Boosting Evolution:
Scaling Erlang up to 64 cores

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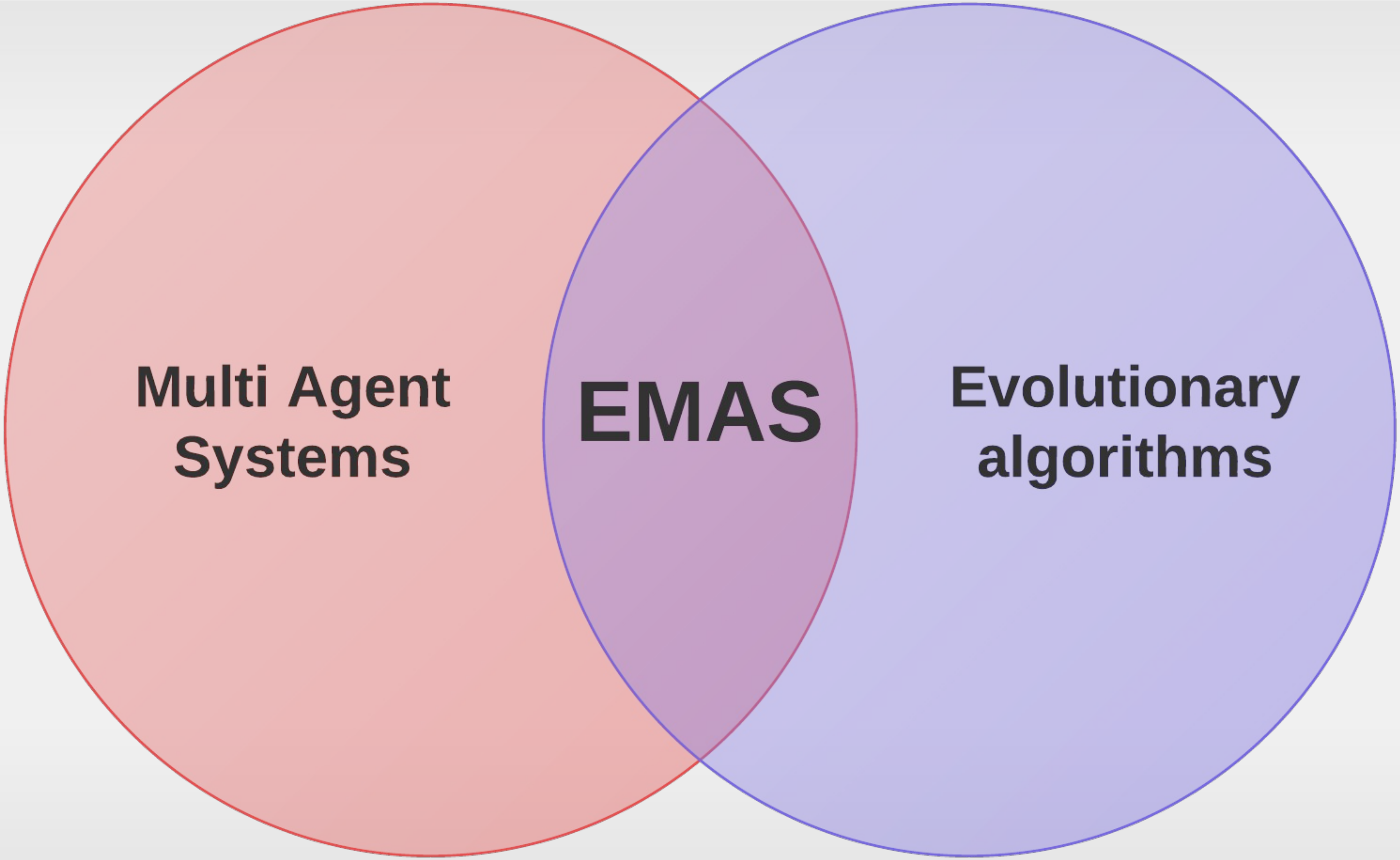
Agenda

1) Algorithm description
2) Different implementations
3) Scaling challenges and applied solutions
4) Summary

