Energy Efficiency Evaluation in Heterogeneous Computers

Borja Pérez, Esteban Stafford, José Luis Bosque, Ramón Beivide

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Motivation

- Energy efficiency is a real hurdle in the path to Exascale
  - Mont-Blanc
- GPUs offer a great FLOPs per Watt ratio but their truly efficient use is not trivial
  - Are based on Host-Device models
- How do work distribution and load balancing affect efficiency?

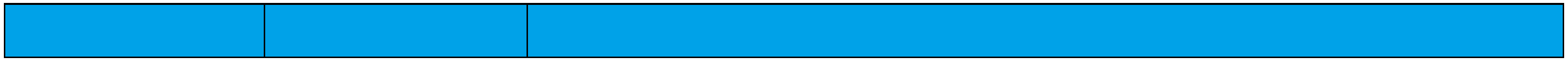
Goal

- Analyze the impact on both time and energy of distributing the load of a single, data-parallel kernel among several devices.
  - We use Maat [1], a library that provides device abstraction and load balancing for OpenCL kernels
    - Focus on data parallelism
    - Synchronisation has an overhead
    - Different applications may have different needs

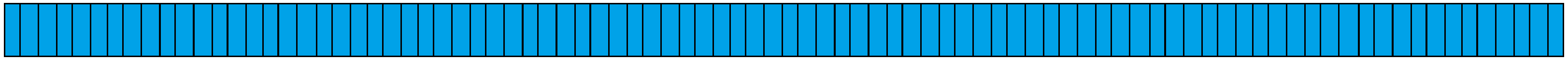
[1] Borja Pérez, José Luis Bosque, and Ramón Beivide. *Simplifying programming and load balancing of data parallel applications on heterogeneous systems*. GPGPU '16.

