Process Cooperativity as a Feedback Metric in Concurrent Message-Passing Languages

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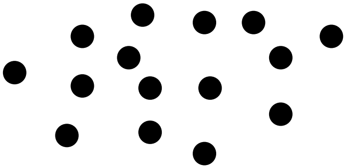
Current Section:

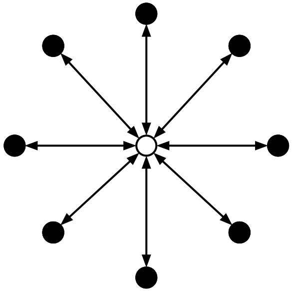
1 Background

- Cooperativity
- Message Passing
- Runtime Scheduling

Background: Cooperativity

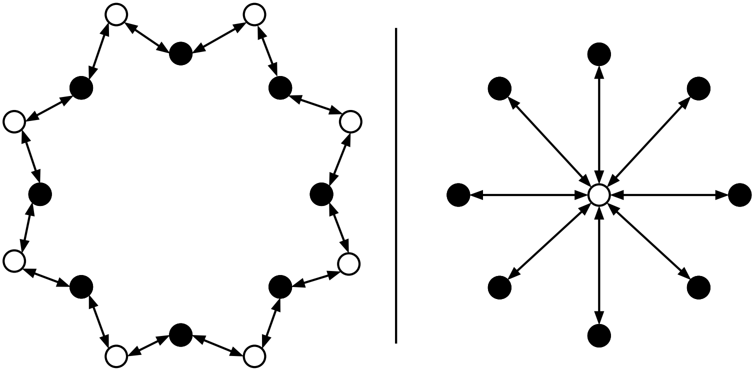
What is Process Cooperativity?





Background: Cooperativity

What does Cooperativity give us?



Background: Message Passing

We use a Symmetric, Synchronous, Message-Passing Primitive:

`swap`

- Purely captures cooperation of processes by synchronizing on the shared channel.
- Ultimately can be extended to take into account:
  - Directionality
  - Asynchrony

Background: Runtime Scheduling

- Schedulers can be defined in a discrete manner:
  1. *Choose* a process from set
  2. *Reduce* it
  3. *Update* private scheduler state
- Statistics can be gathered at every step about process:
  - Number of channel partners,
  - Timestamp of last run,
  - Number of reductions, *etc.*
- *What statistics are neccessary for recognizing cooperativity?*

Current Section:

2 ErLam

- The Language
- Channel Implementations
- Simulation & Visualization

ErLam: The Language

```
<Expression> ::= <Variable>
              |  <Integer>
              |  ‘newchan’
              |  ‘(’ <Expression> ‘)’
              |  <Expression> <Expression>
              |  ‘if’ <Expression> <Expression> <Expression>
              |  ‘swap’ <Expression> <Expression>
              |  ‘spawn’ <Expression>
              |  ‘fun’ <Variable> ‘.’ <Expression>
```

ErLam: The Language

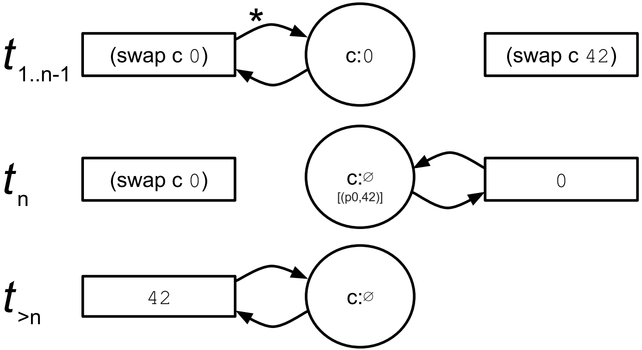
```
elib
    // ...
    omega = (fun x.(x x));
    // ...
    add = _erl[2]{ fun(X) when is_integer(X) ->
                       fun(Y) when is_integer(Y) ->
                           X+Y
                       end
                   end
                };
    // ...
bile
```

```
// pfib.els -
fun N.
    (omega fun f,m.(
        if (leq m 1)
            m
            (merge fun _.(f f (sub m 1))
                   fun _.(f f (sub m 2))
                   add)) N)
```

```
$ els pfib.els
$ ./pfib.ex -r 10
```

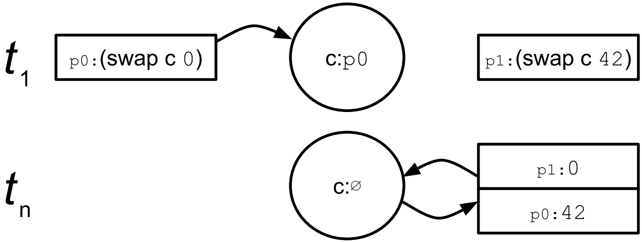
`$ els pfib.els`	(Compile the script)
`$ ./pfib.ex -r 10`	(Finds the 10th Fibonacci number)

