Scalable Performance for Scala Message-Passing Concurrency

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Motivation

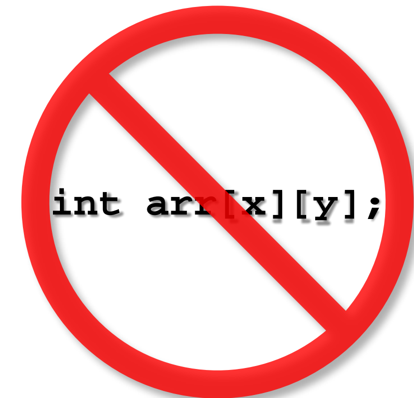
Multi-core commodity hardware

Non-uniform shared memory

Expose potential parallelism

Correctness and formal verification

Compatibility



1. Embedded DSL
2. Bytecode rewriting
3. Channels
4. Scheduler
5. Deadlock detection

EMBEDDED DOMAIN-SPECIFIC LANGUAGE

Why an Embedded DSL?

Ease of implementation

Leverage existing tools

Leverage known syntax

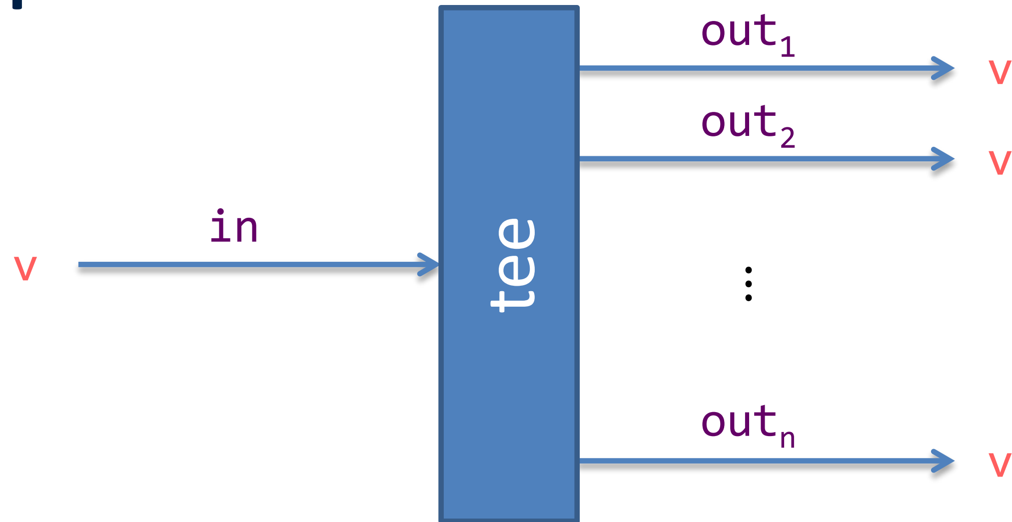
Higher-order functions
Rich type system

Lightweight syntax
Compile-time macros

Examples

```
def map[I, O](f: I => O)(in: ?[I], out: ![O]) =
  proc {
    repeat { out ! (f(in?)) }
    run (proc { in.closein } || proc { out.closeout })
  }
```

Examples




```
def tee[@specialized T](in: ?[T], outs: Seq[![T]]) =
  proc {
    var v = null
    val outputs = (|| (out <- outs) proc { out ! v })
    repeat { v = in?; run outputs }
    run (proc { in.closein } || (|| (out <- outs) proc { out.closeout }))
  }
```

