***scheduler***

Ideally

- Every **correct** transaction **commits**

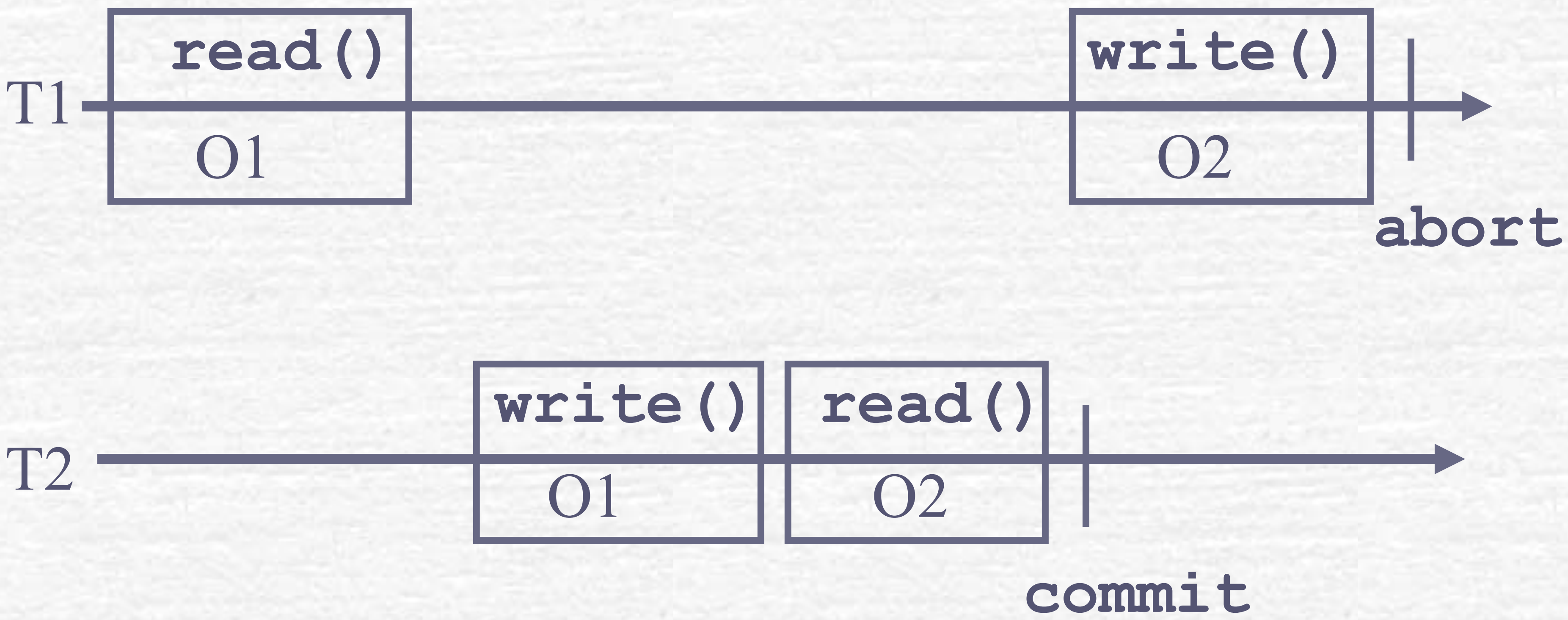
Aborting is a fatality



Eventual progress - wait-freedom -

- Every ***correct*** transaction ***eventually commits***
- NB. We allow the possibility for a transaction to abort a finite number of times as long as it eventually commits

Eventual progress



Eventual progress

- ***Impossible*** in an asynchronous system

- NB. This impossibility is fundamentally different from FLP: It holds for any underlying object

Conditional progress - obstruction-freedom -

- A correct transaction that eventually does not encounter ***contention*** eventually commits
- ***Obstruction-freedom*** is indeed possible

DSTM

- To ***write*** O, T requires a ***write-lock on*** O (use C&S);

T aborts T' if some T' acquired a write-lock on O (use C&S)

- To ***read*** O, T checks if all objects read remain valid - else abort (use C&S)