ErLam: Channel Implementations



Process Blocking Swap

ErLam: Channel Implementations



Process Absorption Swap

ErLam: Simulation & Visualization

- System Behaviours:
  - Degree of Parallelism
  - Consistency of Cooperation
  - Degree of Longevity/Interactivity
  - Partial System Cooperativity
- Logging & Report Generation

ErLam: Simulation & Visualization
System Behaviours: Degree of Parallelism

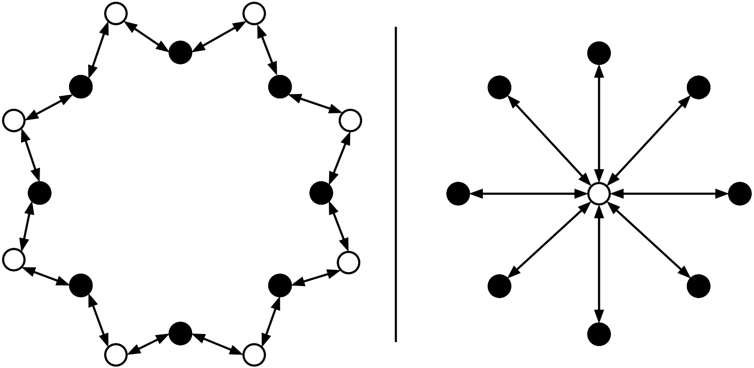


Figure: $PRing_N$, and $ClusterComm_{(N,1)}$ primitives to test degree of parallelism.

ErLam: Simulation & Visualization

System Behaviours: Consistency of Cooperation

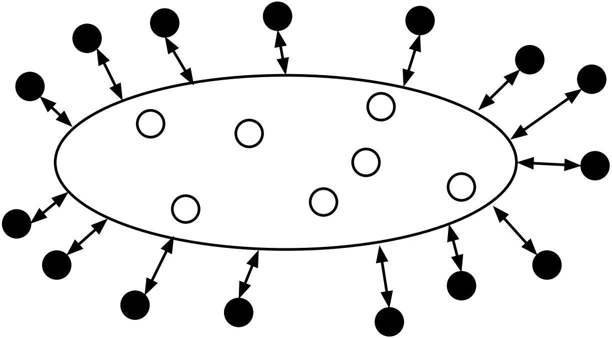


Figure: *ClusterComm*$_{(N,M)}$ to test effect of consistency on scheduler.

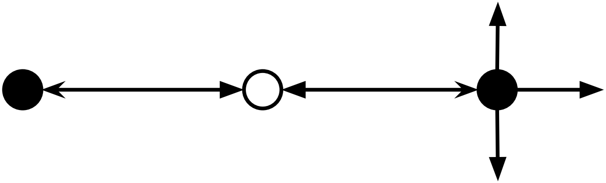


Figure: *UserInput*$_{(T,C)}$, simulates user interaction or a number (C) of external/timed (T) events.

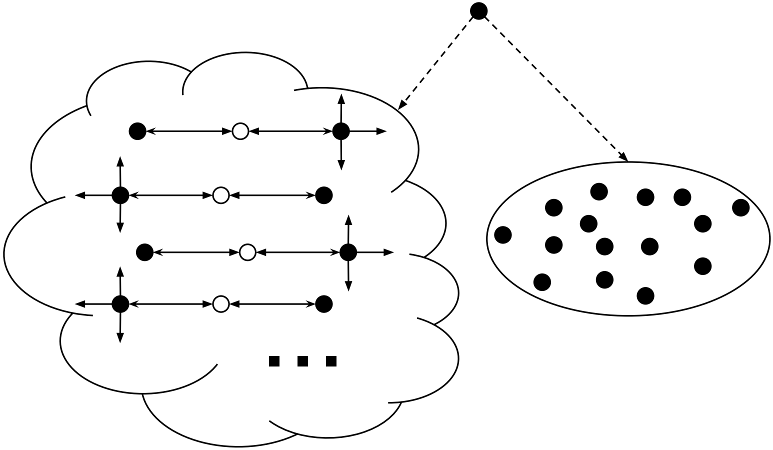


Figure: *Interactivity*$_{(N,M)}$, composure of *ChugMachine*$_N$ (Cloud), and M instances of *UserInput*$_{(5,2)}$.