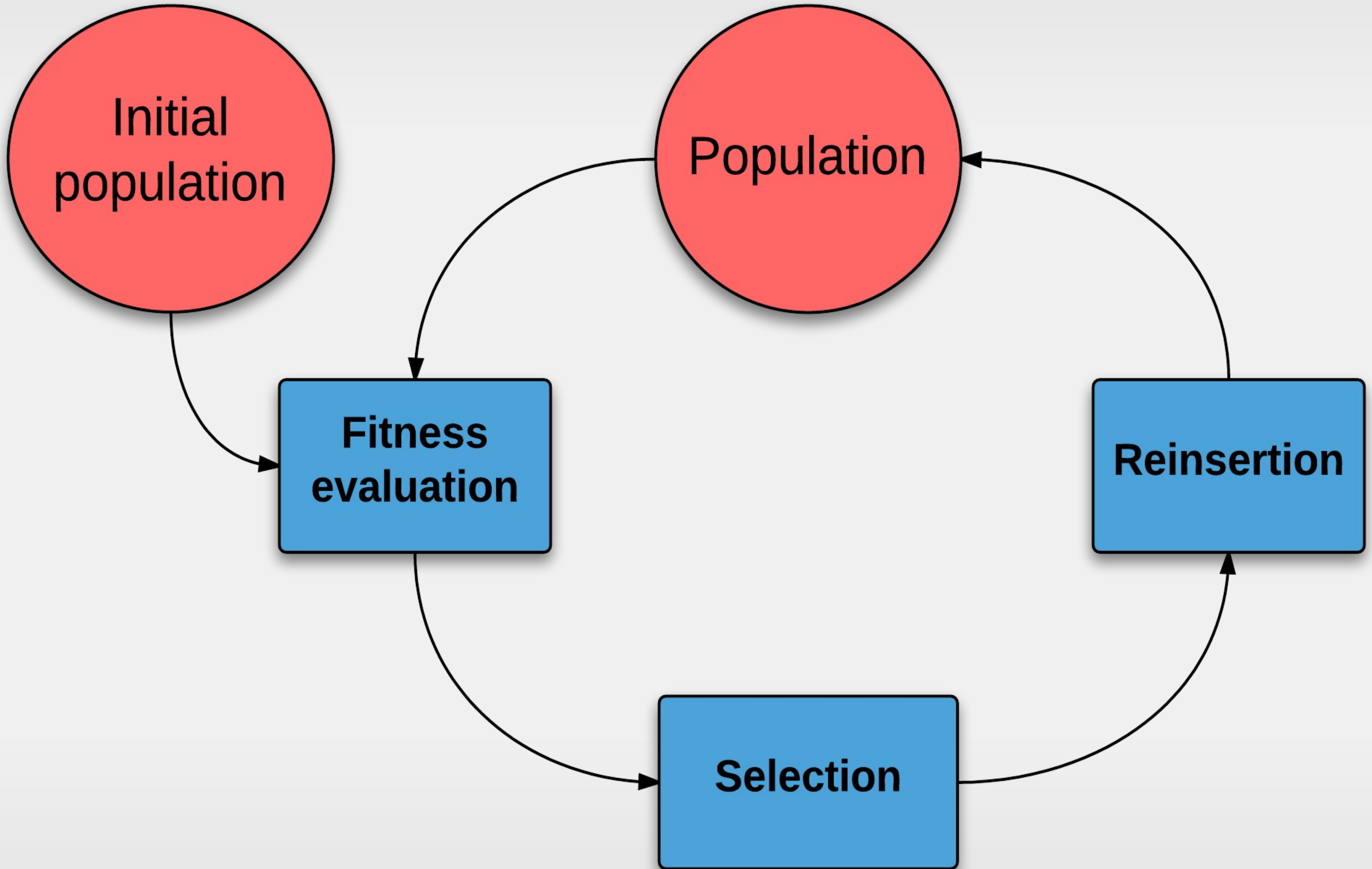
EMAS

Evolutionary Multi Agent System

EMAS



Evolutionary Algorithm

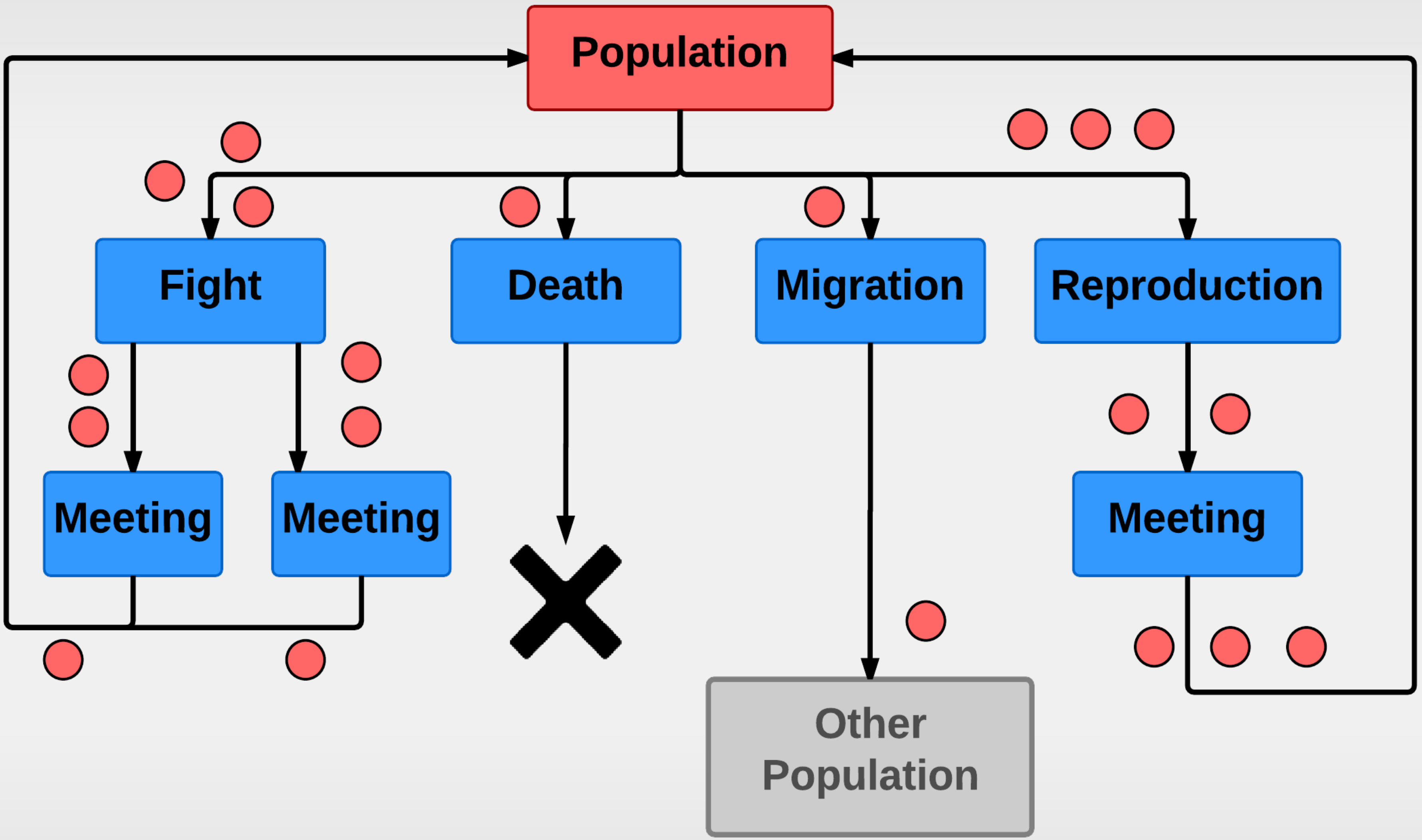


EMAS

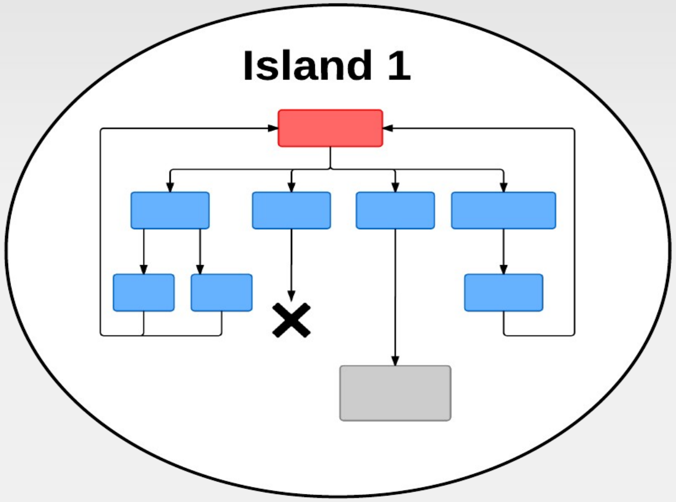
- Optimization algorithm
  - Aims to avoid local optima
  - e.g. for solving scheduling problems
- Autonomous agents
- Decentralized computation
- Easily parallelizable