Load Balancing Methods

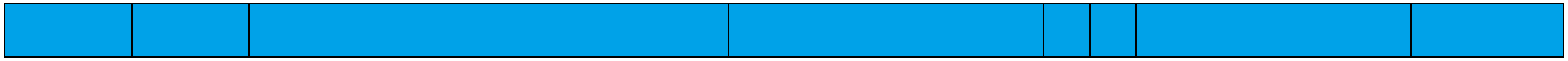
STATIC



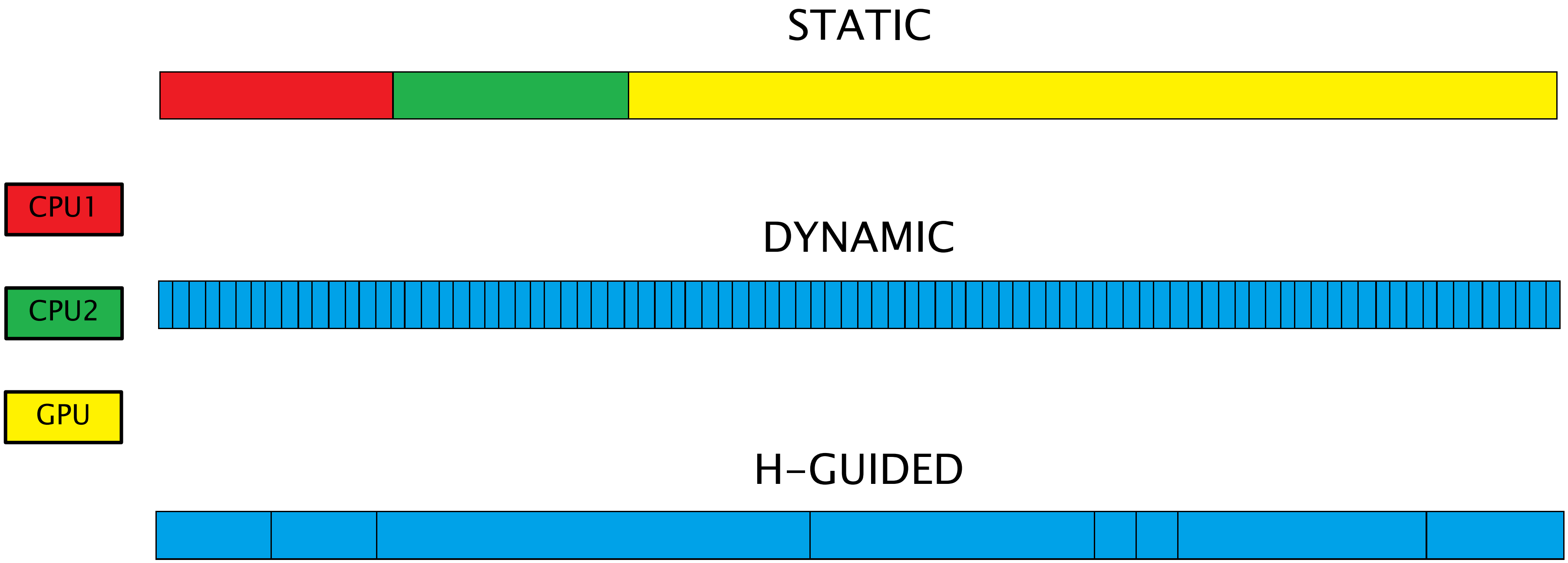
DYNAMIC



H-GUIDED



Load Balancing Methods


STATIC

CPU1

CPU2

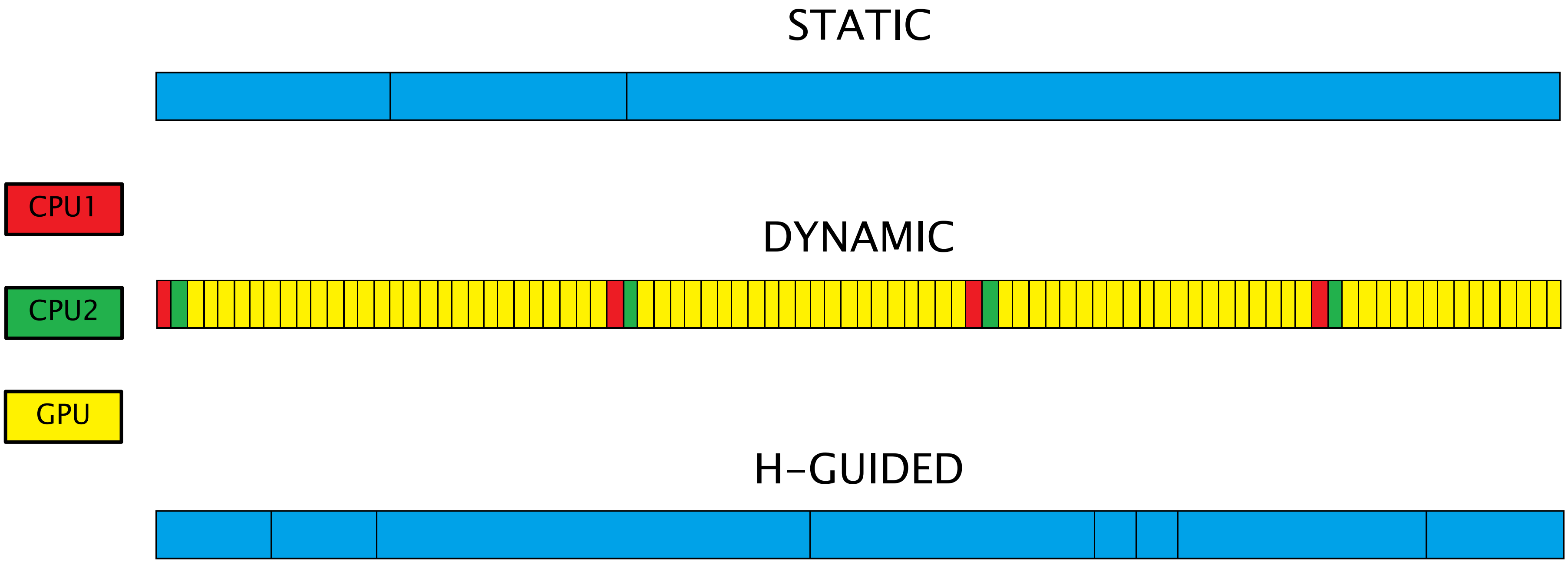
GPU

DYNAMIC

H-GUIDED

- Pros
  - Simple
  - Minimizes synchronisation points
- Cons
  - Determining computing powers
  - Irregular loads

Load Balancing Methods



STATIC

CPU1

CPU2

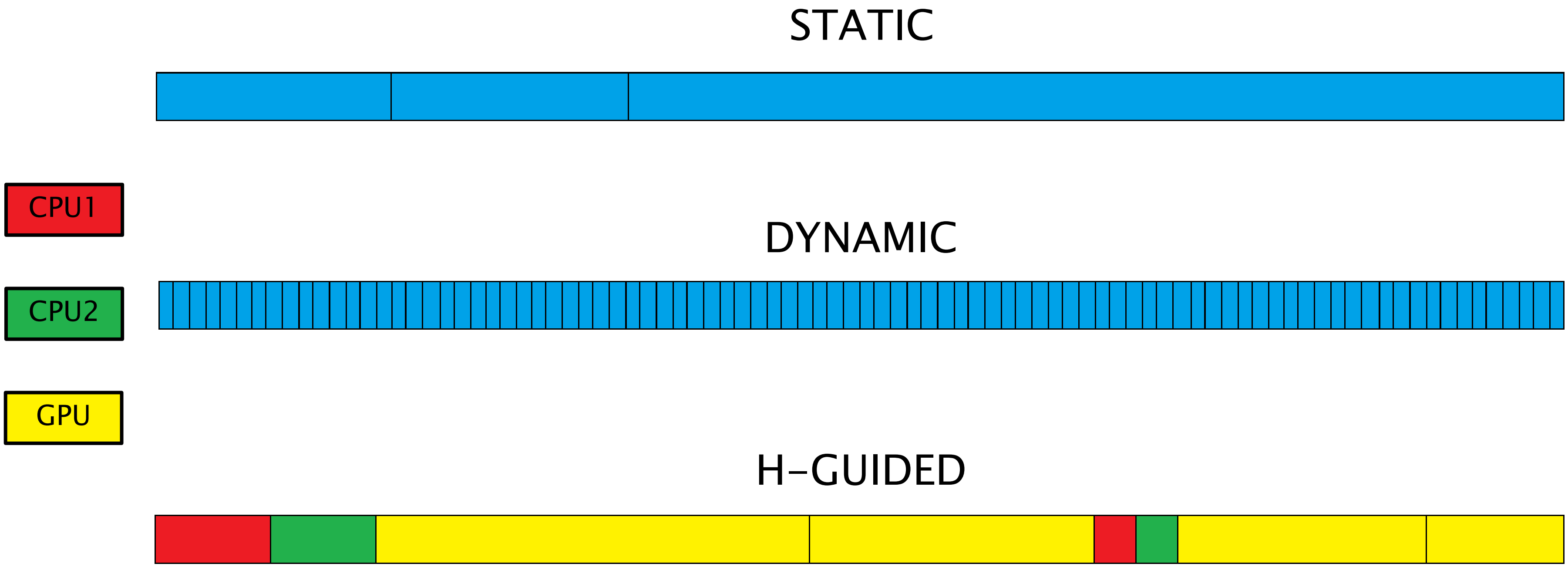
GPU

DYNAMIC

H-GUIDED

- Pros
  - Good for irregular loads
  - Does not use computing powers
- Cons
  - Too many synchronisation points

Load Balancing Methods



- Pros
  - Less synchronization points
  - Still dynamic
- Cons
  - It uses computing powers

