Evaluation of the impact on energy consumption of lazy versus strict evaluation of data-structures

Gilberto Melfe, Alcides Fonseca, João Paulo Fernandes

September 3, 2018

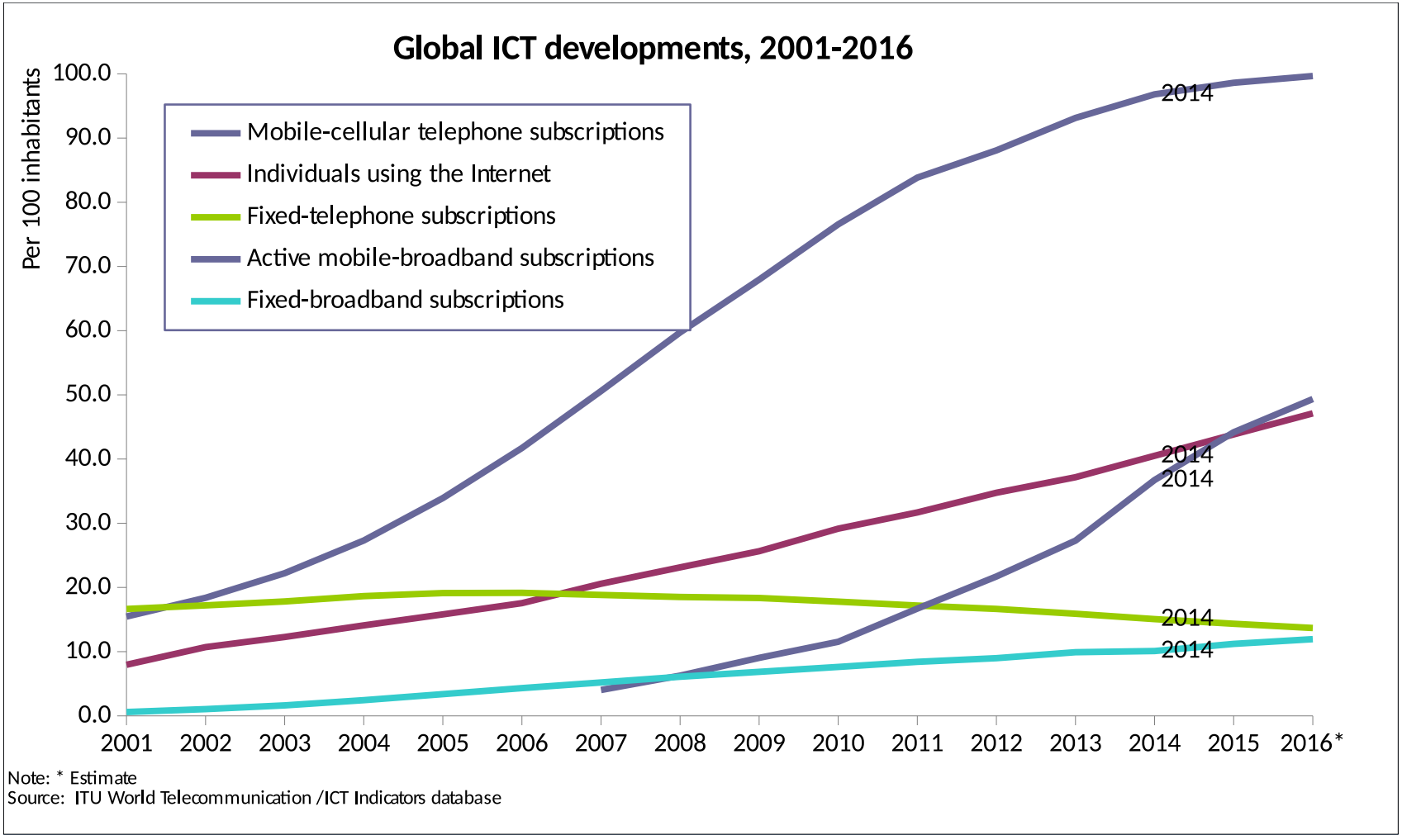
Introduction

Introduction

Where are we? Where are we heading?

