Multicore Scheduling for Lightweight Communicating Processes

Carl Ritson

Computing Laboratory
University of Kent
UK

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Motivation

- `http://www.cosmos-research.org`
  - Large-scale process-oriented models
  - Thousands to millions of agents (processes)
  - Real-time and interactive
- Demo

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Process-Oriented Programming (POP)

- Processes
  - Encapsulate state and code (like objects?)
  - Execute concurrently with other processes
- Communication
  - Processes synchronise and exchange data
  - Share distributed state to accomplish tasks
- Concurrent processes $\Longrightarrow$ parallel execution potential

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Efficiency

- Process-oriented software can be parallelised
- . . . but can it be used to develop efficient software?
- Yes.
- If:
  - Processes are lightweight
    - i.e. thousands of them with little memory
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    - i.e. comparable to a method call

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How?

- Processes:
  - Use cooperative scheduling
  - Processes manage their own state (on stack)
  - Scheduler needs < 8 words of memory per process
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  - Synchronous and unbuffered channels
  - Constrains memory
  - Aids reasoning (CSP, etc)

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  - No room for complex scheduling
  - Hybrid round-robin with priority
- If we can context switch in 100ns . . .
- . . . that's 10,000,000 potential switches a second
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- Kevin Vella suggested sequential batching as solution
- Batch:
  - Group of processes
  - Repeatedly executed
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- How do we form a batch?
  - Unrelated processes? (Vella)
- Related parts of process network:
  - Determine groups dynamically by communication
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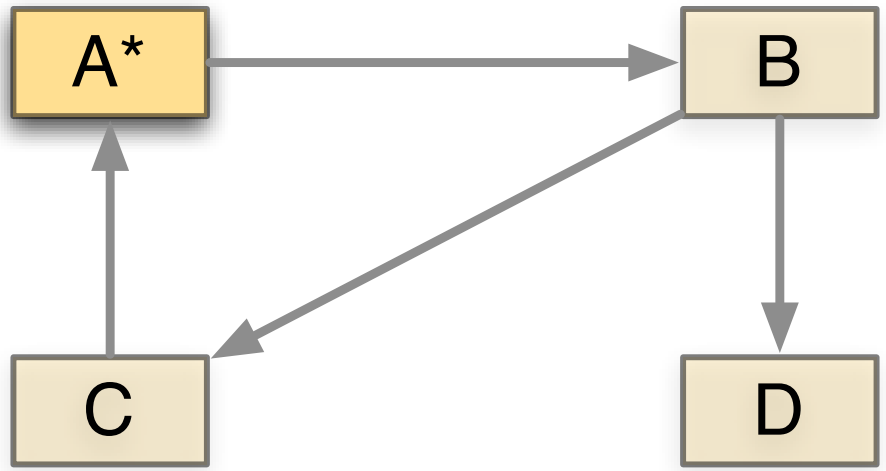
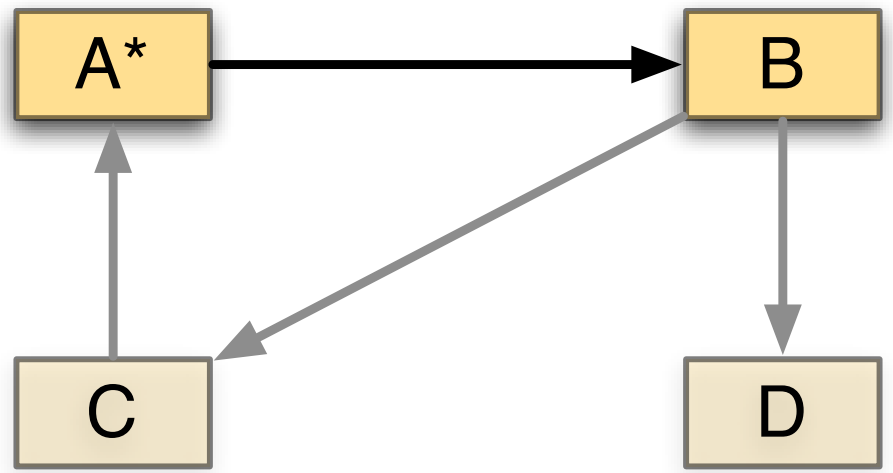


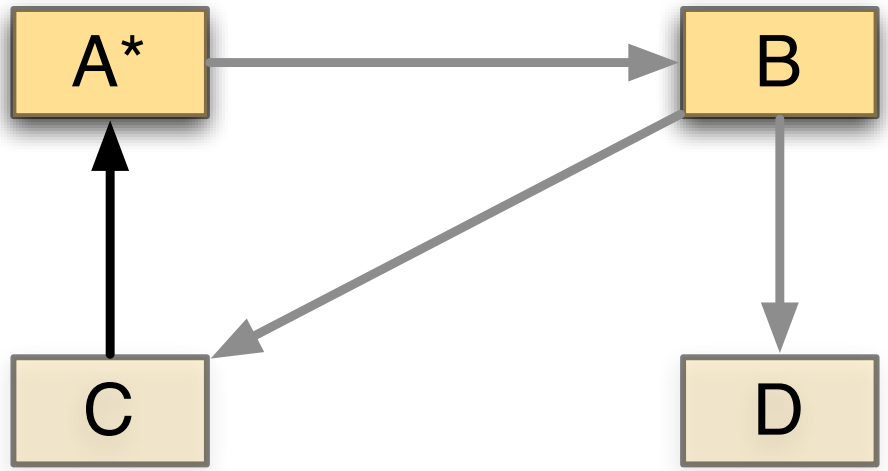
queue =

Batch Formation



queue = B

Batch Formation



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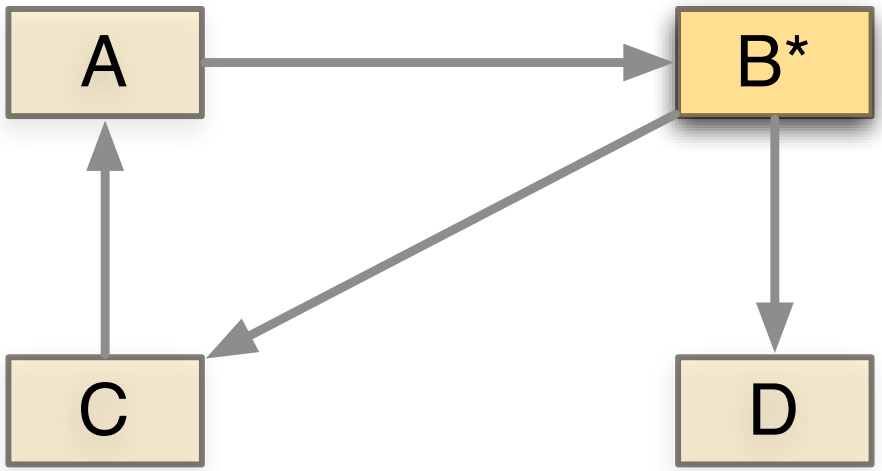

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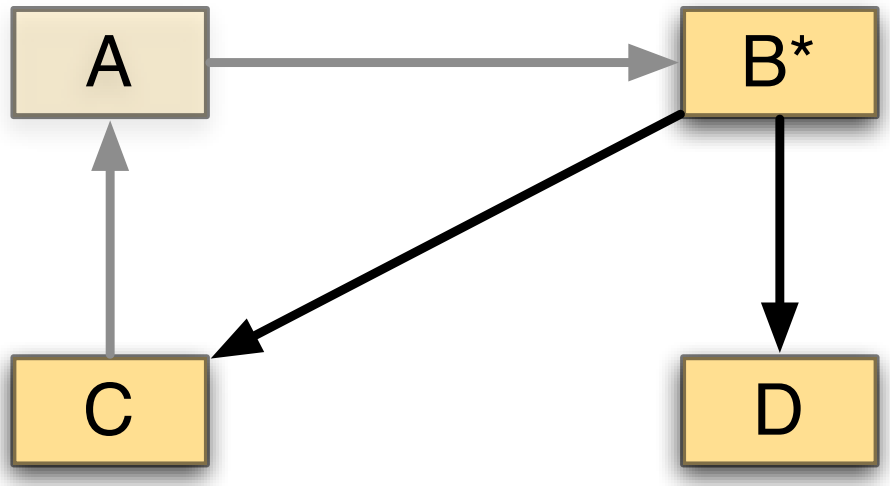

queue = C, D

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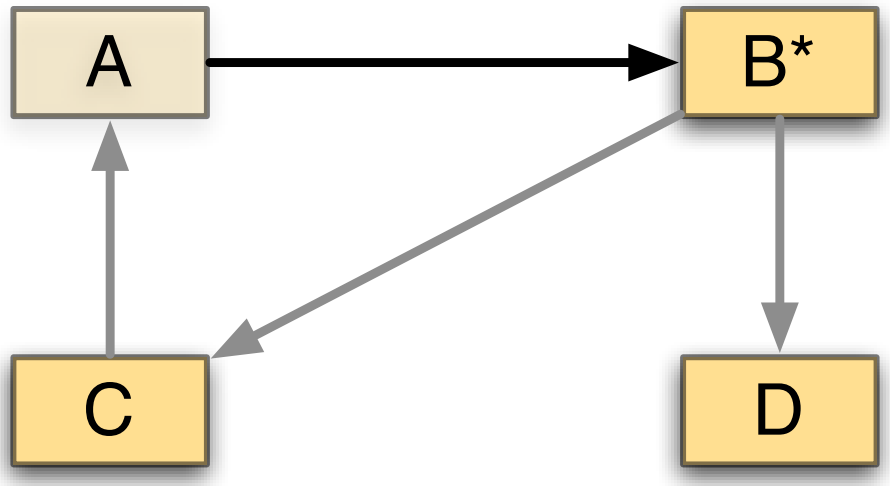