ErLam: Simulation & Visualization

System Behaviours: Partial System Cooperativity

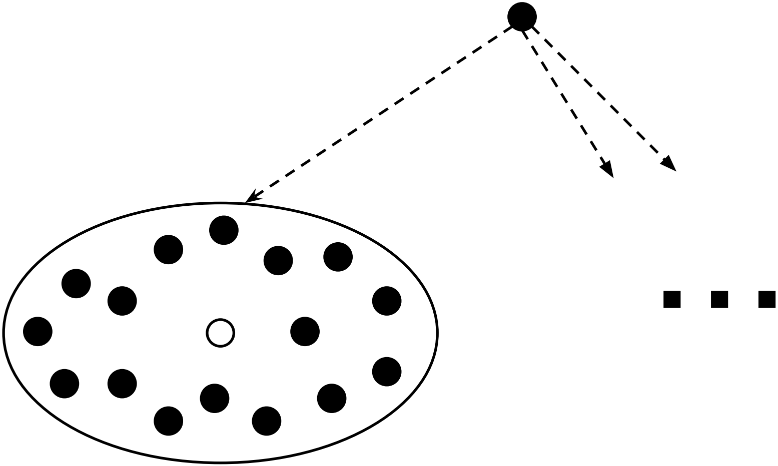


Figure: $PTree_{(W,N)}$, a composure of W $ClusterComm_{(N,1)}$ instances running concurrently.

Things we could log:

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- Process Queue Size (per LPU)

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- ...

Current Section:

3 Scheduler Implementations

- Example Schedulers
- Feedback Schedulers

Scheduler Implementations: Example Schedulers

- Single-Thread Dual-Queue
  - Translation of CML scheduler
- Round-Robin with Single Global Queue (MTRRGQ)
  - No Work-Stealing
  - # LPUs can vary
- Round-Robin with Work-Stealing (MTRRWS)
  - Steal via direct access
  - Steal via advertisement

Scheduler Implementations: Feedback Schedulers

Three types of mechanics:

- Longevity-Based Batching
- Channel Pinning
- Bipartite-Graph Aided Sorting

Scheduler Implementations: Feedback Schedulers
Longevity-Based Batching

- Choose via Round-Robin
  - from batch rather than queue
  - keeps track of number of rounds (batch size)
- Work-Steal whole batches
- Spawn to batch unless: $|b_i| \geq B$
  - Make singleton with new process.
  - Push parent and child into new batch.

Scheduler Implementations: Feedback Schedulers
Longevity-Based Batching

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GOAL: Can batching based on longevity account for fine/coarse parallelism in application?

Scheduler Implementations: Feedback Schedulers

Channel-Pinning

- Upon call to *newchan*, pin to LPU based on spread algorithm:
  - *same* - LPU *newchan* is called is where it is pinned.
  - *even* - Cycle through LPUs and pin based on that.
  - ...
- Work-steal based on channel that's been pinned to you.

Scheduler Implementations: Feedback Schedulers
Channel-Pinning

- Upon call to *newchan*, pin to LPU based on spread algorithm:
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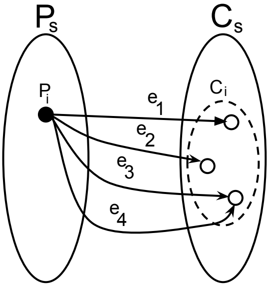
GOAL: Can an *even*-like spread increase early saturation?

Scheduler Implementations: Feedback Schedulers
Bipartite-Graph Aided Sorting

- Based on Round-Robin & Work-stealing
- Keep track of events which may effect cooperativity:
  - Spawning
  - Blocking/Unblocking
  - Steals
- If number of events over some threshold, re-sort.



Scheduler Implementations: Feedback Schedulers

Bipartite-Graph Aided Sorting

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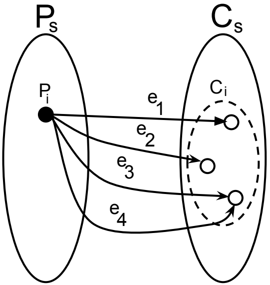


GOAL: Are alternate channel implementations worth exploration?

Current Section:

4 Results

Results:

Longevity-Based Batching

- *Can batching based on longevity recognize fine/coarse parallelism in an application?*

