Software Transactional Memory :

Worst Case Execution Time Analysis

T. Sarni, A. Queudet, P. Valduriez

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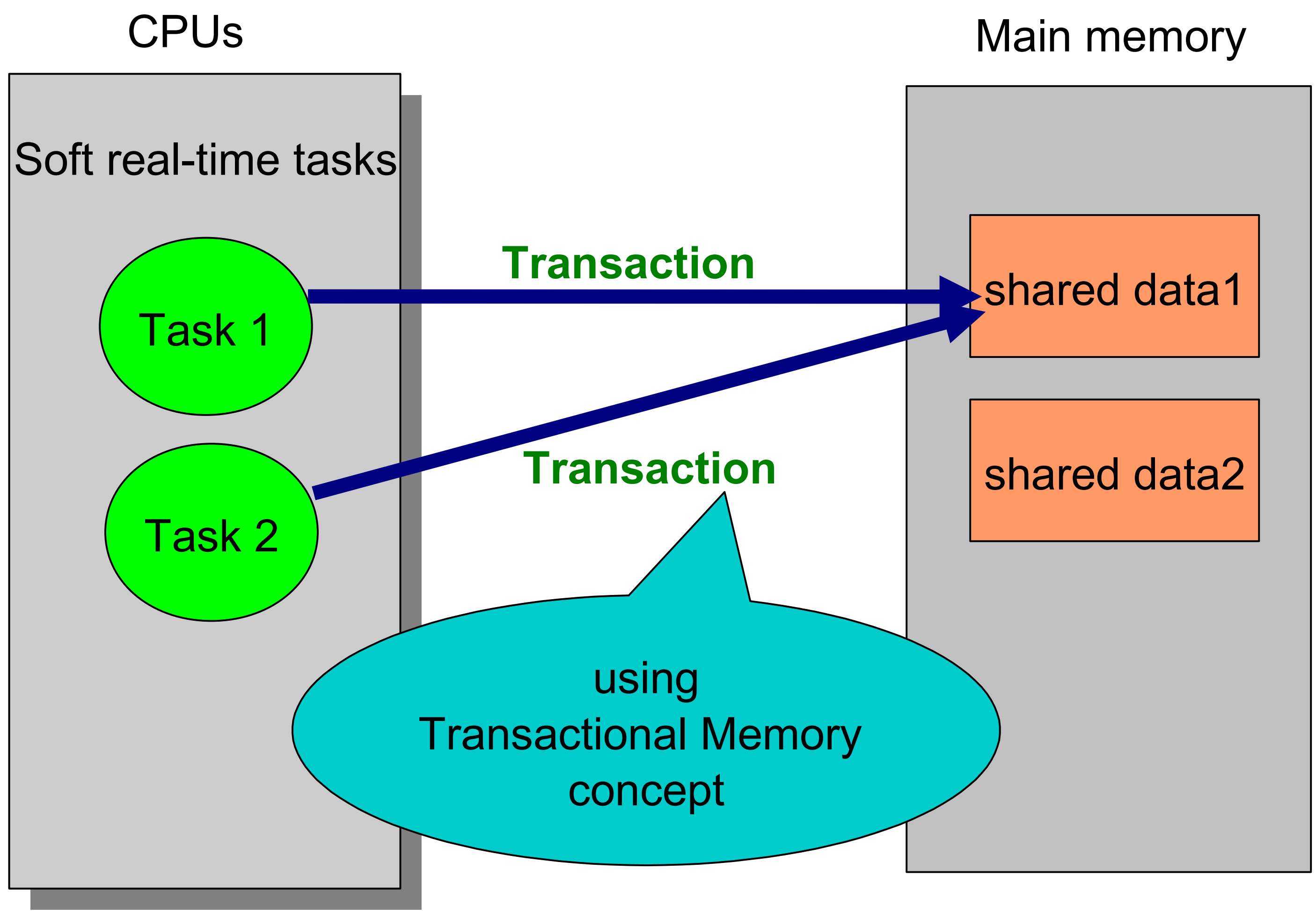
Outline of the talk

1. Introduction
2. Scheduling of transactions
3. Our contribution
4. Conclusion



Concurrent real-time tasks accessing multiple shared resources on multiprocessor systems

Framework Basis

Why transactions instead of locks ?

- Eases programming and avoids problems like deadlocks, priority inversion ...

```
Init Semaphores : S1, S2

P(S1)
 P(S2)

    <instructions>

 V(S1)
V(S2)
```

Lock-based method

```
do{

 <instructions>

}until transaction_commit ()
```

Transaction

Framework Basis

Why transactions instead of locks ?