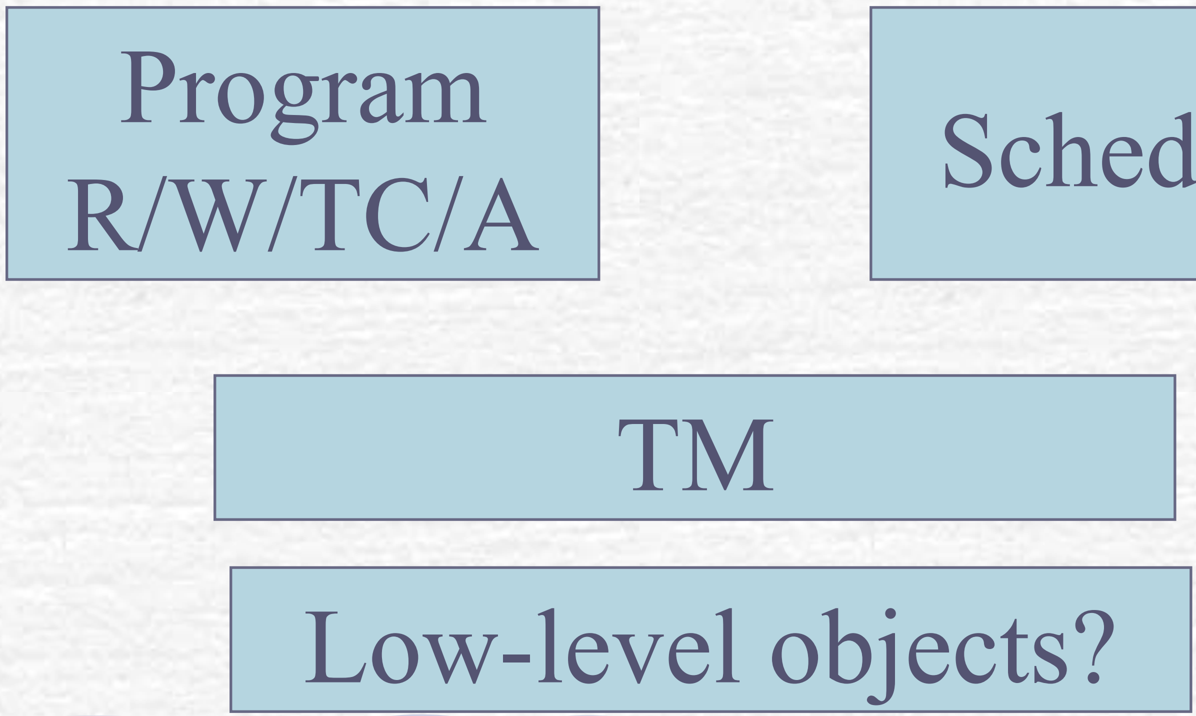
- Before committing, T releases all its locks (use C&S)

DSTM uses C&S

- ***C&S*** is the strongest synchronization primitive

  - Is OF-TM possible with less than C&S? e.g., R/W objects

OF-TM



Consensus number of OF-TM?

(∞)	Compare&Swap
(..)	…
(2)	Queue, Test&Set, Fetch&Add
(1)	Register, Snapshot

FO-consensus

A process can decide or ***abort***

- No two different values can be decided
- A value decided was proposed

- If ***abort*** is returned from propose(v) then (1) there is contention and (2) v cannot be returned

OF-TM <=> FO-consensus

- From OF-TM to FO-consensus: ***propose()*** is performed within a transaction
- From FO-consensus to OF-TM: slightly more tricky - as for DSTM but using a one shot object instead of C&S

Consensus

propose(vi) returns a value vj (no abort)

- No two different values can be decided
- A value decided was proposed

OF-consensus vs consensus

- OF-consensus can implement consensus among exactly 2 processes
- ***Algorithm***
- P1 writes its value and keeps proposing until it decides a value
- P2 either decides or reads the value

