Energy-efficient execution of Federated learning tasks on mobile phones: An exploratory study.

Presented by Patrick Wapet, Post Doc at LIRIS Laboratory, INSA Lyon
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Supervised by by Vlad Nitu,

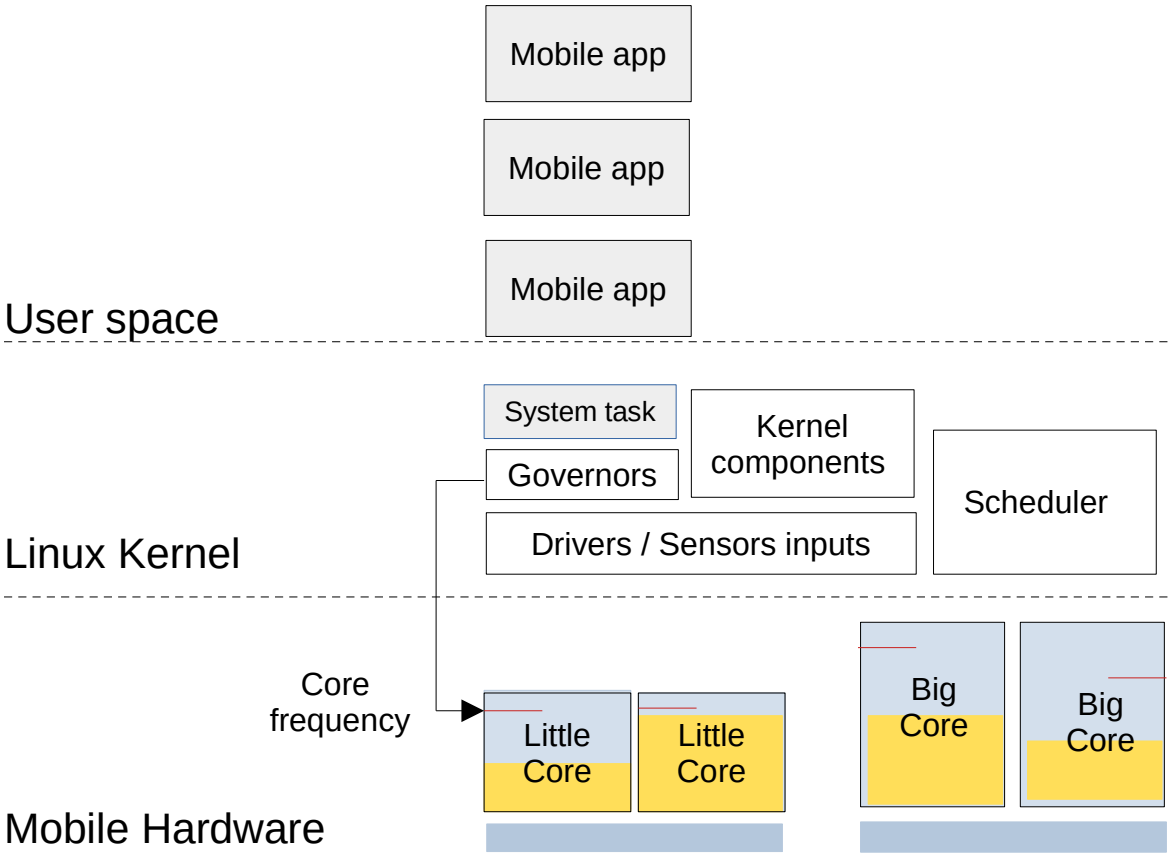
Summary

1. **Context:** Federated Learning and mobile phones.
2. **Problem definition:** global scheme
3. **Challenges:** parameters, metrics, approach and measurement tools.
4. **Experiments and observations:** reported according to the parameters, graphs and partial conclusions.
5. **Next steps:** next experiments, possibly implementations and submissions.

1. Context: Federated Learning

- **Artificial Intelligence is** more and more used in everyday life.
- By default it is a system that **centralizes** data.
- Posing the problem of **privacy**.
- A solution: keep the data with the users.
- On their devices : **Mobile phones**
- Do the processing on these phones: **Federated Learning**

2. Let us state the problem: general scheme



A simplified view of the Android system On big.LITTLE Architecture

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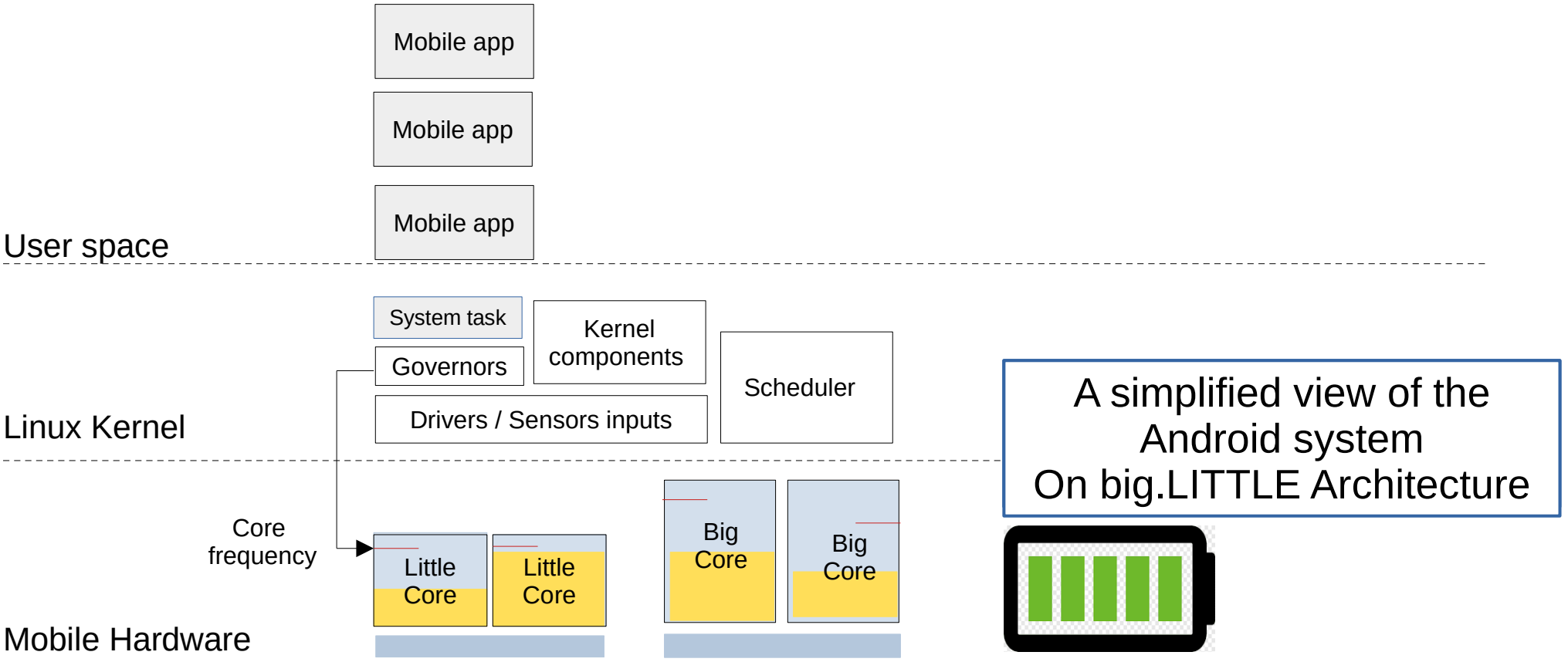

