On the Relevance of Wait-free Coordination Algorithms in Shared-Memory HPC: The Global Virtual Time Case

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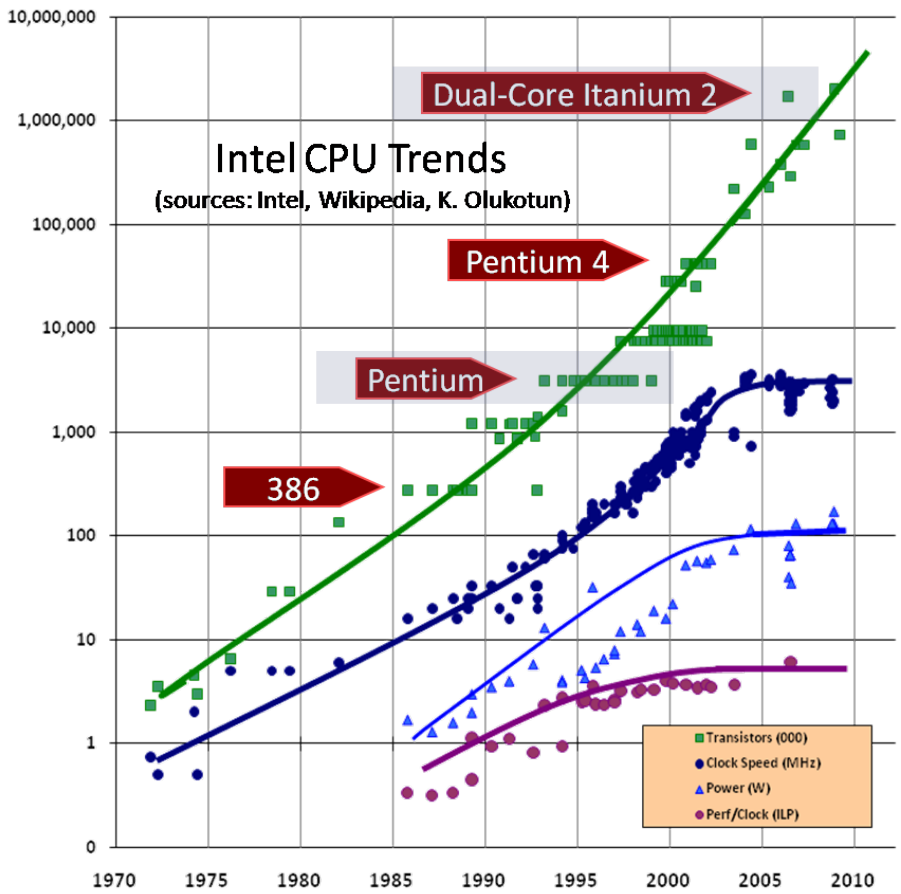
InfQ 2014

Current Technological Trend



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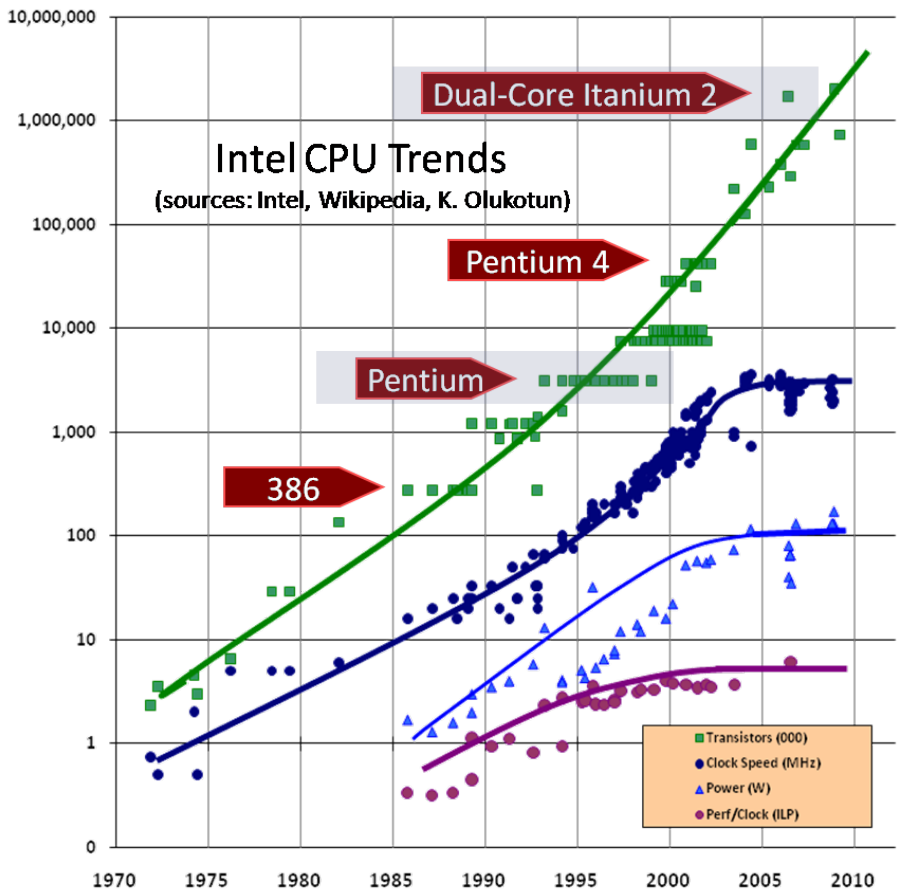

- Implications of Moore's Law have changed since 2003

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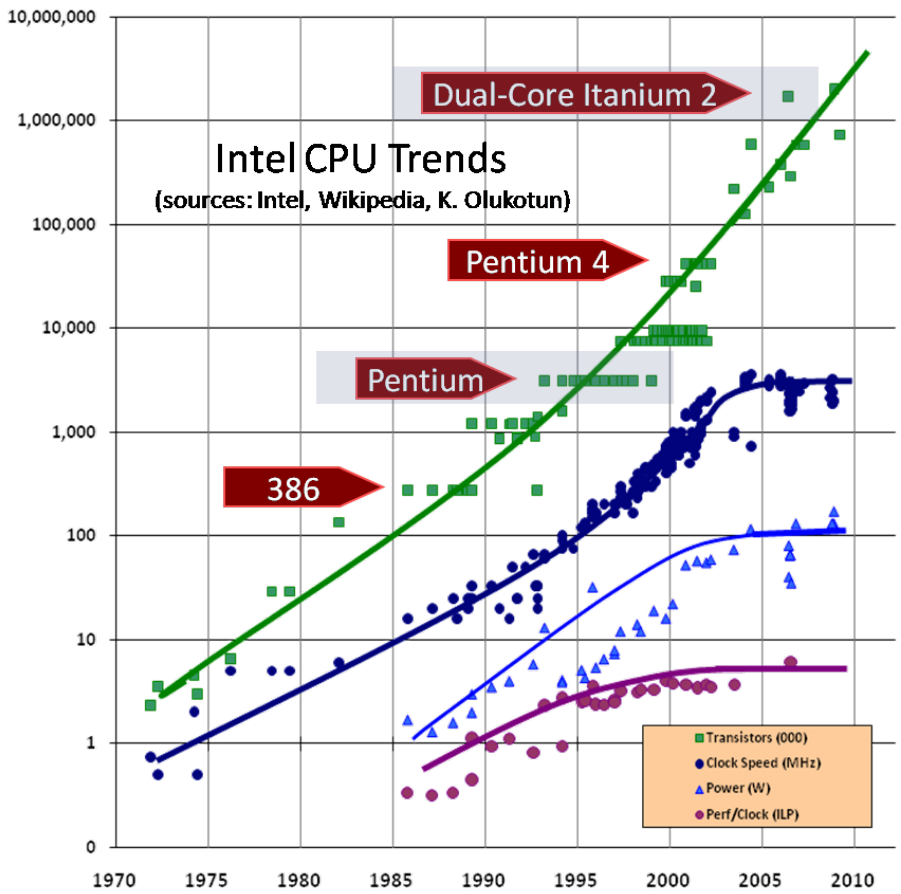
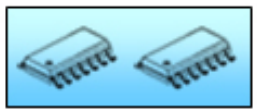


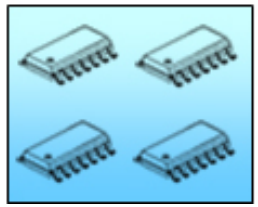
- Implications of Moore's Law have changed since 2003
- 130W is considered an upper bound (the *power wall*)