Computability

The consensus number of OF-TM is 2

- OF-TM cannot be implemented with R/W
- OF-TM does not need C&S

Transactional memory

1. Why do we care?

Simplicity

2. What should we expect?

Opacity

3. What might we expect?

Obstruction-freedom

Those are my principles

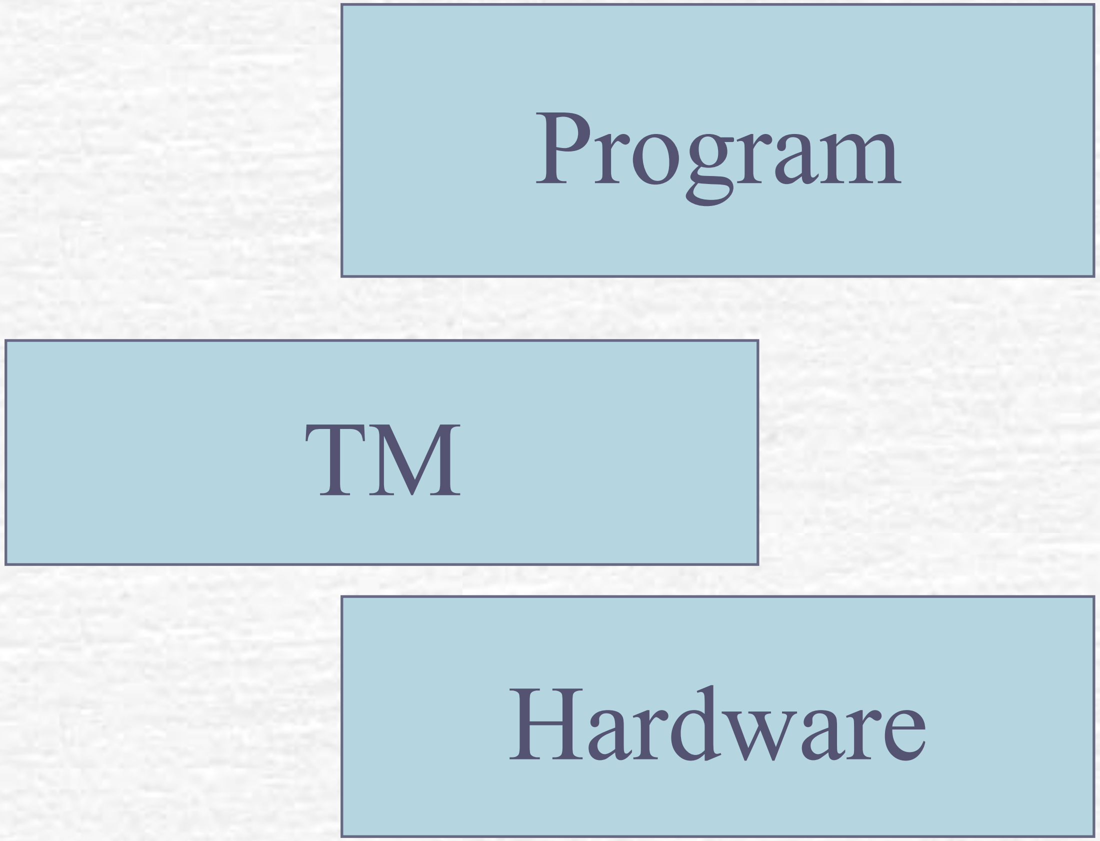
If you don't like them

I have others

G. Marx

What opacity in the jungle ?

Two ways compatibility (GHKS10)



What progress beyond OF?

Boosting obstruction-freedom

OF-TM

CM

Contention managers

- **Aggressive**: always aborts the victim
- **Backoff**: wait for some time (exponential backoff) and then abort the victim
- **Karma**: priority = cumulative number of shared objects accessed – work estimate. Abort the victim when number of retries exceeds difference in priorities.
- **Polka**: Karma + backoff waiting

Greedy contention manager

- State
  - Priority (based on start time)
  - Waiting flag (set while waiting)
- ***Wait*** if other has
  - Higher priority AND not waiting
- ***Abort*** other if
  - Lower priority OR waiting

Off-line scheduler (GHP'95)

- Compare the TM protocol with an off-line scheduler that ***knows***:
  - The starting time of transactions
  - Which objects are accessed