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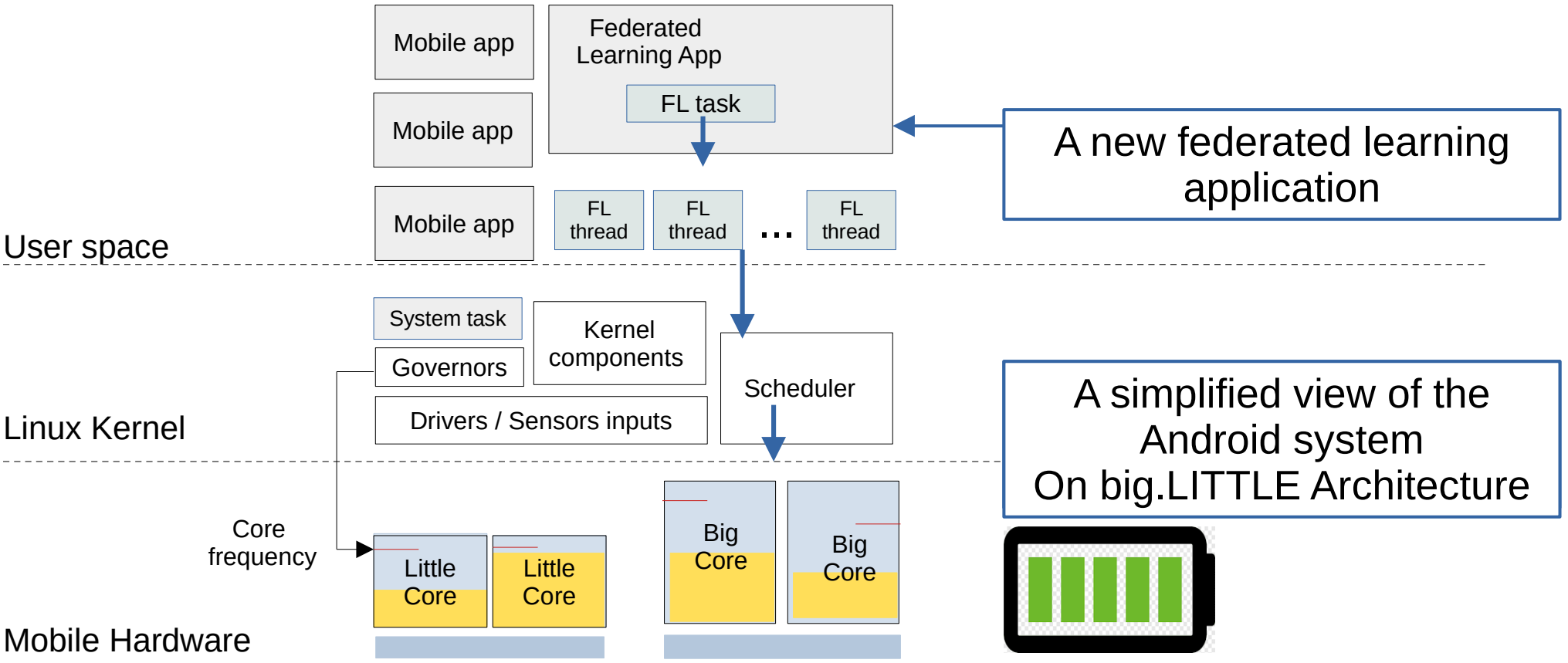

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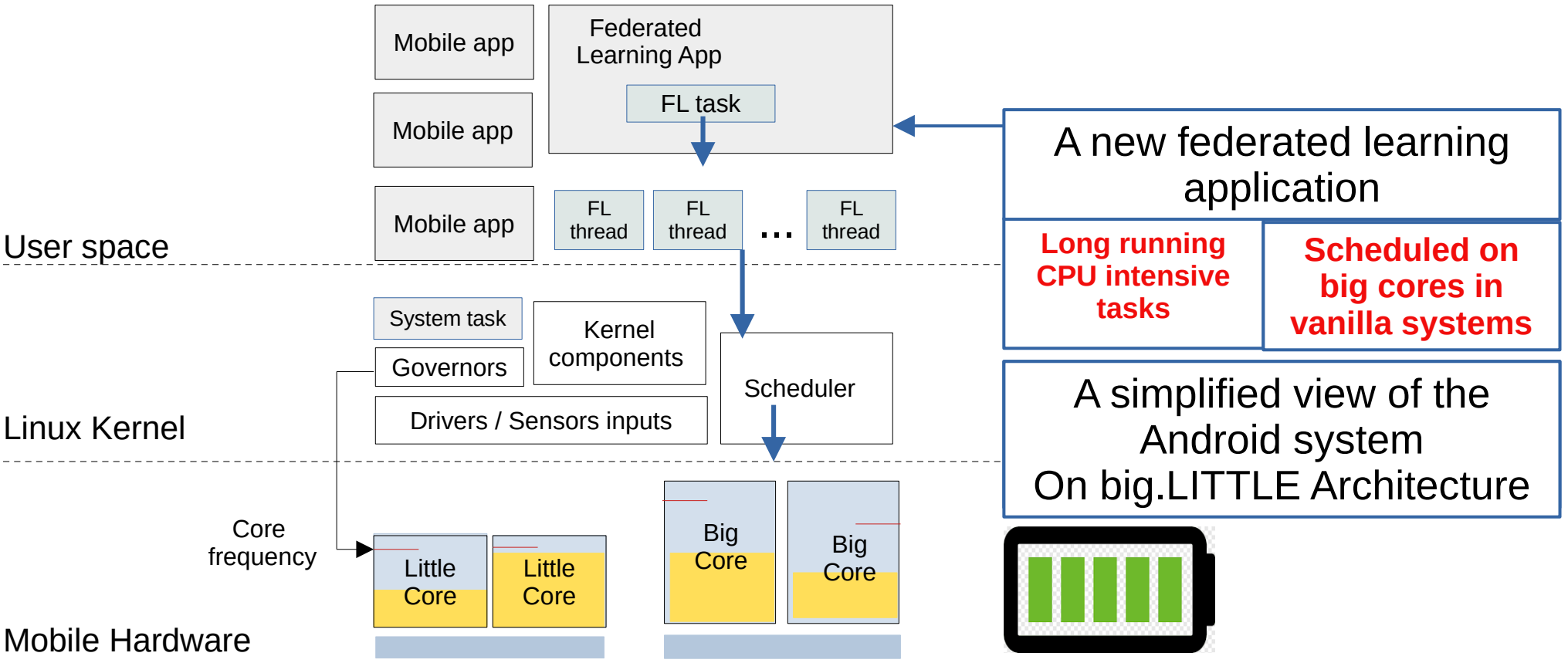