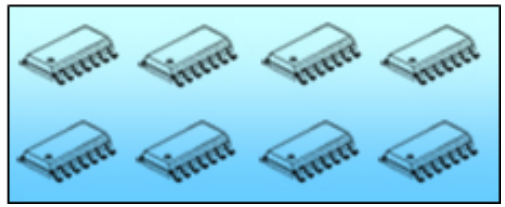
$$P = ACV^2 f$$

Multicore Software Scaling

Cores







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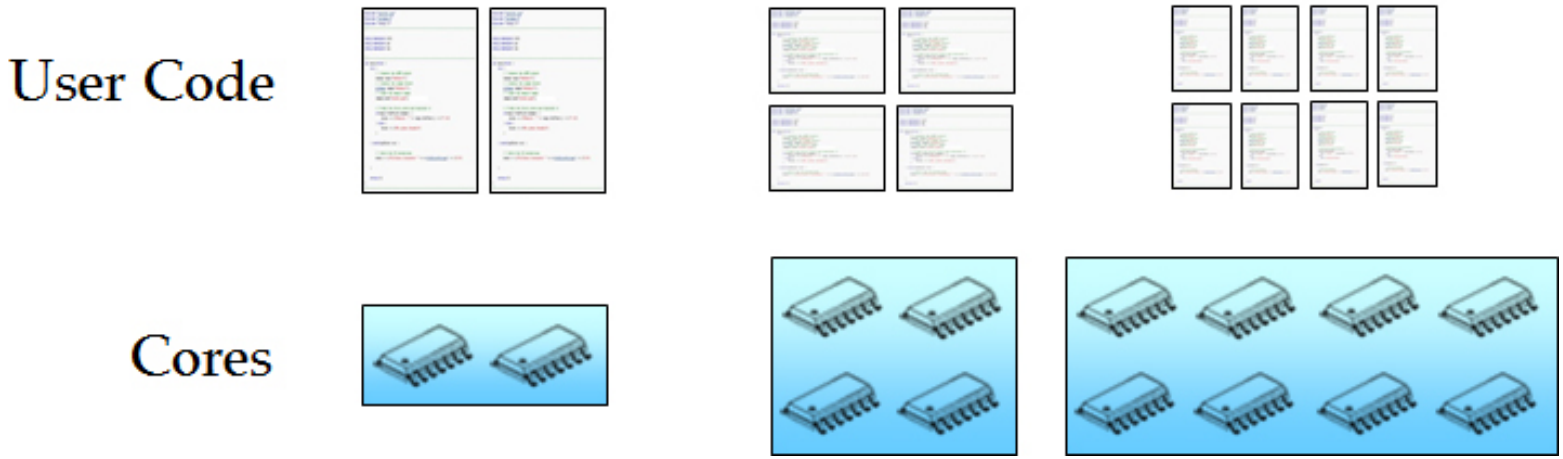

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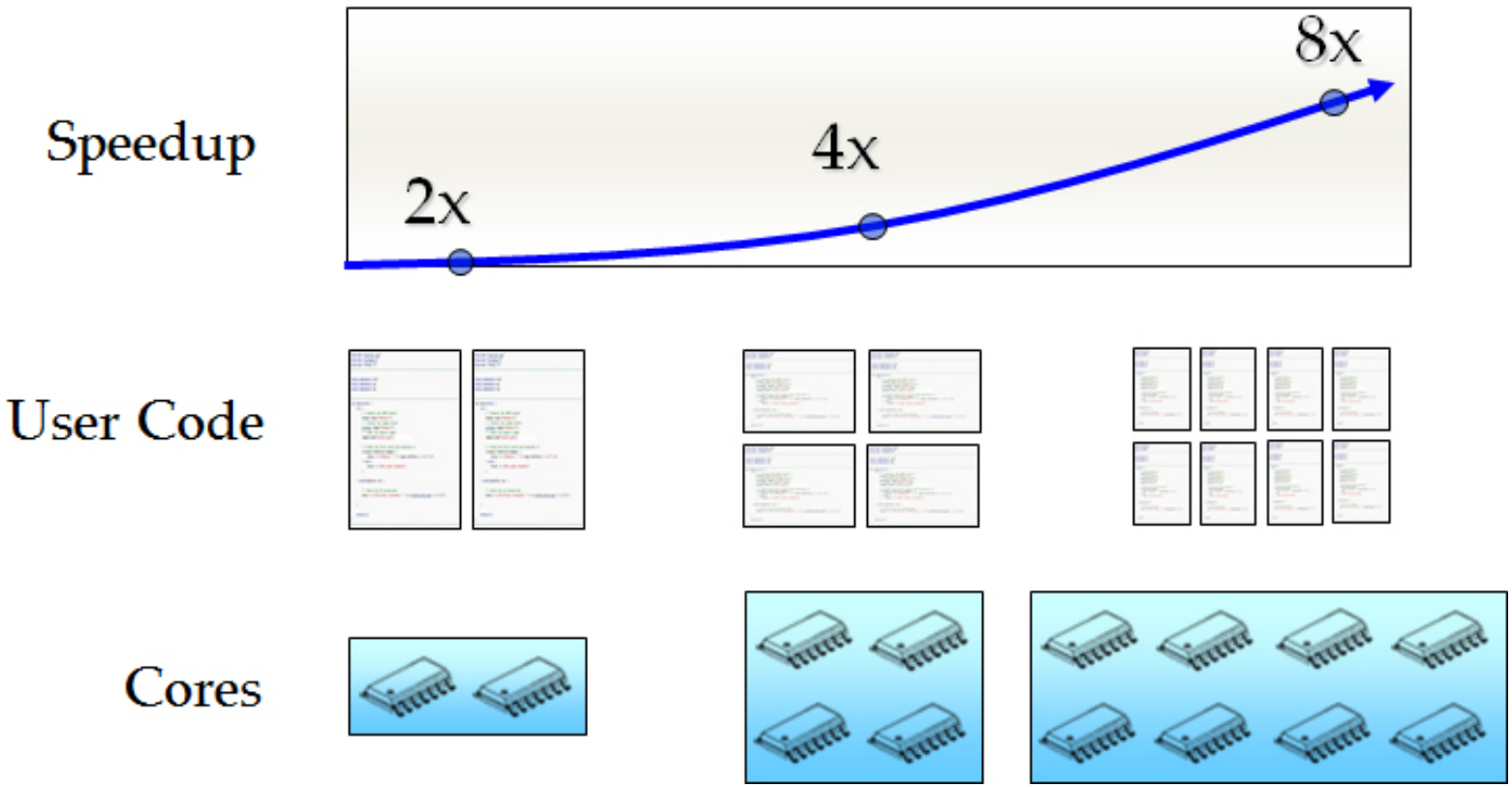

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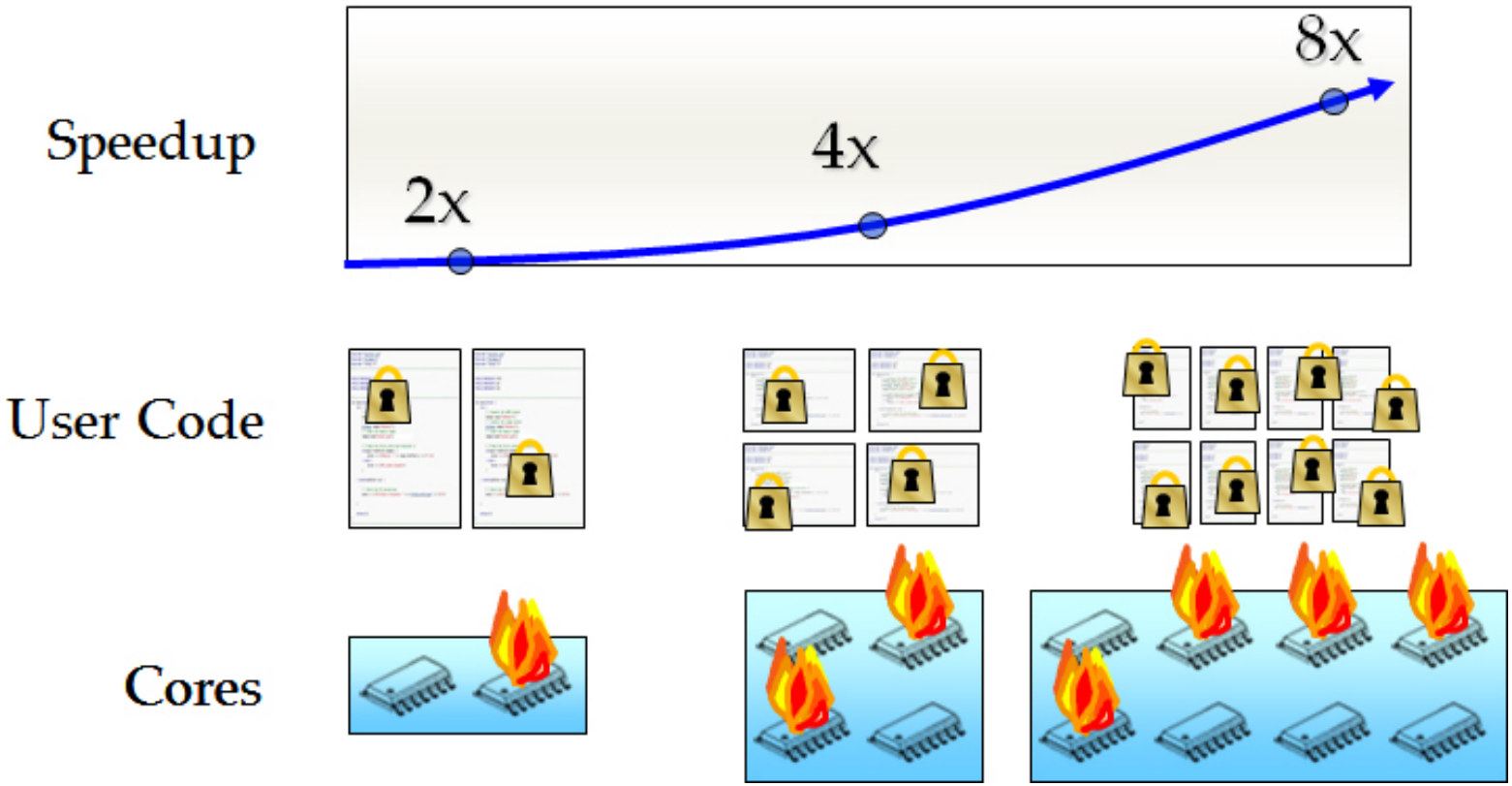