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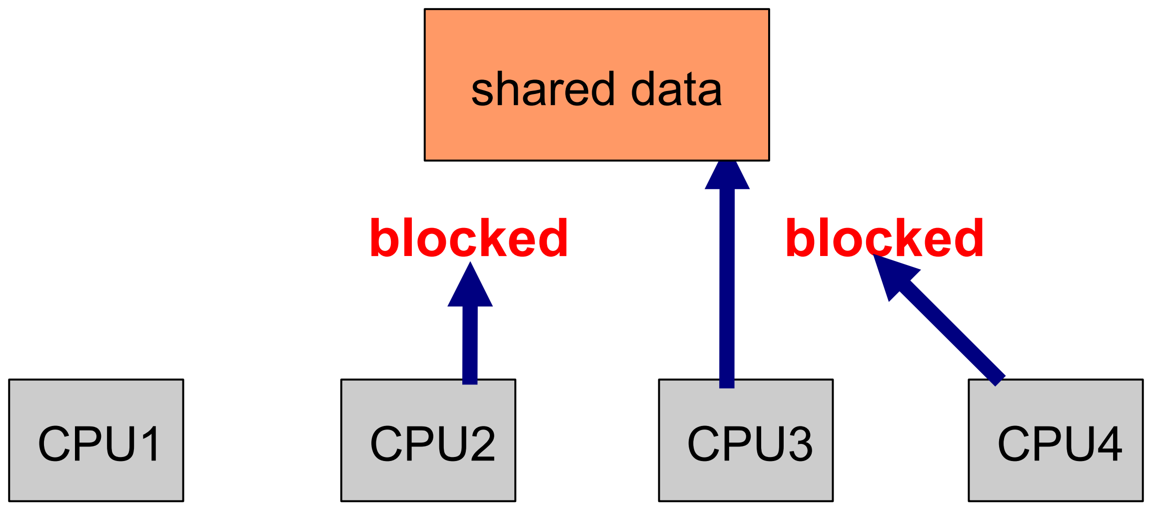
- Locks reduce throughput in multiprocessor systems



Lock-based access

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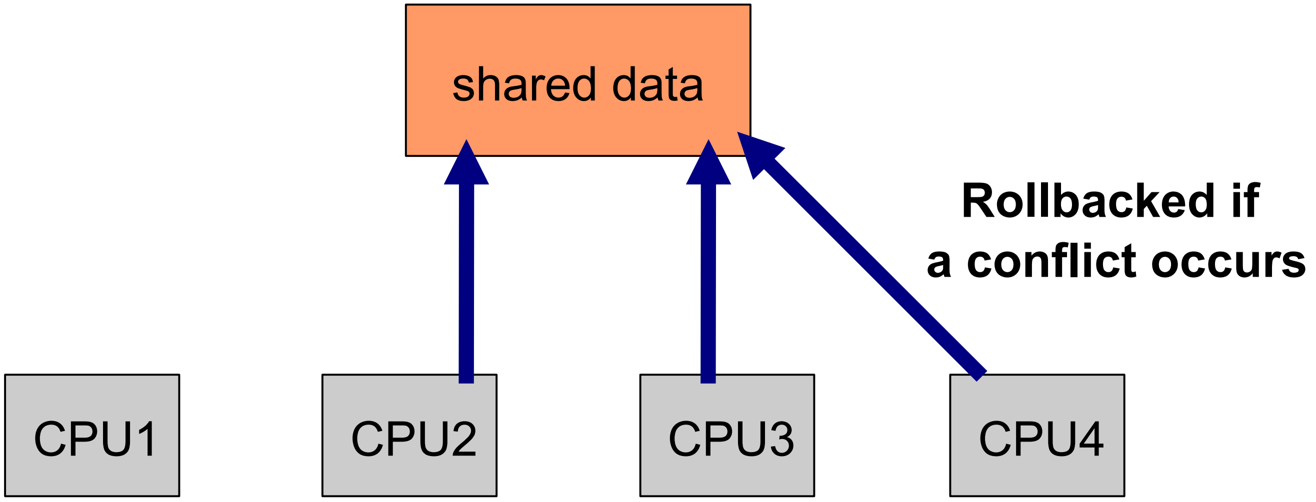