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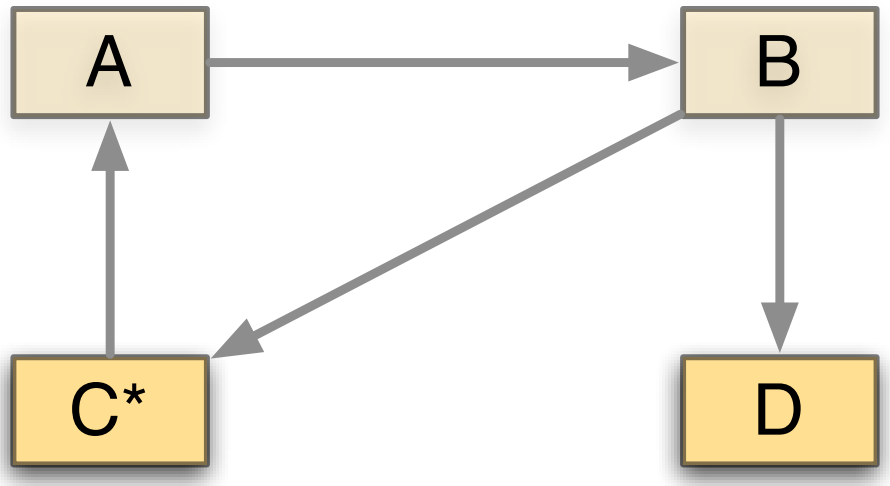

queue = D

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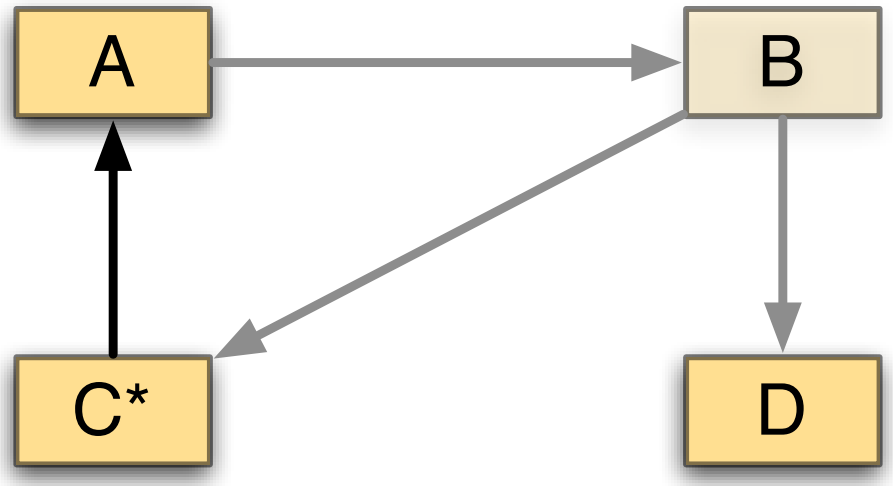

queue = D, A

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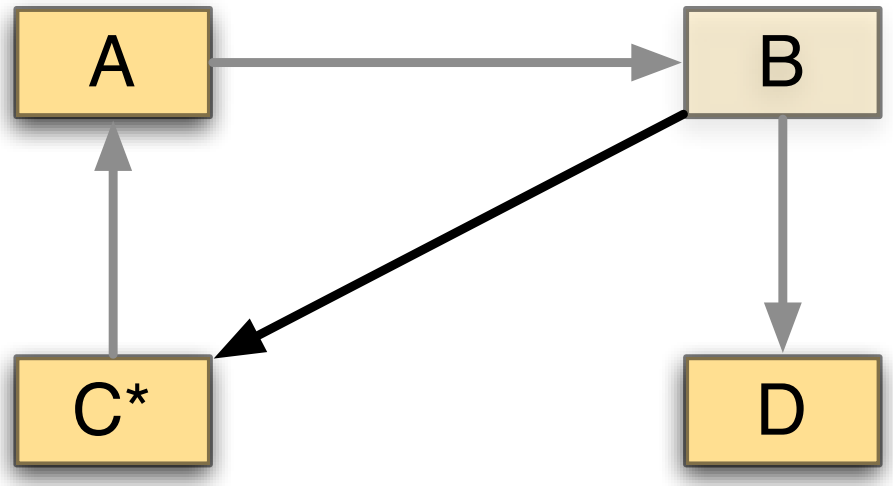

queue = D, A

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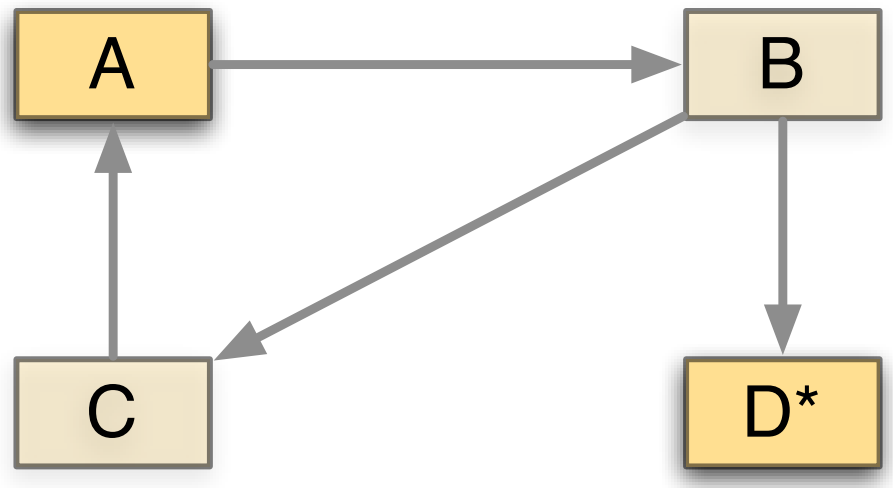

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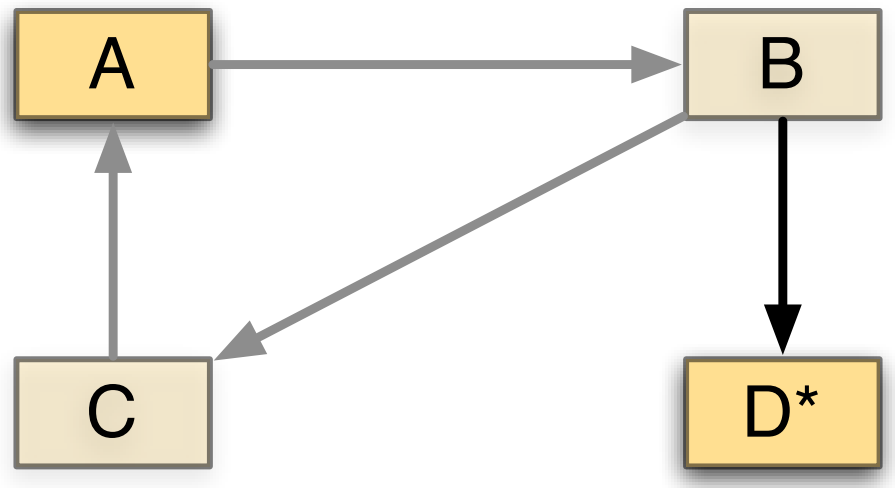

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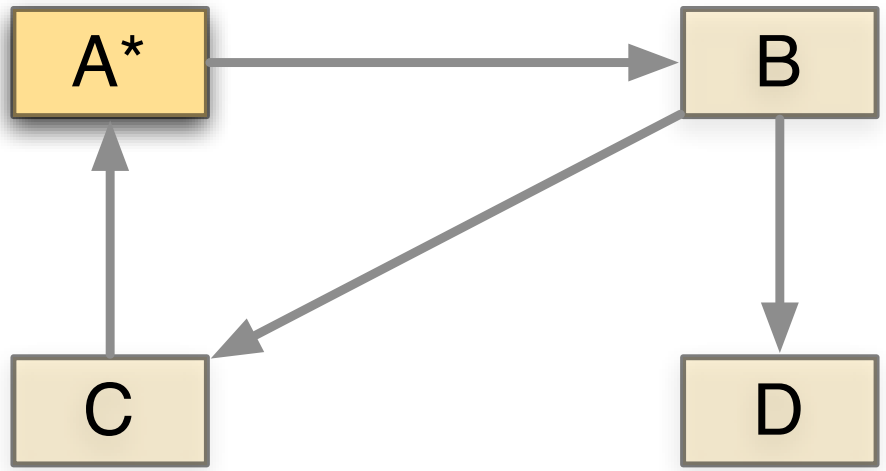
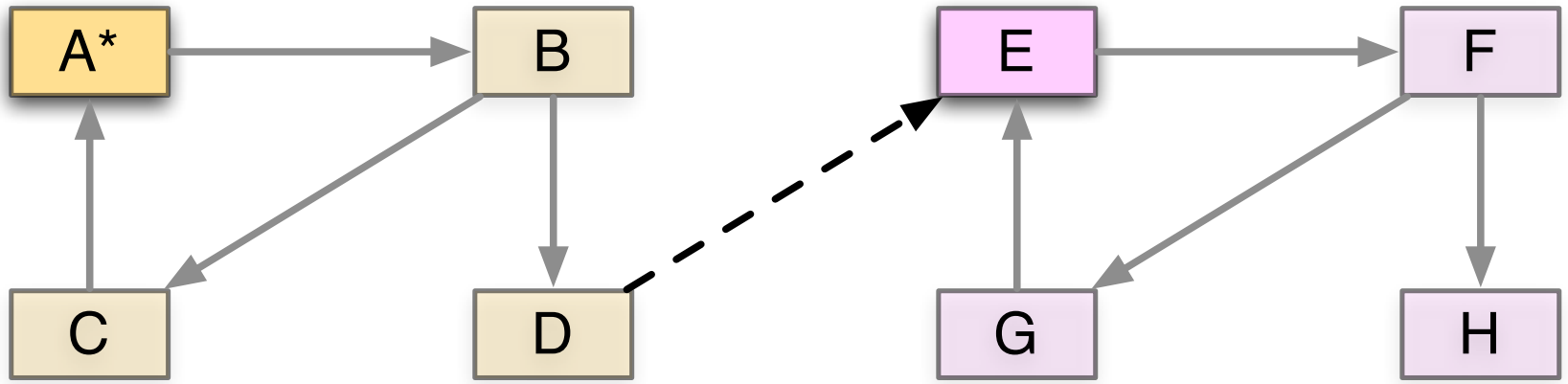