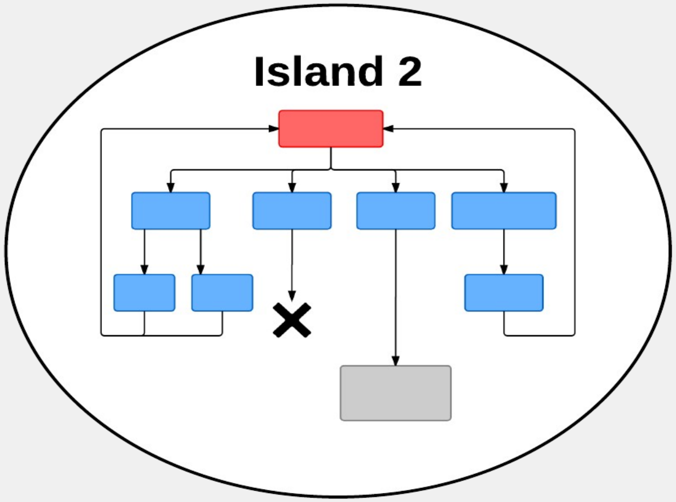
EMAS – how it works

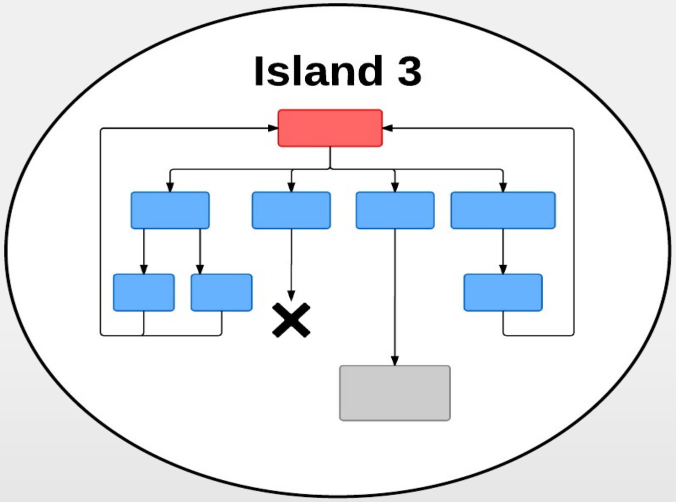
INTELLIGENT INFORMATION SYSTEMS GROUP



EMAS – islands





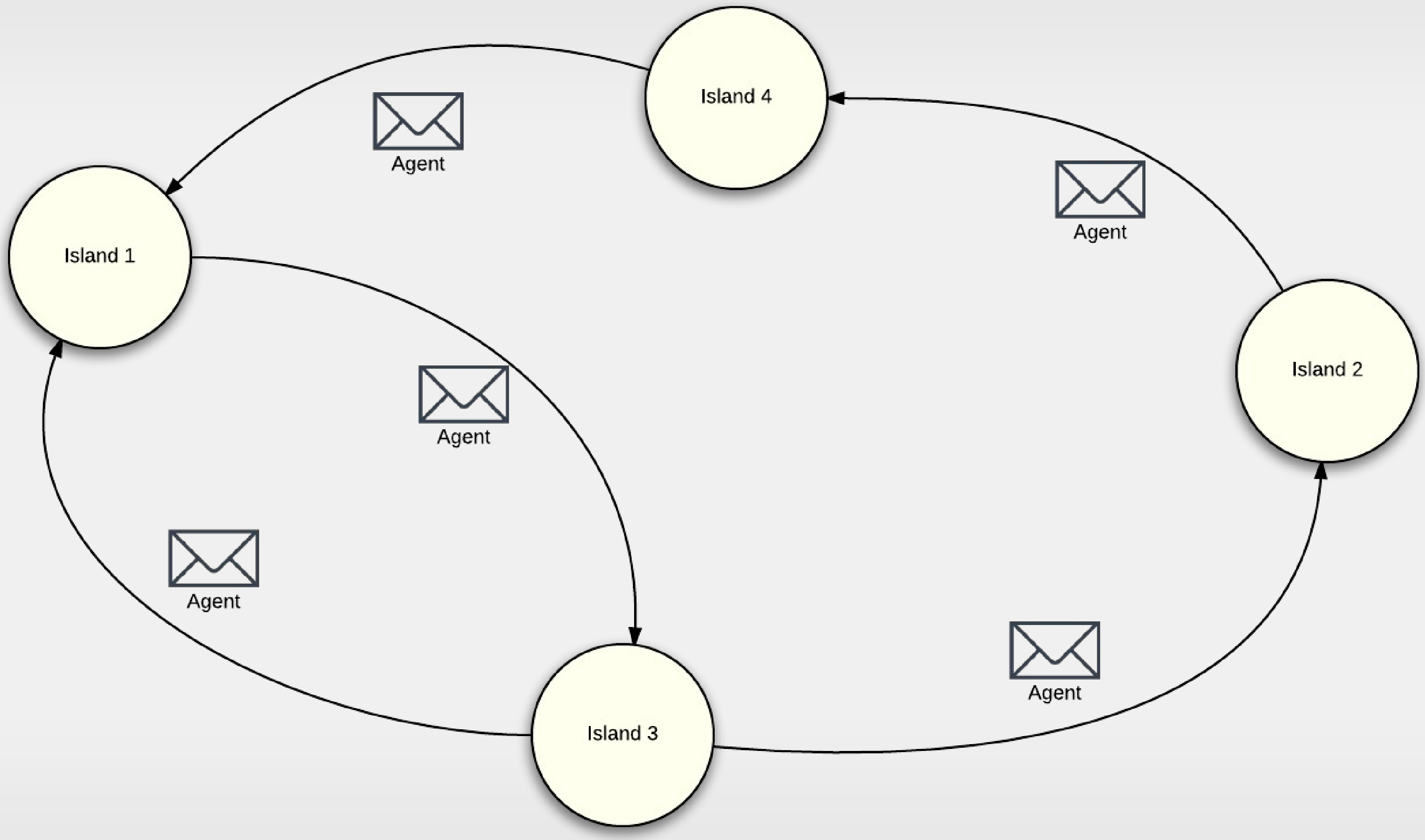


Implementations

- Sequential
- Hybrid (coarse-grained)
- Concurrent (fine-grained)
- Skel (coarse-grained)

Everything implemented in Erlang

Coarse-grained



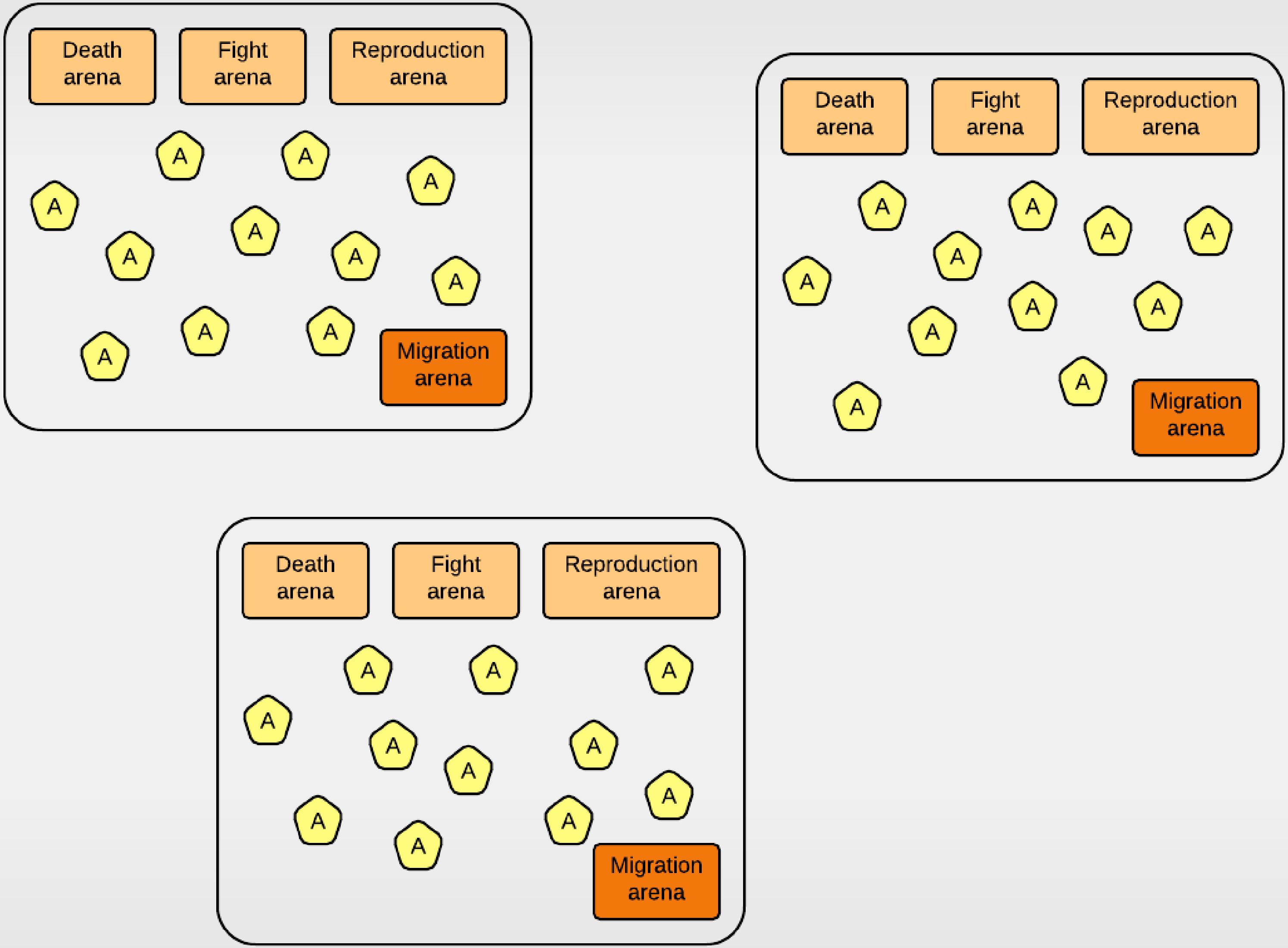
Coarse-grained (skel)

```
ShuffleFun = fun({IsNo, Island}) ->
                      {IsNo, shuffle(Island)}
             end,

Pipe = {pipe, [{seq, TagFun},
               {seq, GroupFun},
               {seq, MigrateFun},
               {seq, WorkFun},
               {seq, ShuffleFun}]},

Result = skel:do([{map, [{feedback,
                          [Pipe],
                          _While = fun(_Islands) ->
                                           os:timestamp() < EndTime
                                   end}],
                   Workers}],
                 [Population]),
```