Transactions-based access

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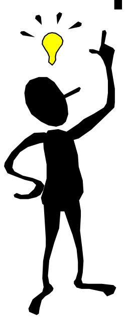
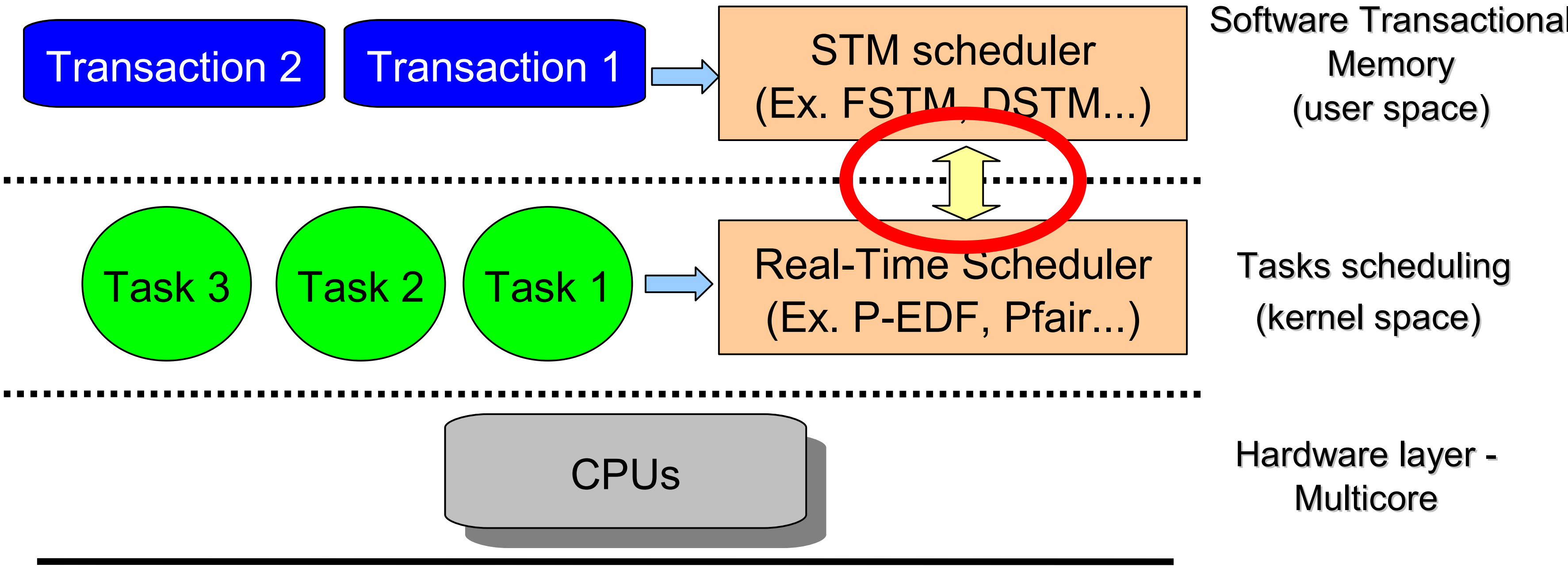
Transactional Memory (TM)



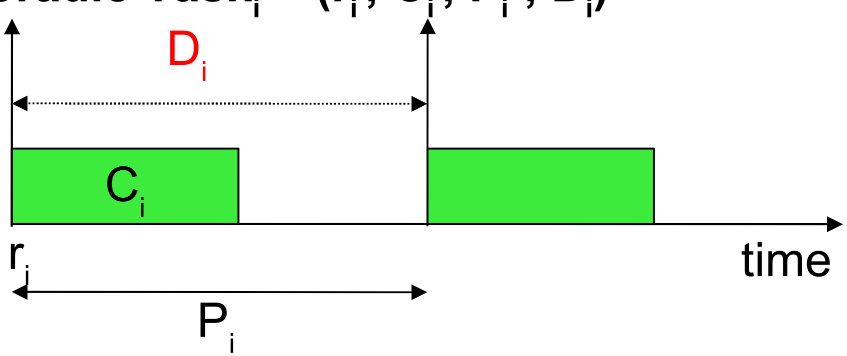
- The term TM is introduced by Herlihy *et al*. 93

- Interest renewed with advent of multicore systems
  - **Hardware-based (HTM)**
  - **Software-based (STM)**
  - **Hybrid-based (HyTM)**

Issue



Sporadic Task$_i$ = (r_i , C_i , P_i , D_i)