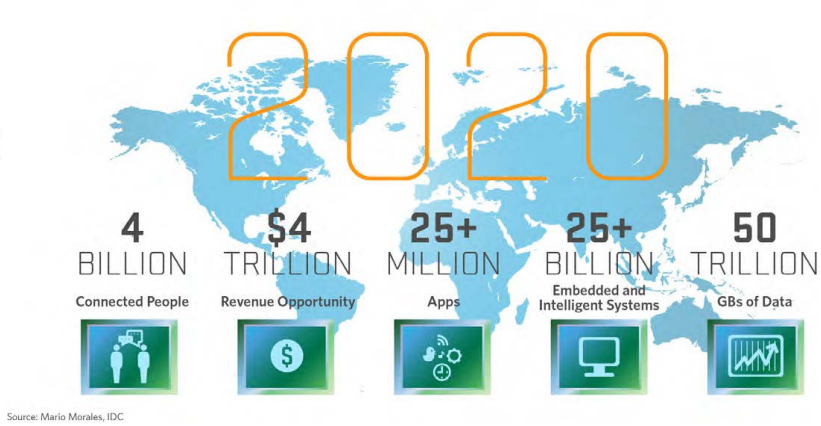
Introduction

Where are we? Where are we heading?



Introduction

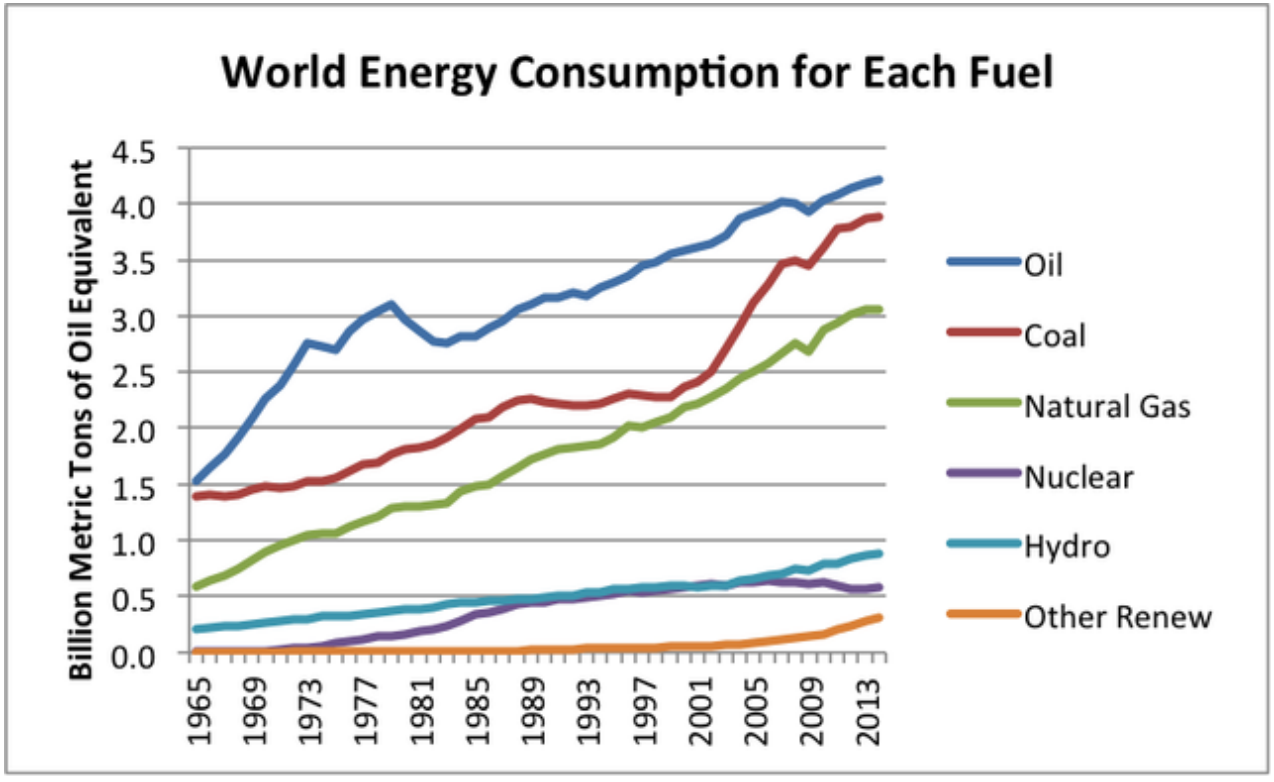
Where are we? Where are we heading?