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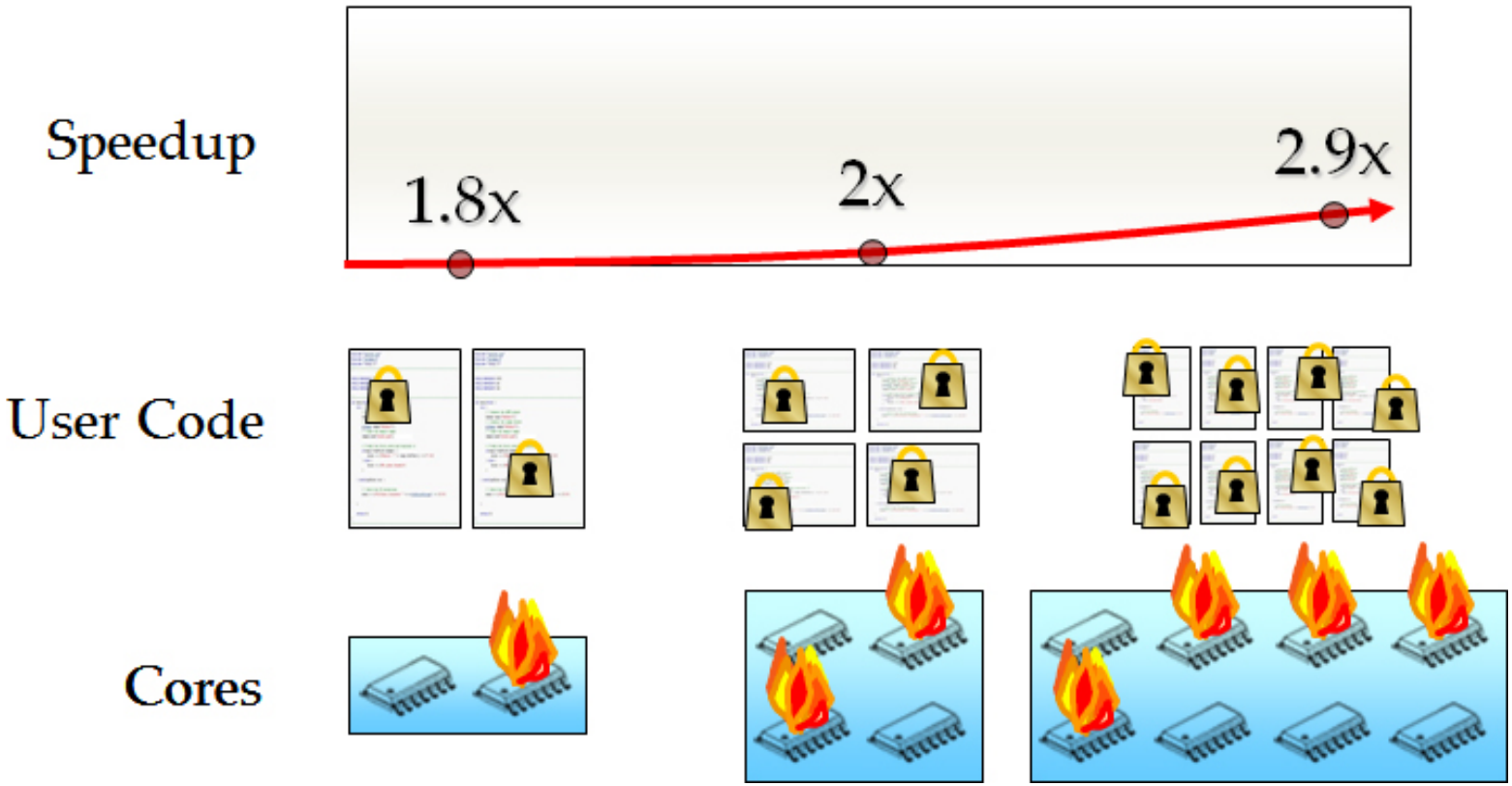

Problem Statement in HPC

- Many HPC applications enforce data separation
  - The amount of synchronization points are already reduced
- Coordination algorithms easily become the bottleneck of HPC Systems on multicore architectures
- They cannot be avoided at all
  - Necessary for the overall correctness
- How to deal with performance issues of HPC Systems on multicores?

Wait-Free Algorithms

- *All threads complete their job in a finite number of steps*

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- Algorithms in which threads communicate using some sort of atomic-update machine instruction
  - Compare and Swap (CAS)
  - Load-Link/Store-Conditional (LL/SC)

- Both CAS & LL/SC will fail if their initial conditions change

- The "fix" for failing is usually to loop and try again.

Target Architecture: PDES

- Exchanged information unit is the *discrete event*
- The involved objects state is updated according to the flow of events

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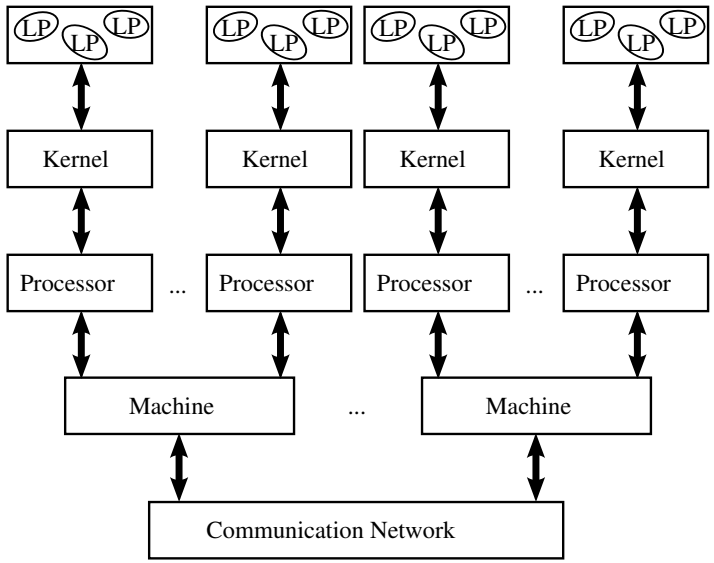

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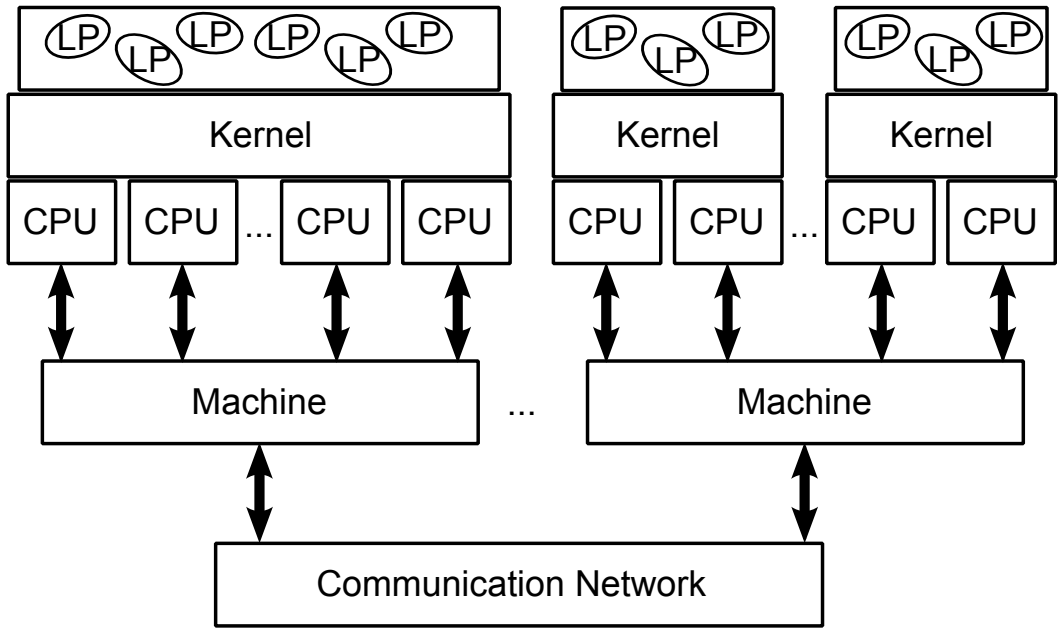