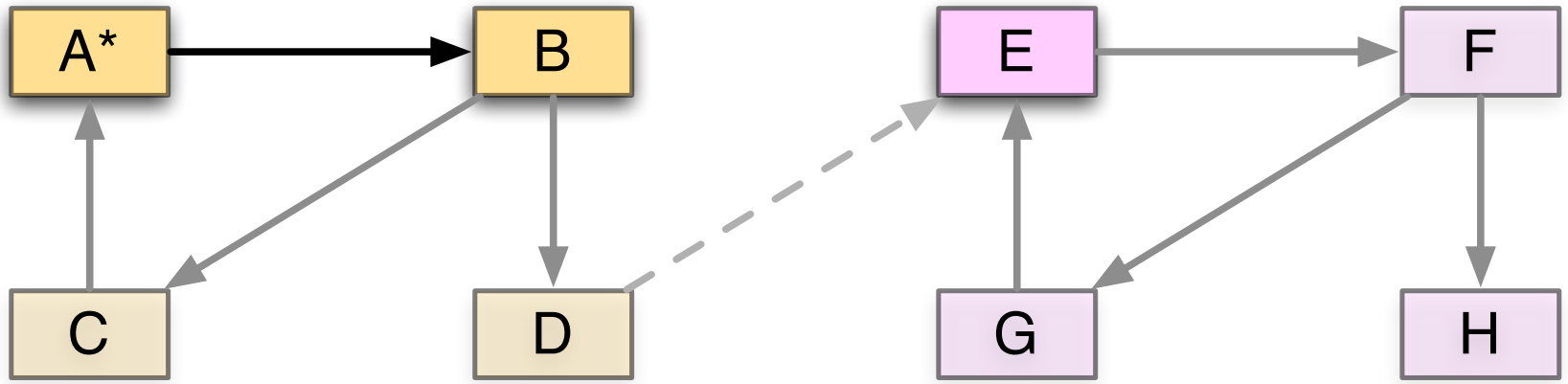
queue =

Batch Formation 2



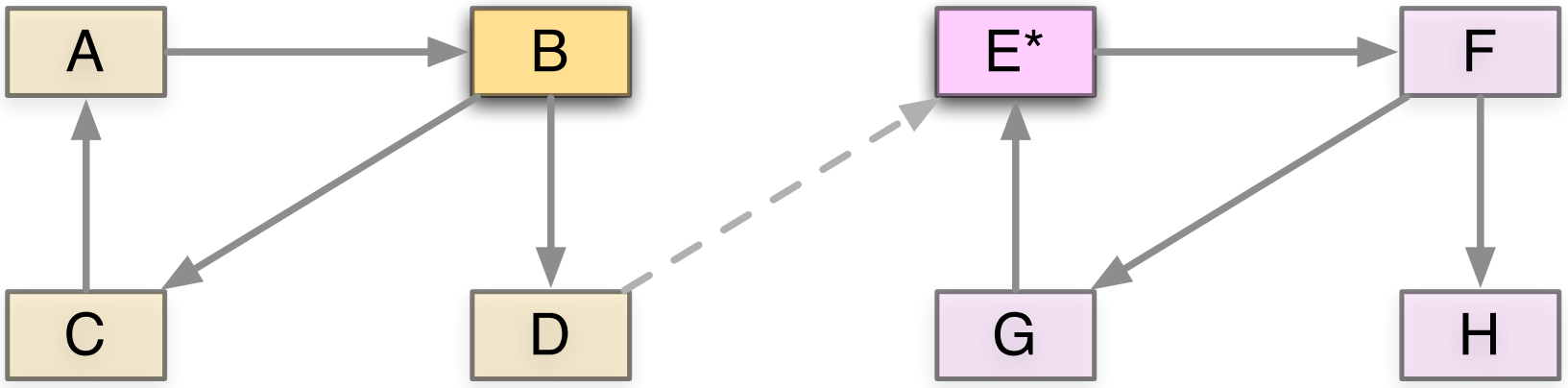
queue = E

Batch Formation 2



queue = E, B

Batch Formation 2



queue = B

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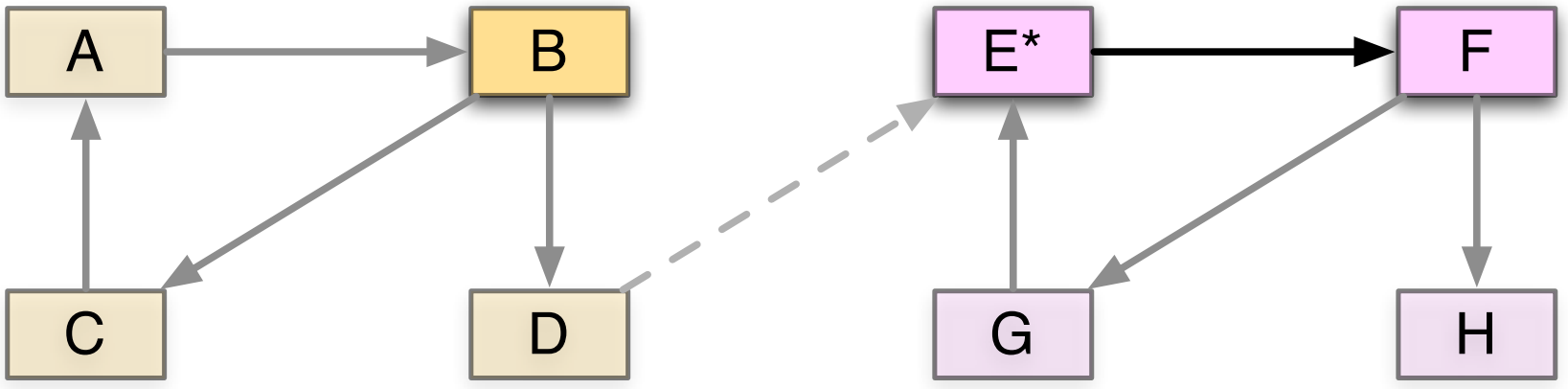

queue = B, F

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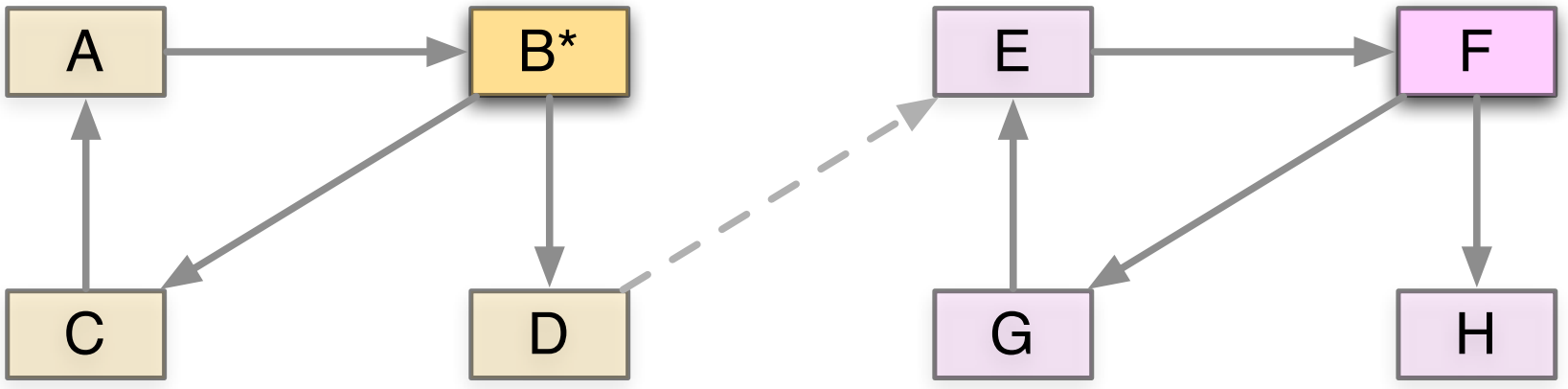

queue = F

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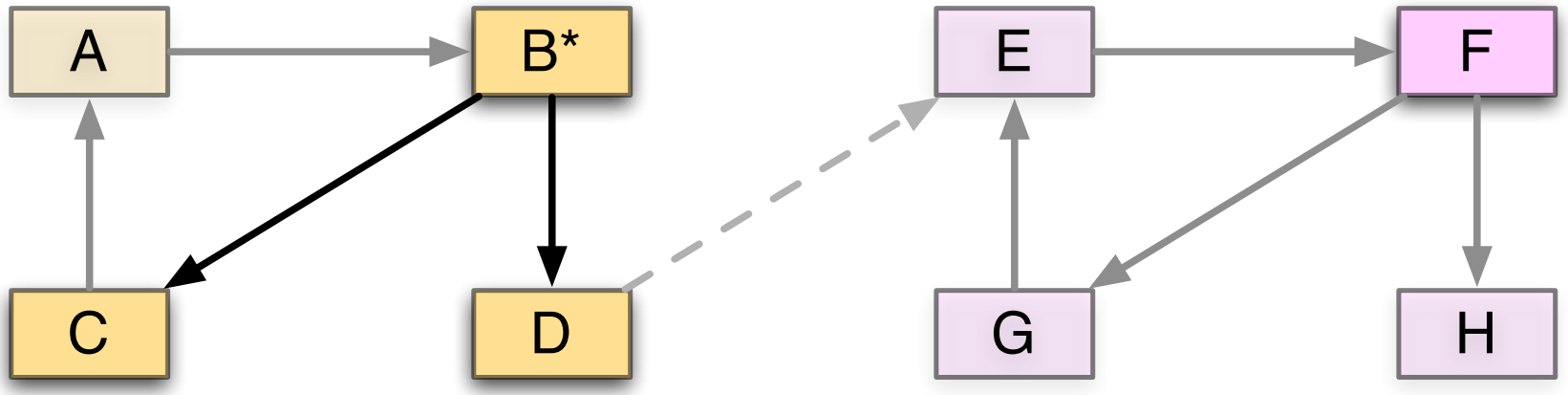

queue = F, C, D

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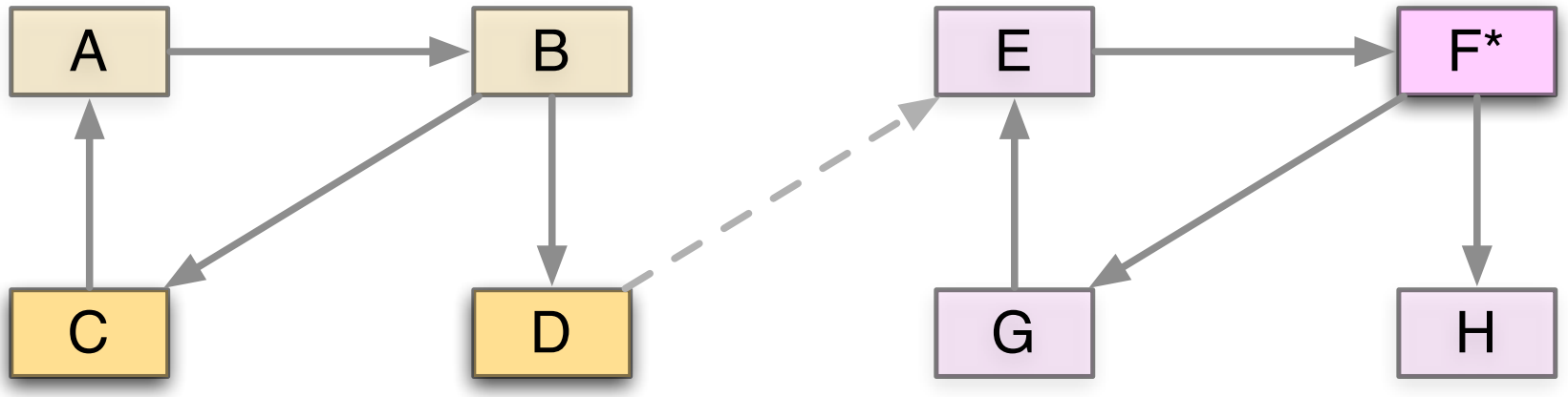

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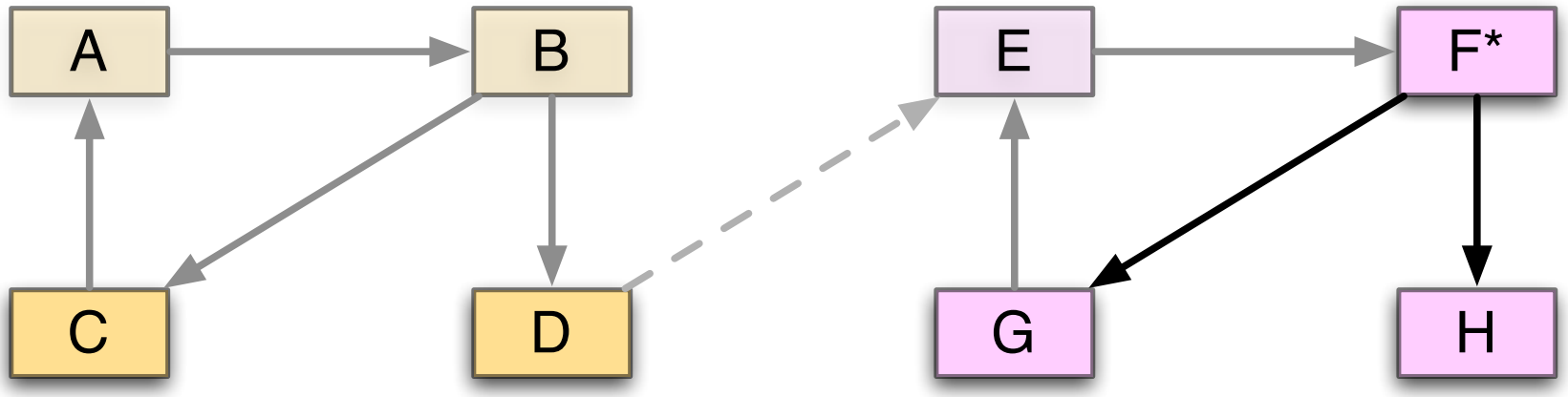