Source: http://cdn2.business2community.com/wp-content/uploads/2016/06/internet-of-things.jpg

Introduction

And the problem is. . .



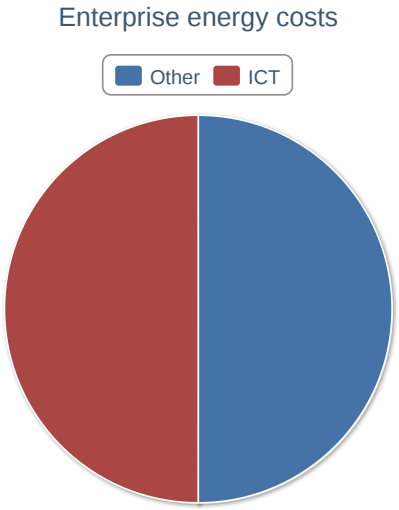
Introduction

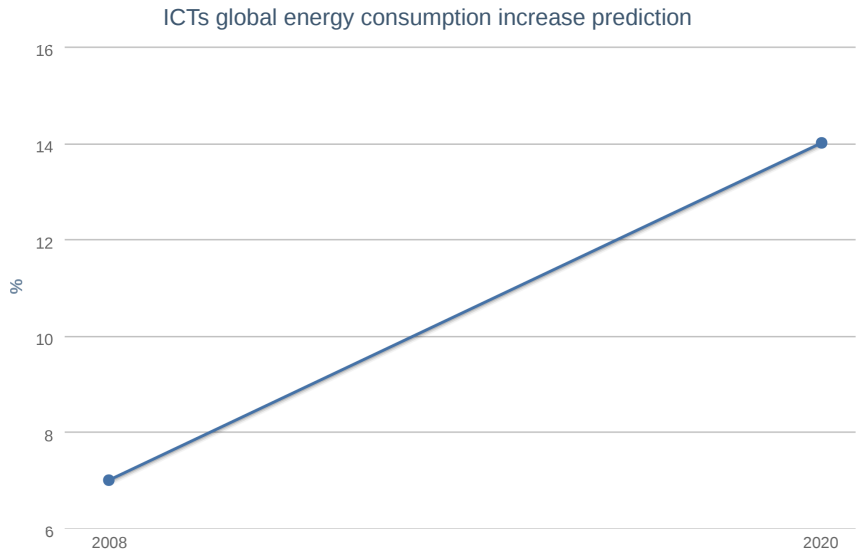
And the problem is. . .

DIBYANGSHU SARKAR/AFP/Getty Images

Introduction

Some numbers...





Introduction

We must. . .

Introduction

We intend to...

- Search possible gains in the energy consumption induced by software
  - Maybe between 30% and 90%?
- Focus on the `Haskell` language

Introduction

We intend to...

- Search possible gains in the energy consumption induced by software
  - Maybe between 30% and 90%?
- Focus on the `Haskell` language

Introduction

We have. . .

- Investigated the `Edison` library
  - Refactoring, to use alternative data structure implementations
  - Concerning Package and RAM energy consumptions
  - Compiler optimizations effect
- http://green-haskell.github.io

Introduction

Research Question!

RQ. How do execution time and Package and RAM energy consumptions are affected by the use of a lazy or strict data structure implementation?