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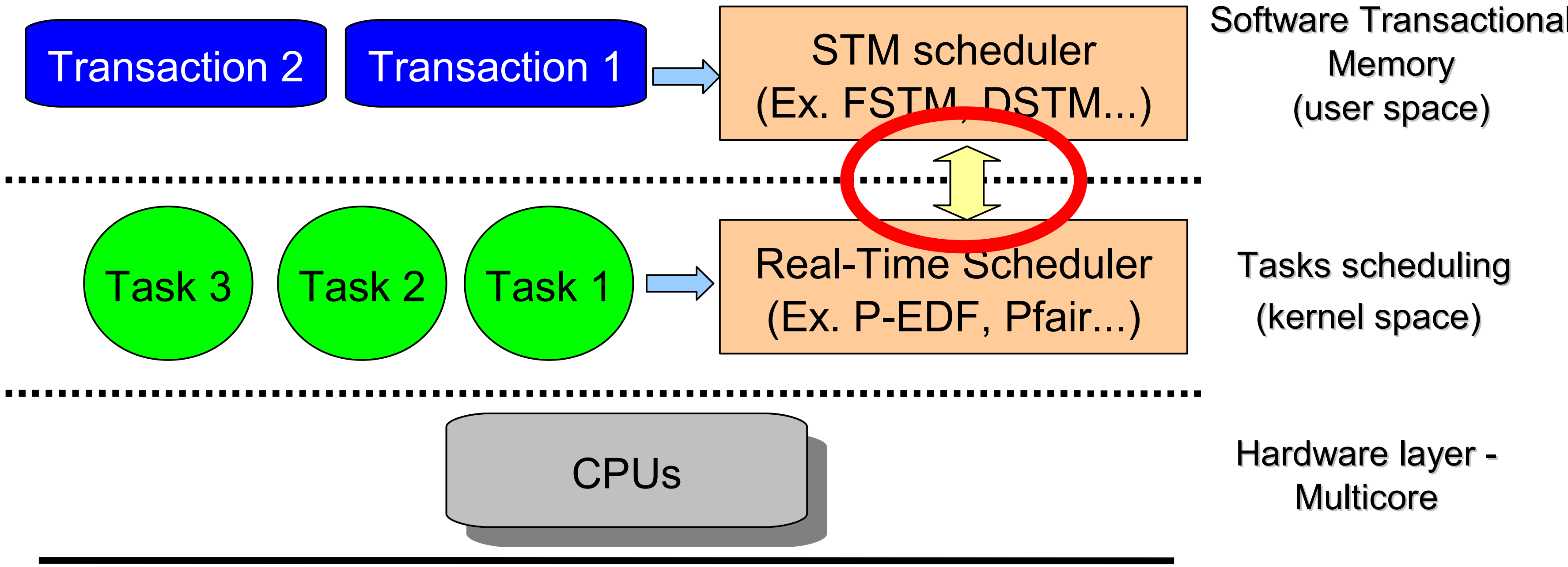
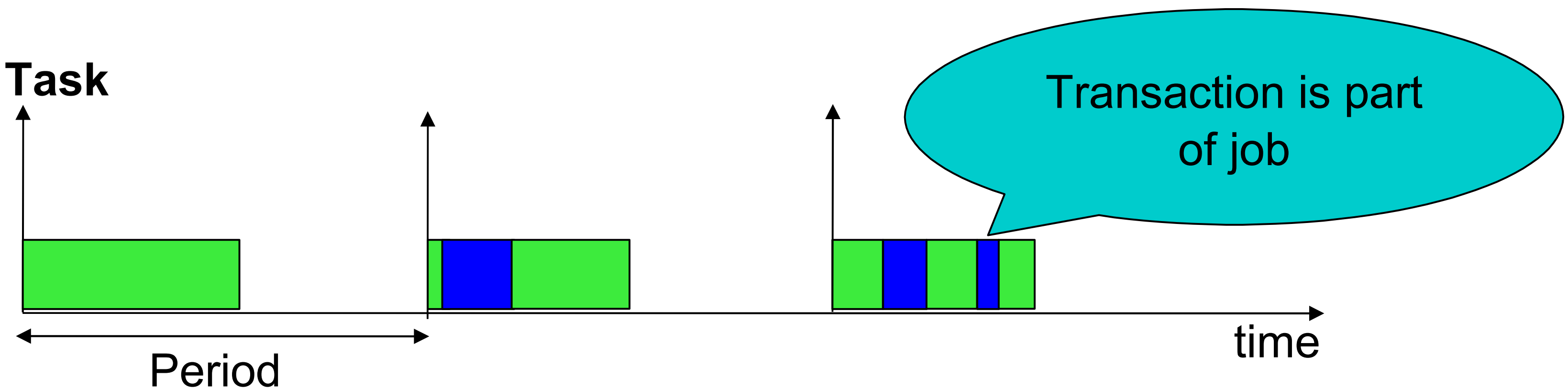

Transaction 2
Transaction 1
STM scheduler
(Ex. FSTM, DSTM...)
Software Transactional Memory
(user space)
Task 3
Task 2
Task 1
Real-Time Scheduler
(Ex. P-EDF, Pfair...)
Tasks scheduling
(kernel space)
CPUs
Hardware layer - Multicore