Fine-grained

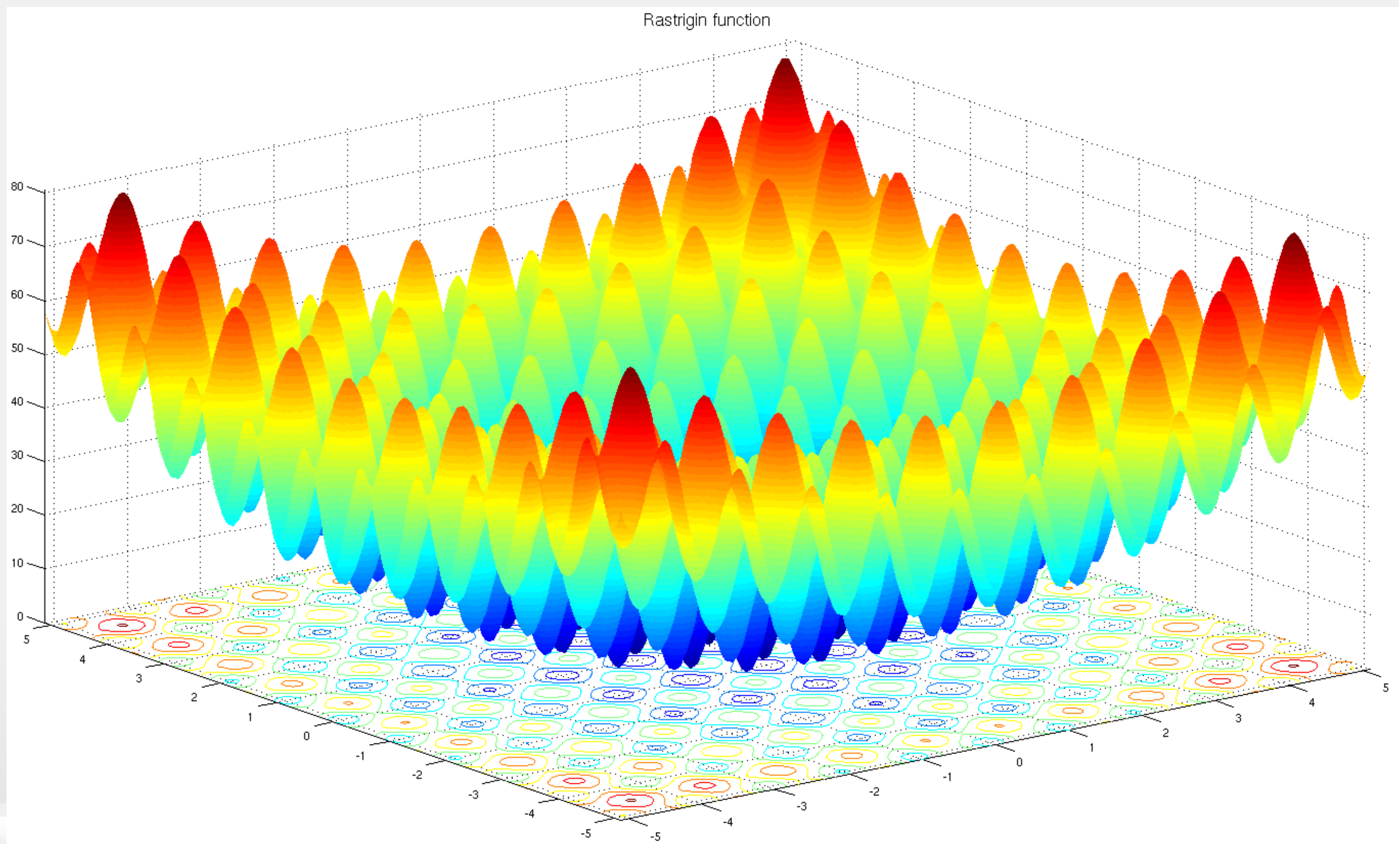


Scaling

Optimized function

- Optimization of Rastrigin function
- 100 dimensions
- 64 islands

$$f(\mathbf{x}) = An + \sum_{i=1}^{n} \left[x_i^2 - A\cos(2\pi x_i)\right]$$



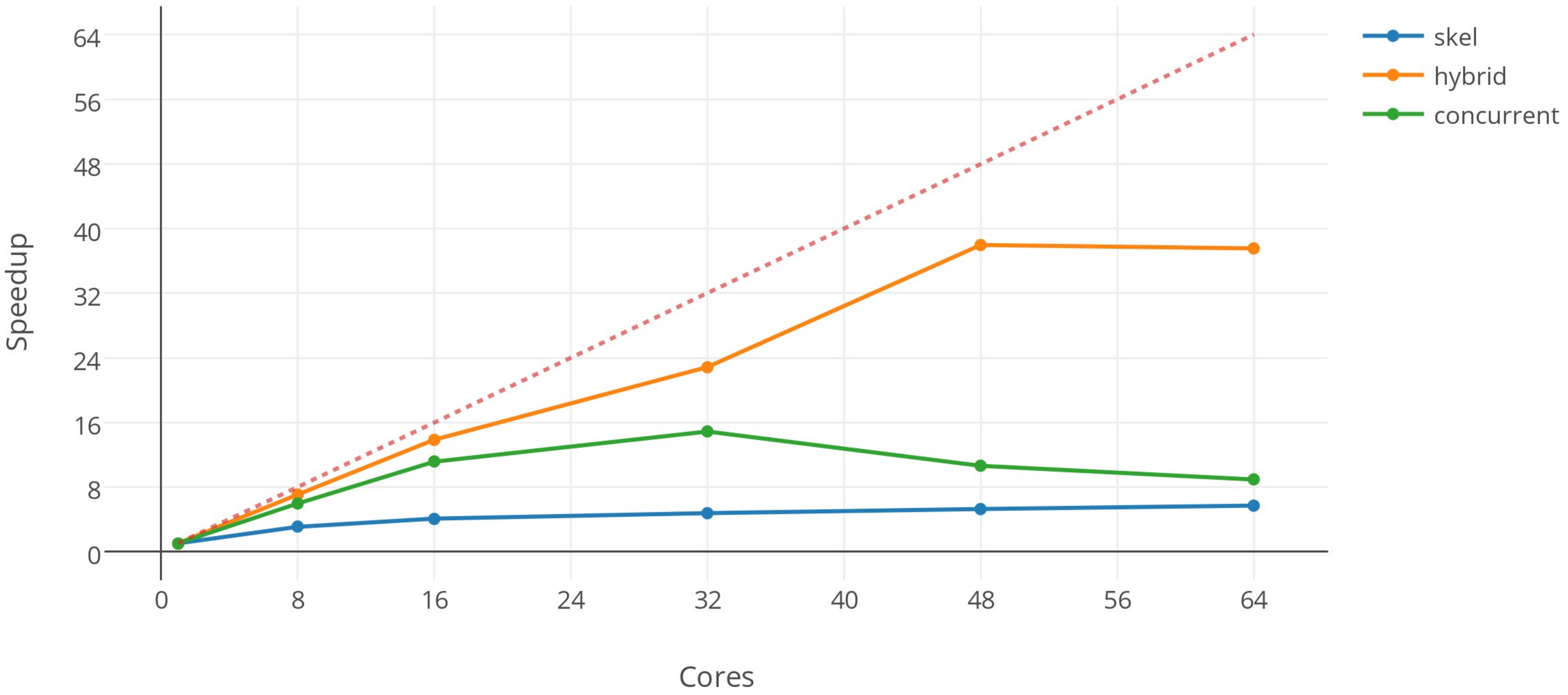
Test infrastructure

- Academic Computer Centre CYFRONET AGH Kraków, Poland
- Testing machine:
  - 1 hardware node
  - Processor: AMD Opteron 6276 2,3 GHz
  - Number of CPUs: 4
  - Total cores: 64
  - RAM: 256 GB
  - OS: Scientific Linux

Initial approach

- N cores, N times faster – not that simple!
- Up to 8 cores Erlang scales well
- Problems arise when the application is run on a higher number of cores

Initial approach



Diagnosing issues

- Not a typical Erlang use case
- Standard profilers (eprof, percept, bencherl)
- Checking schedulers load
  - `erlang:statistics(scheduler_wall_time)`
- lcnt (http://www.erlang.org/doc/man/lcnt.html)
  - Runtime system lock profiling tool
  - Measures lock contention
  - Requires VM recompilation (`--enable-lock-counter`)
  - Introduces some overhead

lcnt output

32 CORES:

lock	id	#tries	#collisions	collisions [%]	time [us]	duration [%]
make_ref	1	13247682	3057885	23.0824	14192658	22.0958
timeofday	1	6757268	1318938	19.5188	7911404	12.3168
run_queue	64	74262017	847072	1.1407	3879060	6.0391
pix_lock	1024	29215	17	0.0582	1390432	2.1647