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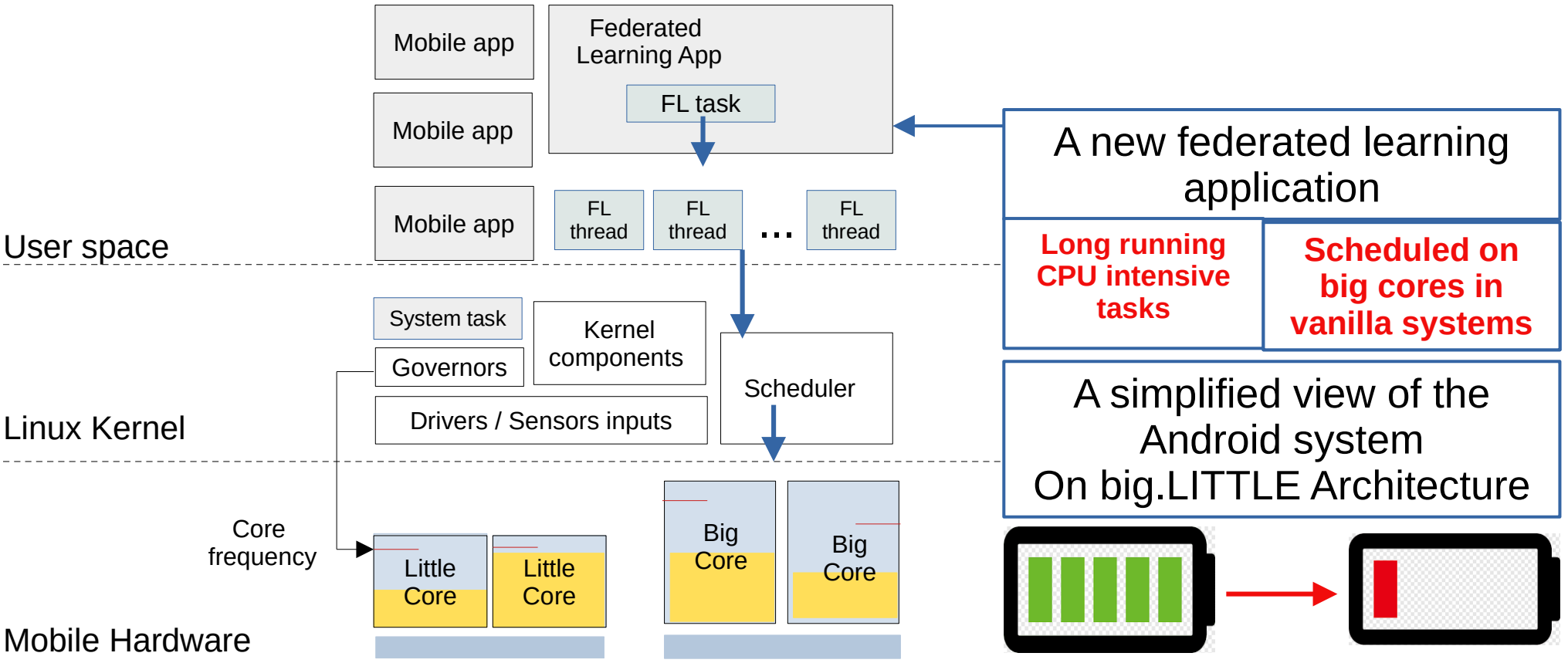

3.a. Let us define the **metric** to optimize

- The metric should reflect both:
  - **Computing power** of the FL task execution
  - **Electrical power absorption** of the phone.
- To compute this metric we have:
  - The **workload** of the FL task: number of CPU operations.
  - The **energy** consumed by the system: obtained by measurements.
- Metric adopted for the project: **energy efficiency**

$$energy_{eff} = \frac{Energy\ consumed}{workload\ computed} = \frac{Power\ absorbed}{Computing\ power}$$

- **Energy efficiency of the SYSTEM : FL task and others tasks**

3.b. What influences the energy efficiency

- The type of cores executing the task
  - Intuitively Big cores consumed high amount of Energy
  - Some research experiments prove that it can be a factor. [1]
- The task already present of the cores.
  - Energy discounted approach [2].
- The core frequency.

[1] Full-System Simulation of big.LITTLE Multicore Architecture for Performance and Energy Exploration. *Anastasiia Butko et al*
[2] Energy Discounted Computing on Multicore Smartphones, *Meng Zhu Kai Shen University of Rochester*
[3] Machine Learning-Based Approaches for Energy-Efficiency Prediction and Scheduling in Composite Cores Architectures Hossein Sayadi et al.
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- The core frequency.
- The Number of threads of the best effort task [3].
- Core temperature [4].