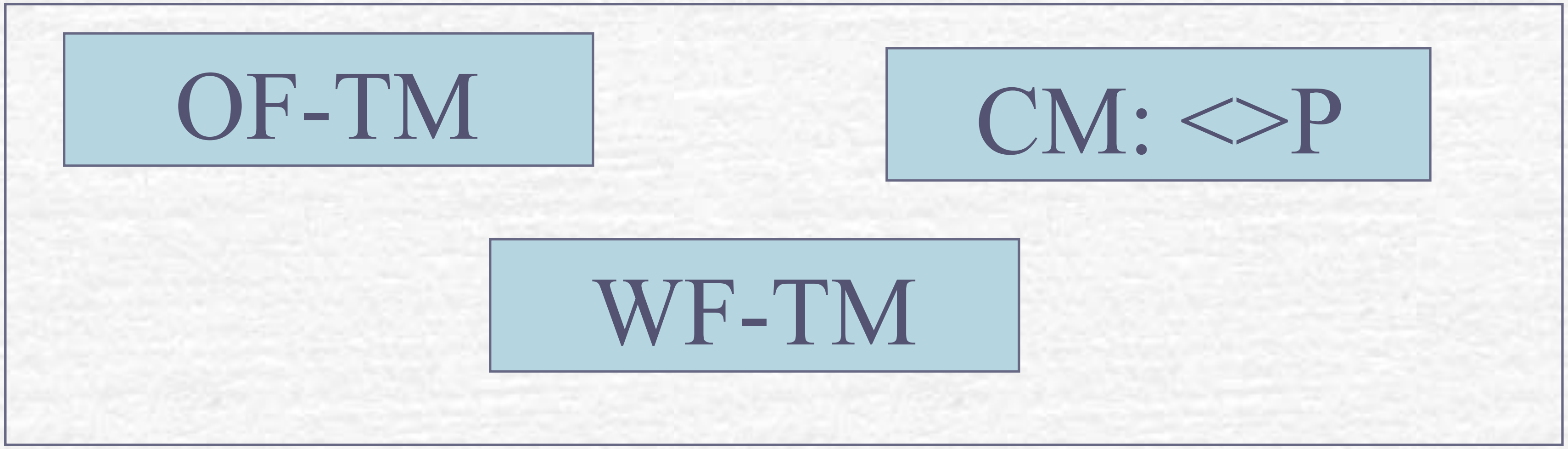
  (i.e., conflicts)

Competitive ratio

- Let s be the number of objects accessed by all transactions
- Compare time to ***commit all transactions***
- Greedy is O(s)-competitive with the off-line scheduler
  - GHP'05 $O(s^2)$
  - AEST'06 O(s)

What progress beyond OF?

The weakest CM-FD to implement WF-TM (GKK'06)



Eventual global progress - lock-freedom -

- Some ***correct*** transaction ***eventually commits***
- NB. OSTM ensures eventual global progress
- Eventual global progress is the strongest liveness property that can be ensured by an STM

Permissiveness (GHS'08)

A TM is permissive if it never aborts when it should not

Permissiveness

- Let P be any ***safety*** property and H any P-safe history prefix of a deterministic TM

- We say that a TM is ***permissive*** w.r.t P if
  - Whenever <H;commit> satisfies P
  - <H;commit> can be generated by the TM

Permissiveness

- No TM can be ***permissive*** with respect to ***opacity*** (or ***serializability***)

Probabilistic permissiveness

- Let P be any safety property and H any history generated by a TM
- The TM is ***probabilistic permissive*** with respect to P if
  - Whenever <H;commit> satisfies P:
  - <H;commit> can be generated by TM with a ***positive probability***

Probabilistic permissiveness

- There is a probabilistically permissive TM with respect to opacity: ***AVSTM***
- AVSTM should ***outperform*** all TMs
  - In theory…