Benchmarks

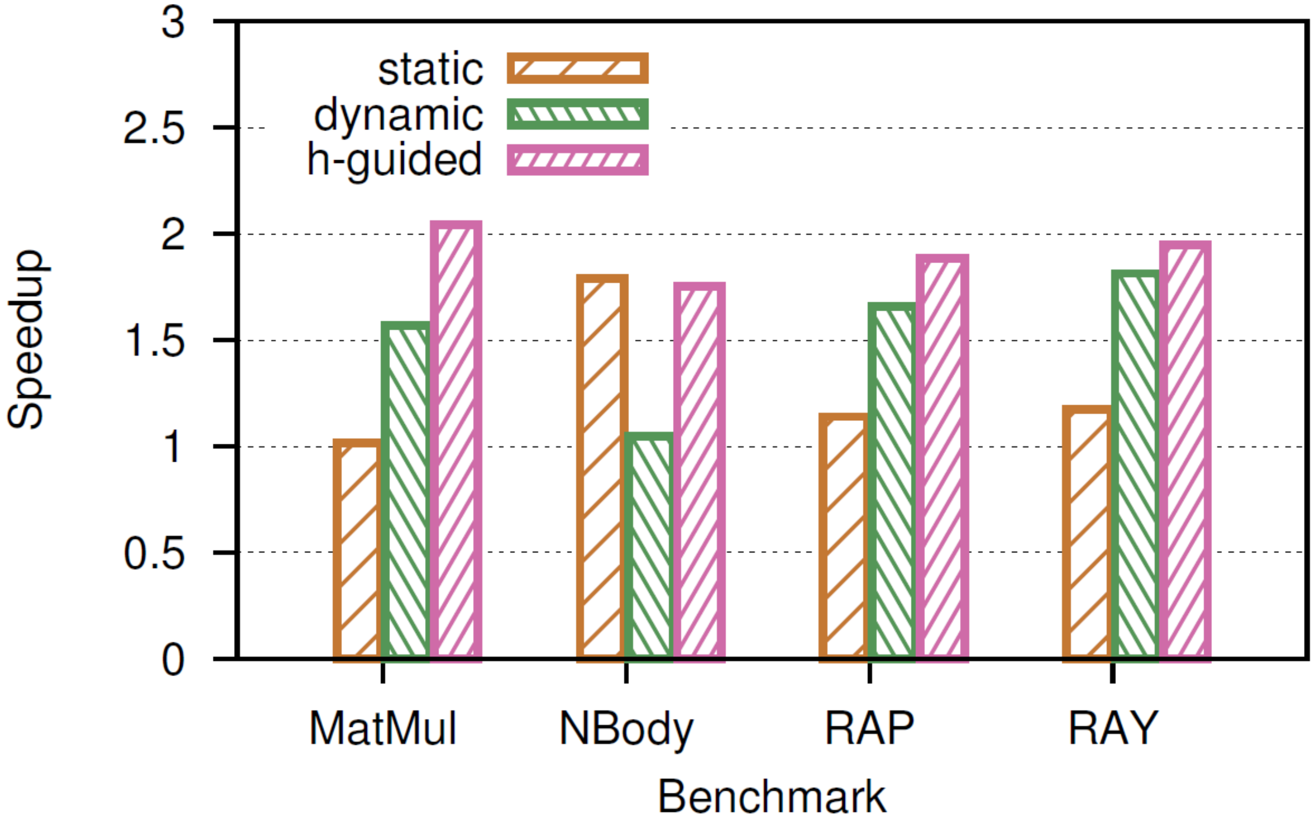
- Several available suites
  - Parboil, AMD APP SDK, Rodinia…
- Selected applications (have to be ported):
  - Regular
    - Nbody
    - MatMul
  - Irregular
    - RAP *(Resource Allocation Problem)*
    - Raytracing

Experimental Results

- The system:
  - 2xKepler K20m
  - 2xIntel Xeon E5-2670 (12 cores in total)
- Considered metrics
  - Speedup
  - Energy Consumption
  - EDP
- To measure energy, a monitor was developed that periodically samples the power consumption of each device
  - GPU power sensors through the NVIDIA Management Library (NVML)
  - Running Average Power Limit (RAPL) registers of the CPUs