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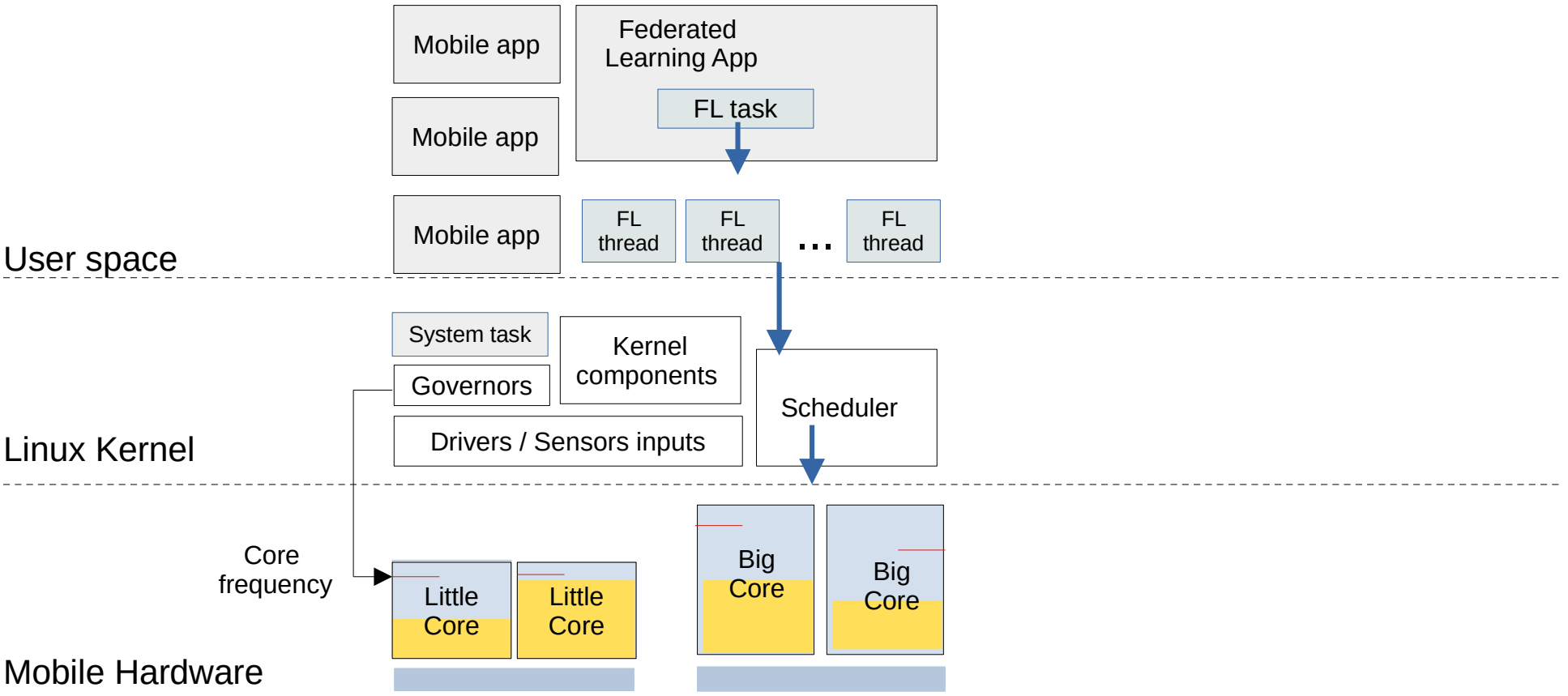

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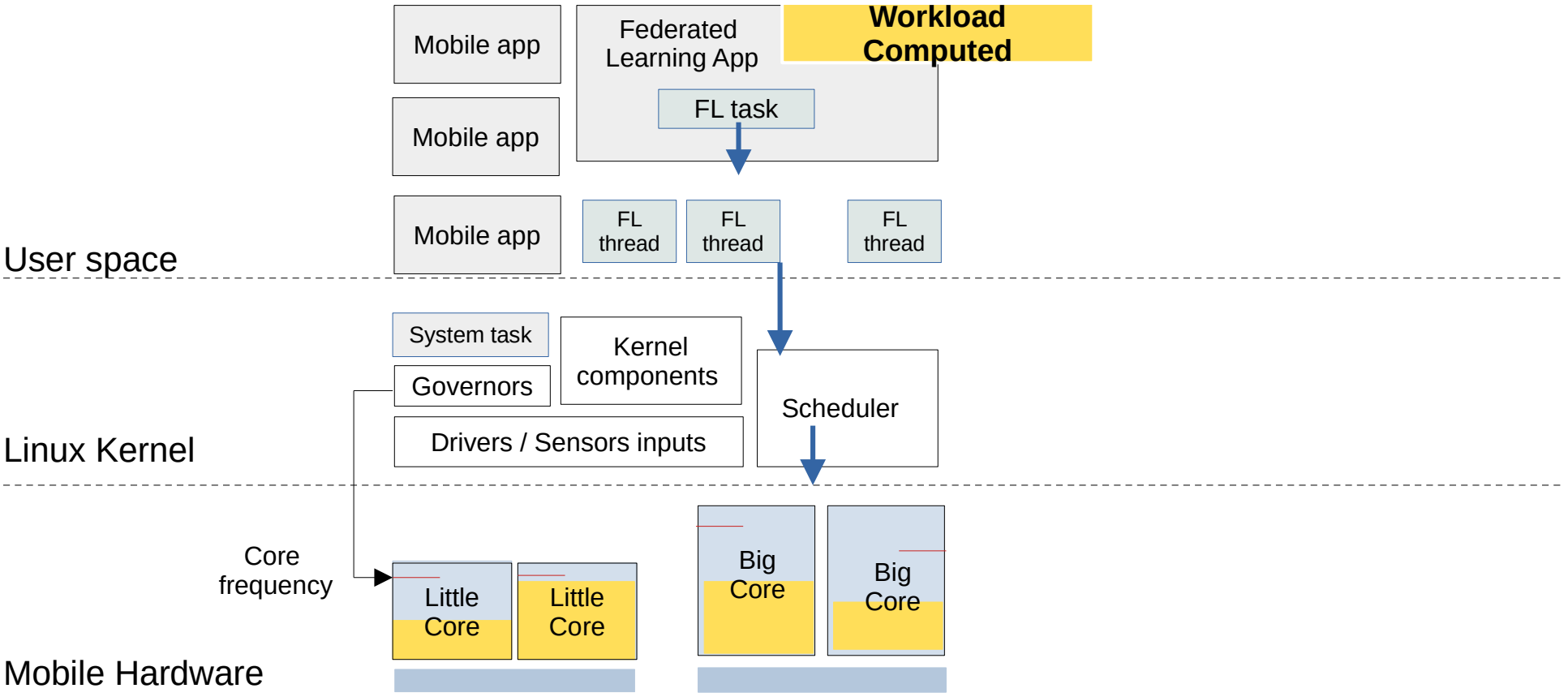