queue = C, D, G, H

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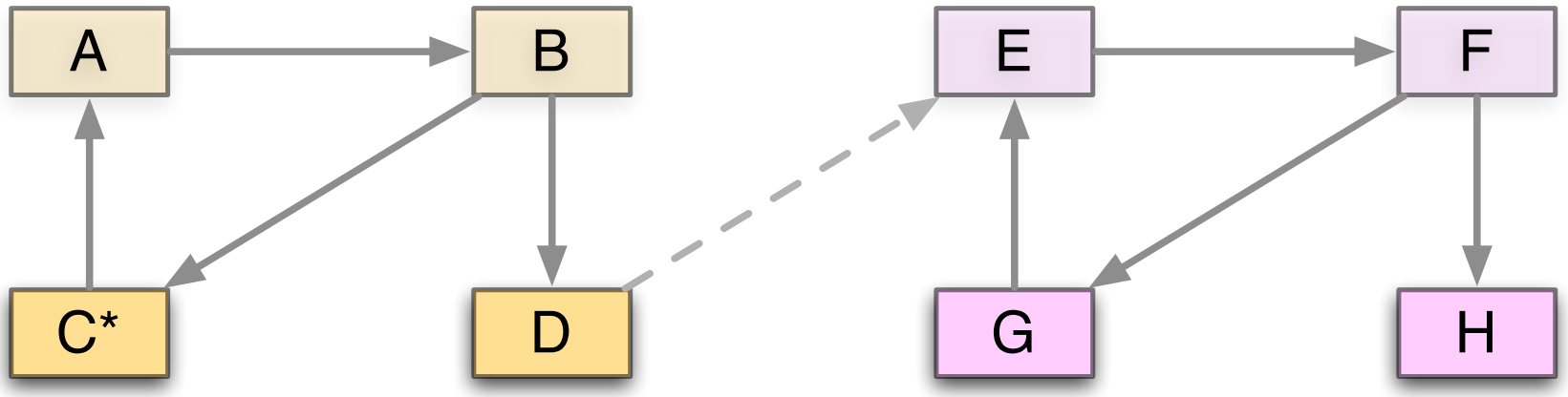

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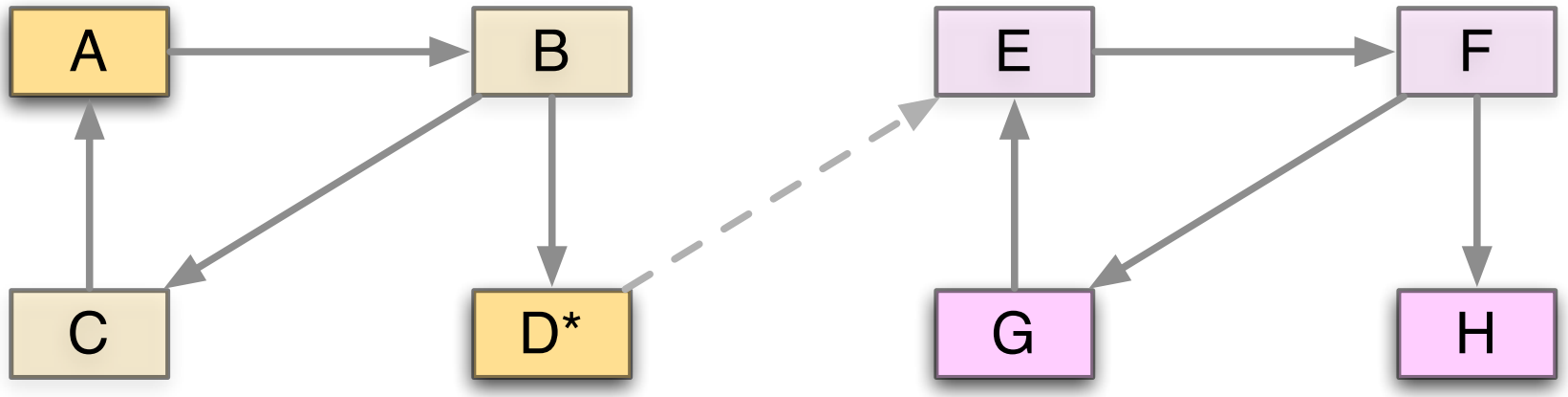

queue = G, H, A

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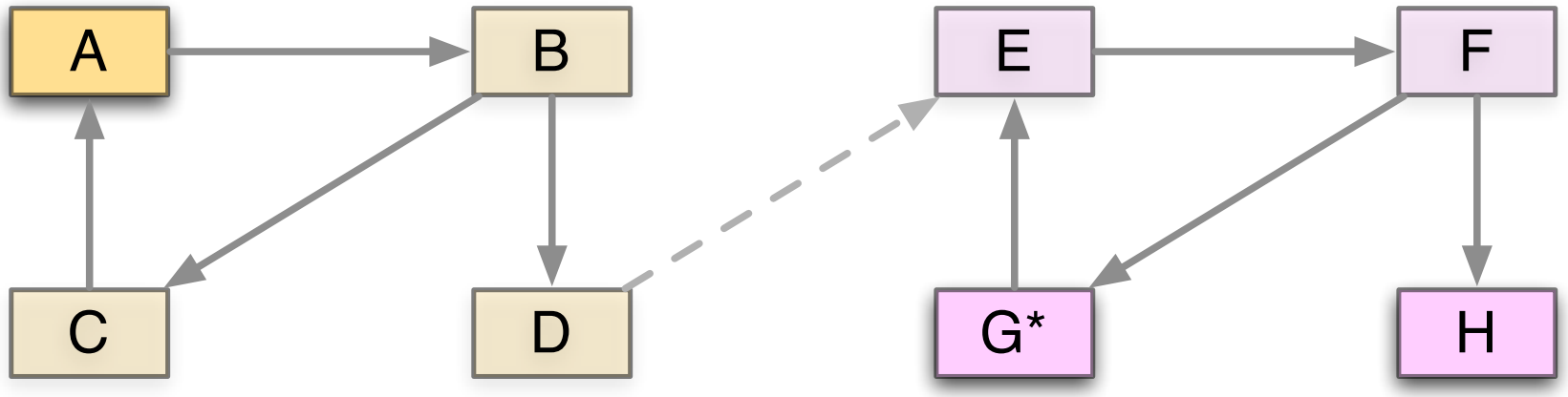

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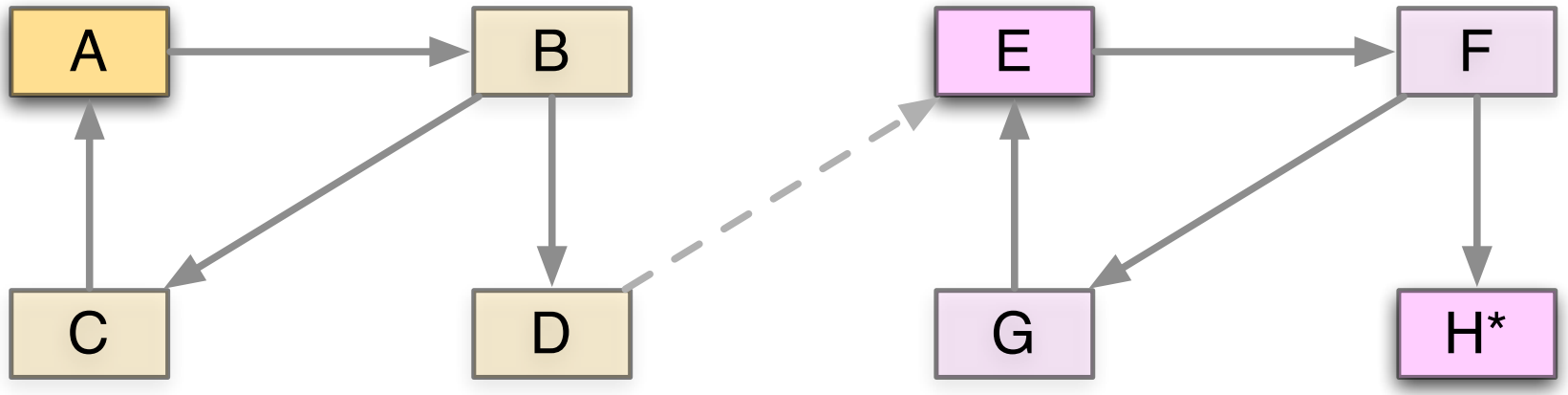

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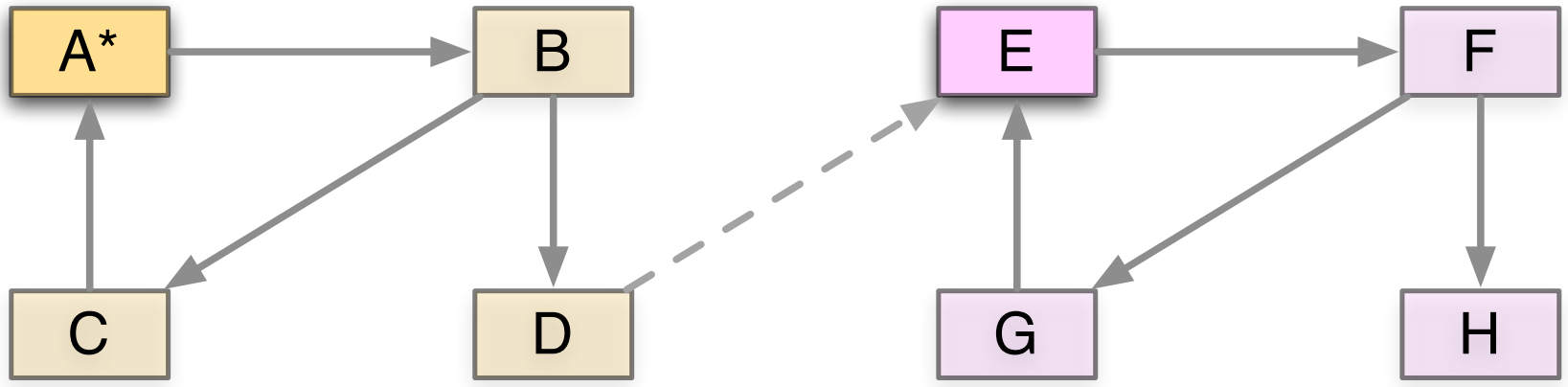