Experimental Results

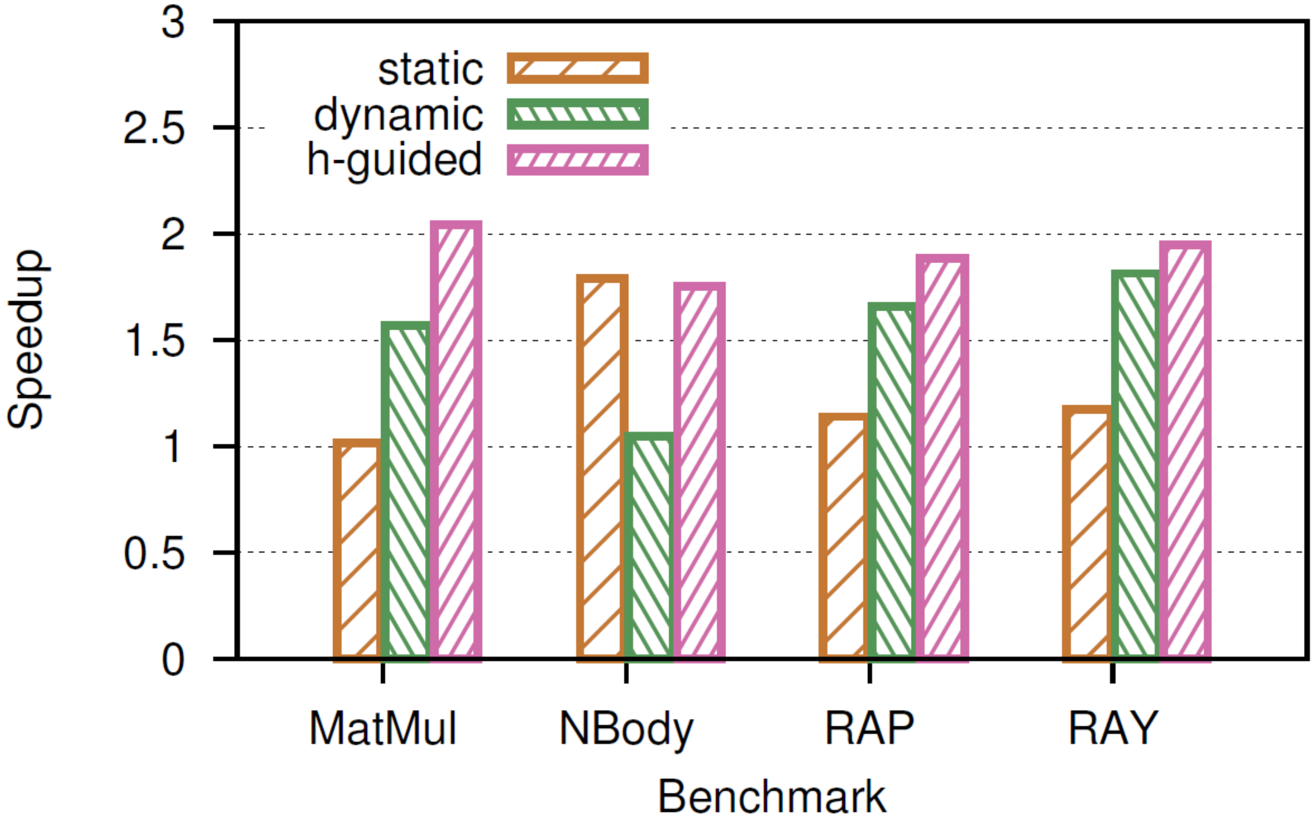
- Speedup



- Static succeeds at regular loads

Experimental Results

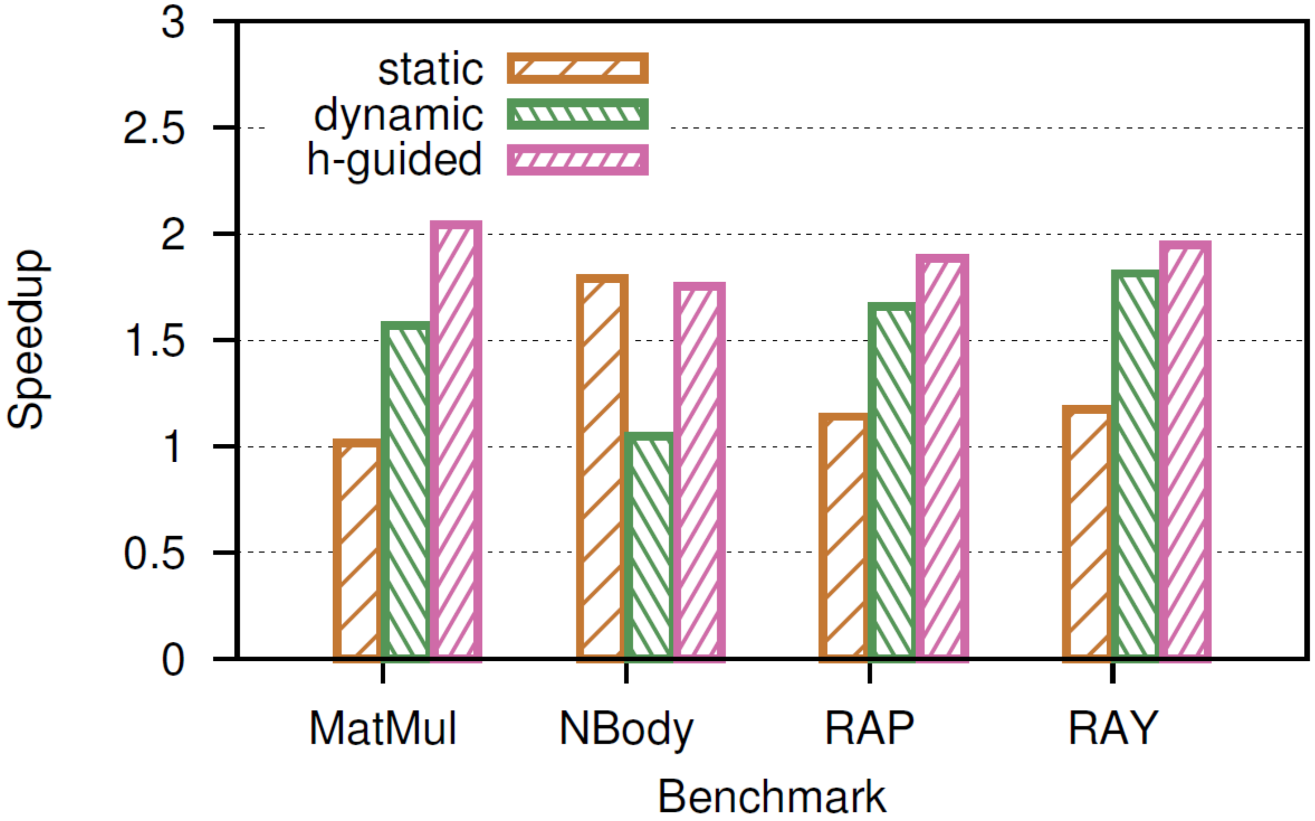
- Speedup



- Smallest package is too big for the CPU in MatMul

Experimental Results

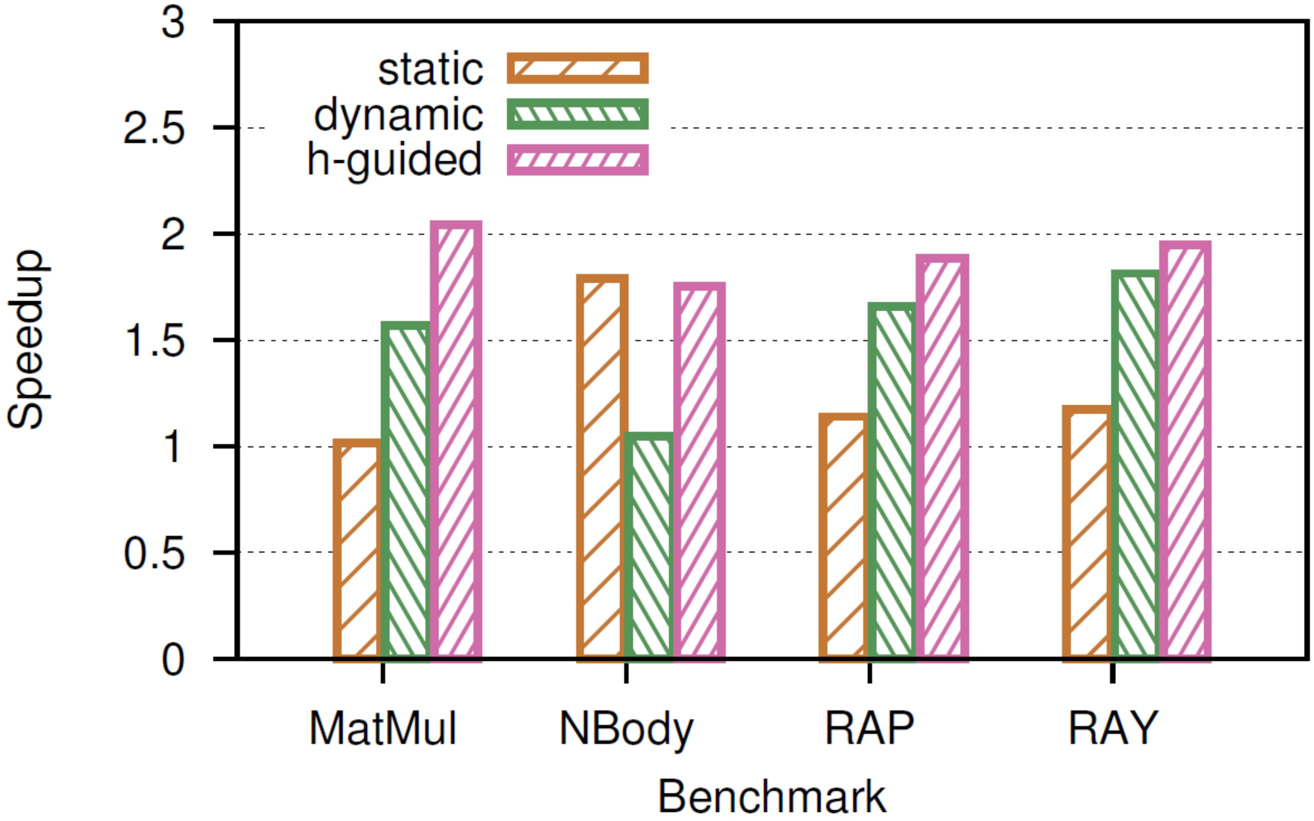
- Speedup



- Nbody is highly affected by overhead

Experimental Results