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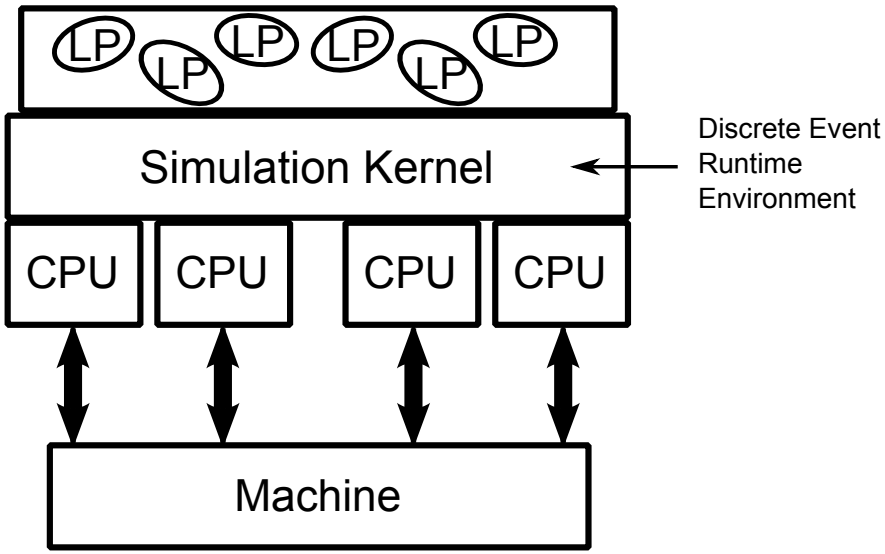
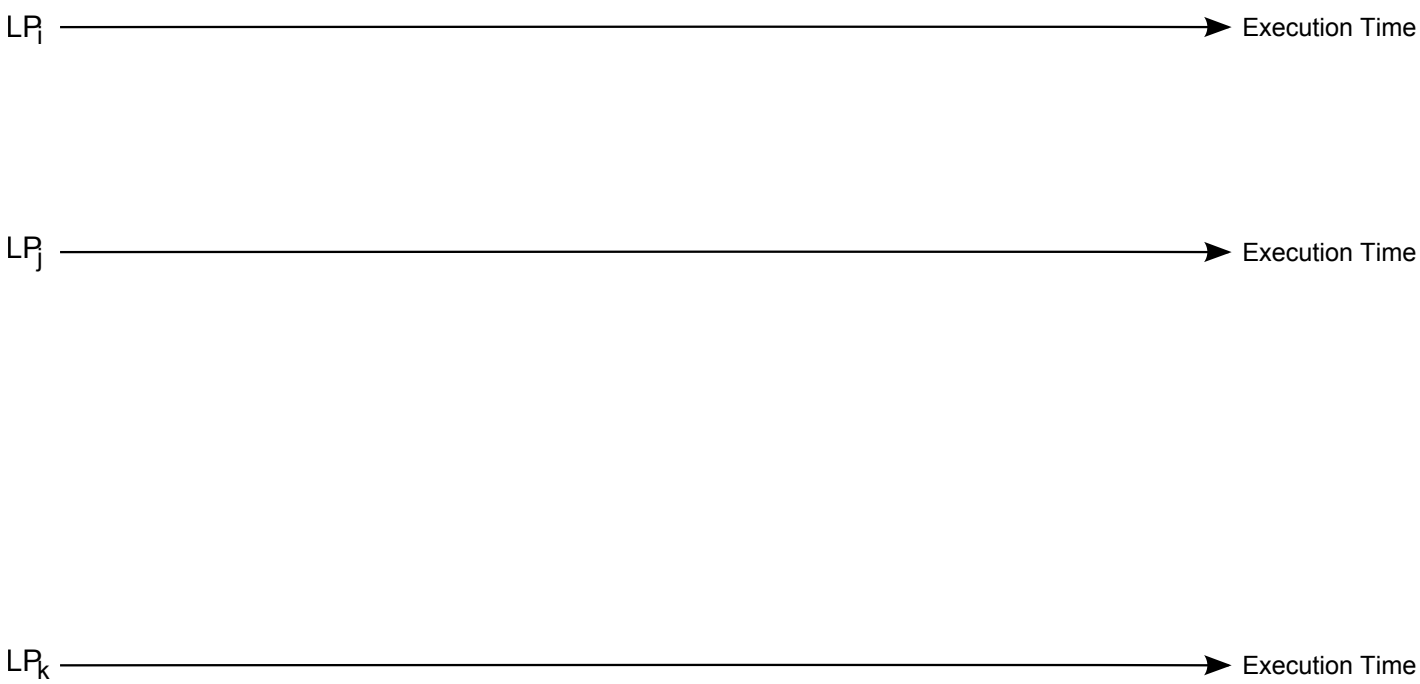


Coordination Algorithm in PDES: GVT



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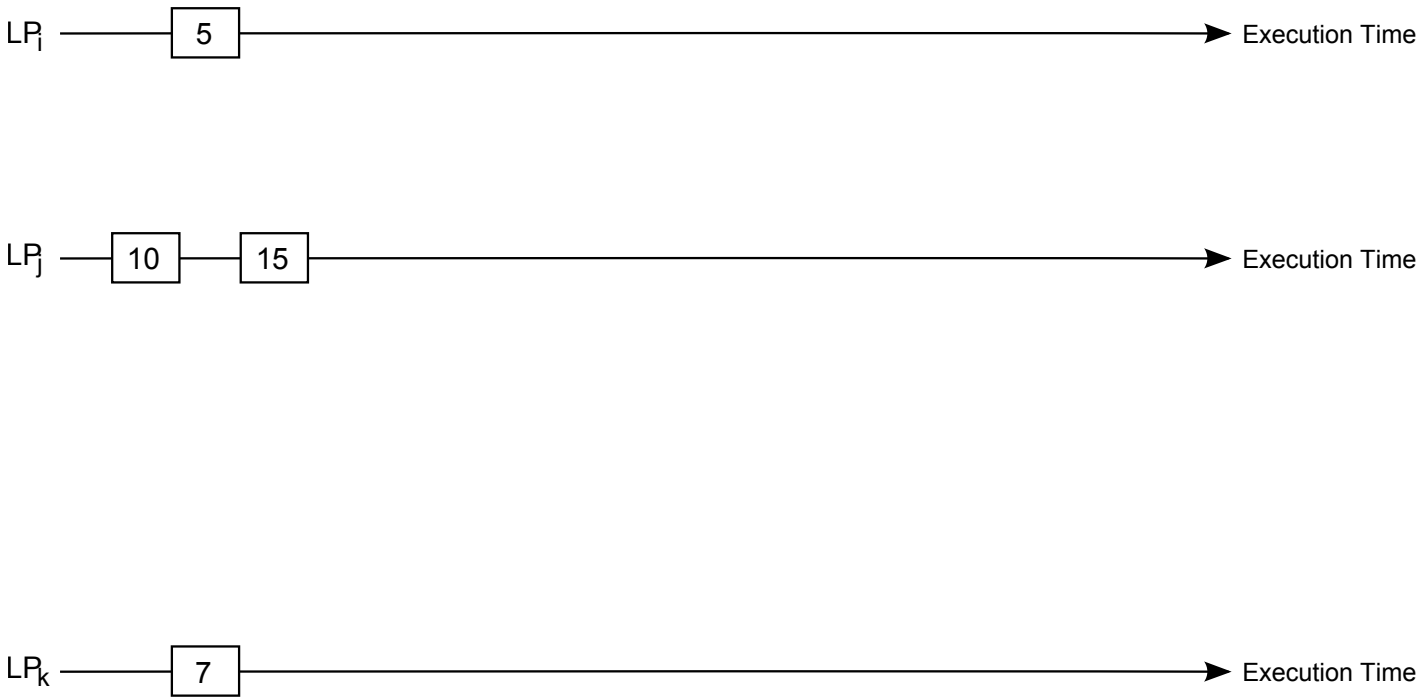

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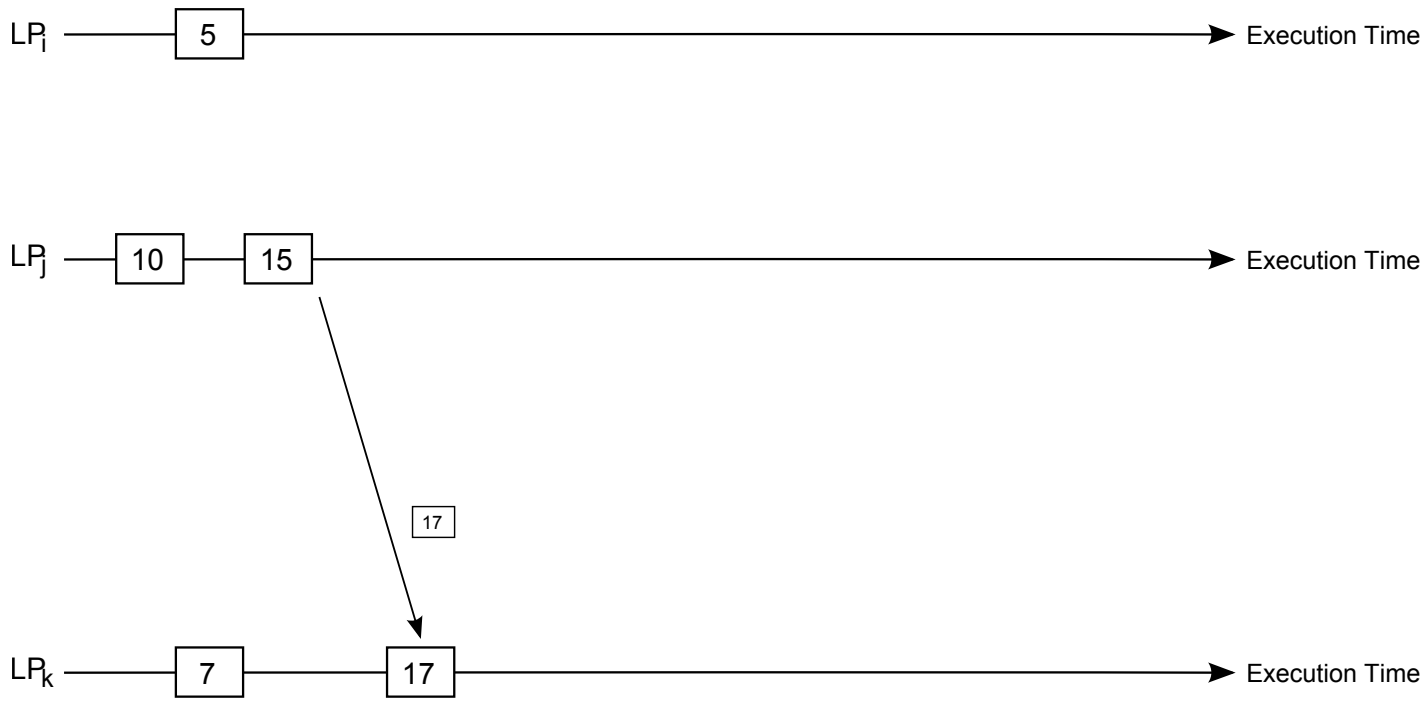