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Multicore

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- Single run-queue?
  - Enqueue/dequeue $\Longrightarrow$ lock/transaction/etc
  - Single point of contention
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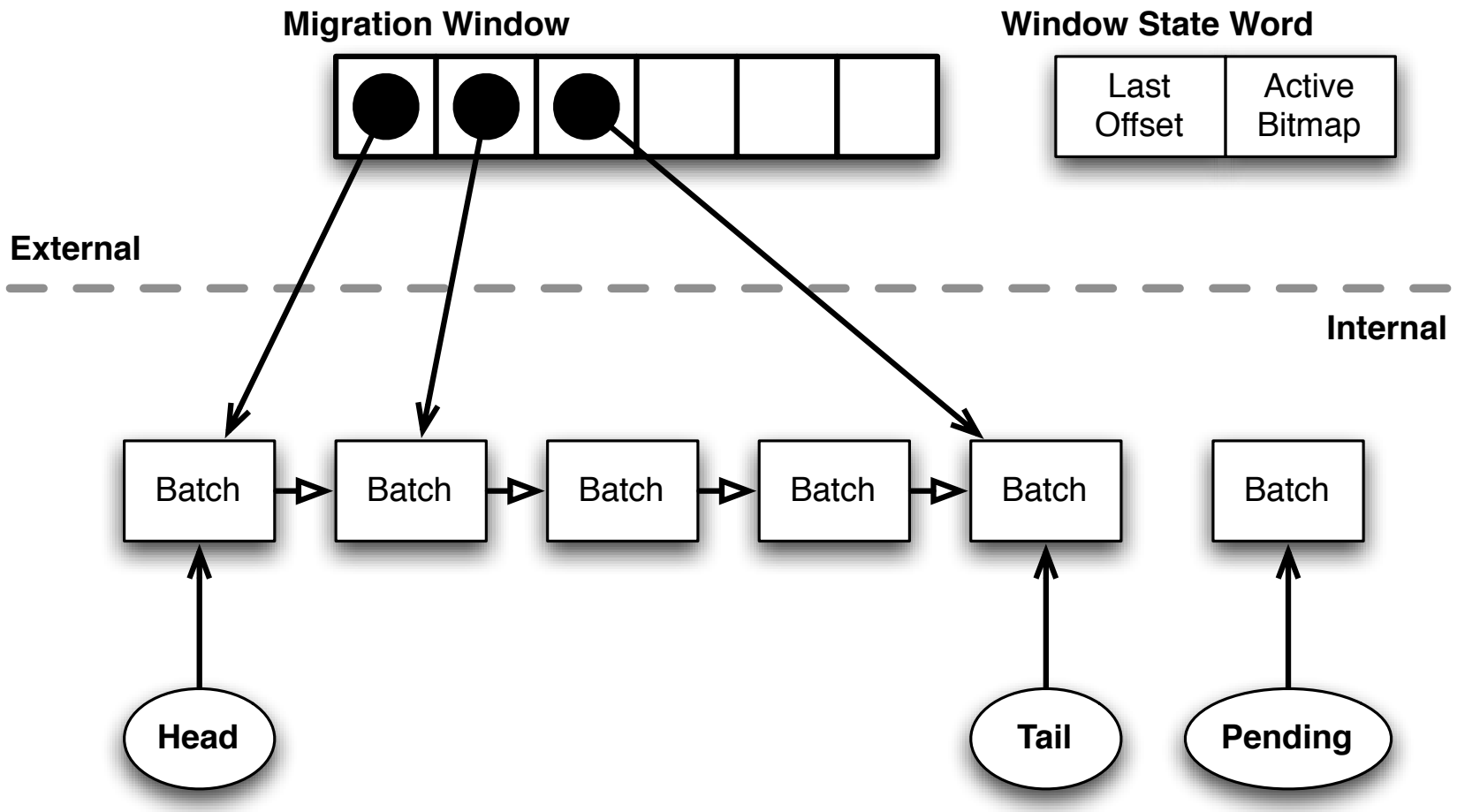
Distributed Run-queues

- Processors run scheduler instances
- Schedulers independent
- Batches are exposed via a migration window
- Idle schedulers steal batches

Migration Window



Lock Freedom

- *Non-blocking*:
  - cannot be indefinitely blocked by other threads
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- Load-link and store-conditional
- Pipeline flush on most modern processors $\Rightarrow$ expensive
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Minimising Atomic Operation Usage

- Migration Window
  - wait-free enqueue, dequeue, steal batch
- Communication
  - average 1, worst-case 2 atomic operations
- Choice over events (`ALT`)
  - maximum 4 operations per event, typically less
- Mutual exclusion
  - typically 1 atomic operation for lock/unlock
- Barriers
  - typically 1 atomic operation per synchronising process

Communication Time

- Use ring of processes to calculate communication time:

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CCSP occam-π	46	39
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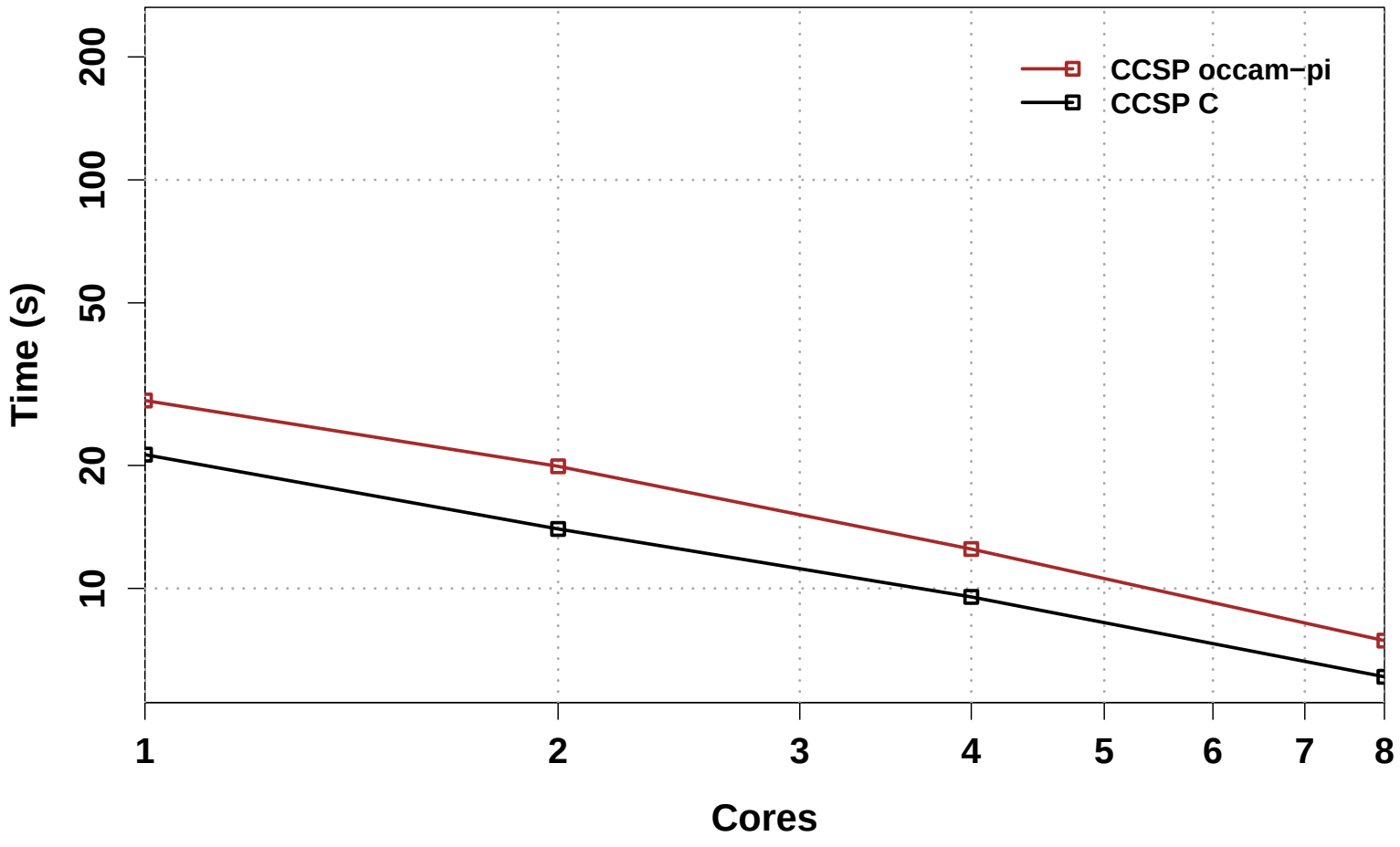

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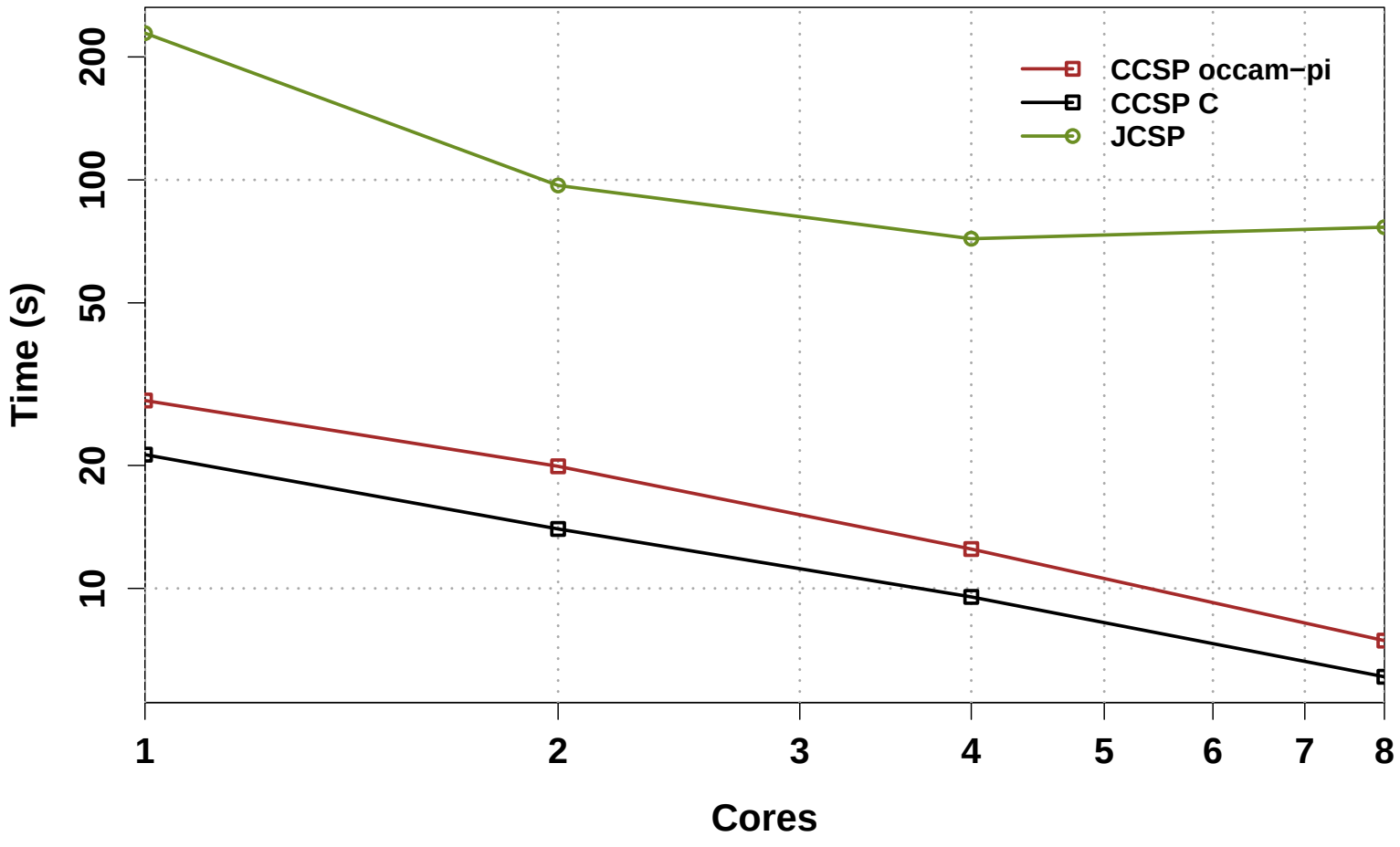