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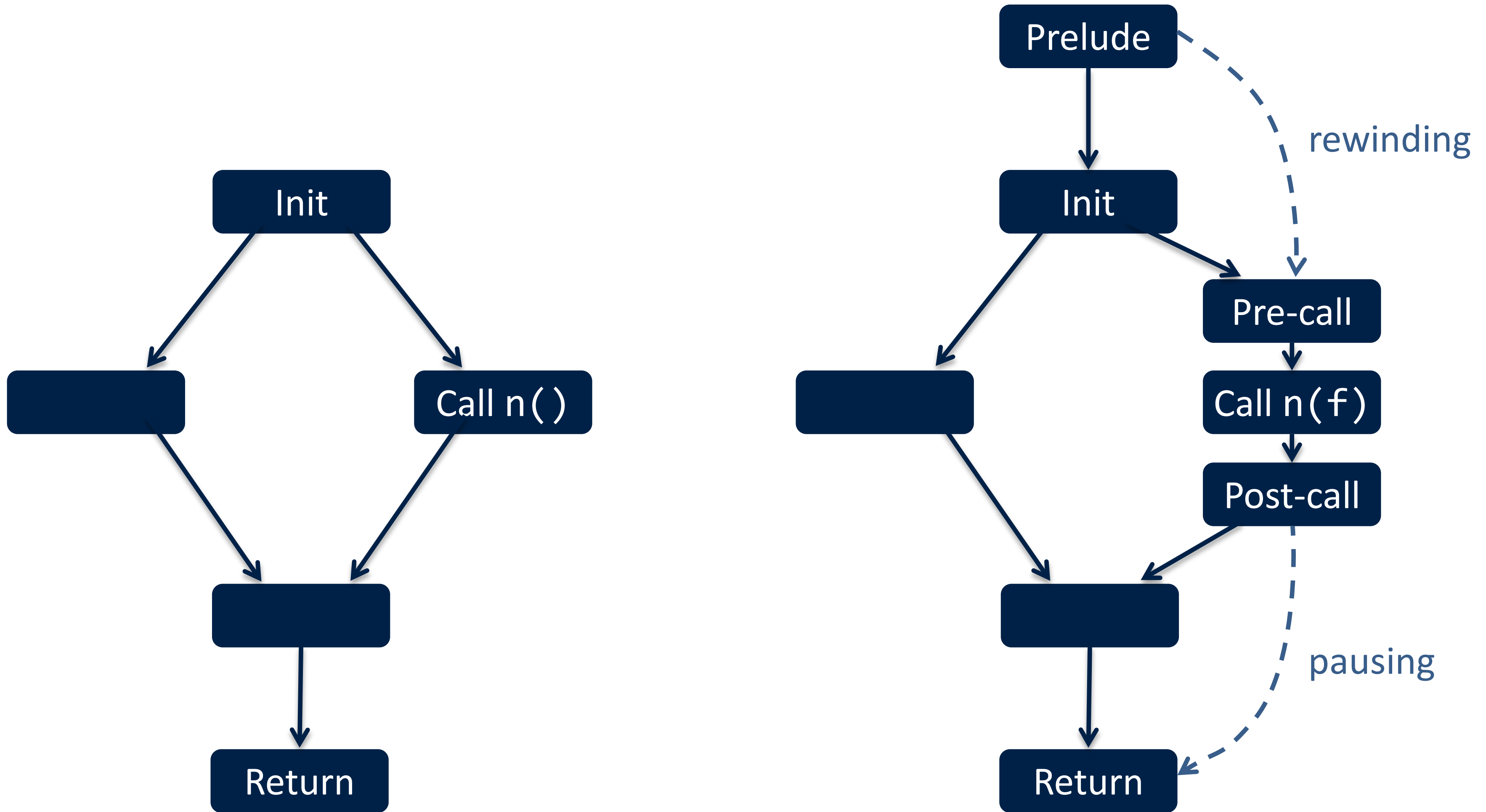
