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

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Background

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.

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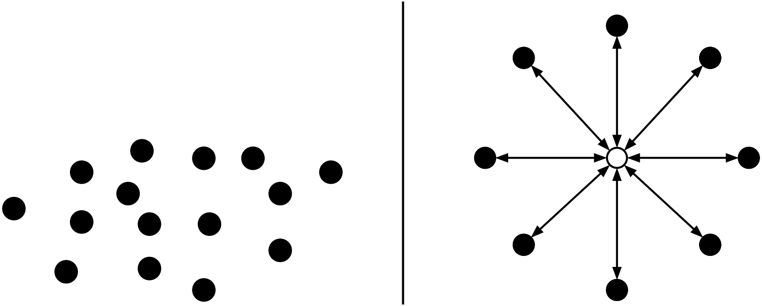
- *What statistics are useful?*

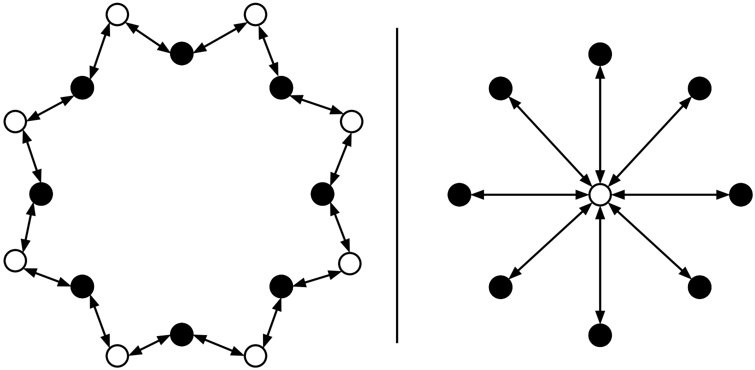
Background: Cooperativity

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 through synchronizing on a shared channel.

ErLam Toolkit

2 ErLam Toolkit

- The Language
- Channel Implementations
- Simulation & Visualization

ErLam Toolkit: The Language

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

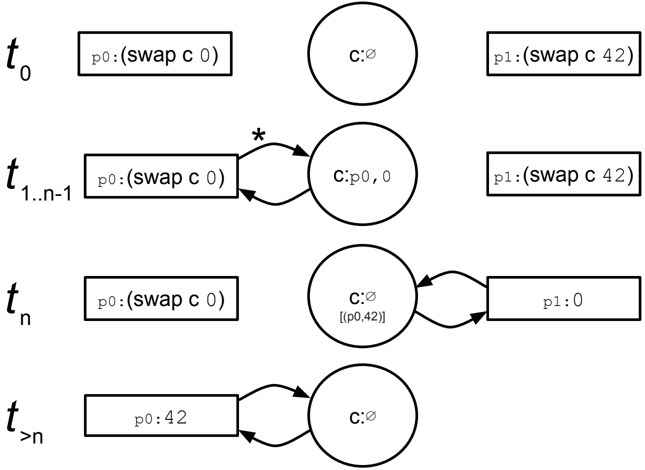
ErLam Toolkit: The Language

```
elib
    // ...
    ignore = (fun _.(fun y.y));
    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
```

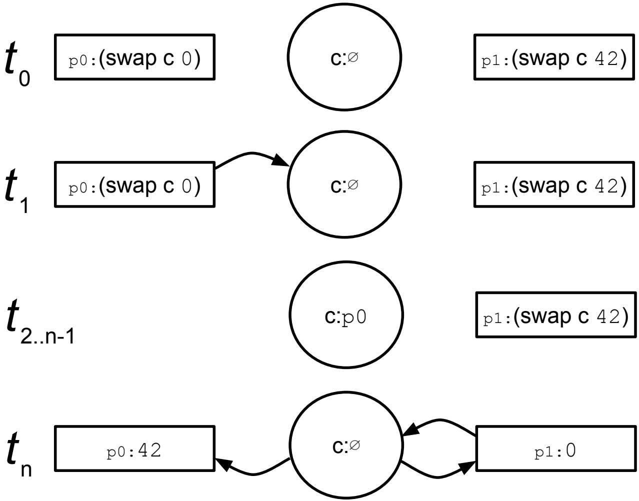
```
(fun c.
     (ignore
       (spawn (fun _.(swap c 42)))
       (swap c 0))
 newchan)
```