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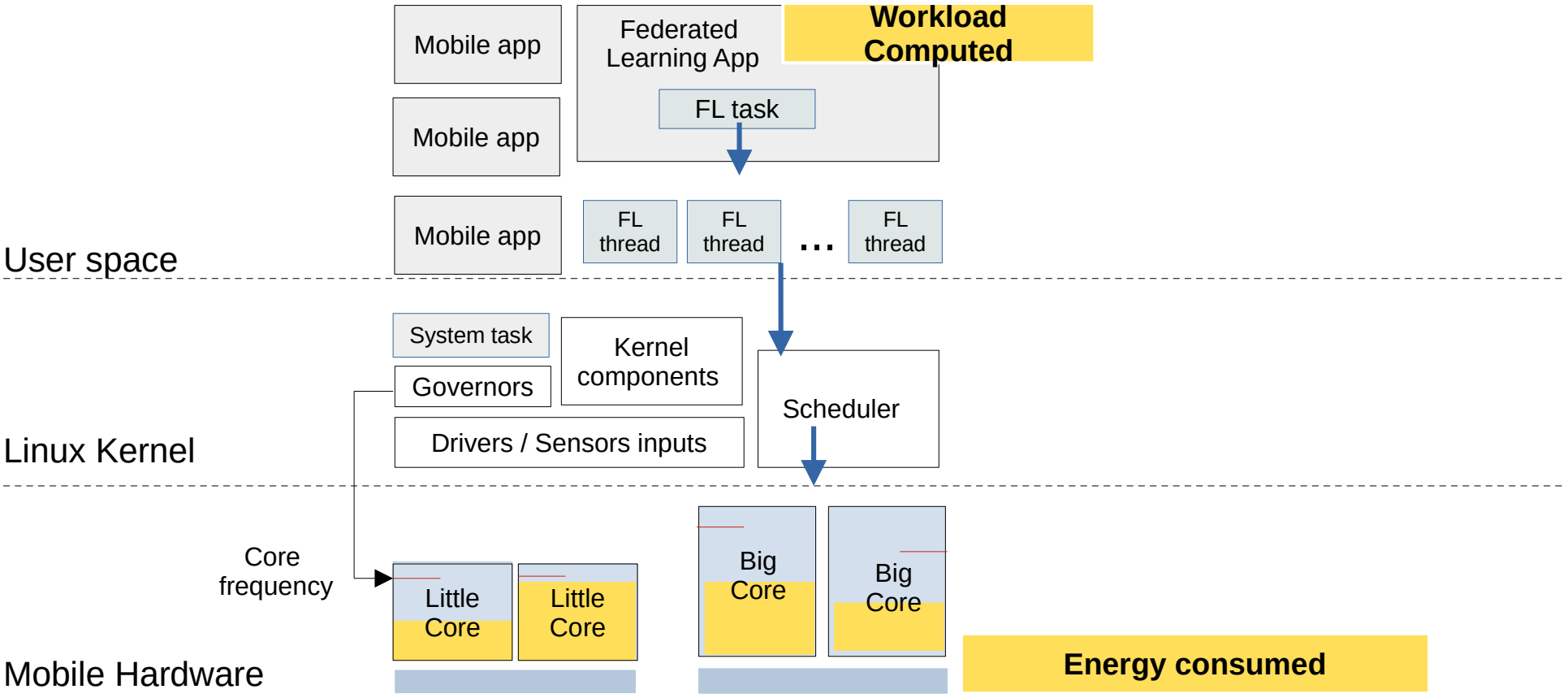

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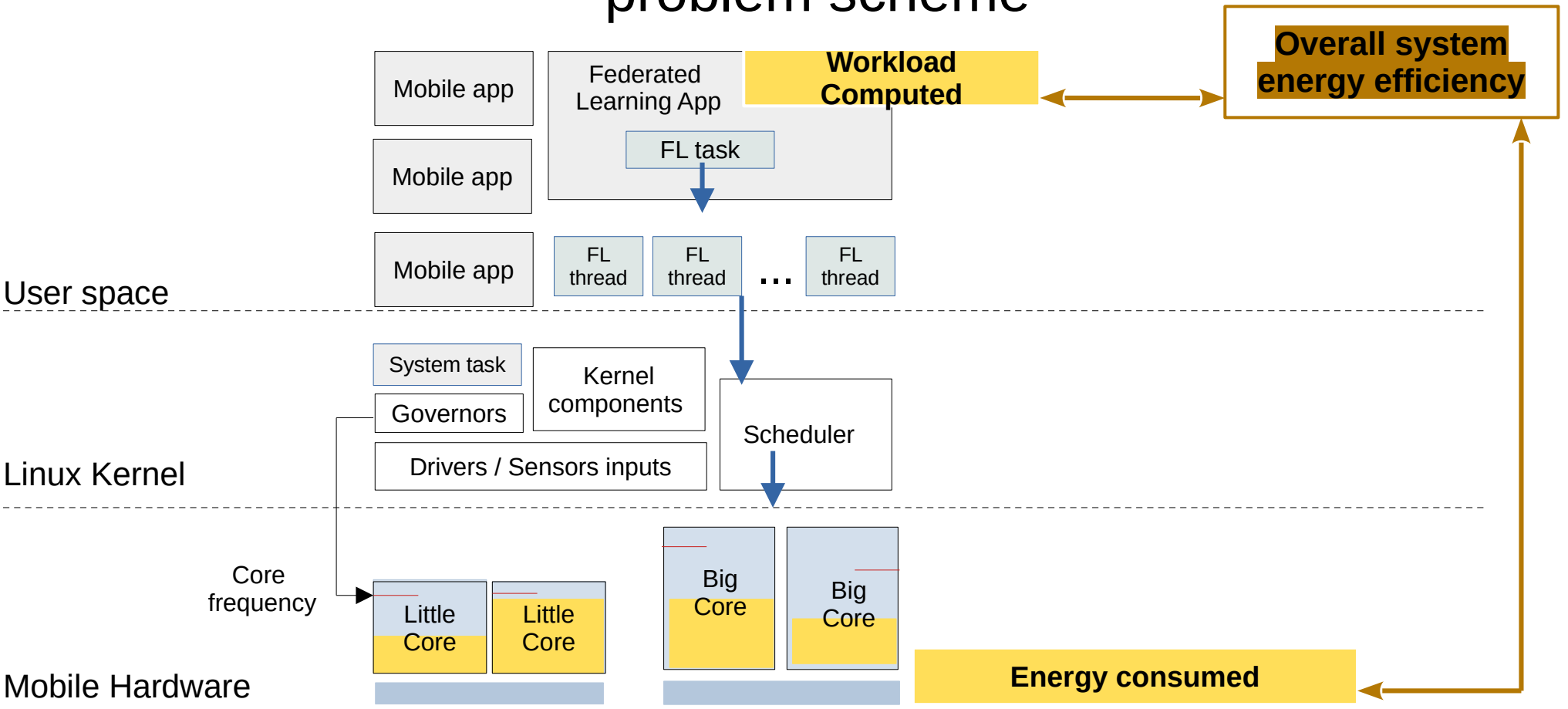