Task
Transaction is part of job
time
Period

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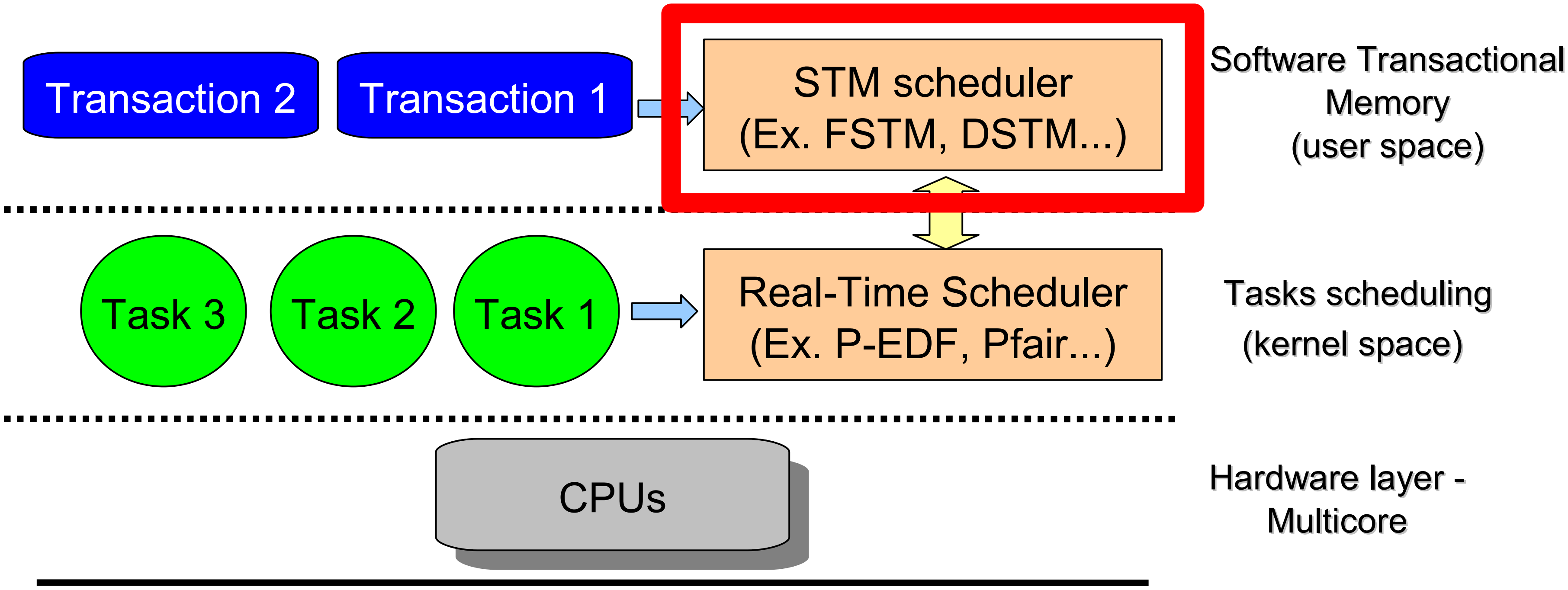
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Classification

Transaction progress guarantuees

- **Wait-free**
  - Strongest guarantee for transactions to make progress
  - Hard real-time
- **Lock-free**
  - Ensures that at least one transaction is making progress
  - Soft real-time
- **Obstruction-free**
  - Weakest guarantee for transaction to make progress
  - Non real-time

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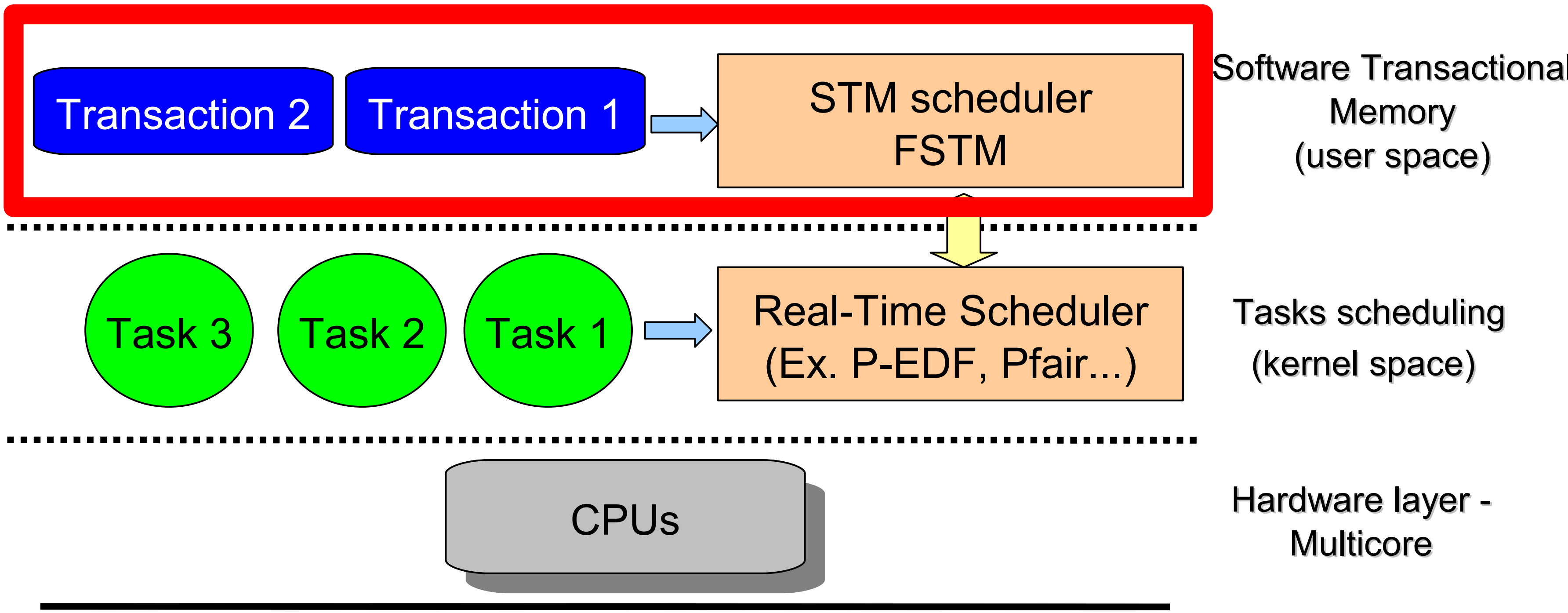
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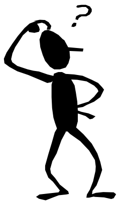
Studying STM