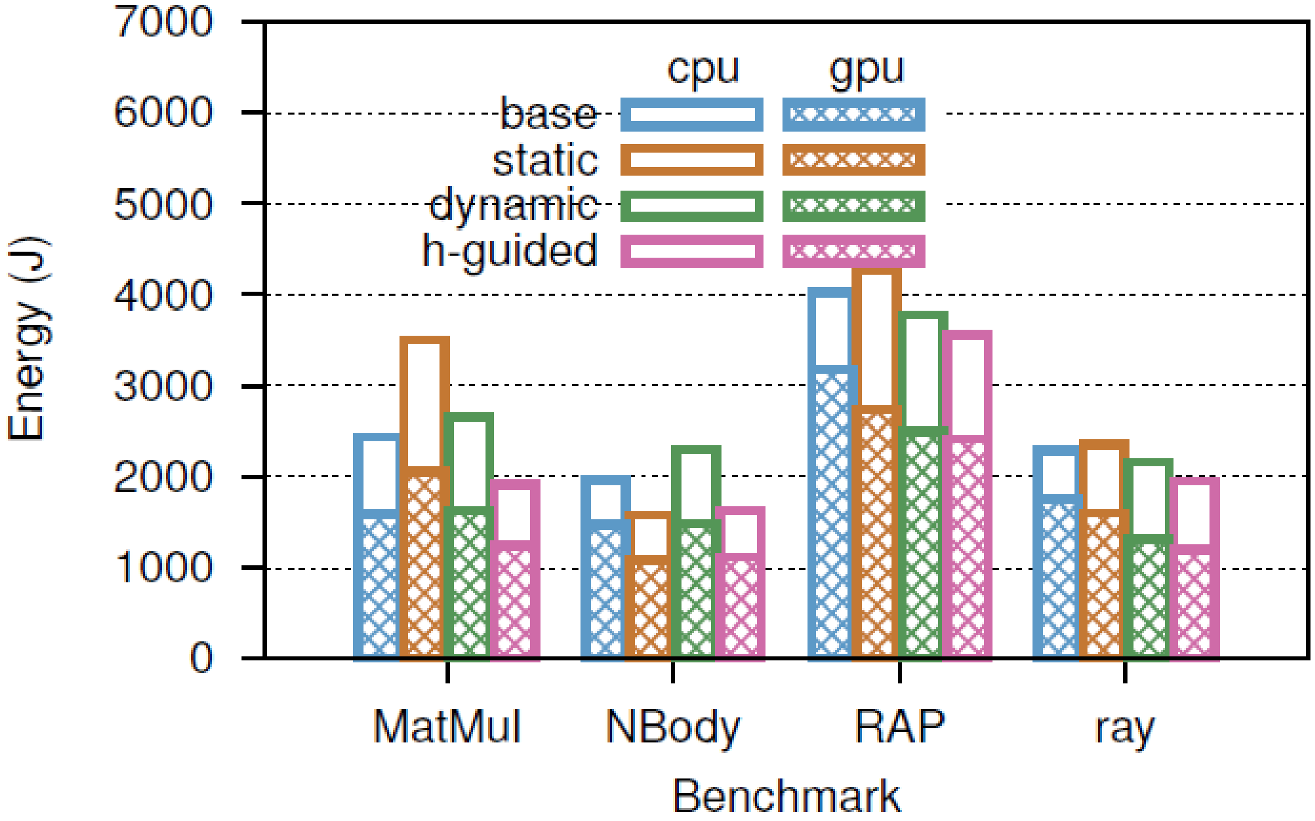
- Speedup



- Guided (and dynamic) succeed at irregular loads

Experimental Results

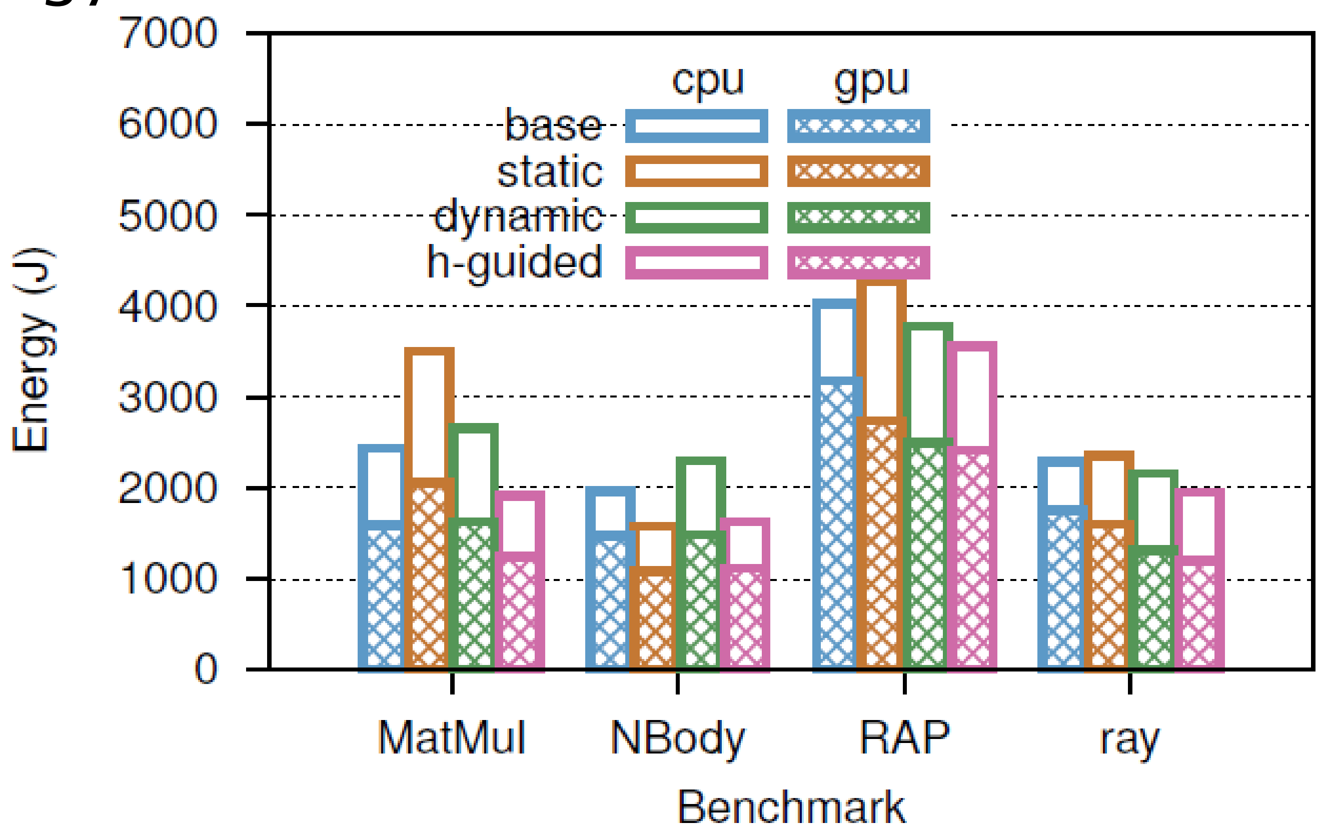
- Energy



- There is at least one option that improves energy for all benchmarks

Experimental Results

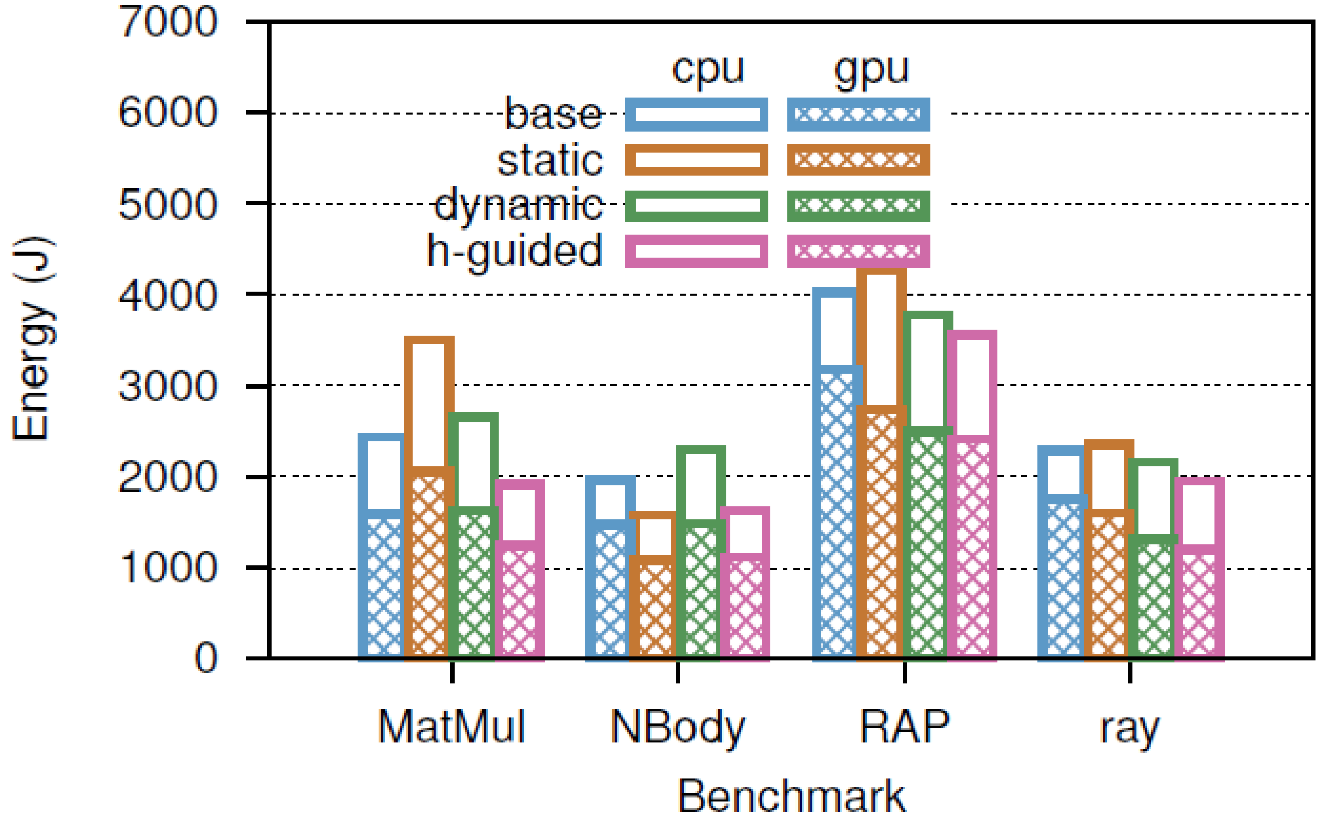
- Energy



- Best results with static for Nbody

Experimental Results