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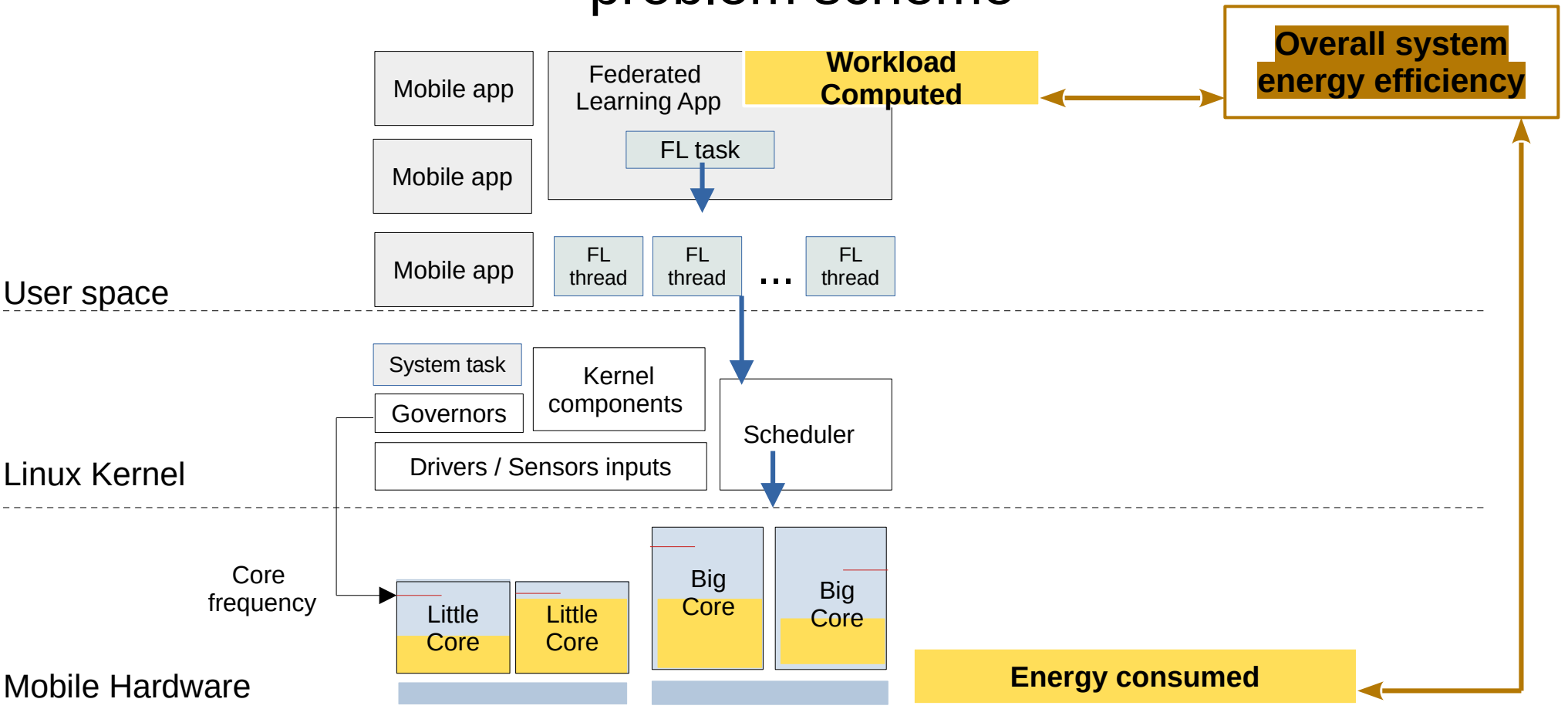