Which parts cause execution time variation ?

- Intuitively : The number of transaction retries (rollback times)

  But STMs are usually based upon a dynamic memory allocator ...

Impact of task scheduling on the execution time of transactions ?

- Evaluation of rollback and objects allocation times under : P-EDF, G-EDF, Pfair

Performance metrics

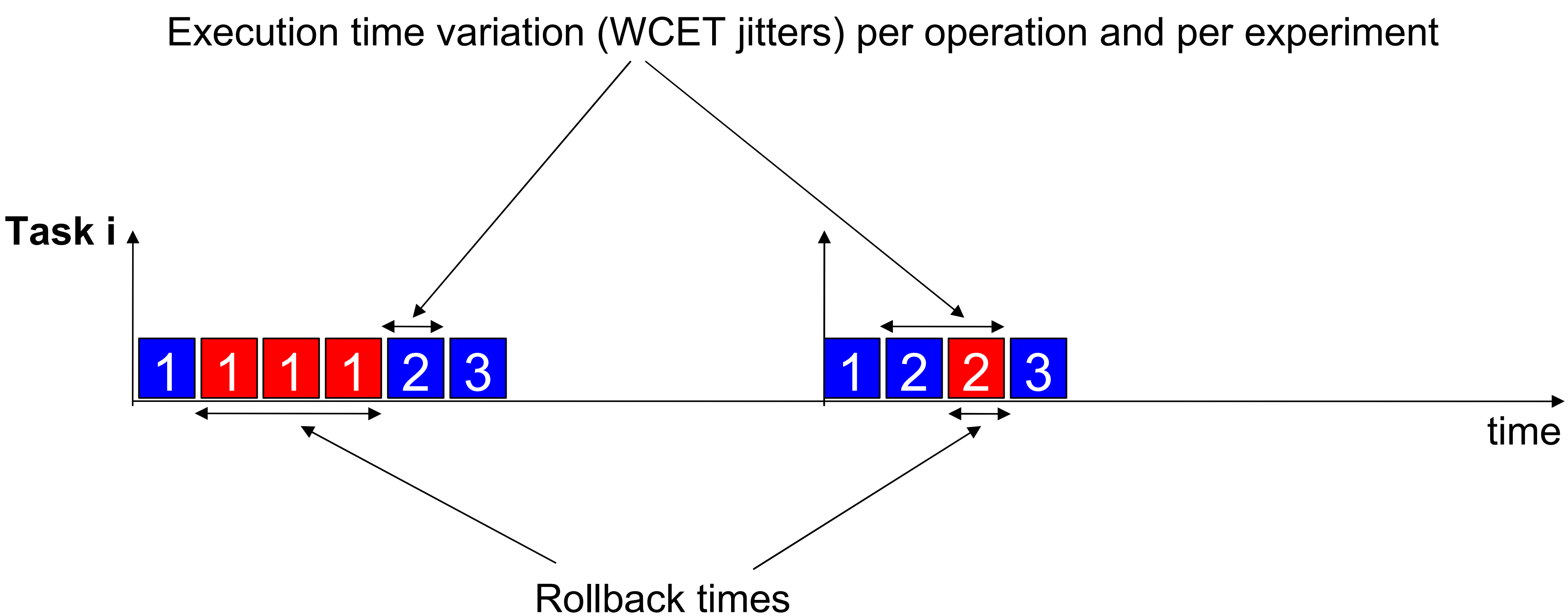
Rollback times

- Measuring the rollback time ratio for the whole set of tasks
- Global mean

WCET jitters

- **Observed** WCET jitter over 10 experiments

Performance metrics (example)



Legend

Red-black tree operations : 1 **Lookup** 2 **Update** 3 **Remove**

x Retry (=rollback)

Experimental context

Real-Time Operating System

- We choose LITMUS^{RT} (developed at University of North Carolina)
- LITMUS^{RT} is a Linux-based kernel
  - °Implements real-time multiprocessor scheduling policies

Software Transactional Memory

- Enhanced Fraser's STM for real-time [*Sarni et al*. RTCSA'09]
- Based on a lock-free algorithm