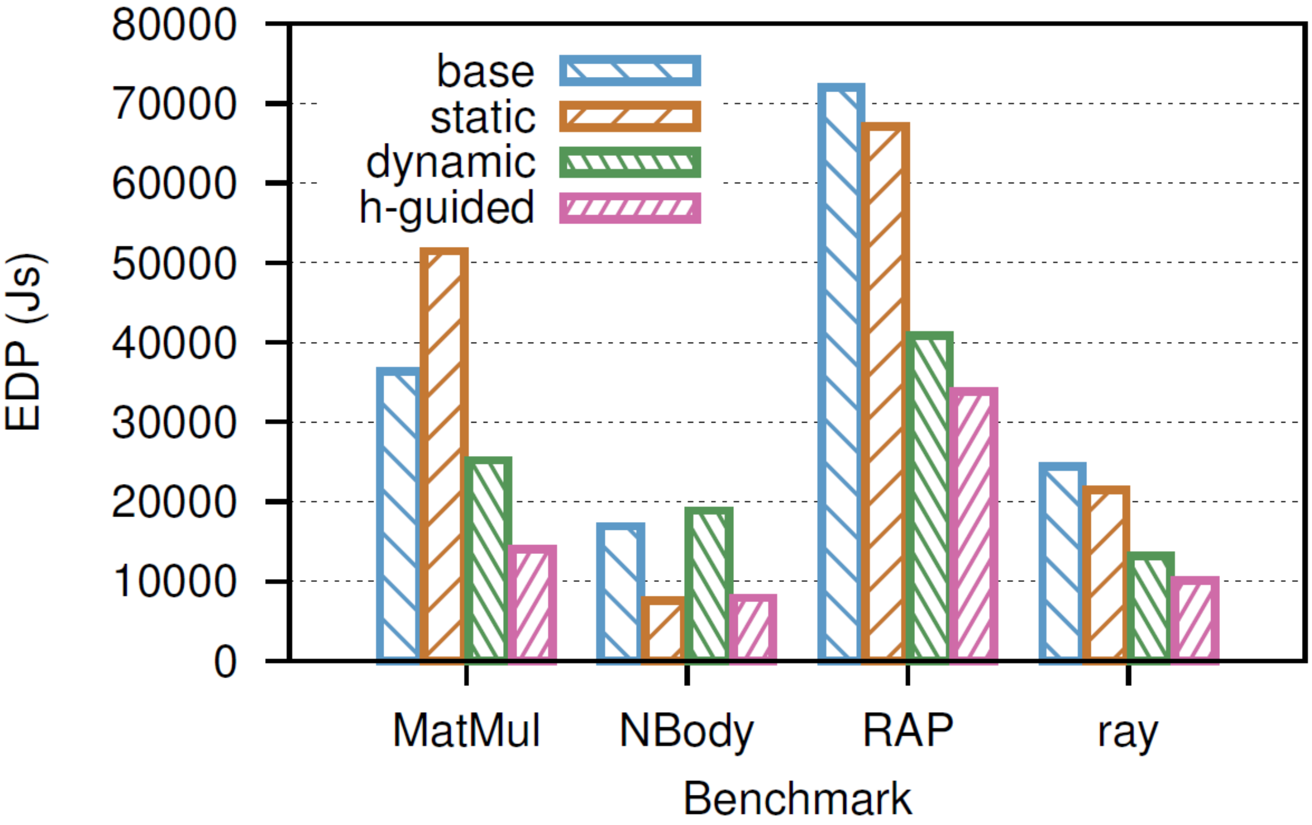
- Energy



- Almost same energy with guided and dynamic

Experimental Results

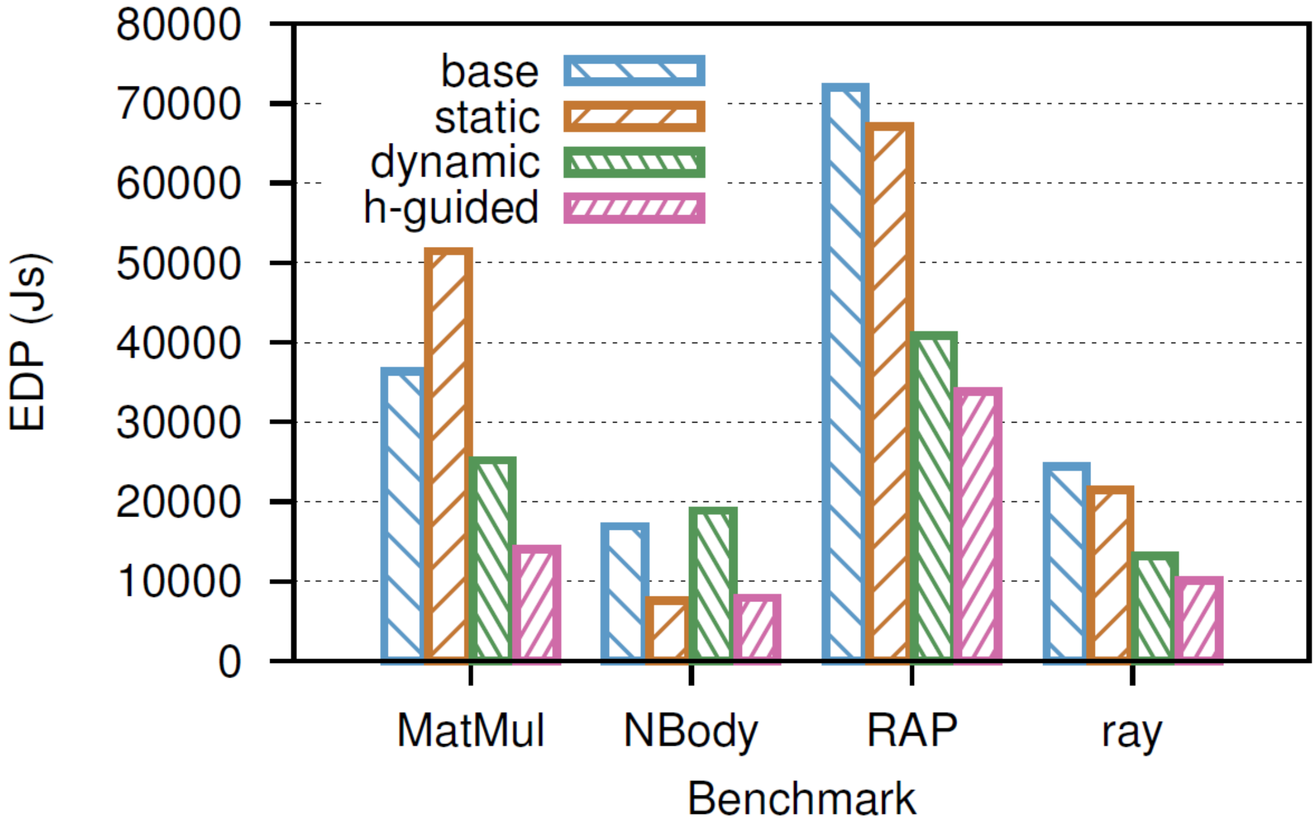
- EDP



- Confirms the previous results

Experimental Results

- EDP



- Improves even if the balancing is not the best

Conclusions

- Using all the available devices is worth it both performance-wise and efficiency-wise