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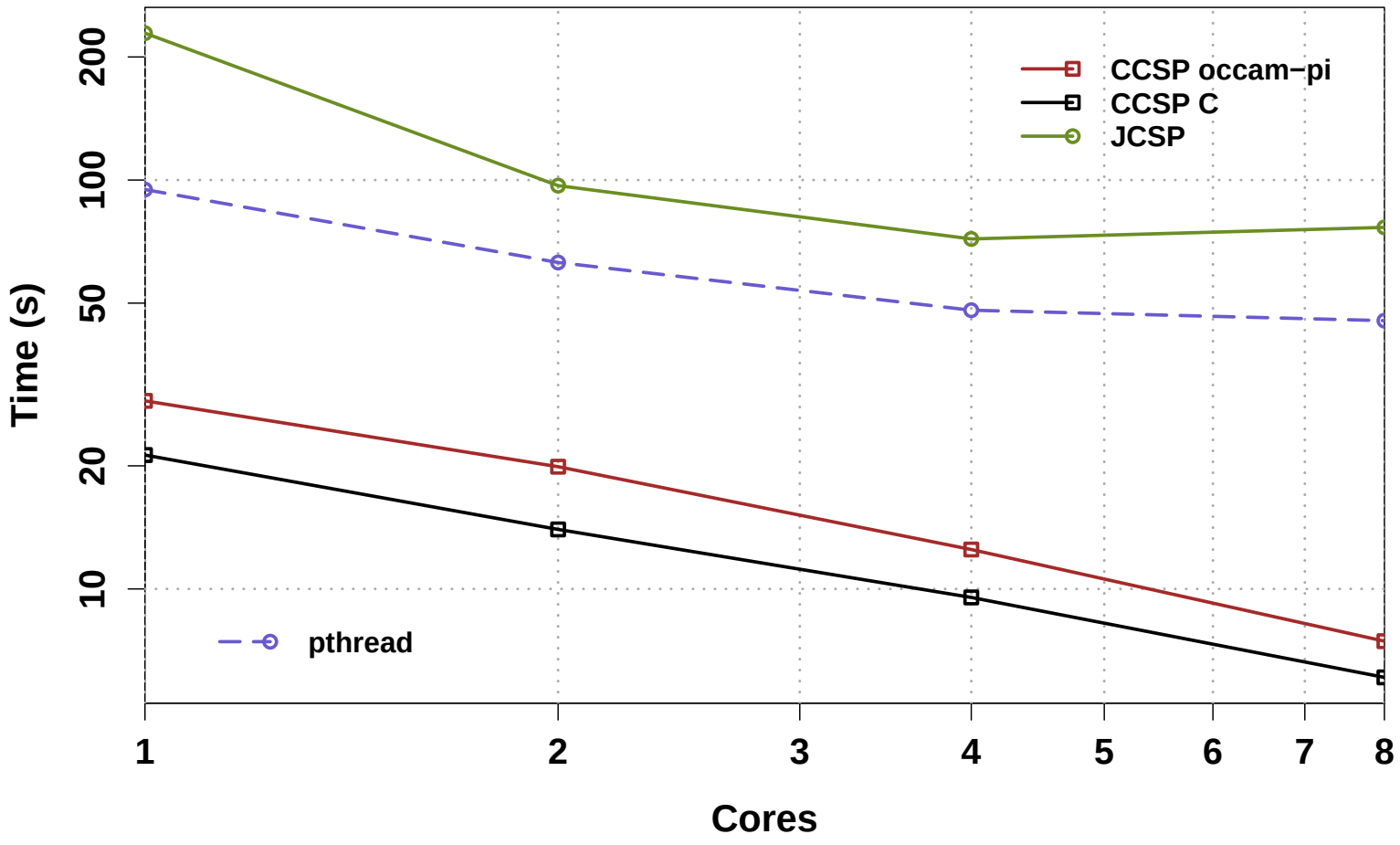

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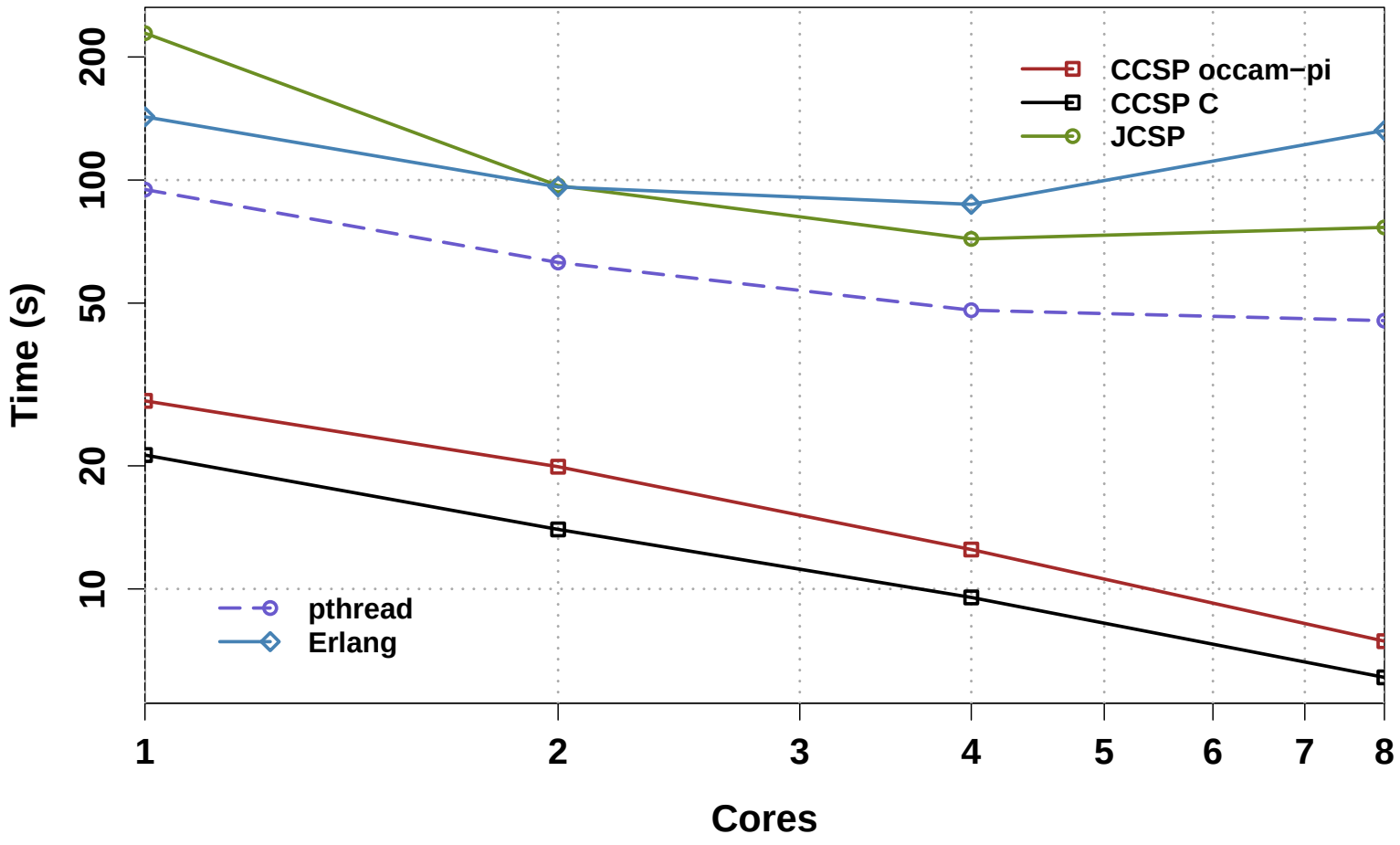

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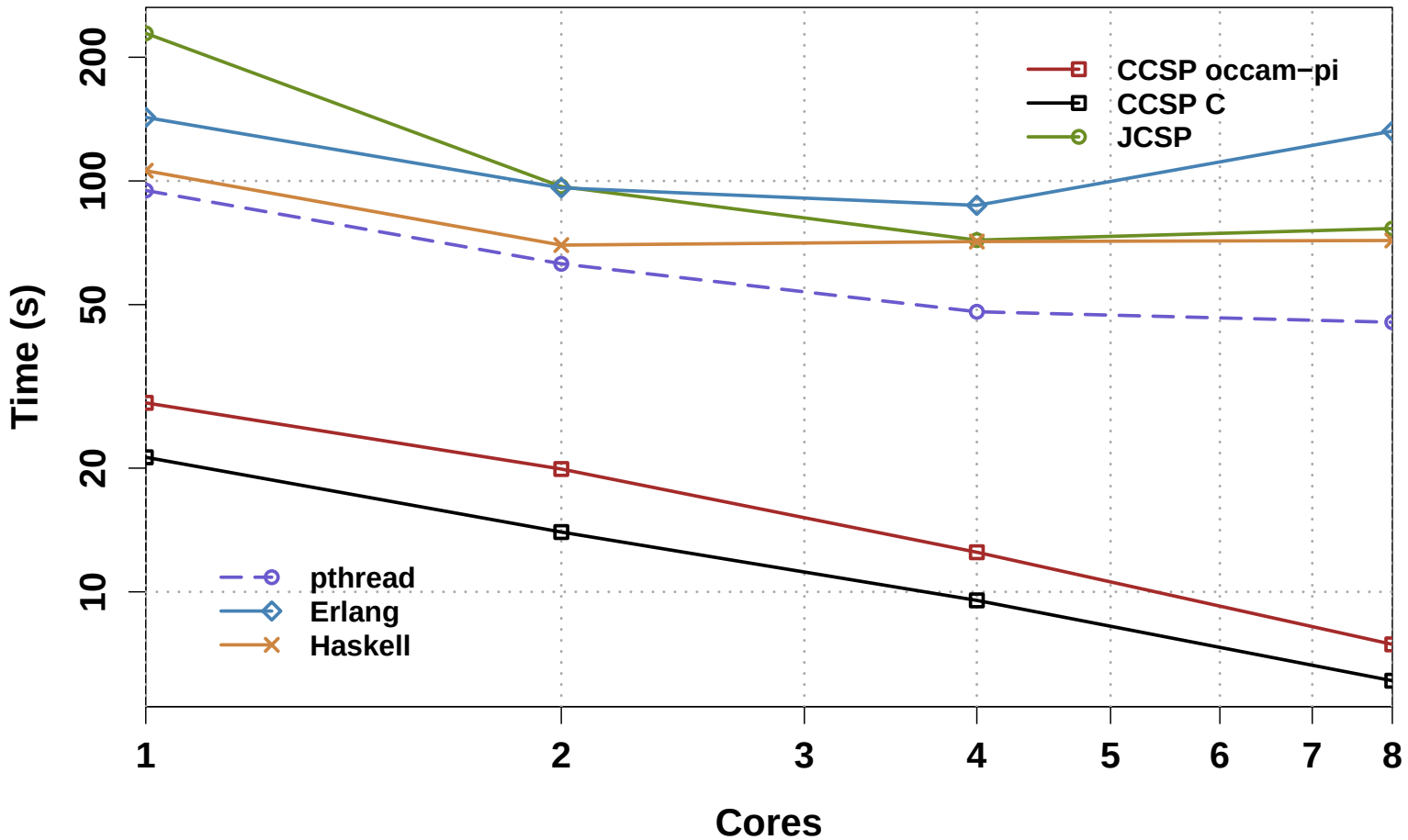
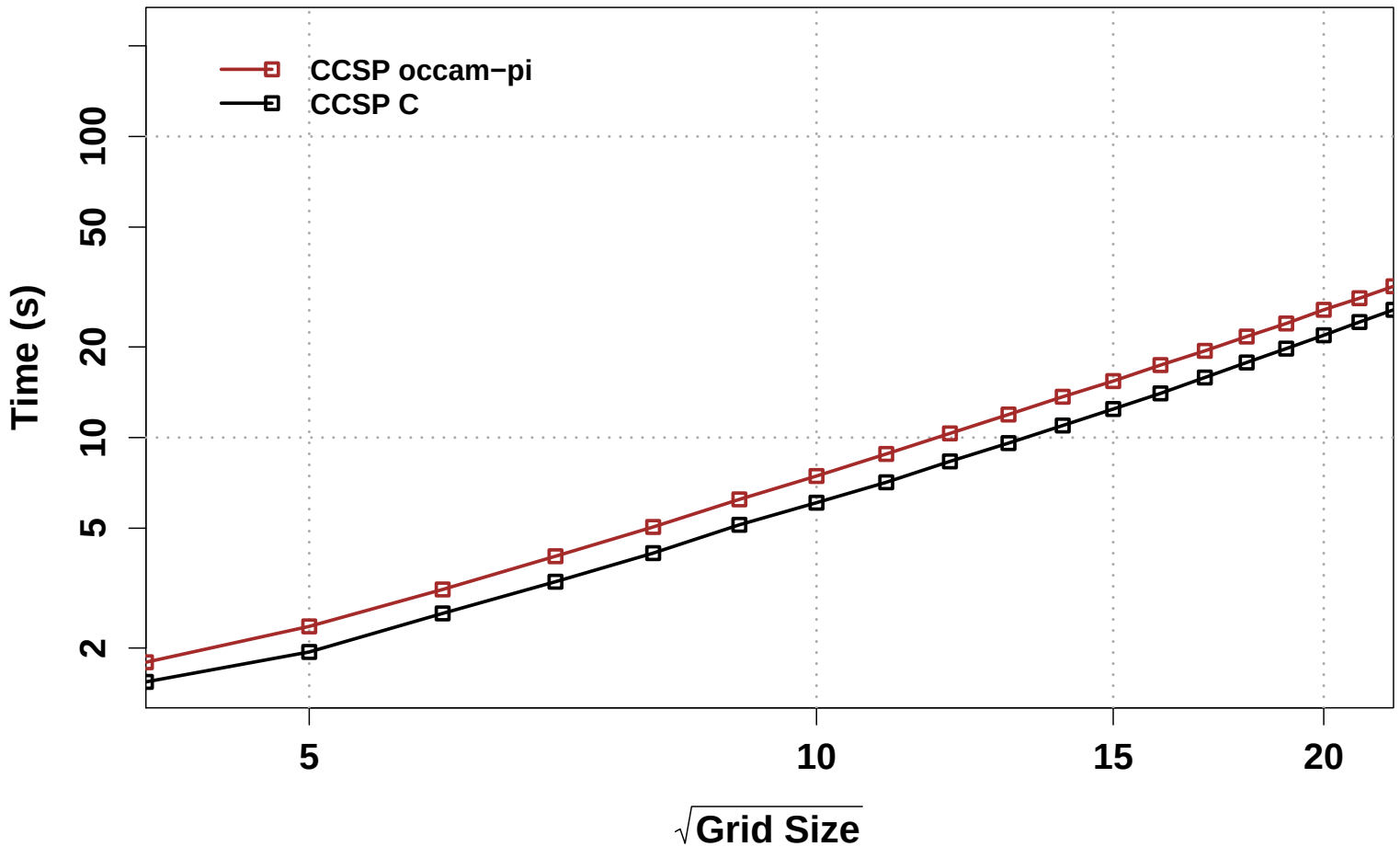