Experimental context

- Using a x86 Dual-core processor (m = 2)
- Under Ubuntu 8.04
- *N* tasks (C_i = ***20ms*** , $P_i = (N * C_i) / m$, $D_i = P_i$) => **heavy loads** (in order to obtain a high contention for shared resources accesses)

Experimental context

Dlmalloc (Linux allocator)

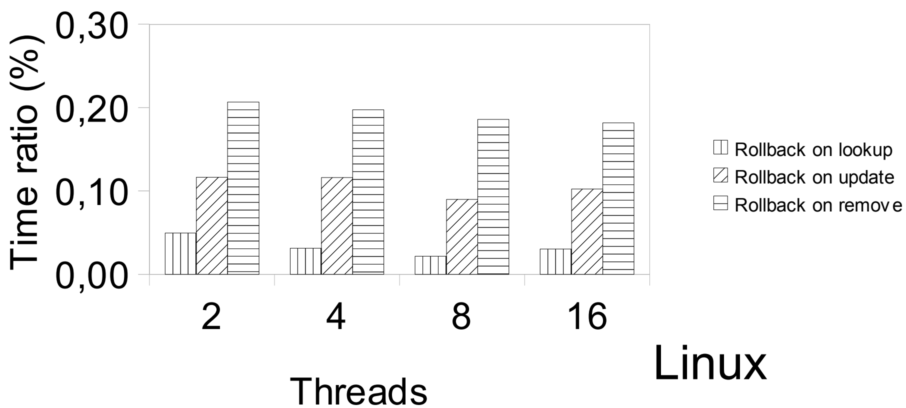
- Allocation $O(M/m)$ **M**: Maximum memory size, **m**: Largest allocated block
- Deallocation $O(1)$

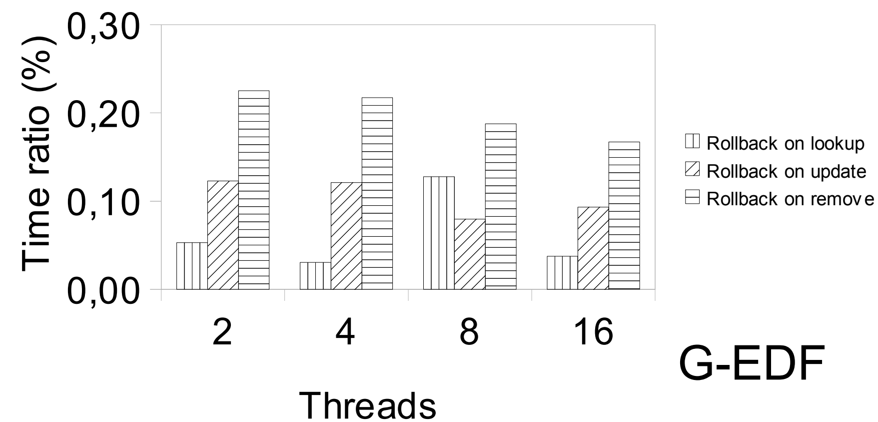
TLSF (Two-Level Segregate Fit) [Masmano *et al.* 04]

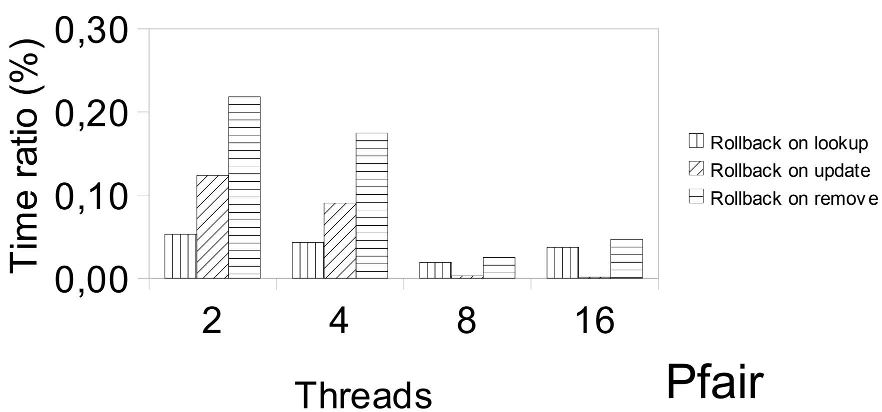
- Dynamic memory allocator
- Based on an algorithm with constant cost $\Theta(1)$
- Therefore, reasonable use in real-time context