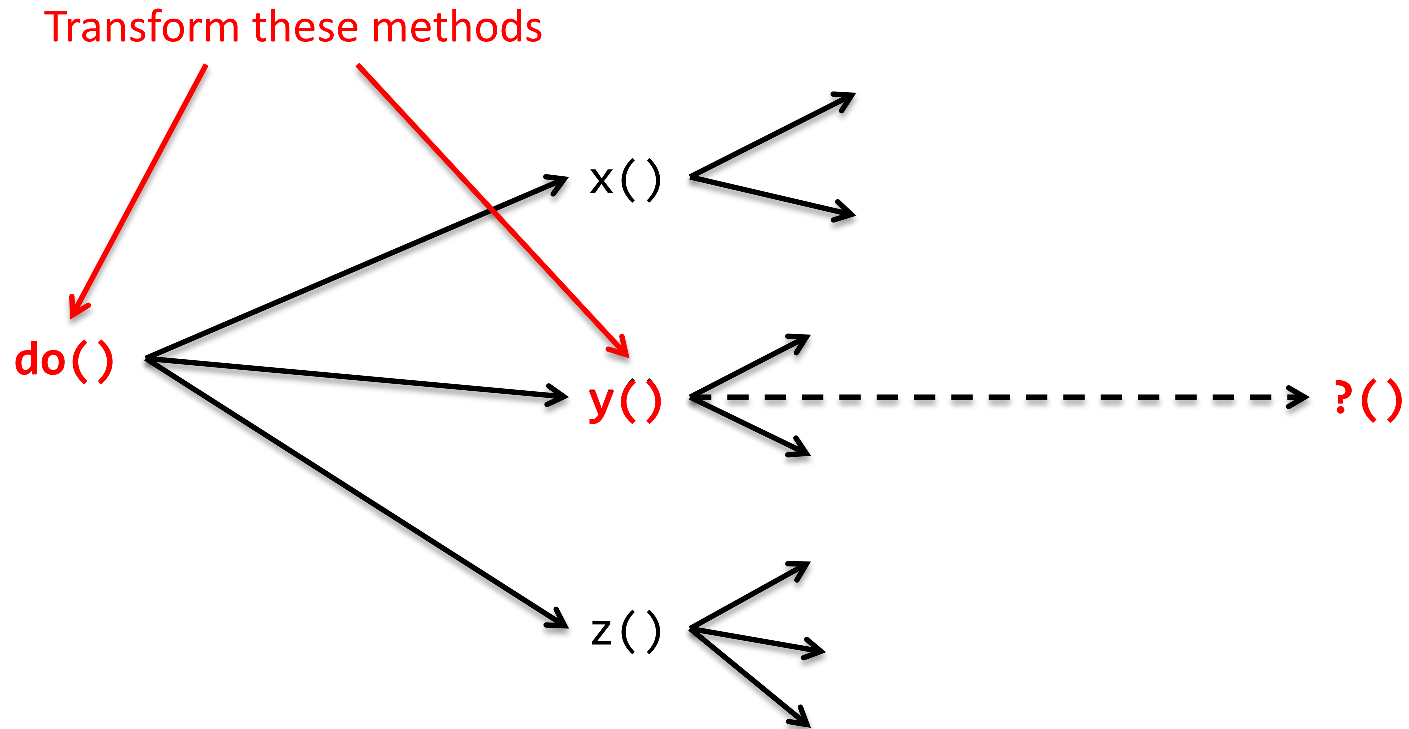
SCALABLE PERFORMANCE