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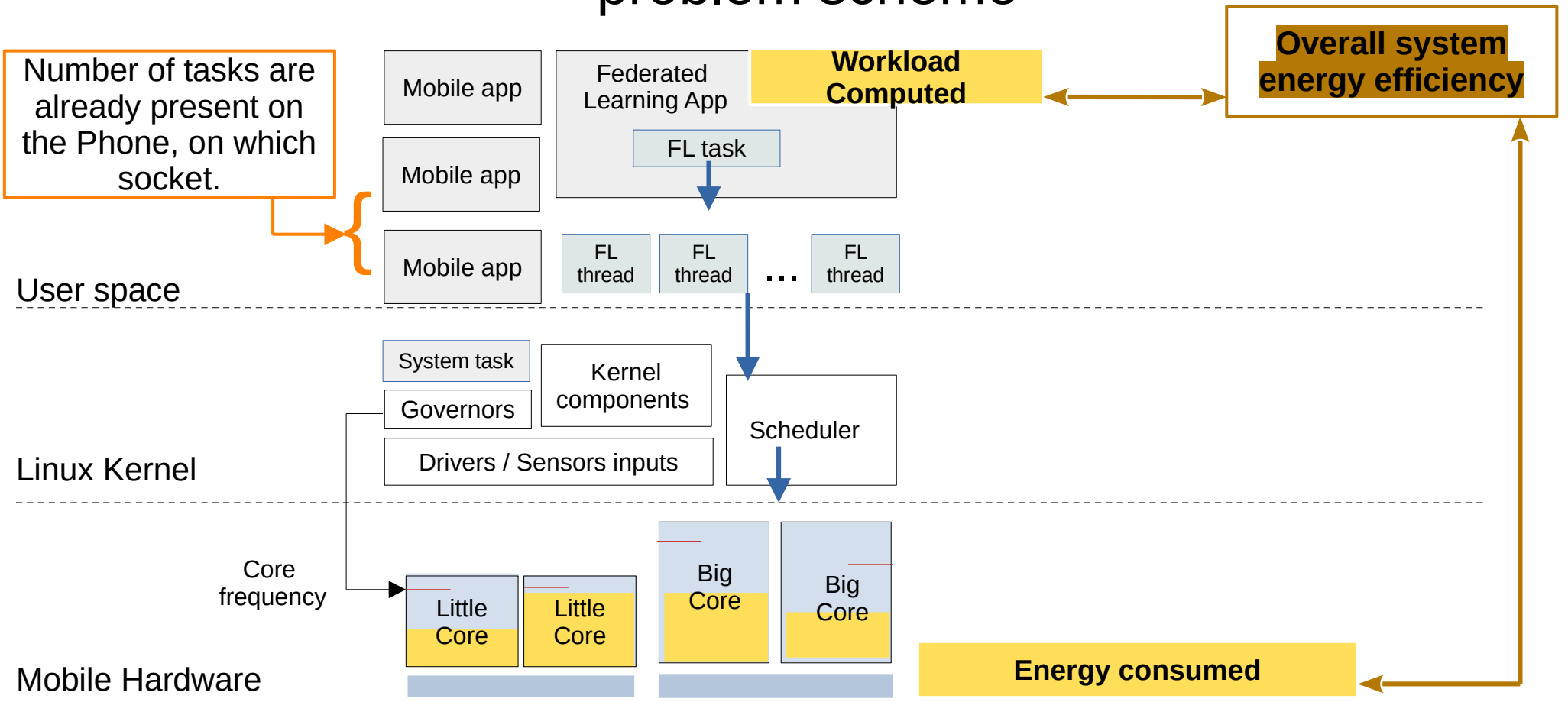

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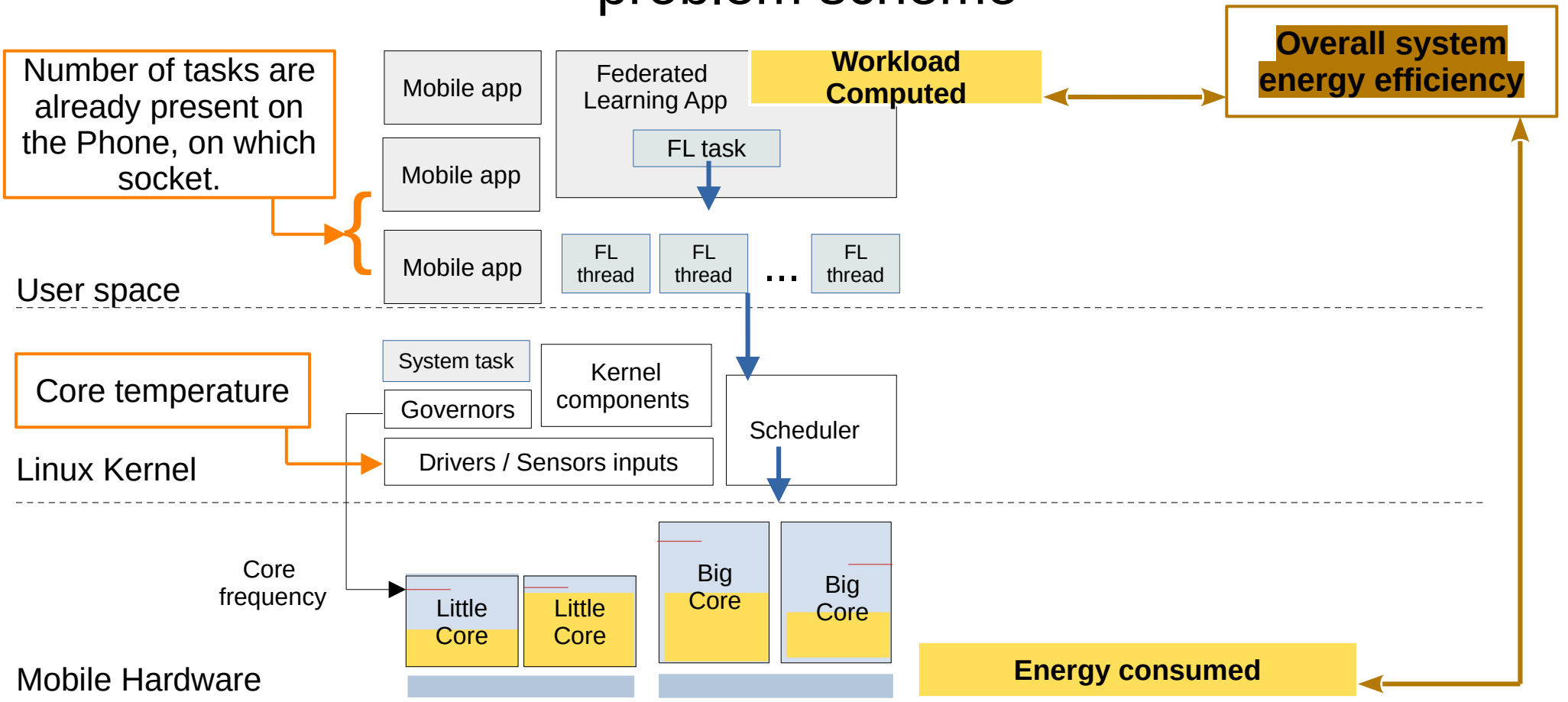