48 CORES:

make_ref	1	7899140	1209364	15.3101	37203715	54.5142
pix_lock	1024	127348	192	0.1508	8623504	12.6359
timeofday	1	3953082	686742	17.3723	7072442	10.3632
run_queue	64	44374363	305127	0.6876	3094534	4.5344

64 CORES:

make_ref	1	8257415	2978439	36.0699	775283090	1134.5281
pix_lock	1024	632012	896	0.1418	31974180	46.7901
timeofday	1	4203173	631989	15.0360	5324563	7.7918
run_queue	64	47934713	316483	0.6602	2276438	3.3313

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Removing *make_ref*

- Attempt to get rid of the *make_ref* lock
- Application consists of several *gen_server* processes
- Substitute *gen_server:call* with *gen_server:cast* wherever possible

```
call_arena(Pid, Agent) ->
    gen_server:cast(Pid, {interact, self(), Agent}),
    receive
        {response, Reply} ->
            Reply
    end.
```

lcnt results

32 CORES:

lock	id	#tries	#collisions	collisions [%]	time [us]	duration [%]
timeofday	1	7345211	1666056	22.6822	11071384	17.1615
run_queue	64	75714562	931454	1.2302	5378769	8.3375
timer_wheel	1	3613450	224958	6.2256	1131863	1.7545
pix_lock	1024	22168	85	0.3834	919860	1.4259

48 CORES:

timeofday	1	5299733	1239475	23.3875	13788049	21.6985
pix_lock	1024	78638	46	0.0585	5809275	9.1422
run_queue	64	54858096	459805	0.8382	5007581	7.8805
timer_wheel	1	2385084	112436	4.7141	1000315	1.5742