Increasing Problem Size (8-core)



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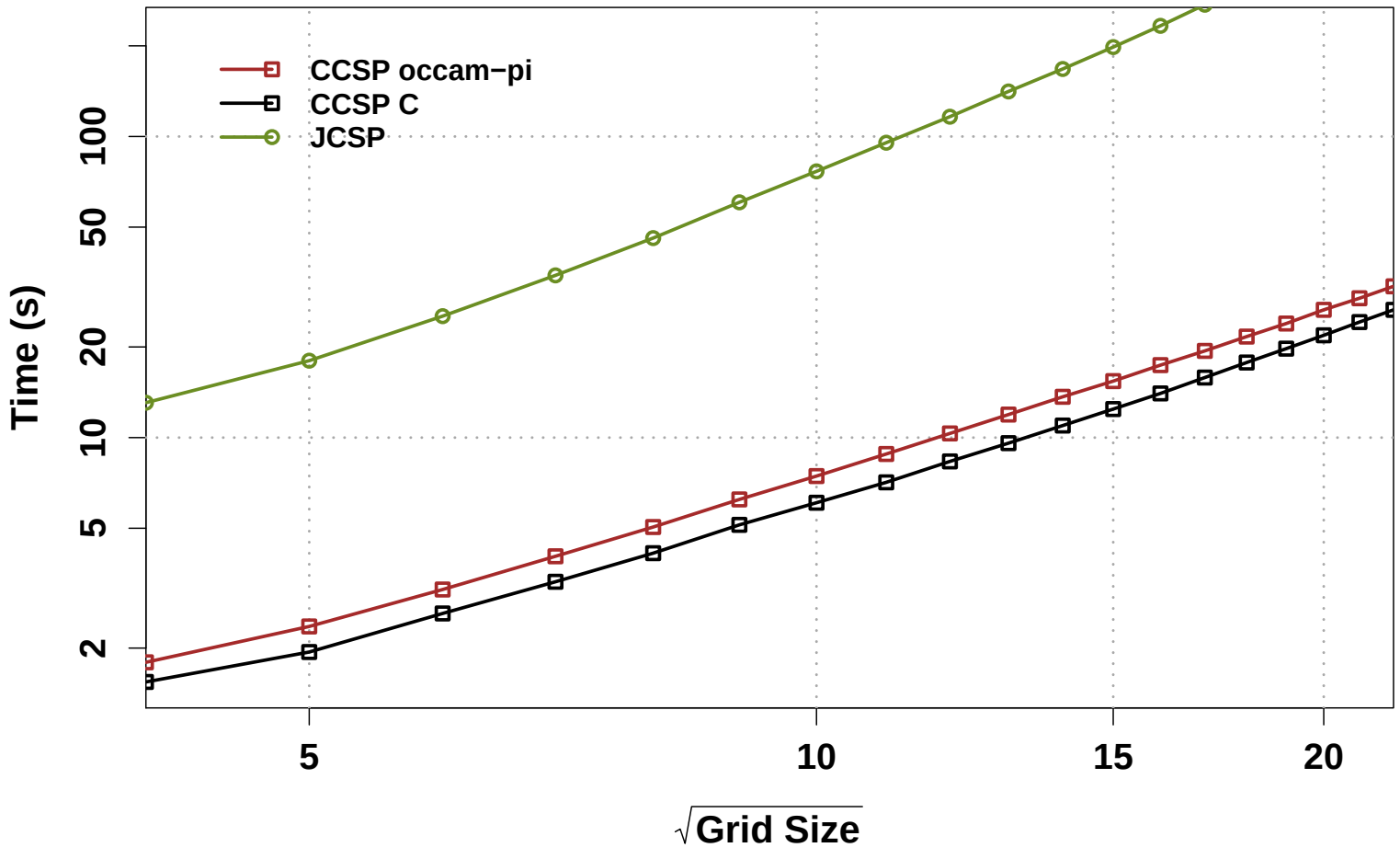

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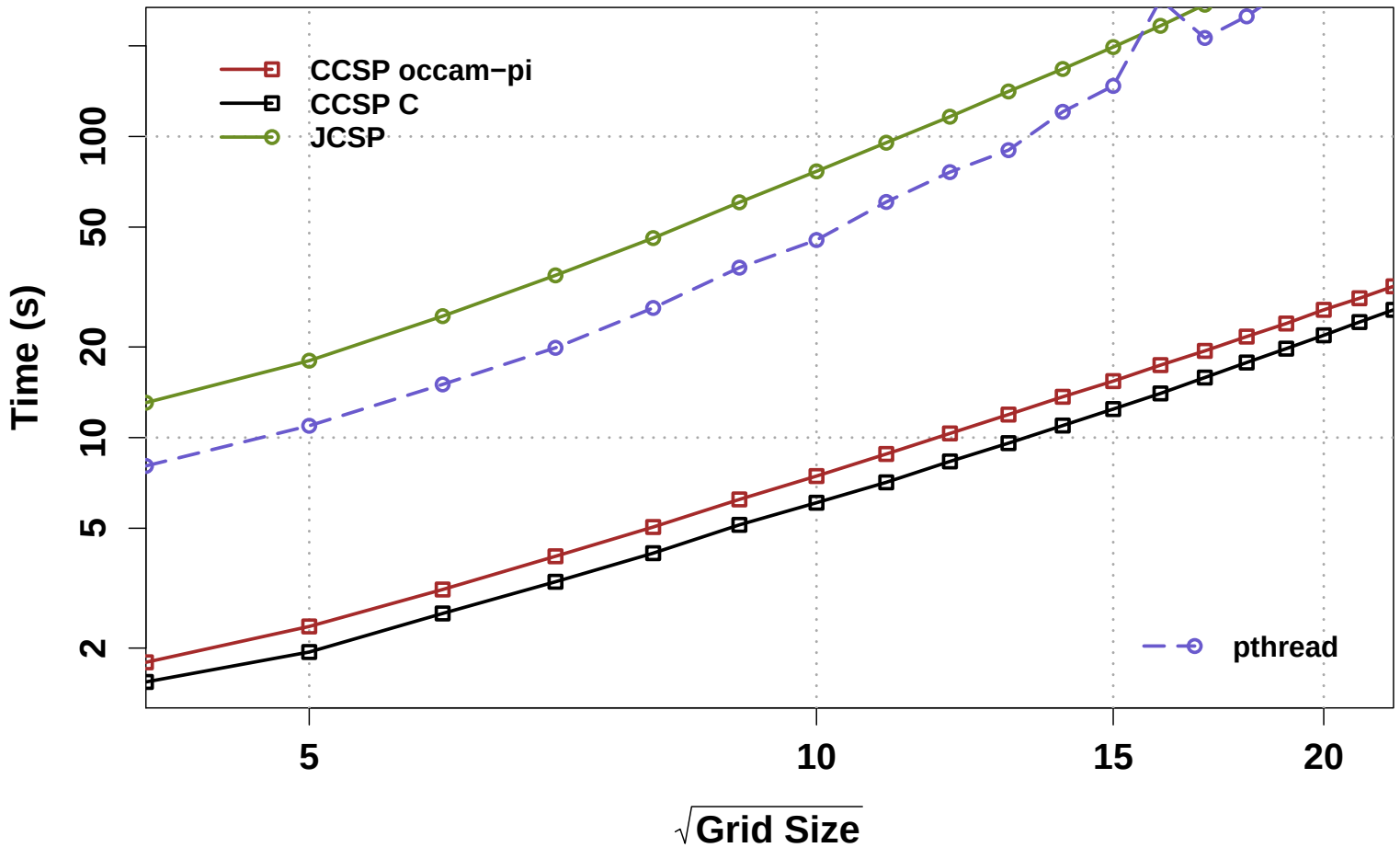