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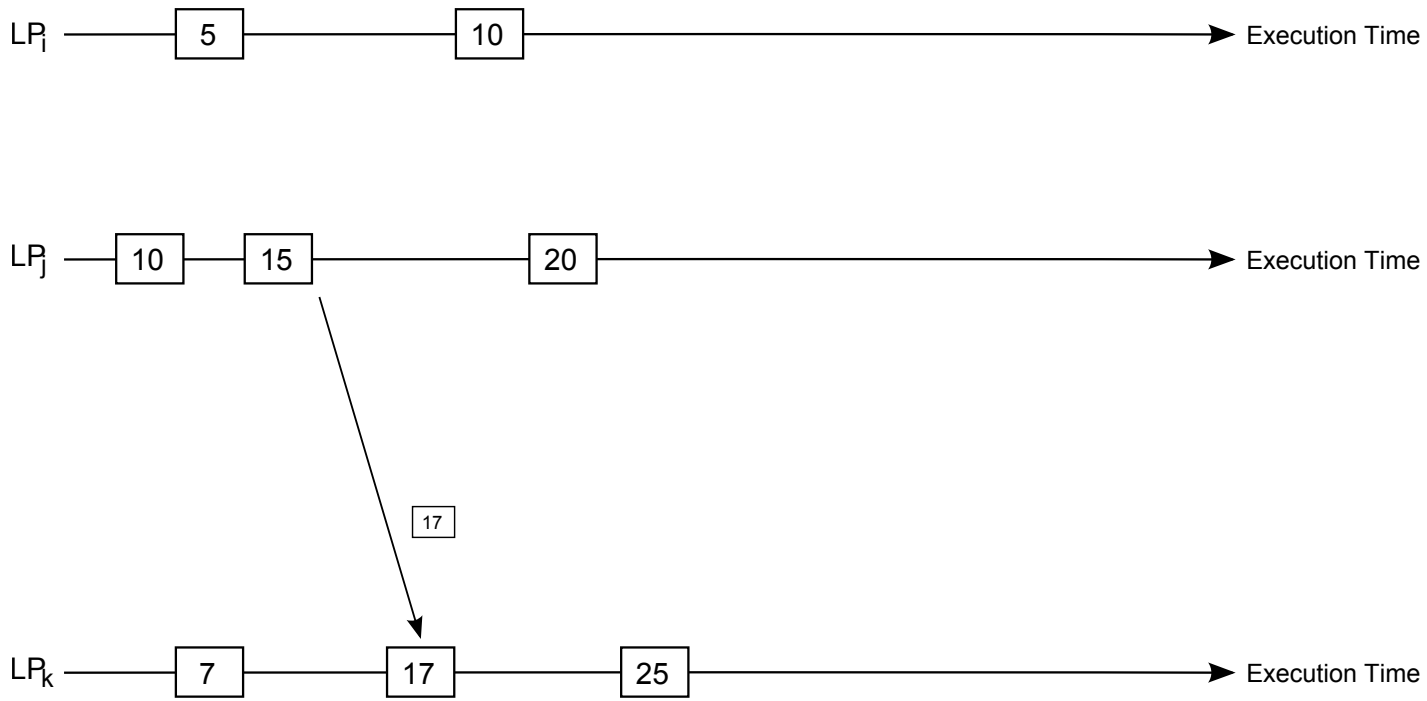

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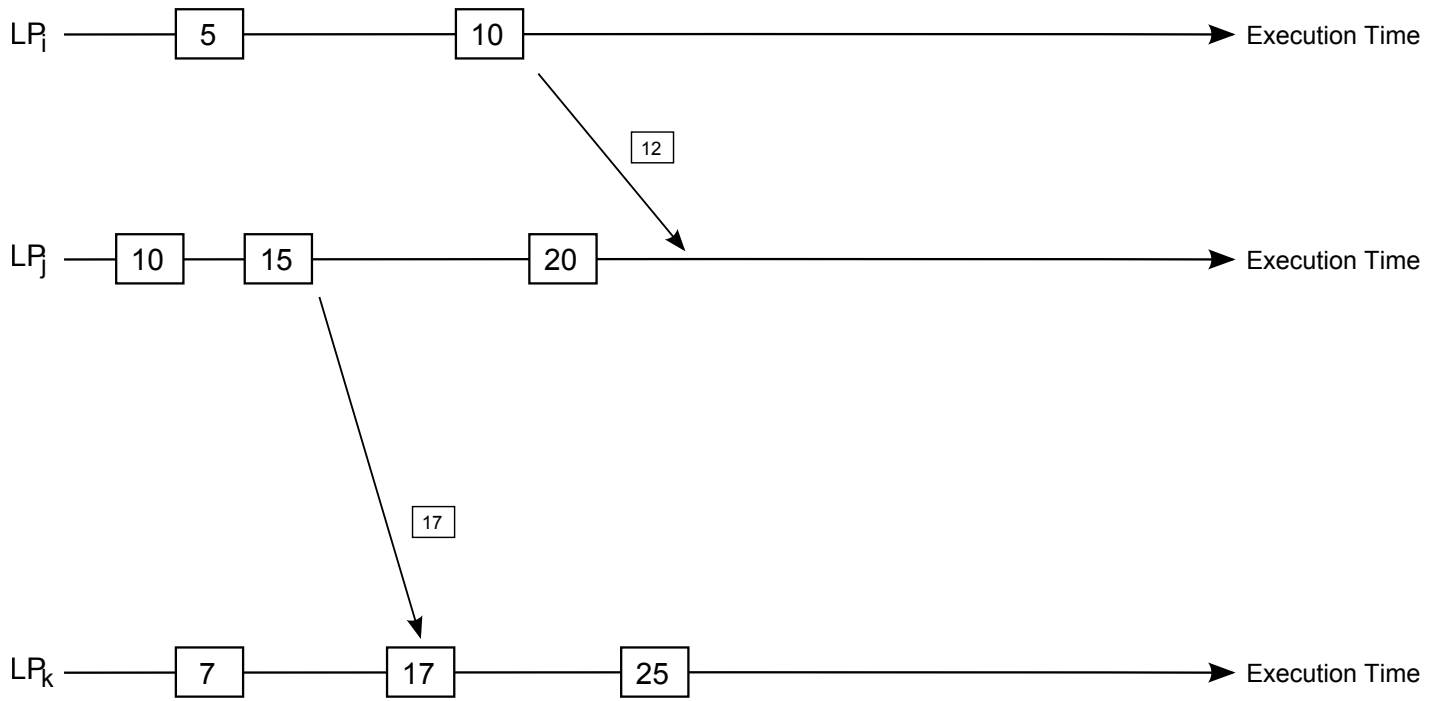

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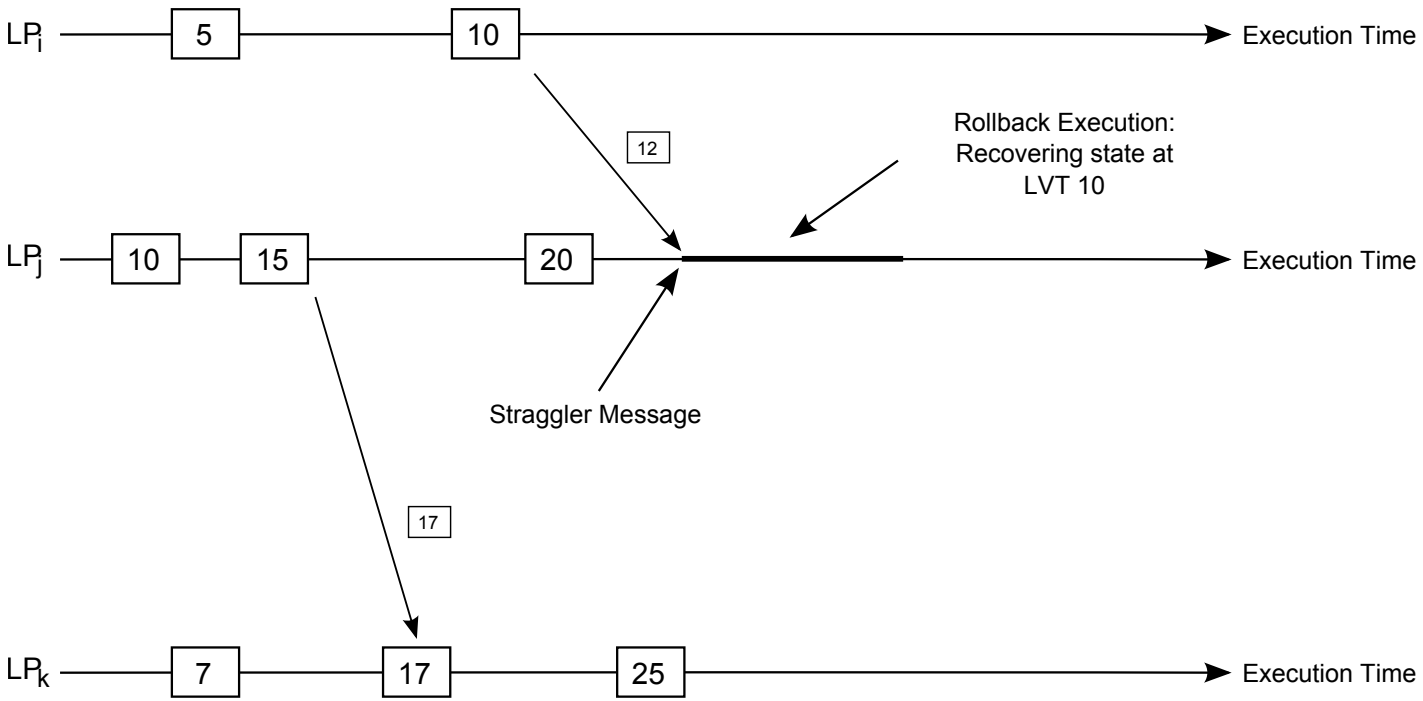