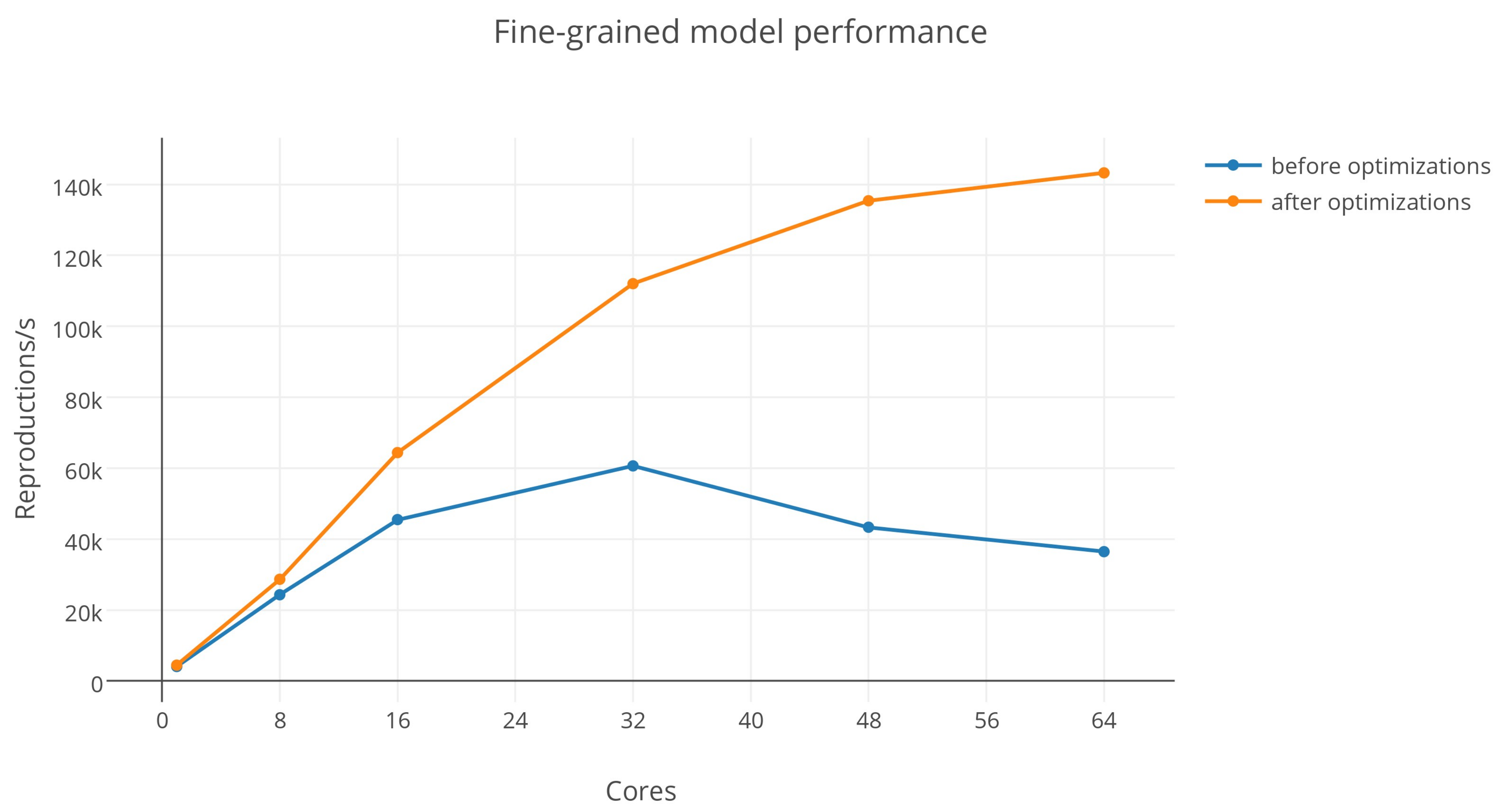
64 CORES:

pix_lock	1024	348272	154	0.0442	21450829	33.2841
timeofday	1	5085784	845736	16.6294	7829344	12.1484
run_queue	64	51053700	310745	0.6087	2571008	3.9893
timer_wheel	1	2317335	79159	3.4159	501694	0.7785

Logger

- Introduced *exometer* in the place of a previous logger `https://github.com/Feuerlabs/exometer`
- Attempt to reduce contentions on the *timeofday* lock
- Built-in counters work well
- Fitness monitoring is <u>expensive</u>. Approaches:
  - Built-in histogram entry
  - ETS probes
  - NIFs