through bytecode rewriting

CPS Transformation



Analysing the call graph



Engineering

Live variable analysis

Lazy load and store

Constant inlining

Functional Expressions

```
for (i <- 0 until n; j <- i until n) println(i)
```

```
intWrapper(0).until(n).foreach(
  i: Int => intWrapper(i).until(n).foreach(j: Int => println(i))
)
```

```
var i = 0
while (i < n) {
  var j = i
  while (j < n) { println(i); j += 1 }
  i += 1
}
```

More Features

Tail call optimisations

Shared memory

SBT plugin support

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CHANNELS

More Features

Generalised alt

Specialization for primitives

Optimised extended rendezvous

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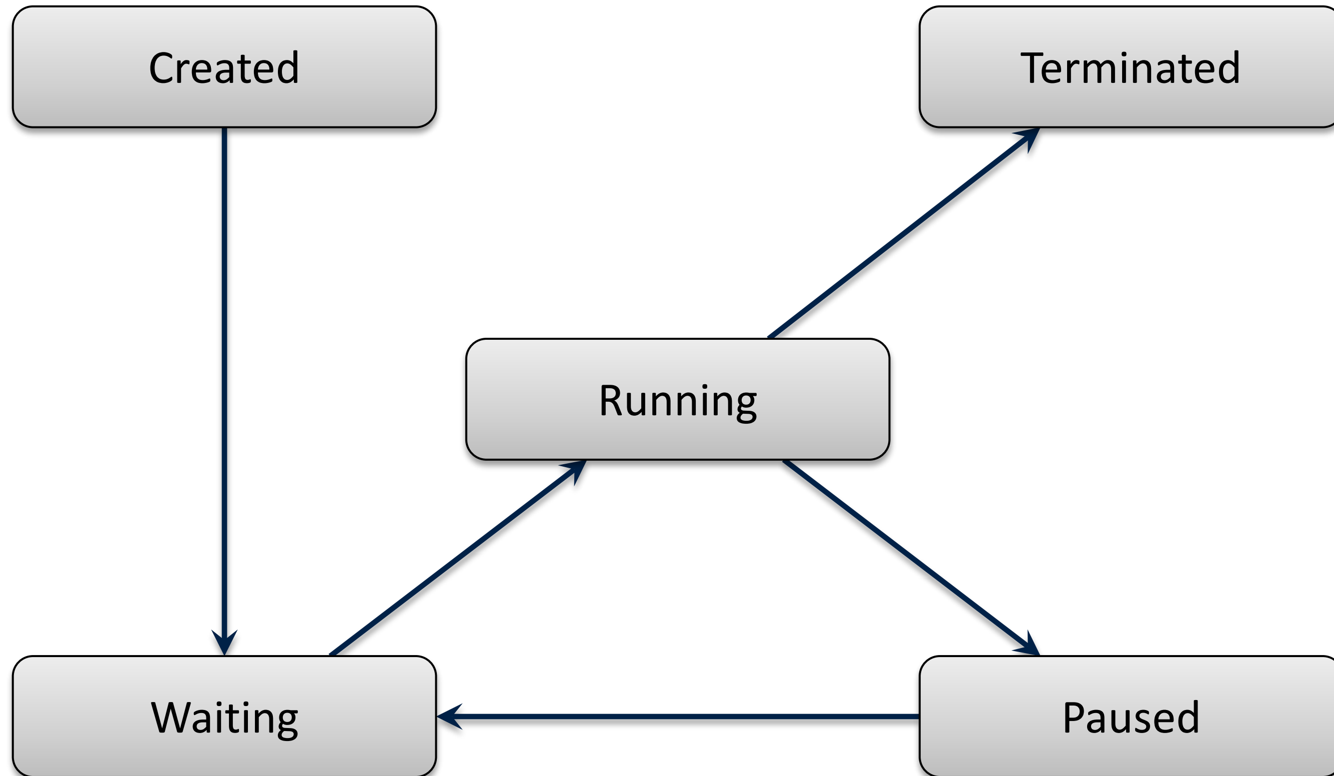
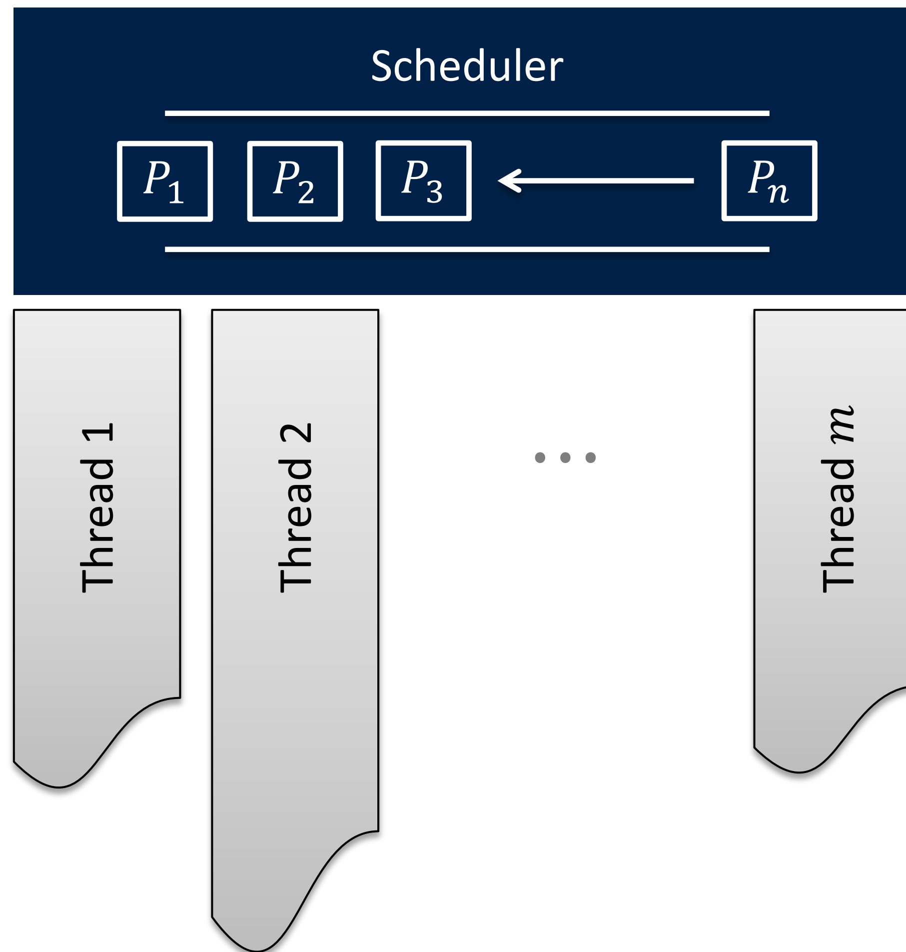
SCHEDULER