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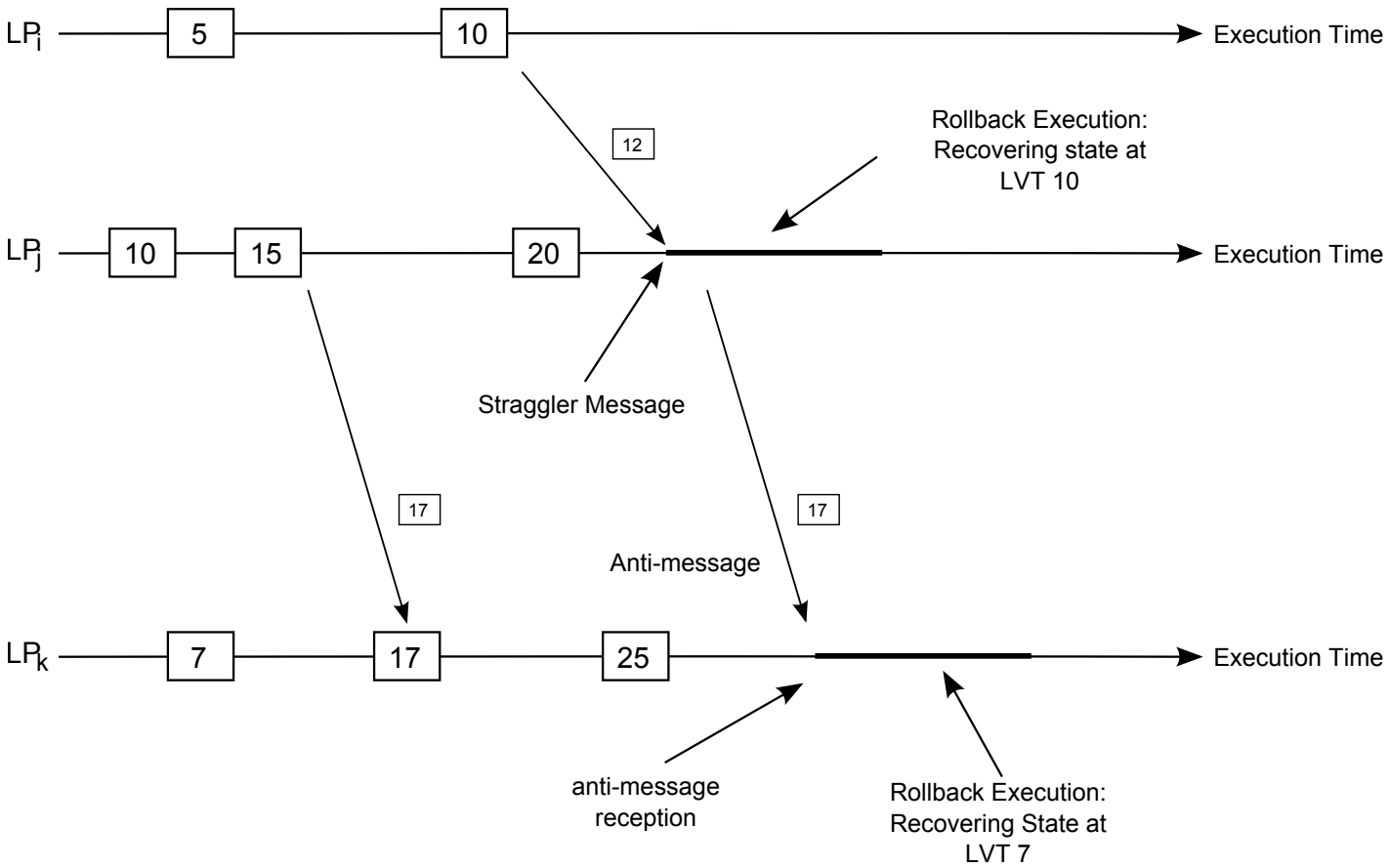

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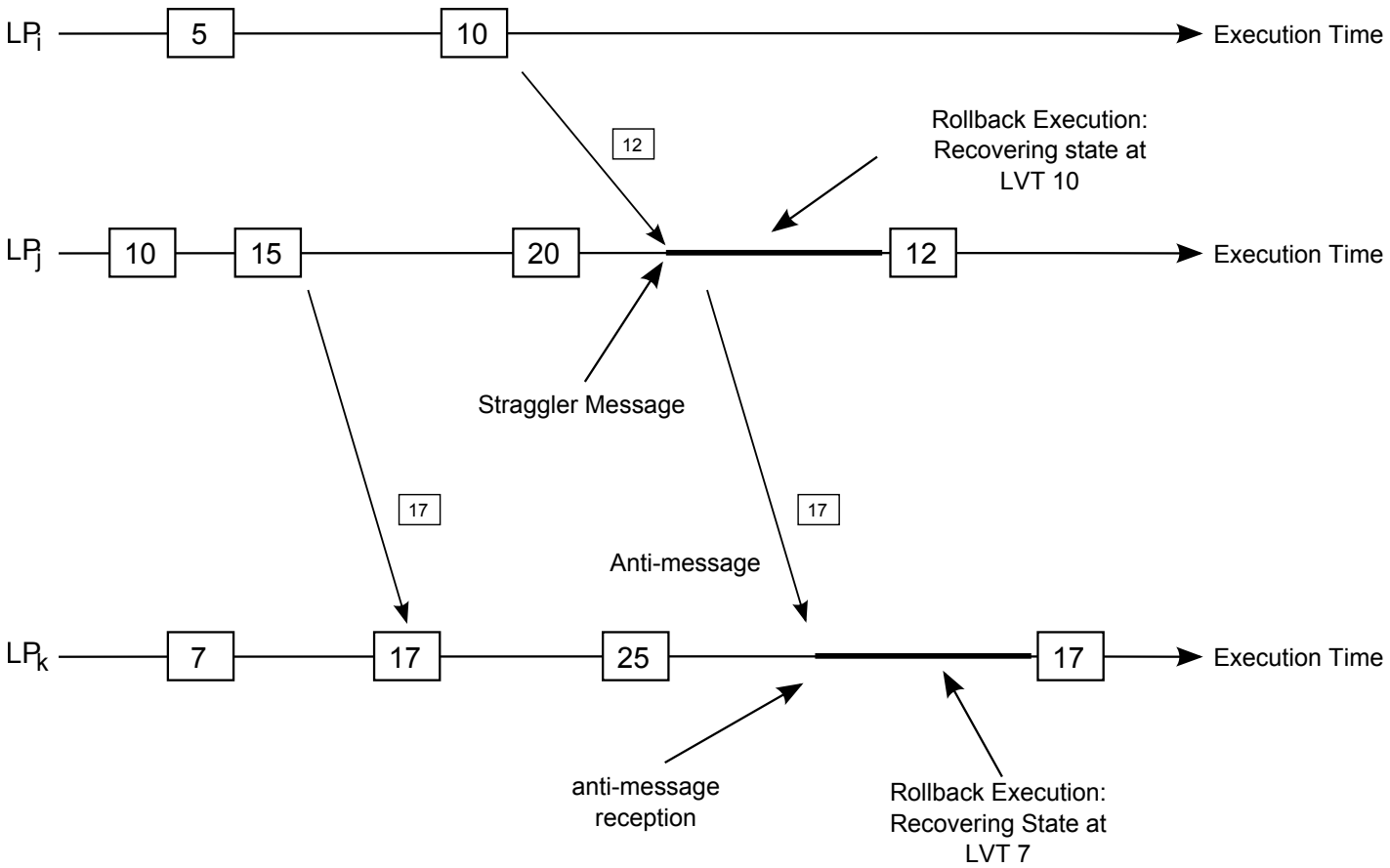