ErLam Toolkit: Channel Implementations

Process Blocking Swap



ErLam Toolkit: Channel Implementations
Process Absorption Swap



ErLam Toolkit: Simulation & Visualization

System Behaviours:

- Degree of Parallelism
- Consistency of Cooperation
- Degree of Longevity/Interactivity
- Partial System Cooperativity

Logging & Report Generation

ErLam Toolkit: Simulation & Visualization

System Behaviours: Degree of Parallelism

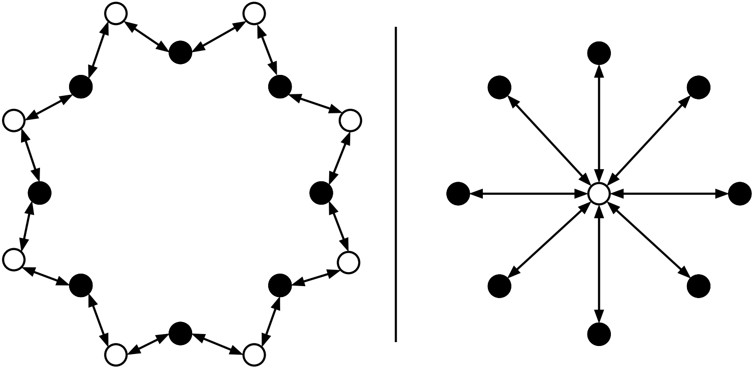


Figure: $PRing_N$, and $ClusterComm_{(N,1)}$ primitives to test degree of parallelism.

ErLam Toolkit: Simulation & Visualization

System Behaviours: Consistency of Cooperation

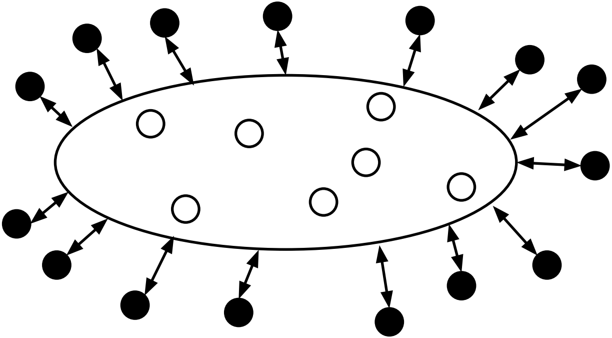


Figure: $ClusterComm_{(N,M)}$ to test effect of consistency on scheduler.

ErLam Toolkit: Simulation & Visualization

System Behaviours: Degree of Interactivity

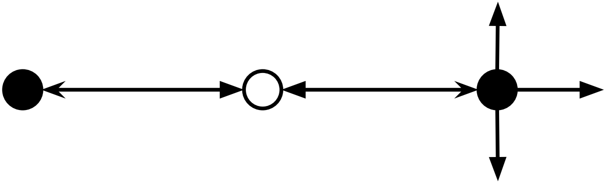


Figure: $UserInput_{(T,C)}$, simulates user interaction or a number (C) of external/timed (T) events.