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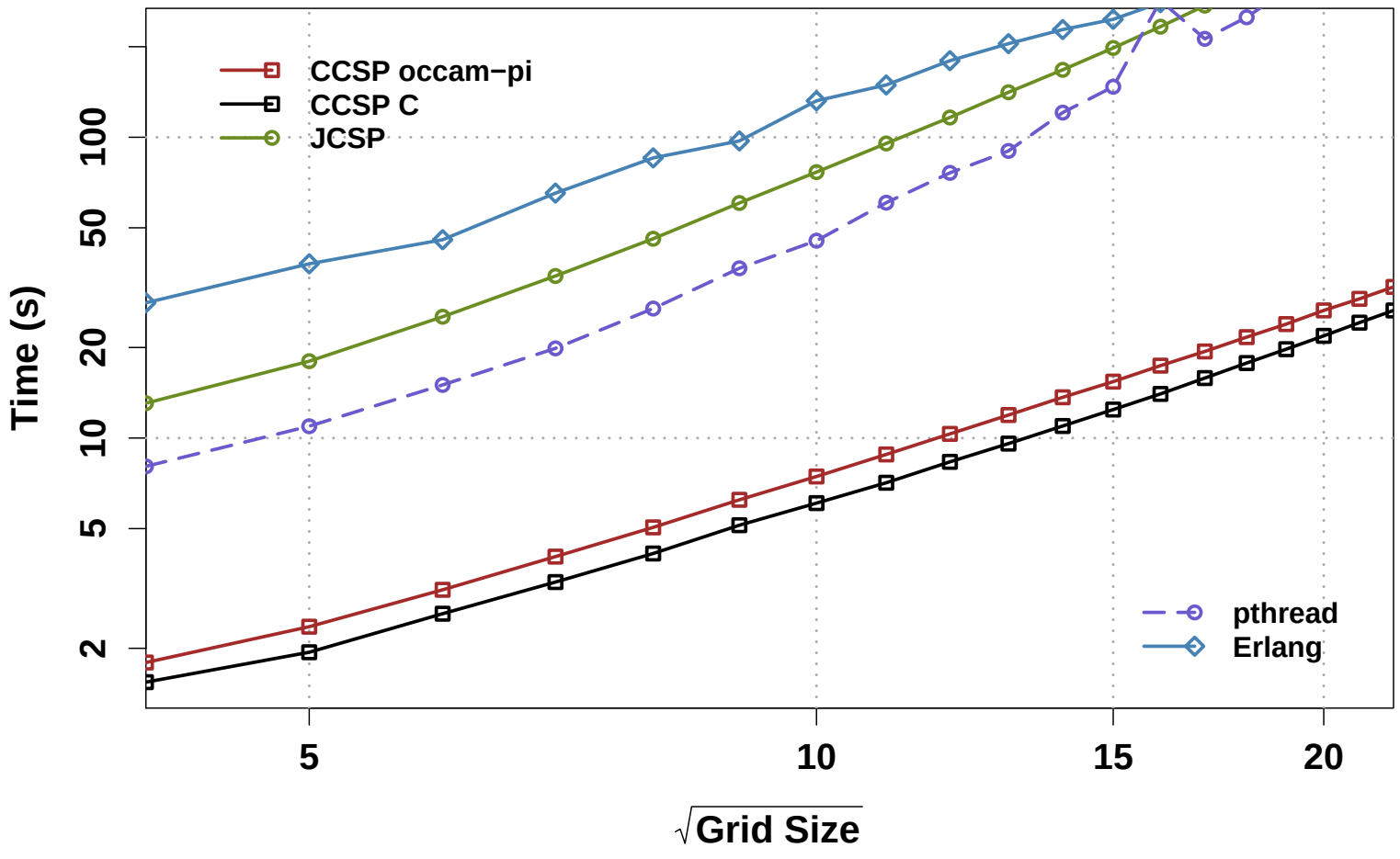

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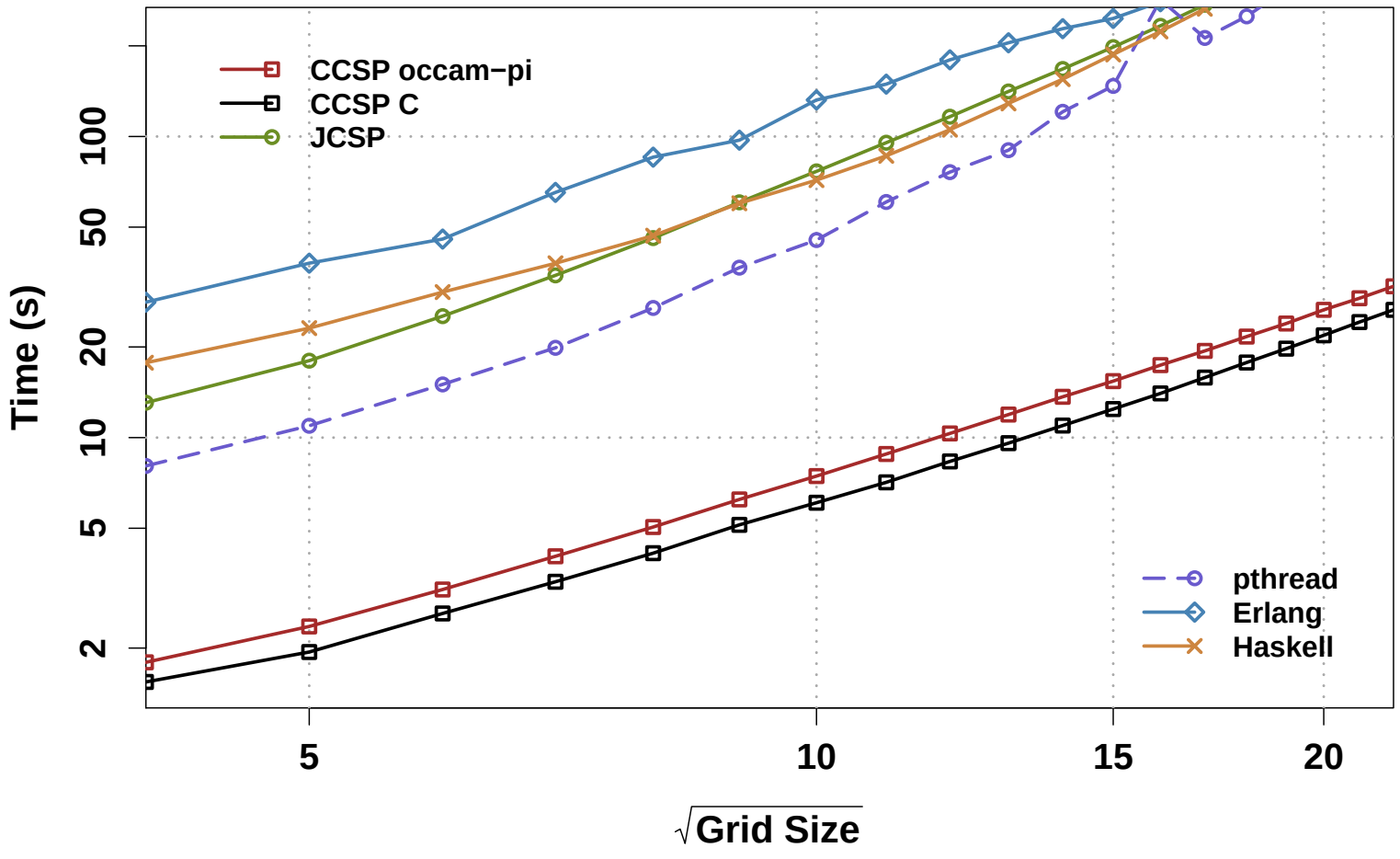
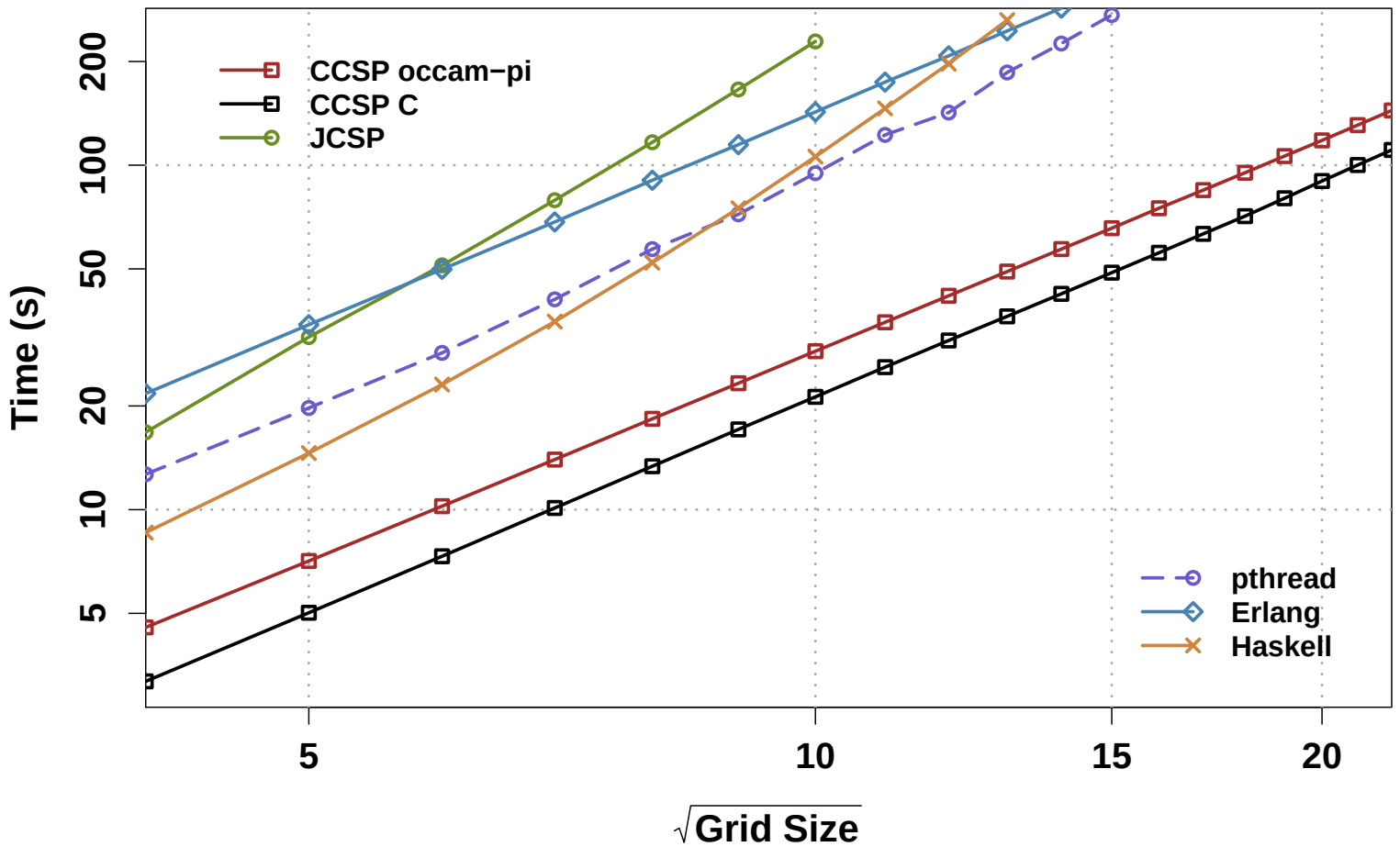


Increasing Problem Size (1-core)



Conclusions

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  - In use by CoSMoS and RMoX EPSRC funded projects
- Automatic parallelisation of concurrent software
  - No programmer intervention
  - Dynamic batching
  - *n*-core, scalable, asymmetric scheduling
- Room for improvement
  - Smaller code
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