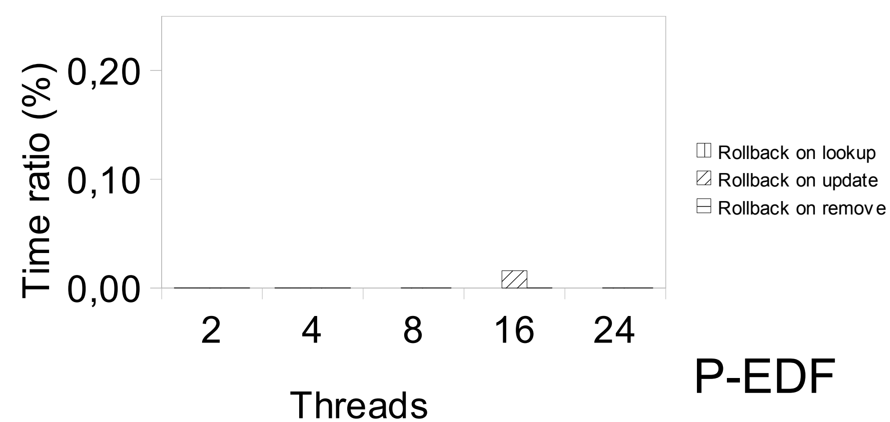
Experiment results

Rollback times



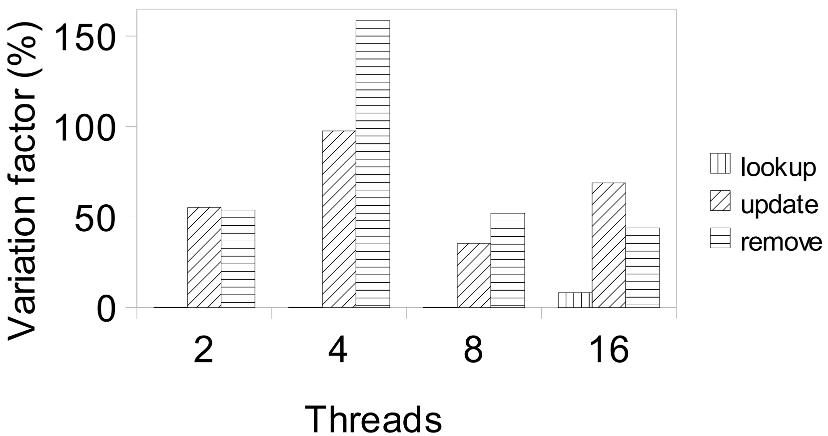




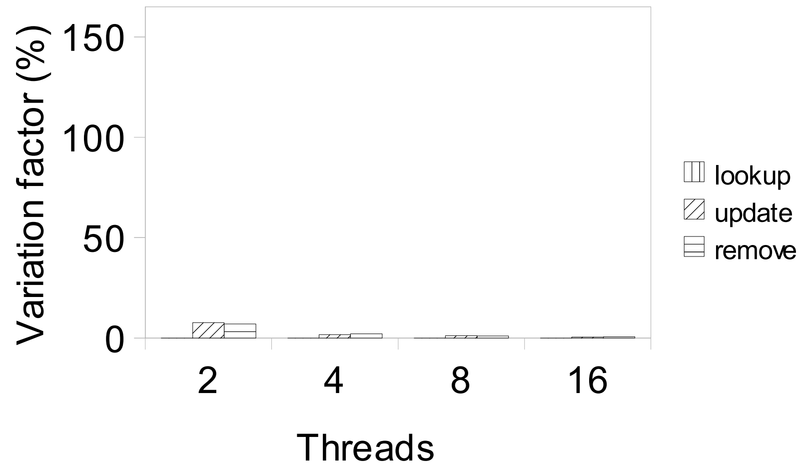


Experiment results

WCET Jitters

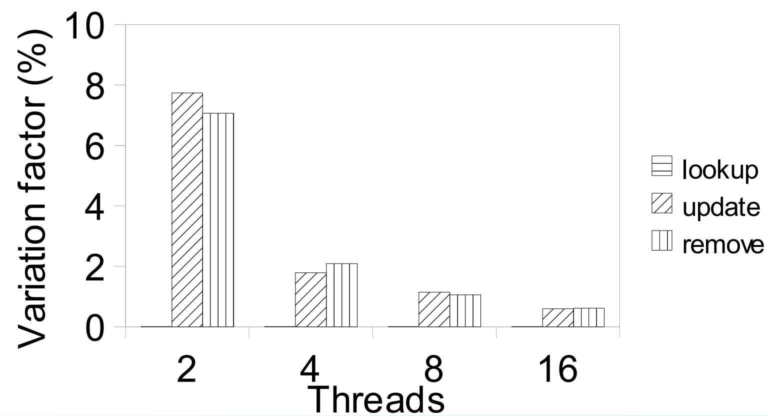


Using classical malloc (P-EDF)



Using TLSF (P-EDF)

Zoom (TLSF)



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Based on a <u>real platform</u> and for soft real-time constraints :

- In STM and **for real applications**, the rollback times are not the main cause of the execution time variation,
- A good memory allocator must be provided to bound the execution time of transactions

TO DO **Future work**

Study of the interaction between the real-time scheduler of transactions and that of tasks

Questions?