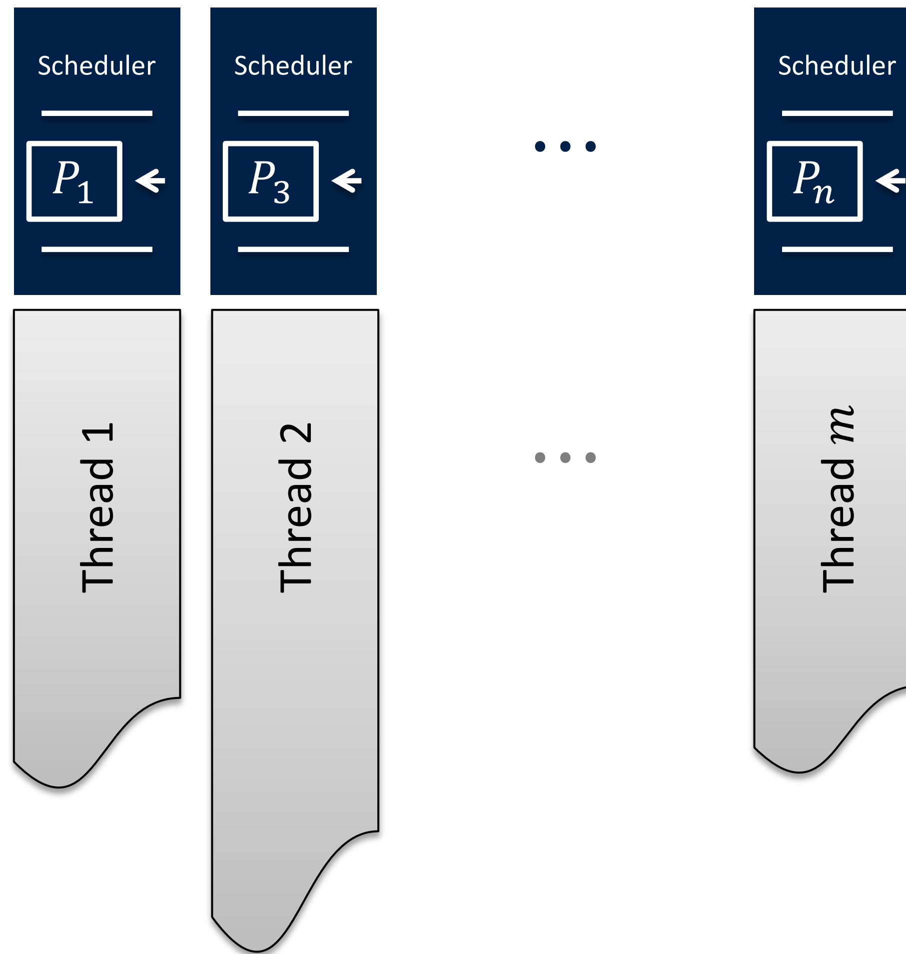
Scheduler States



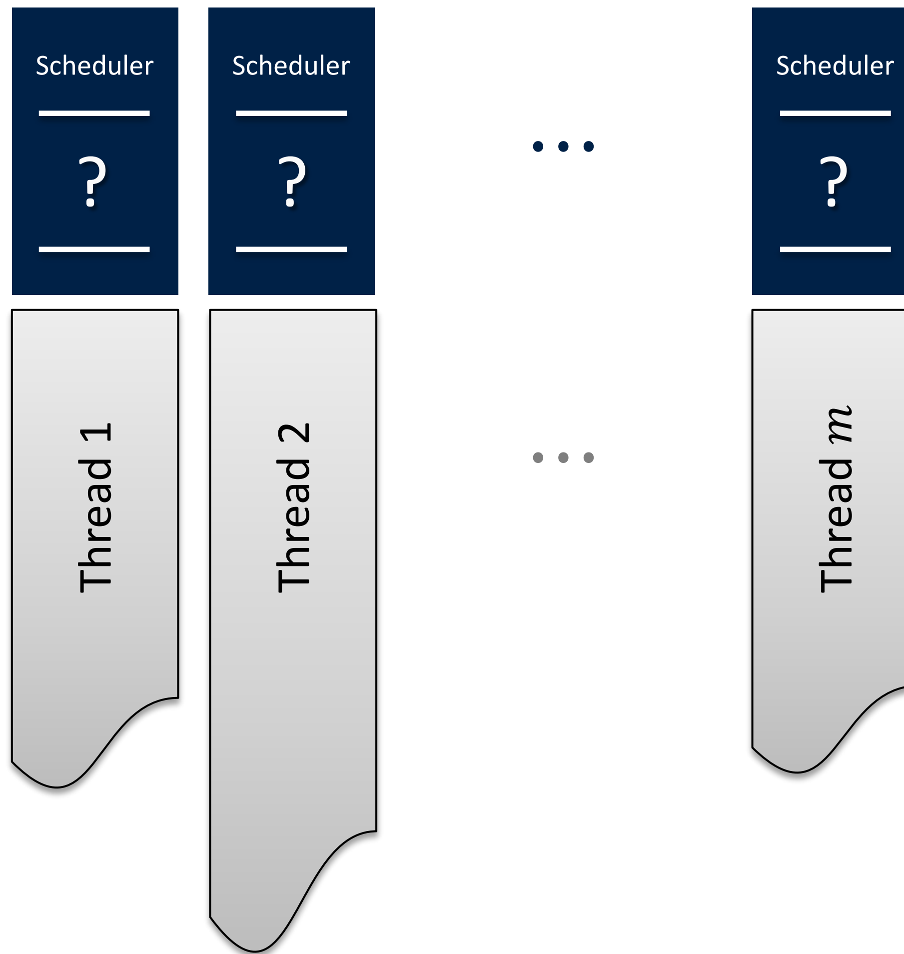
Scheduling: Central FIFO