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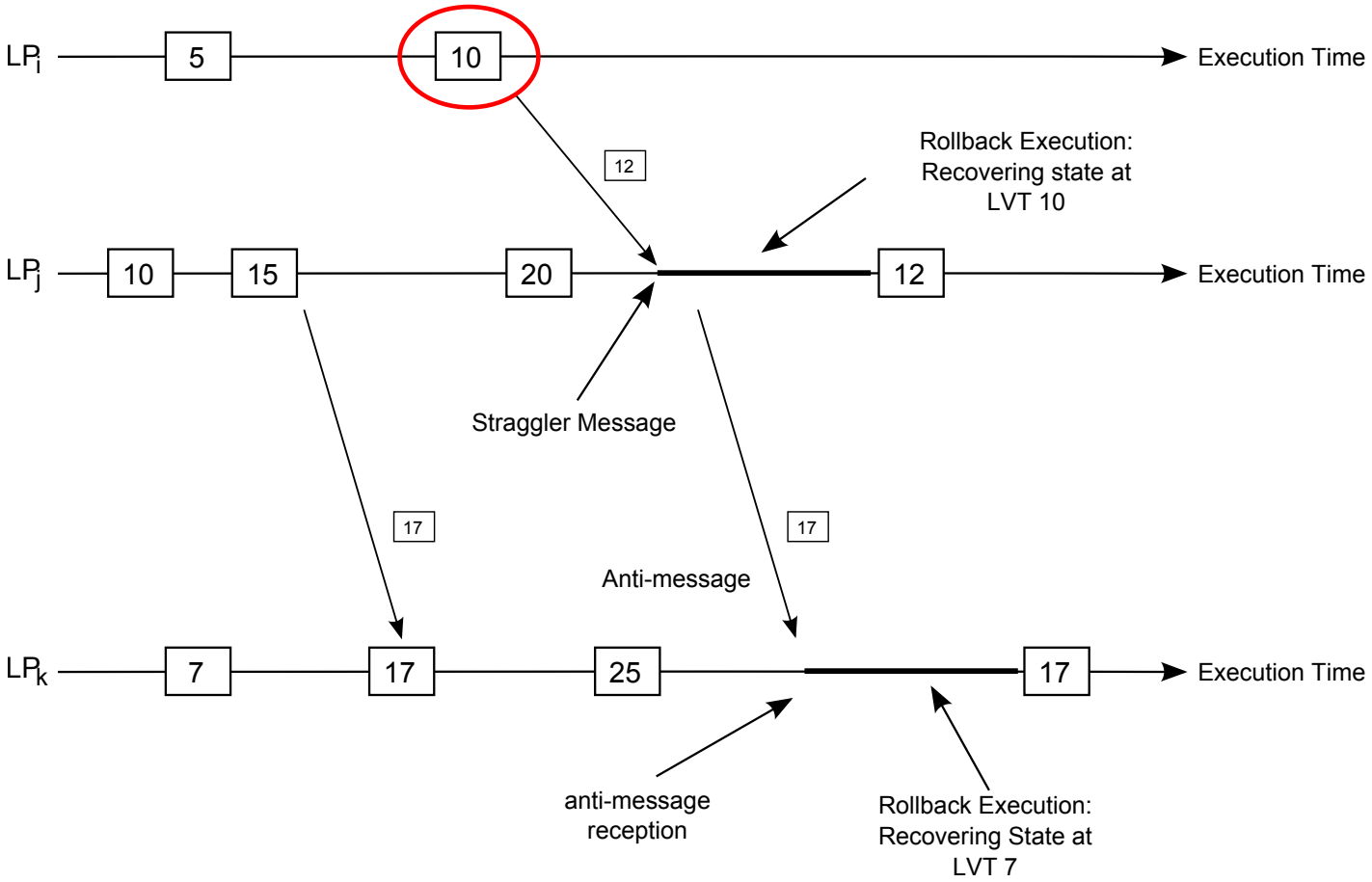


Fujimoto & Hybinette

- Reference algorithm has been so far Fujimoto's and Hybinette's GVT for Shared-Memory Multiprocessors (1998)
- It targets *observable* Time Warp Systems
  - Essentially the send operation leads to the direct incorporation into the message queue
  - This removes the notion of *in-transit* messages
- It relies on the notion of *GVT computation phase*

Fujimoto & Hybinette (2)

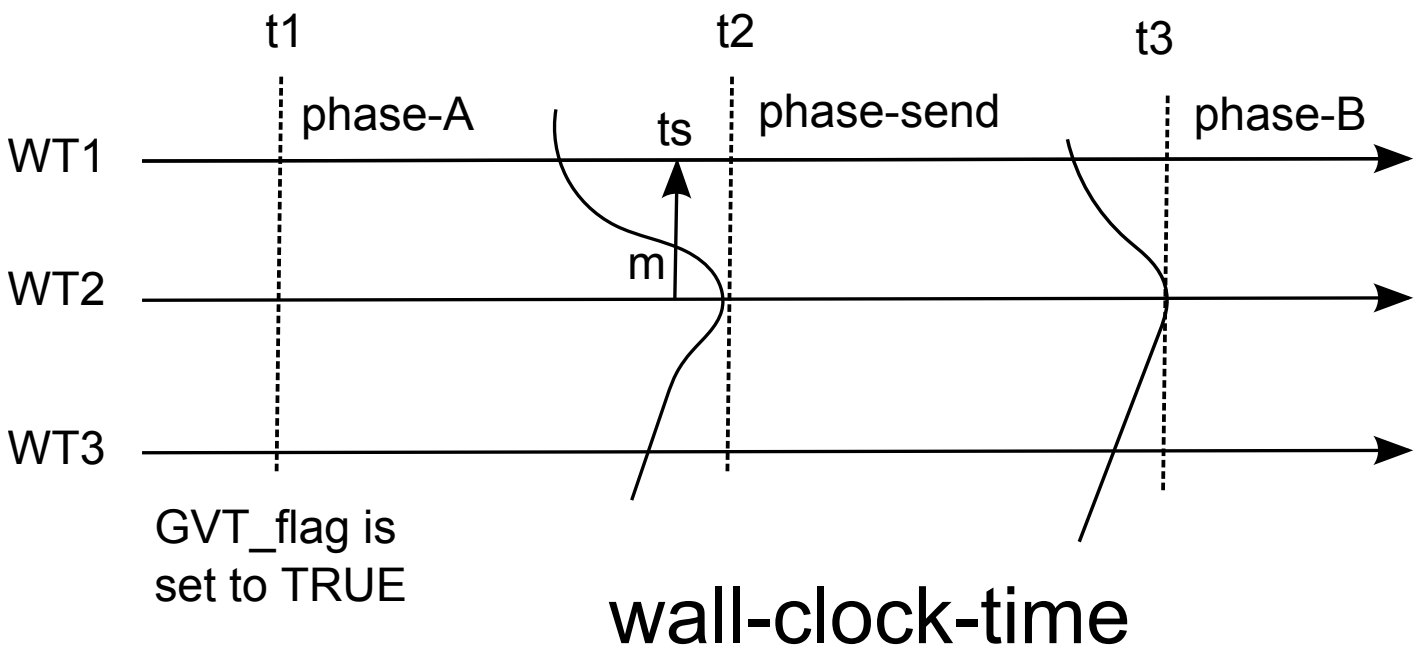
```
procedure MAIN-LOOP
    while there are events to process do
        LocalGVTFlag ← GVTFlag                          ▷ Atomically set to NPE
        Receive messages and process rollbacks
        Receive antimessages, process annihilations and rollbacks
        Select next event M
        if LocalGVTFlag > 0 and LocalMin not computed then          ▷ CS
            PEMin[PE] ← min{SendMin, TS(M)}
            GVTFlags ← GVTFlags - 1
            if GVTFlag = 0 then
                GVT ← min{PEMin[1], ..., PEMin[NPE]}
            end if
        end if
    end while
end procedure
```

Wait-Free GVT Algorithm

- Each worker thread manages a set of LPs
- Event-queues are directly accessible by worker threads
  - No message/anti-message is ever in-flight across worker-threads

- GVT protocol entails determining the right moment to look at data structures and compute the local minimum
  - It is computed after the incorporation of incoming messages/anti-messages into the event-queue
  - No need to account for anti-messages and canceled events timestamp
- The algorithm is wait-free because it relies on a sequence of phases

Wait-Free GVT Algorithm (2)

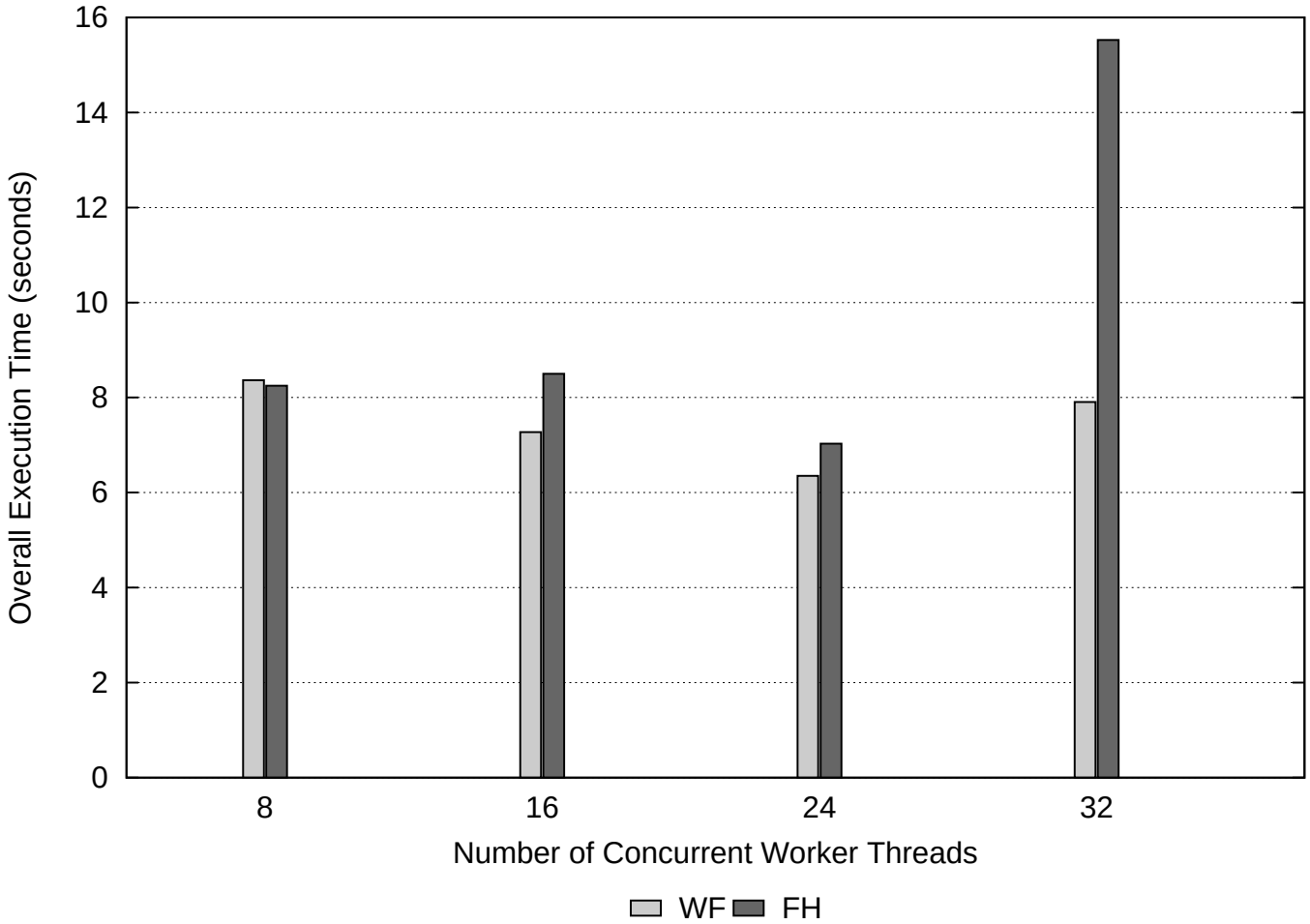


Test-Bed Scenario

- 32-cores HP ProLiant Server
- 64GB of RAM
- 2.6.32-5-amd64 Linux kernel
- ROOT-Sim Simulation Kernel v. 1.0.2