Approach

Data structures

Maps

Data.Map	a general-purpose implementation of ordered maps (dictionaries), based on balanced binary trees
Data.IntMap	an efficient implementation of maps, with integer keys, based on big-endian patricia trees
Data.HashMap	an implementation of unordered maps from hashable keys to values, optimized for performance, based on hash array mapped tries

Benchmark

Benchmark Operations

iters	*operation*	*base*	*elems*
1	add	100000	100000
1000	addAll	100000	1000
1	clear	100000	n.a.
1000	contains	100000	1
5000	containsAll	100000	1000
1	iterator	100000	n.a.
10000	remove	100000	1
10	removeAll	100000	1000
10	retainAll	100000	1000
5000	toArray	100000	n.a.

$$iters * operation(base, elems)$$

Benchmark

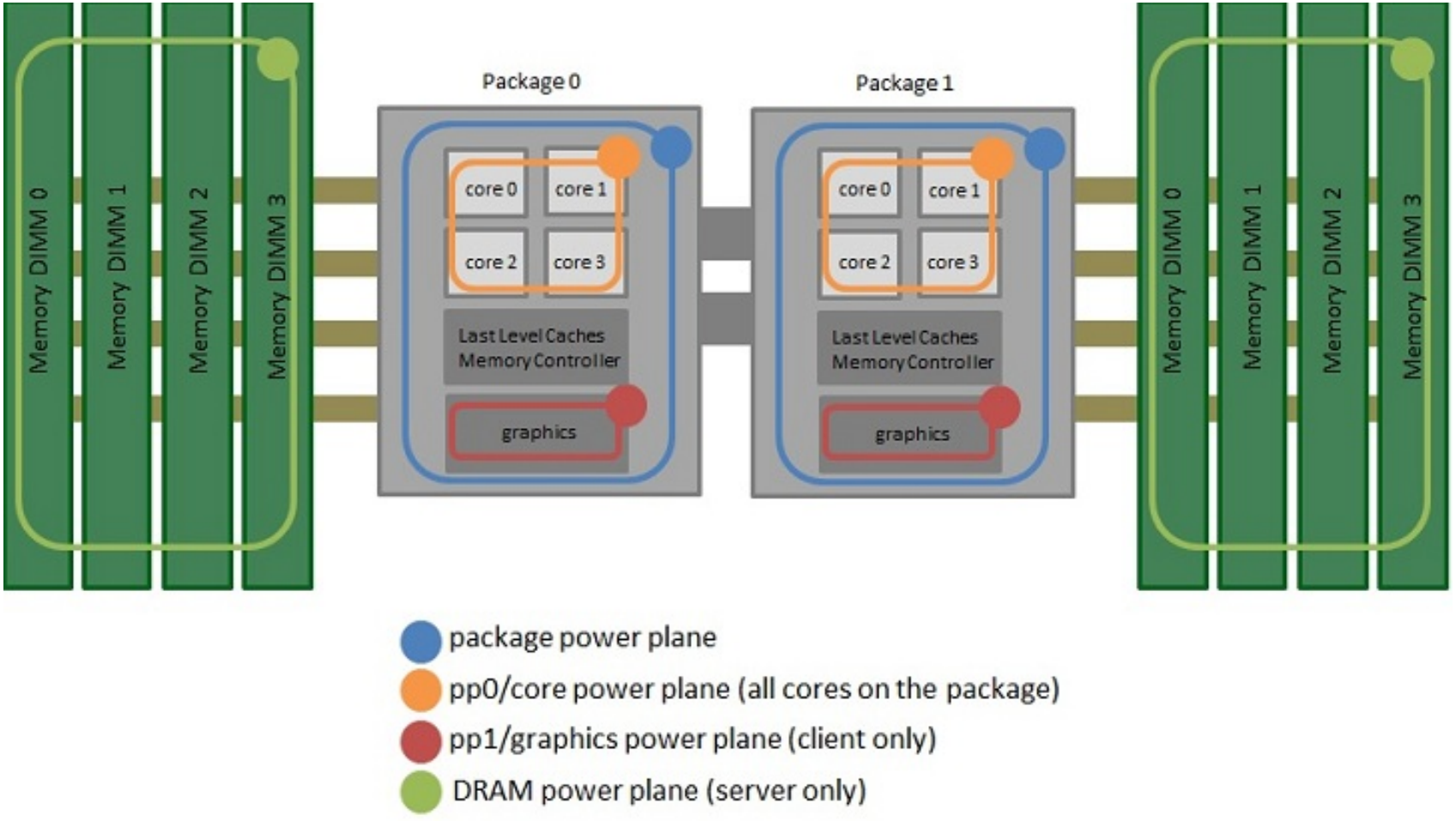
Benchmark Operations

```
removeAll :: Map Key Datum -> Map Key Datum -> Map Key Datum
removeAll = difference

retainAll :: Map Key Datum -> Map Key Datum -> Map Key Datum
retainAll = intersectionWith const
```