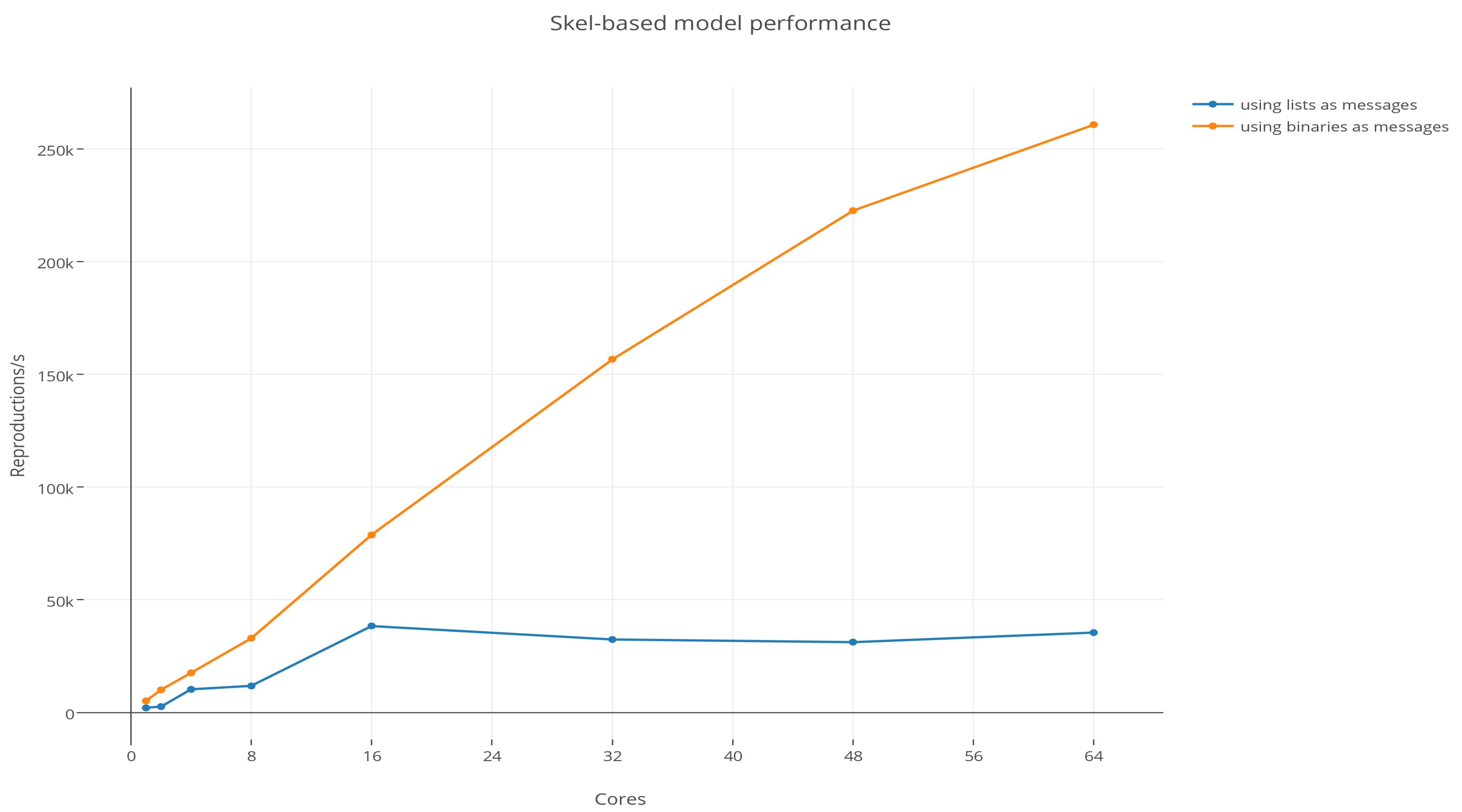
Performance improvement



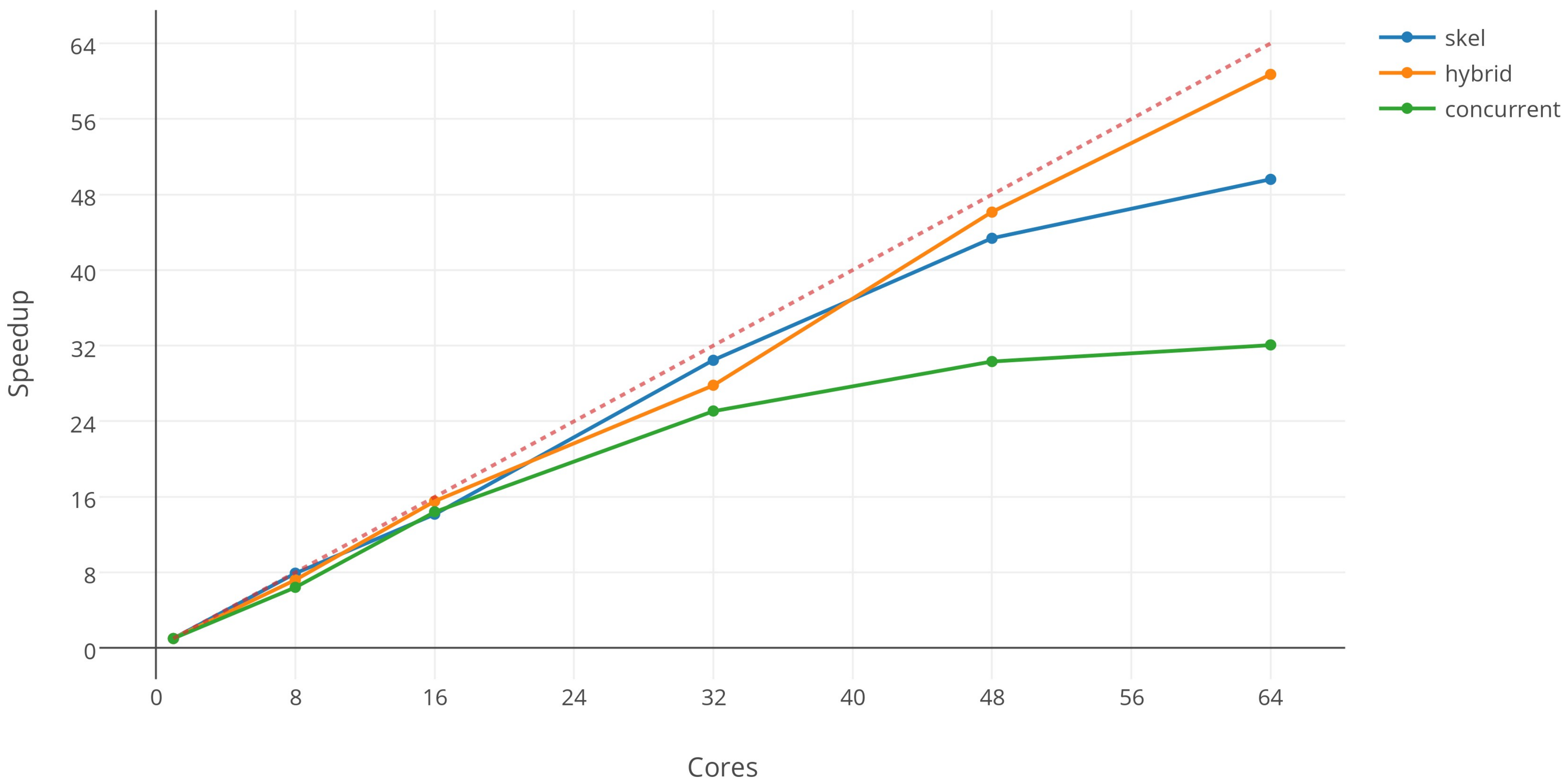
Skel improvement

- Using binary data type instead of Erlang lists
- All data is copied in messages between processes
  - Except for binaries over 64 bytes on the same node
- Cost of decoding/encoding becomes smaller than gain of not copying

Skel improvement results



Final scalability



Summary

- Scaling Erlang vertically is not completely painless
- Asynchronous communication
- Don't check the time/timer too often
- Use binaries instead of lists
- Check your locks (lcnt)
- Use the latest VM
- Ask other people

Links

- http://github.com/ParaPhraseAGH/erlang-emas
- http://github.com/ParaPhraseAGH/erlang-mas
- http://www.paraphrase.agh.edu.pl/
- http://paraphrase-ict.eu/
- http://github.com/ParaPhrase/skel