Channel Pinning

- *Can an* even-*like spread increase early saturation?*

Bipartite-Graph Aided Sorting

- *Are alternate channel implementations worth exploration?*

Results: Longevity-Based Batching

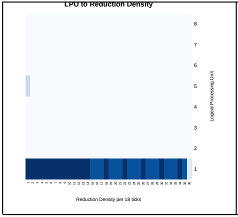
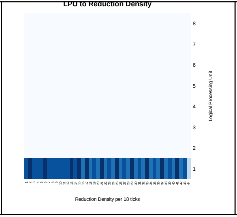
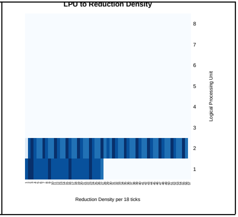
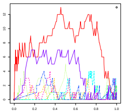
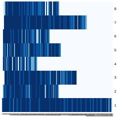
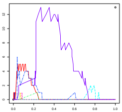
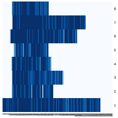
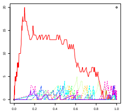
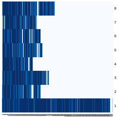
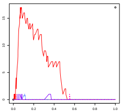
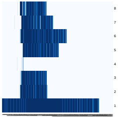
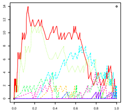
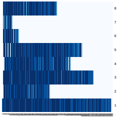
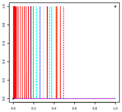
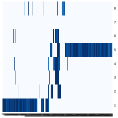
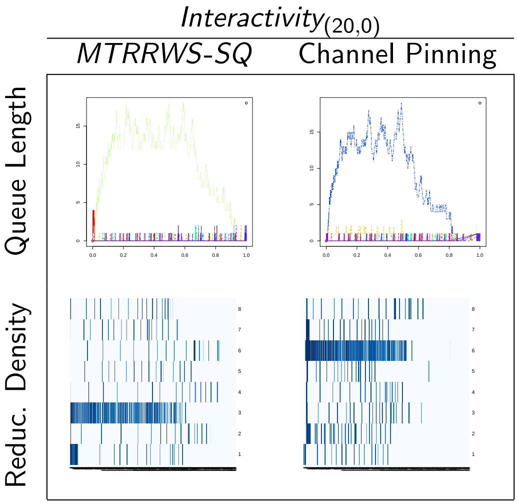
<table>
<tr><th></th><th colspan="3">$PRing_N$</th></tr>
<tr><th></th><th>$N = P = 8$</th><th>$N = B = 10$</th><th>$N = 2 * B = 20$</th></tr>
<tr><td>Reduc. Density</td><td>
</td><td>
</td><td>
</td></tr>
</table>

Table: Comparison of different sized $PRing_N$ on the Longevity Batching Scheduler with batch size $B = 10$.

Results: Longevity-Based Batching

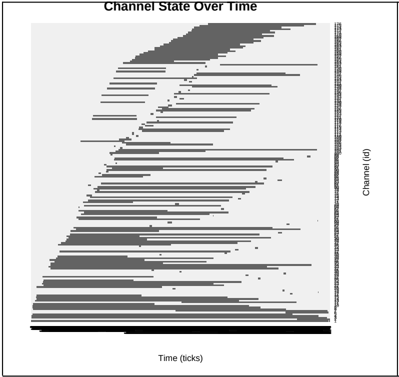
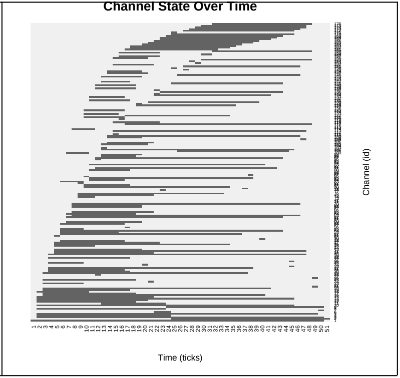
Time Quantum	$PTree_{(4,8)}$			
	MTRRWS-SQ		Long. Batcher	
	Chan. State	**Reduc. Density**	**Chan. State**	**Reduc. Density**
$R = 30$				
$R = 40$				
$R = 50$				

Results: Channel Pinning



Results: Bipartite-Aided Graph Sorting

Parallel Fibonacci

MTRRWS-SQ	Sorting Scheduler
	

Current Section:

5 Conclusions & Future Work

- ErLam Toolkit
- Cooperative Schedulers
- Cooperativity as a Metric

Conclusions & Future Work: ErLam Toolkit

- Test Primitives were nicely composable process behaviours.
  - More research into generating behaviours.
  - More compositions: PTree with Rings.
- Log generation, lots of overhead, but good observations.

Conclusions & Future Work: Cooperative Schedulers

- **Longevity Batching:**
  - Would benefit from heuristic based Quantum selection.
  - As it stands, limited gain from longevity recognition.
- **Channel Pinning:**
  - Promising saturation and work-stealing mechanic.
- **Bipartite-Graph Aided Sorting:**
  - Supprising results on MapReduce style applications.
  - Worth studying Blocking-Channels further for gains from sorting.

Conclusions & Future Work: Cooperativity as a Metric

- Possible to recognize and benefit from.
- The three example mechanics are promising and can be extended for practicle modern languages, despite simplistic simulation language.
- More to explore:
  - Alternate Message-Passing Types (Asymmetric?)
  - ...

Questions/Comments?

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Thank You!

Links

- https://github.com/dstar4138/erlam
- https://github.com/dstar4138/thesis_cooperativity
- http://dstar4138.com