  - Contrary to other authors
- There is always a load balancing approach that improves efficiency
  - Usually several
- Currently working on analyzing different frequencies for the GPU

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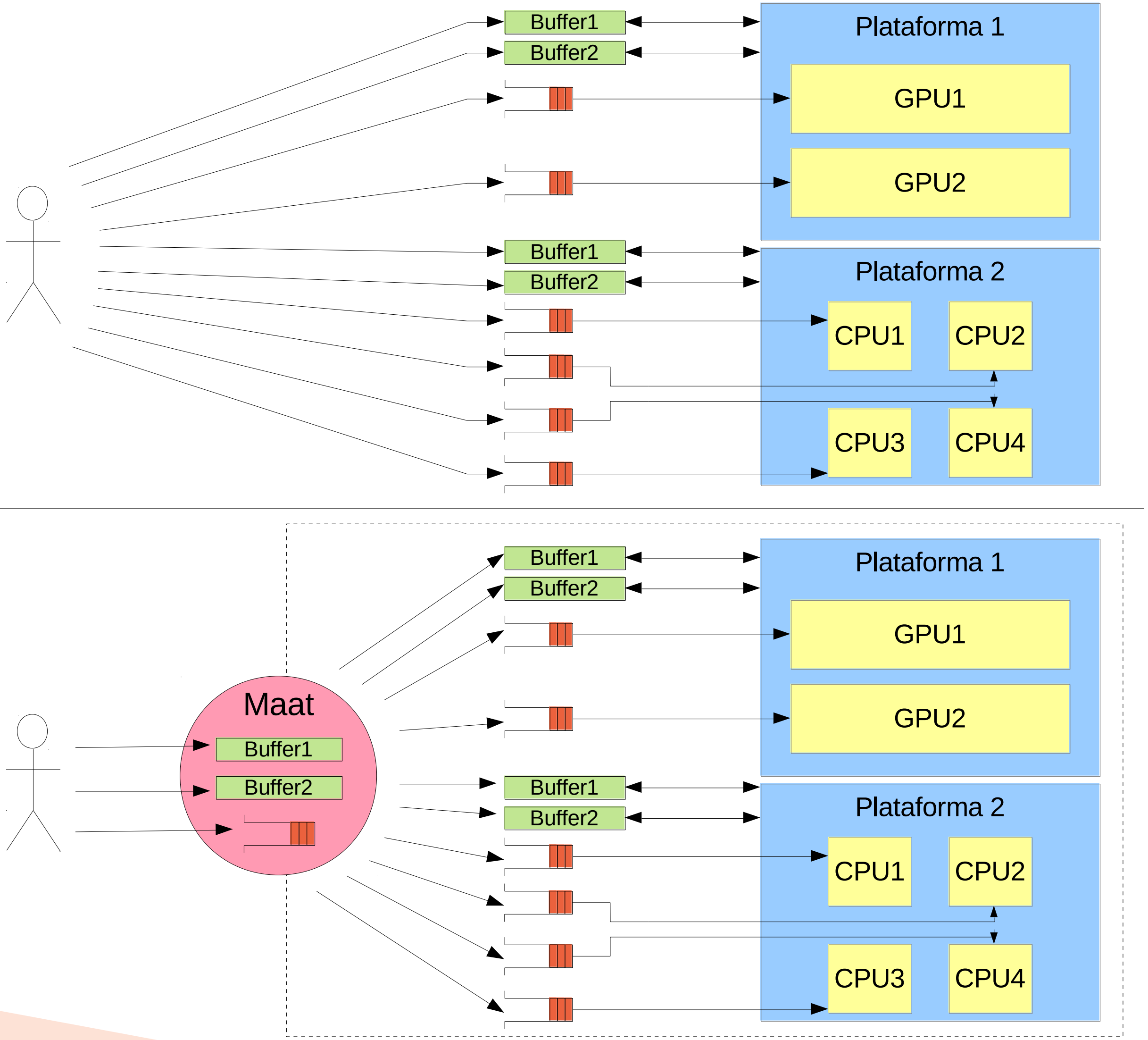
Abstraction of the system

- The programmer communicates with the whole system
- Transparent system management


Buffer1
Buffer2
Plataforma 1
GPU1
GPU2
Buffer1
Buffer2
Plataforma 2
CPU1
CPU2
CPU3
CPU4
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Buffer1
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Buffer1
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Plataforma 1
GPU1
GPU2
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Plataforma 2
CPU1
CPU2
CPU3
CPU4