Probabilistic permissiveness

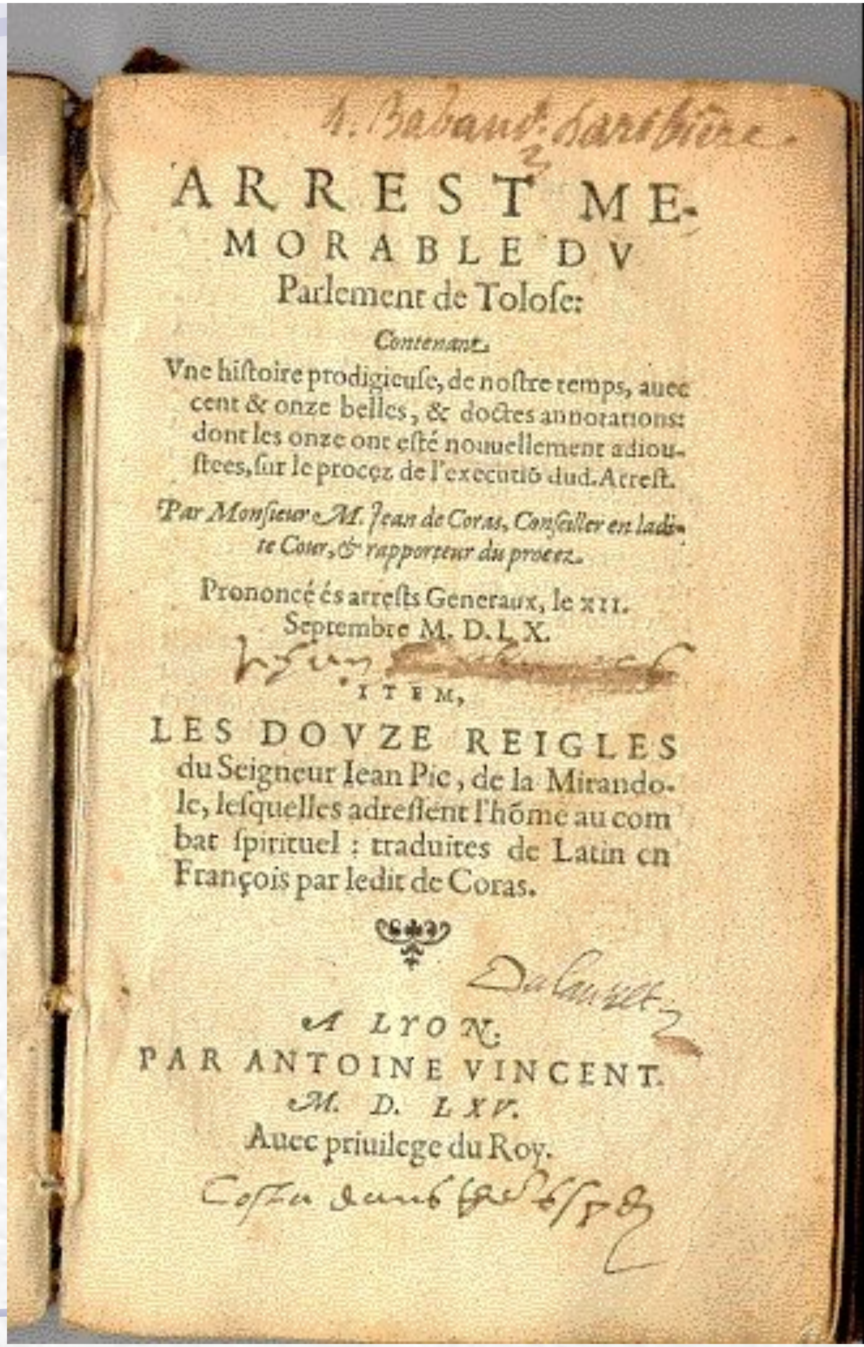
- ***AVSTM*** indeed outperforms all TMs under very ***high contention***
- ***AVSTM*** does not perform well under ***low contention***
- ***AVSTM*** combined with a pragmatic TM:
  - ***TL2*** under normal mode and then fall-back to ***AVSTM***

A slide to remember

Transactions are conquering the parallel programming world

They sound familiar and thus make the programmer happy

Getting them correct is in fact tricky and that should make YOU happy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Biblio

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