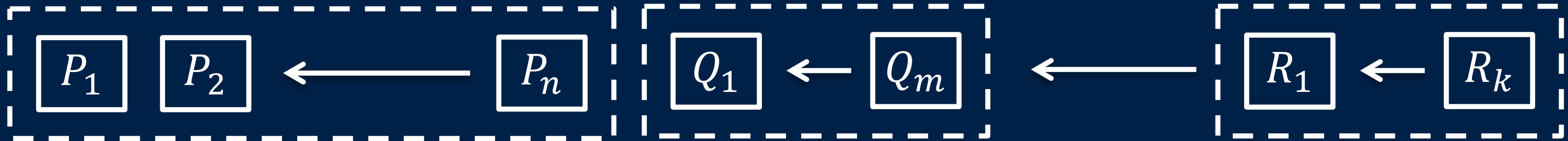
Scheduling: FIFO per thread



Scheduling: Batches per thread



Scheduling: Batches per thread



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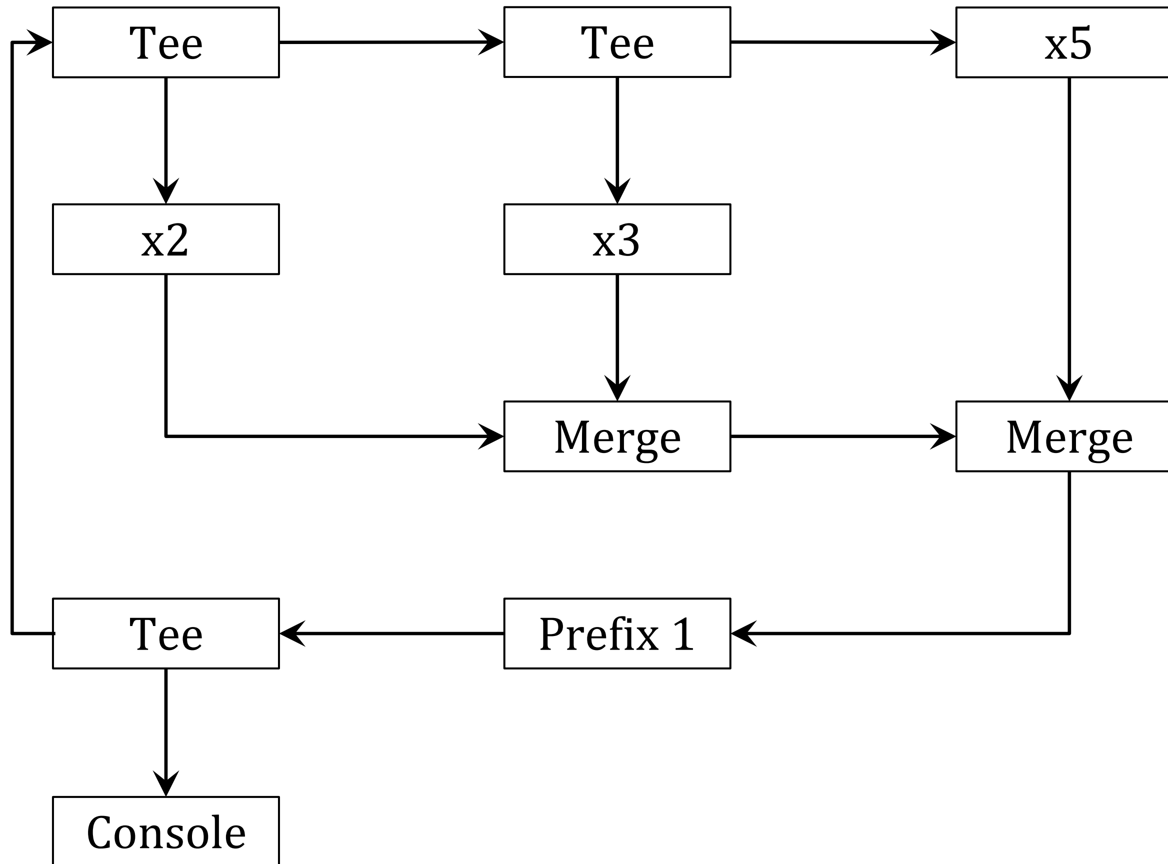
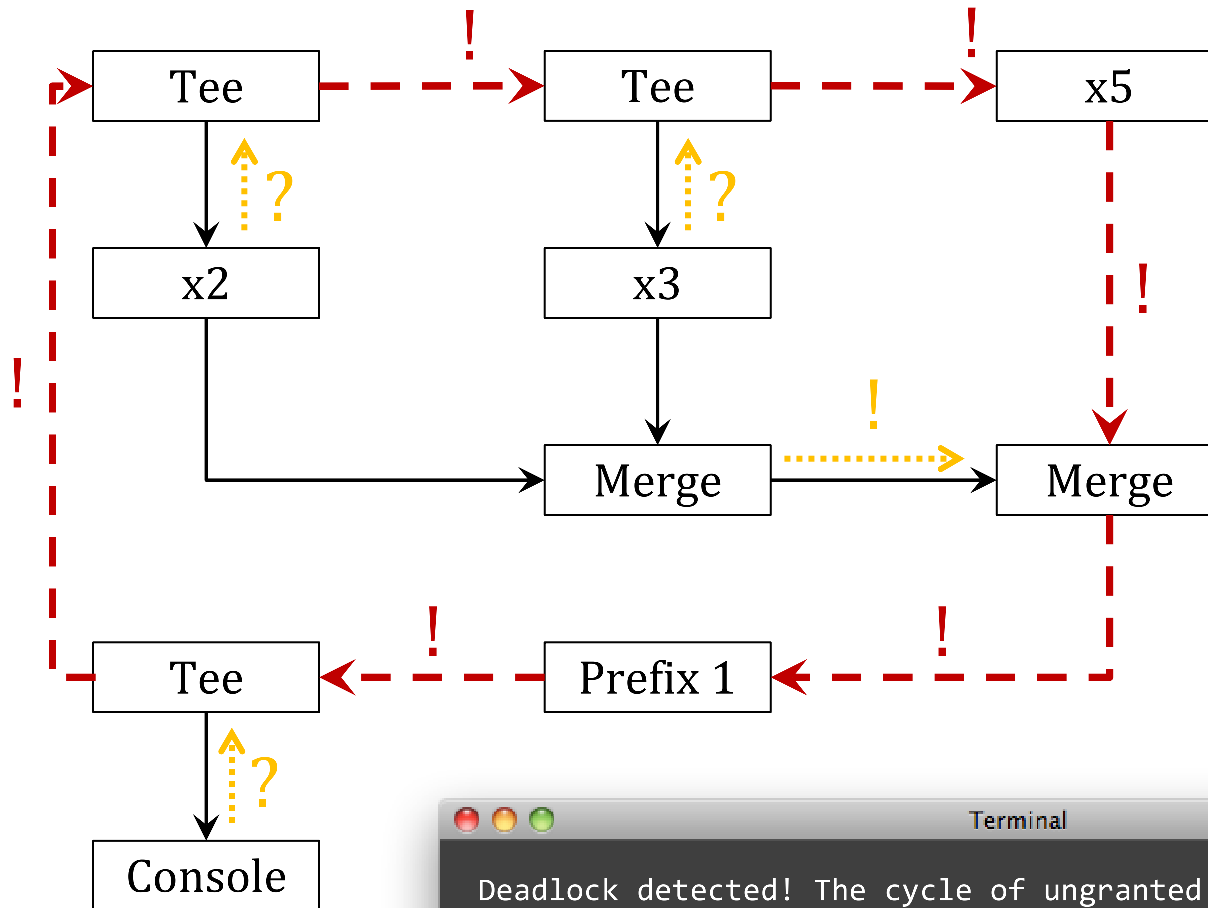
5. **Deadlock detection**