An interface for measuring energy consumption

RAPL



Source: https://software.intel.com/en-us/articles/intel-power-governor

Benchmark execution and analysis

Criterion

```
import Criterion.Main

-- Our benchmark harness.
main = defaultMain [
    bgroup "Map/" [
        env (...) -> bench addAllOpDesc $
            nf ( addAllNTimes a b ) addAllNRepeats
    ]
]
```

Benchmark execution and analysis

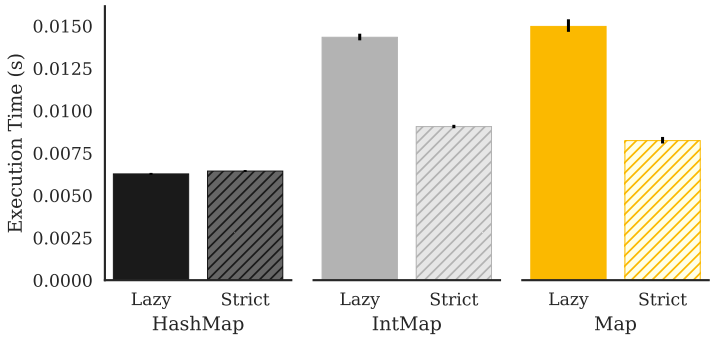
Criterion

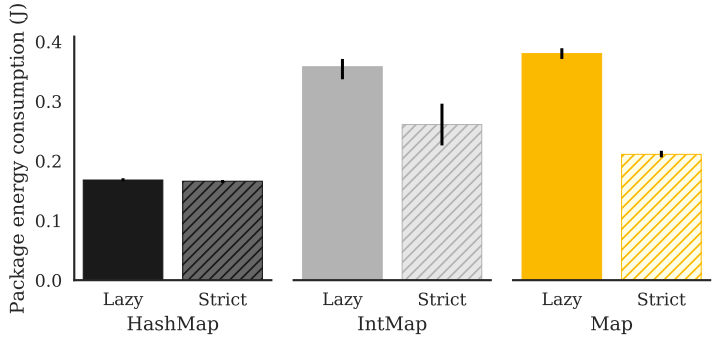
```
benchmarking (...)/addAll_1000_times_1000_elements_to_100000
time                    1.245 s    (1.234 s .. 1.261 s)
                        1.000 R^2   (1.000 R^2 .. 1.000 R^2)
mean                    1.248 s    (1.246 s .. 1.251 s)
std dev                 3.883 ms   (0.0 s .. 4.130 ms)
packageEnergy:          1.000 R^2   (0.998 R^2 .. 1.000 R^2)
  iters                 31.288     (29.594 .. 33.275)
  y                     0.545      (-2.154 .. 5.209)
dramEnergy:             1.000 R^2   (1.000 R^2 .. 1.000 R^2)
  iters                 10.404     (10.214 .. 10.680)
  y                     0.121      (-0.262 .. 0.671)
```