ErLam Toolkit: Simulation & Visualization

System Behaviours: Degree of Interactivity

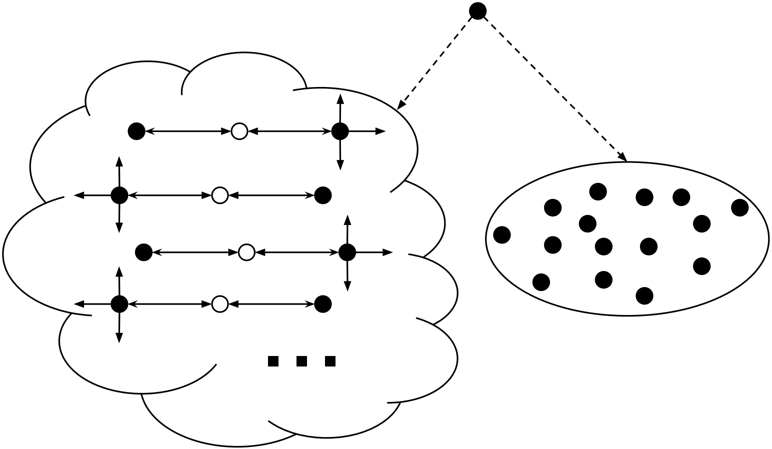


Figure: *Interactivity*$_{(N,M)}$, composure of *ChugMachine*$_N$ (Cloud), and M instances of *UserInput*$_{(5,2)}$.

ErLam Toolkit: Simulation & Visualization
System Behaviours: Partial System Cooperativity

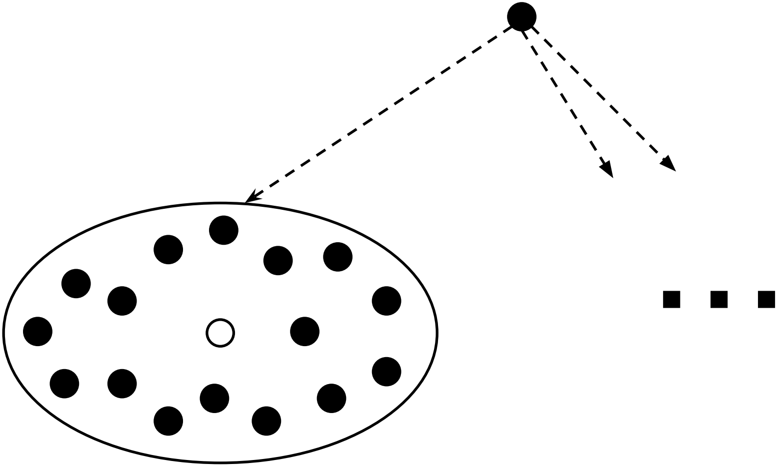
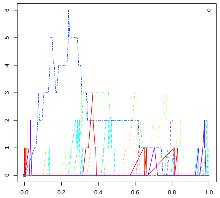
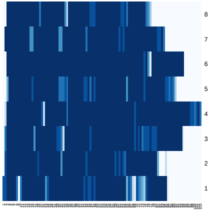
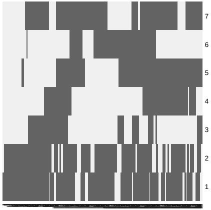


Figure: $PTree_{(W,N)}$, a composure of W $ClusterComm_{(N,1)}$ instances running concurrently.

Things we could log:

- Process Queue Size (per LPU)
- Quantity of Reductions/Yields/Preempts
- State of the Scheduler (waiting/running)
- Channel State (Blocked/Unblocked)
- ...

ErLam Toolkit: Simulation & Visualization

Queue Size	Reduc. Density	Channel State
		

Scheduler Implementations

3 Scheduler Implementations

- Example Schedulers
- Feedback Mechanisms

Scheduler Implementations: Example Schedulers

- (MTRRGQ) - Round-Robin with Single Global Queue
  - All LPUs share a Process Queue.
- (MTRRWS-SQ) - Round-Robin with Work-Stealing via Direct Access
  - All LPUs have their own Process Queue.
  - LPUs can steal processes by grabbing them off the end of another LPU's queue.

Scheduler Implementations: Feedback Mechanisms

Three types of mechanics:

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

Scheduler Implementations: Feedback Mechanisms

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.

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

Scheduler Implementations: Feedback Mechanisms
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 Mechanisms

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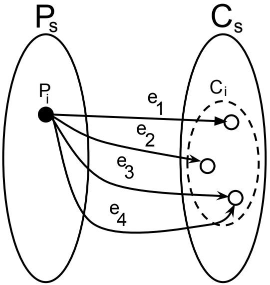
GOAL: Can an *even*-like spread increase early saturation?