- Modified version of PHOLD benchmark
  - homogeneous LPs that perform memory allocation/deallocation operations and read/write operations
  - LPs modify their memory layout
  - few and small-granularity events $\Rightarrow$ increased likelihood of competing for the critical section

Experimental Results



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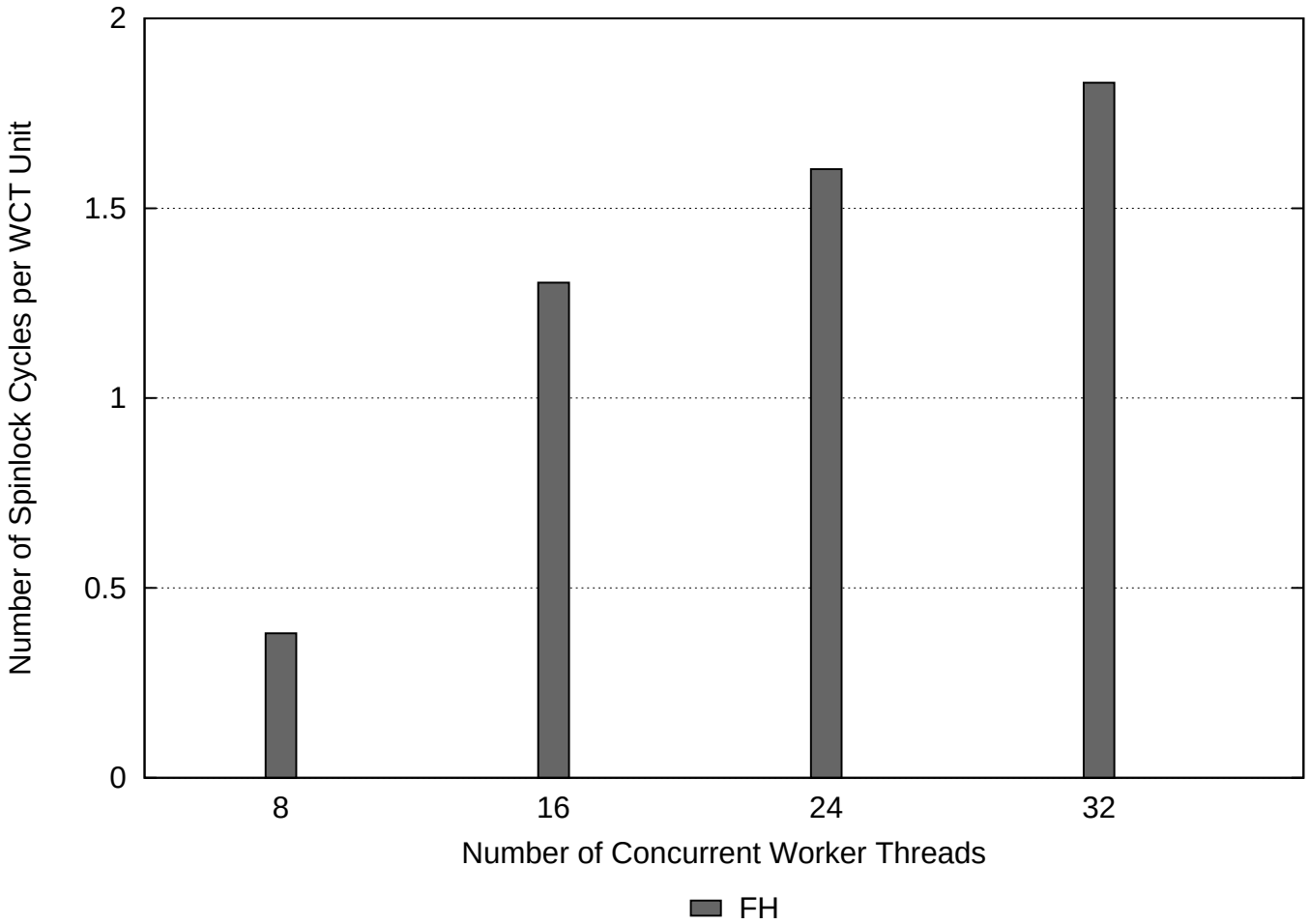
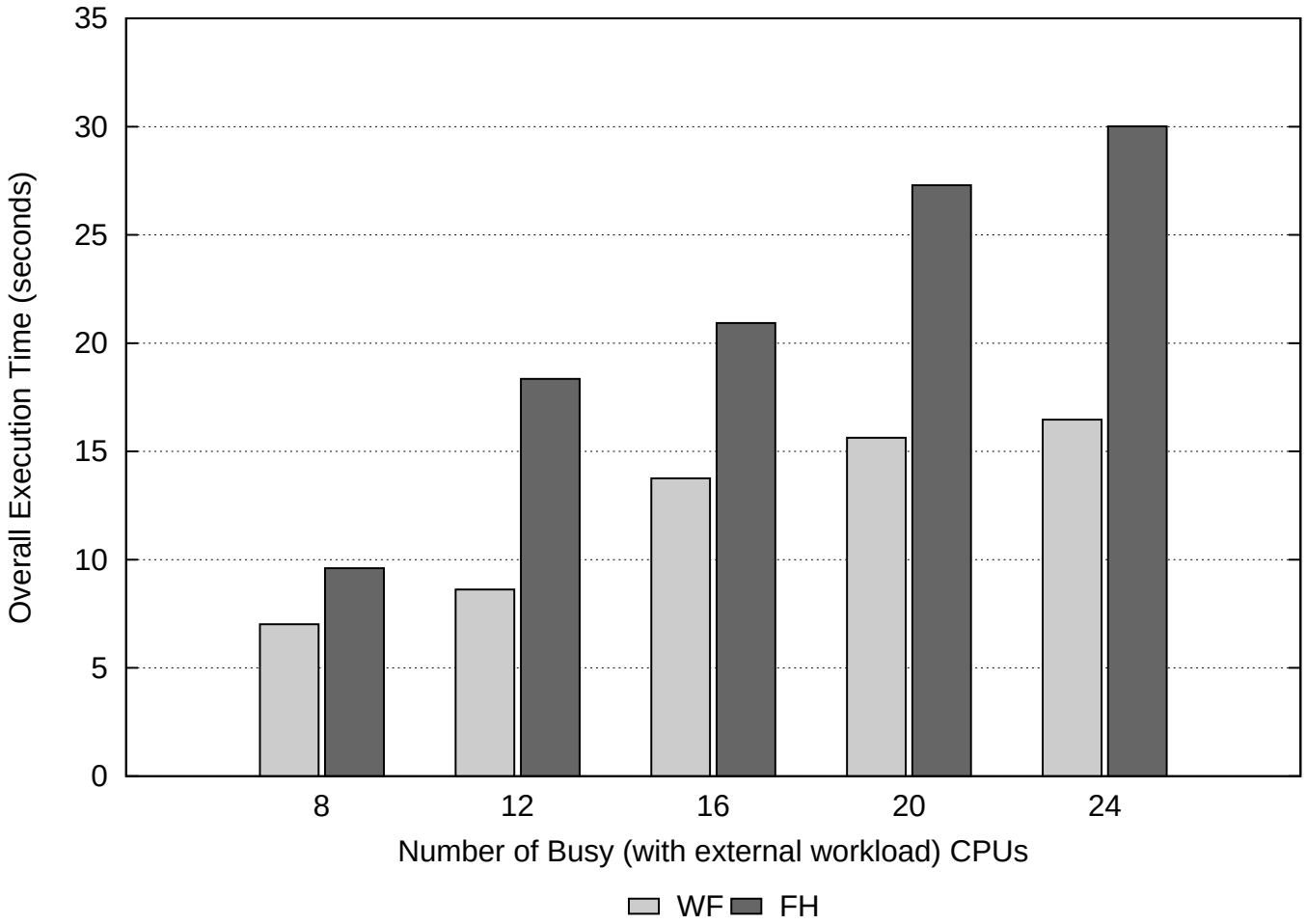


Experimental Results (3)



Conclusions

- HPC Applications usually have few synchronization points
  - There is a high demand for enhanced synchronization schemes
- Modern multicore architectures enhance the impact of synchronization points
  - Contention due to locks can hamper scalability
- Wait-free algorithms can be a viable solution to be studied to face this issue
  - They can provide enhanced scalability
  - There is a benefit in non-dedicated environments as well

Thanks for your attention

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