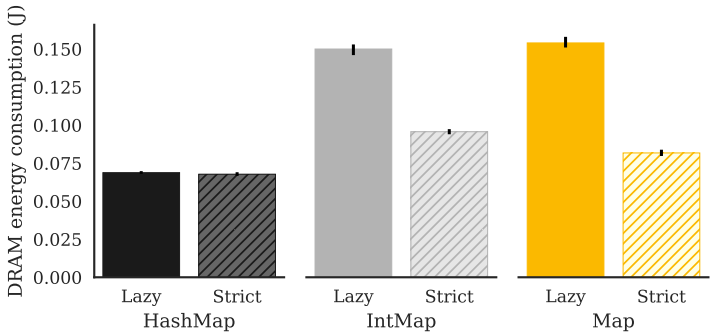
Results

Results

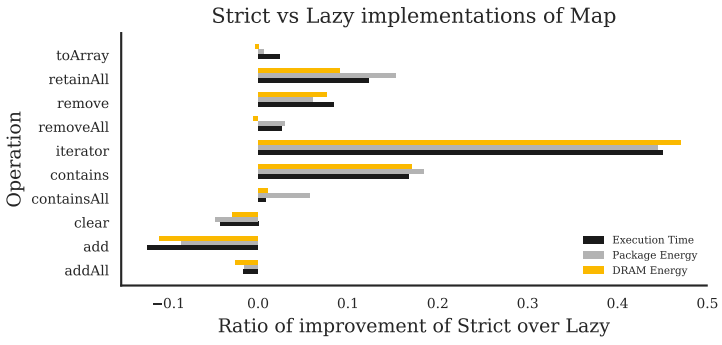
Lazy vs Strict, Iterator

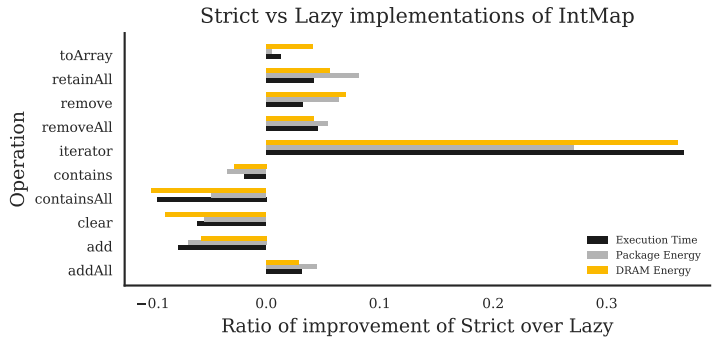


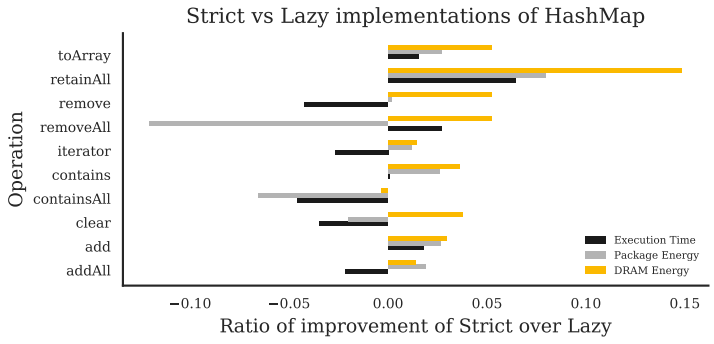




Results


Strict vs Lazy implementations of Map
Operation
toArray
retainAll
remove
removeAll
iterator
contains
containsAll
clear
add
addAll
Execution Time
Package Energy
DRAM Energy
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
Ratio of improvement of Strict over Lazy


Strict vs Lazy implementations of IntMap
Operation
toArray
retainAll
remove
removeAll
iterator
contains
containsAll
clear
add
addAll
Execution Time
Package Energy
DRAM Energy
−0.1
0.0
0.1
0.2
0.3
Ratio of improvement of Strict over Lazy


Strict vs Lazy implementations of HashMap
Operation
toArray
retainAll
remove
removeAll
iterator
contains
containsAll
clear
add
addAll
Execution Time
Package Energy
DRAM Energy
−0.10
−0.05
0.00
0.05
0.10
0.15
Ratio of improvement of Strict over Lazy

Conclusions

Conclusions

The answer to the RQ. is...

RQ. How do execution time and Package and RAM energy consumptions are affected by the use of a lazy or strict data structure implementation?

- Energy consumption is proportional to the execution time, and
- strict evaluation tends to be more efficient in terms of execution time and energy consumption than the lazy evaluation

Future Work

Future Work

What's next?

- create/use more real-world benchmarks
- explore laziness vs strictness in more complex algorithms that rely on data structures (sorting or graph search algorithms)

Evaluation of the impact on energy consumption of lazy versus strict evaluation of data-structures

Gilberto Melfe, Alcides Fonseca, João Paulo Fernandes

September 3, 2018

http://green-haskell.github.io