Scheduler Implementations: Feedback Mechanisms
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 Mechanisms
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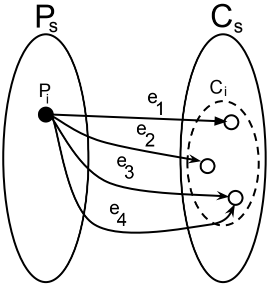


GOAL: Are alternate channel implementations worth exploration?

Results

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

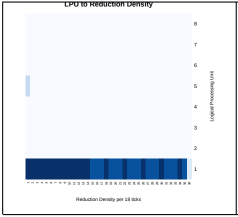
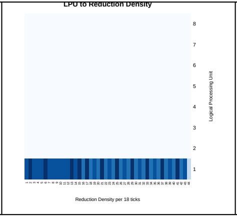
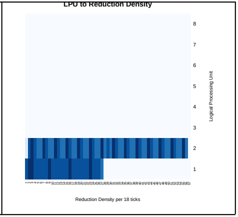
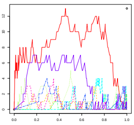
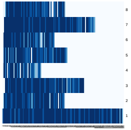
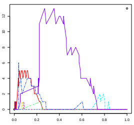
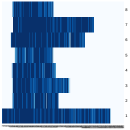
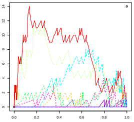
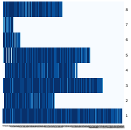
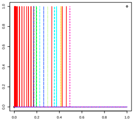
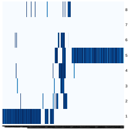
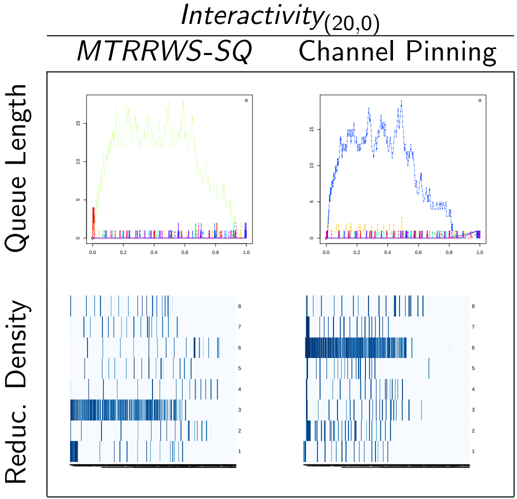
	$PRing_N$		
	$N = P = 8$	$N = B = 10$	$N = 2 * B = 20$
Reduc. Density			

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

Results: Longevity-Based Batching

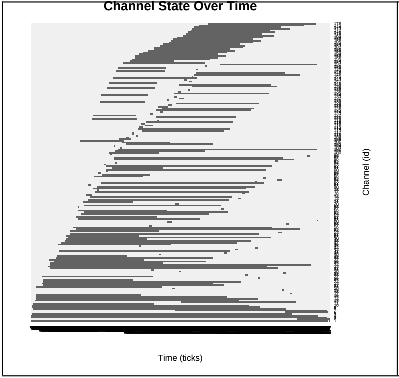
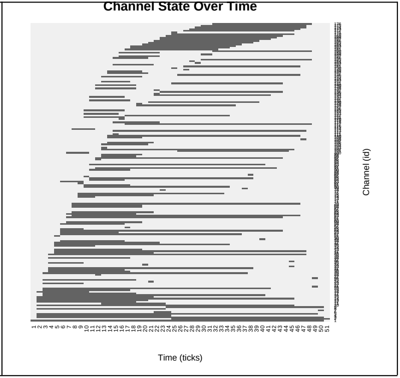
Time Quantum	$PTree_{(4,8)}$			
	MTRRWS-SQ		Long. Batcher	
	Chan. State	**Reduc. Density**	**Chan. State**	**Reduc. Density**
$R = 30$				
$R = 50$				

Results: Channel Pinning



Results: Bipartite-Aided Graph Sorting

Parallel Fibonacci

MTRRWS-SQ	Sorting Scheduler
	

Conclusions & Future Work

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