DEADLOCK DETECTION

Example



Example



Terminal

```
Deadlock detected! The cycle of ungranted requests is:
Prefix1 -!-> Tee1        Tee3   -!-> x5
Tee1    -!-> Tee2        x5     -!-> Merge2
Tee2    -!-> Tee3        Merge2 -!-> Prefix1
```

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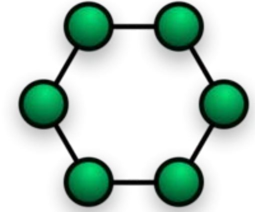
PERFORMANCE EVALUATION

Ring topology



Java primitives

CSO$_2$ FIFO Scheduler

CSO$_2$ Batch Scheduler

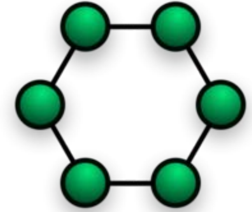
Time to pass a message 300 times around an n process ring (ms)

100000
10000
1000
100

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes spawned

Ring topology



Java primitives

CSO_2 FIFO Scheduler

CSO_2 Batch Scheduler

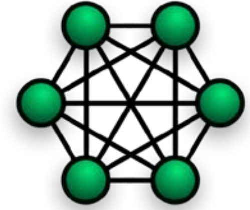
Time to pass a message 300 times around an n process ring (ms)

300000
250000
200000
150000
100000
50000
0

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes spawned

Fully connected topology



Time to pass n^2 messages (ms)

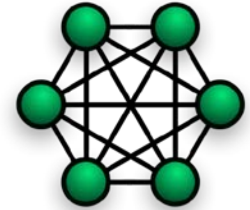
1000000
100000
10000
1000
100
10

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes / actors spawned

Erlang
Scala Actors
JCSP
Java Primitives
Occam
CSO_2 FIFO Scheduler
CSO_2 Batch Scheduler
Go

Fully connected topology



Time to pass n^2 messages (ms)

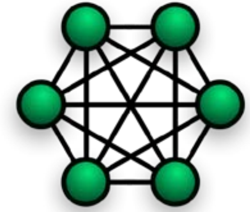
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0

- Erlang
- Scala Actors
- JCSP
- Java Primitives
- Occam
- CSO_2 FIFO Scheduler
- CSO_2 Batch Scheduler
- Go

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes / actors spawned

Fully connected topology



Time to pass n^2 messages (ms)

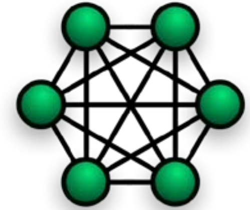
60000
50000
40000
30000
20000
10000
0

JCSP
Occam
CSO_2 FIFO Scheduler
CSO_2 Batch Scheduler
Go

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes / actors spawned

Fully connected topology



CSO$_2$ FIFO Scheduler

Go

CSO$_2$ Batch Scheduler

Time to pass n^2 messages (ms)

16000
14000
12000
10000
8000
6000
4000
2000
0

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Number n of processes / actors spawned

Summary

- High performance library for building massively concurrent systems on the JVM
- Deadlock detection
- Outperforms Java primitives, JCSP, Scala Actors, Occam, and very close to Go