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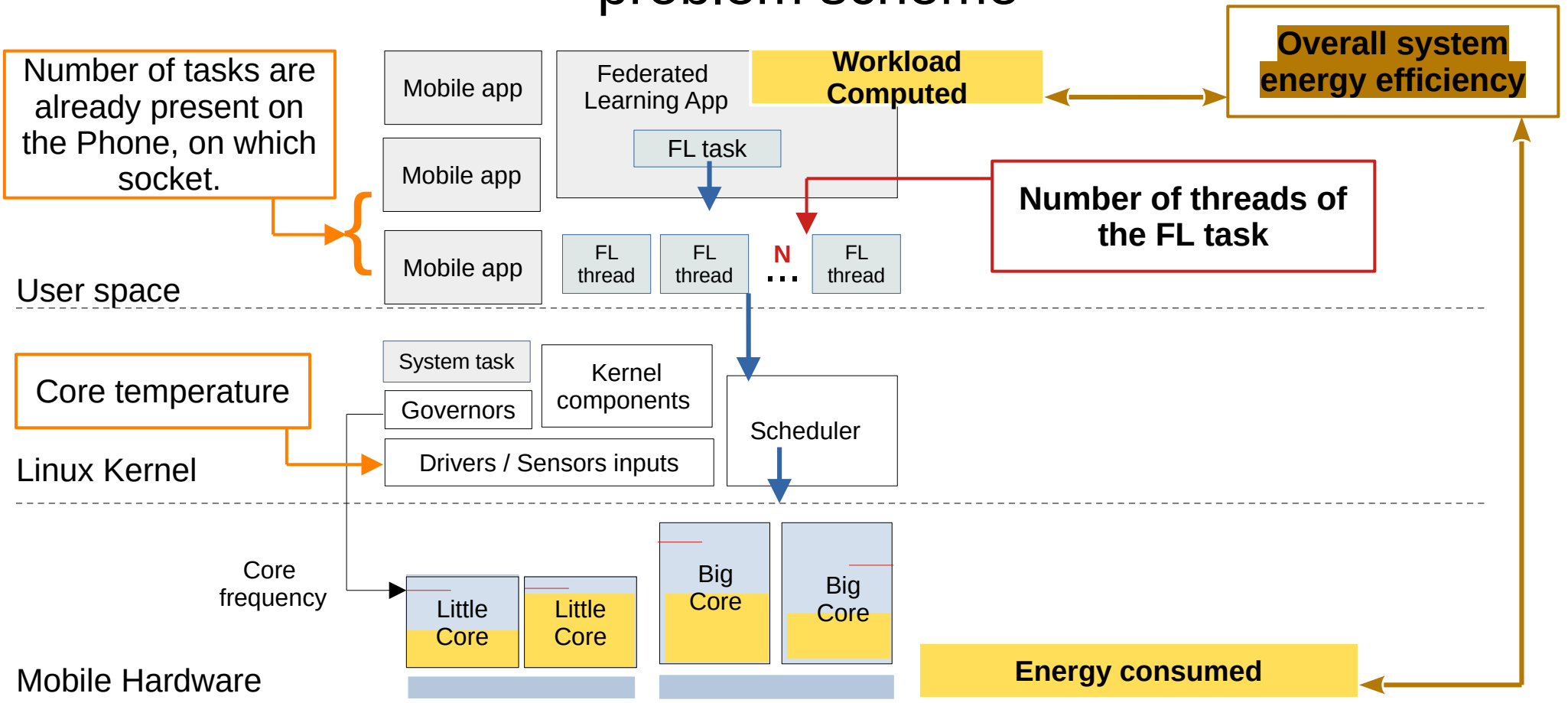

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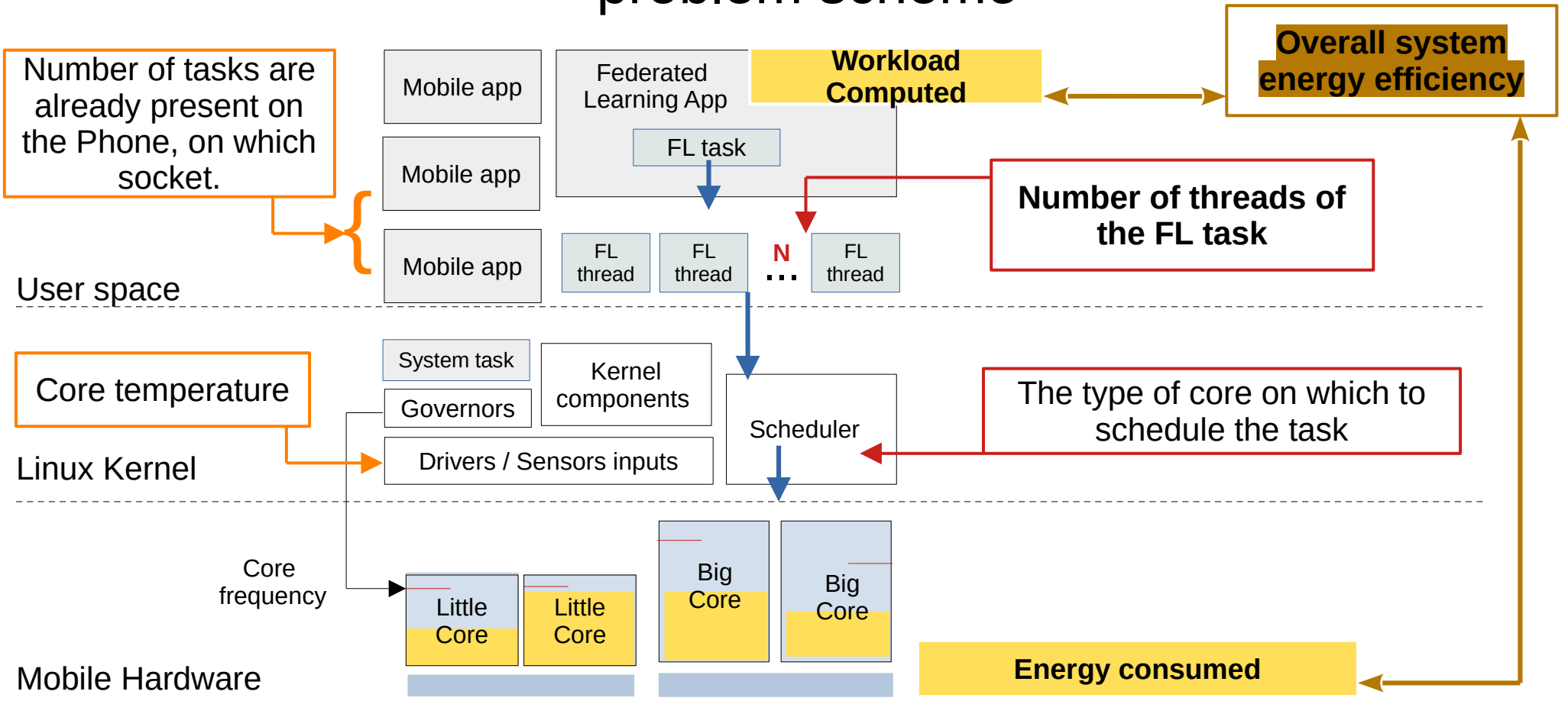

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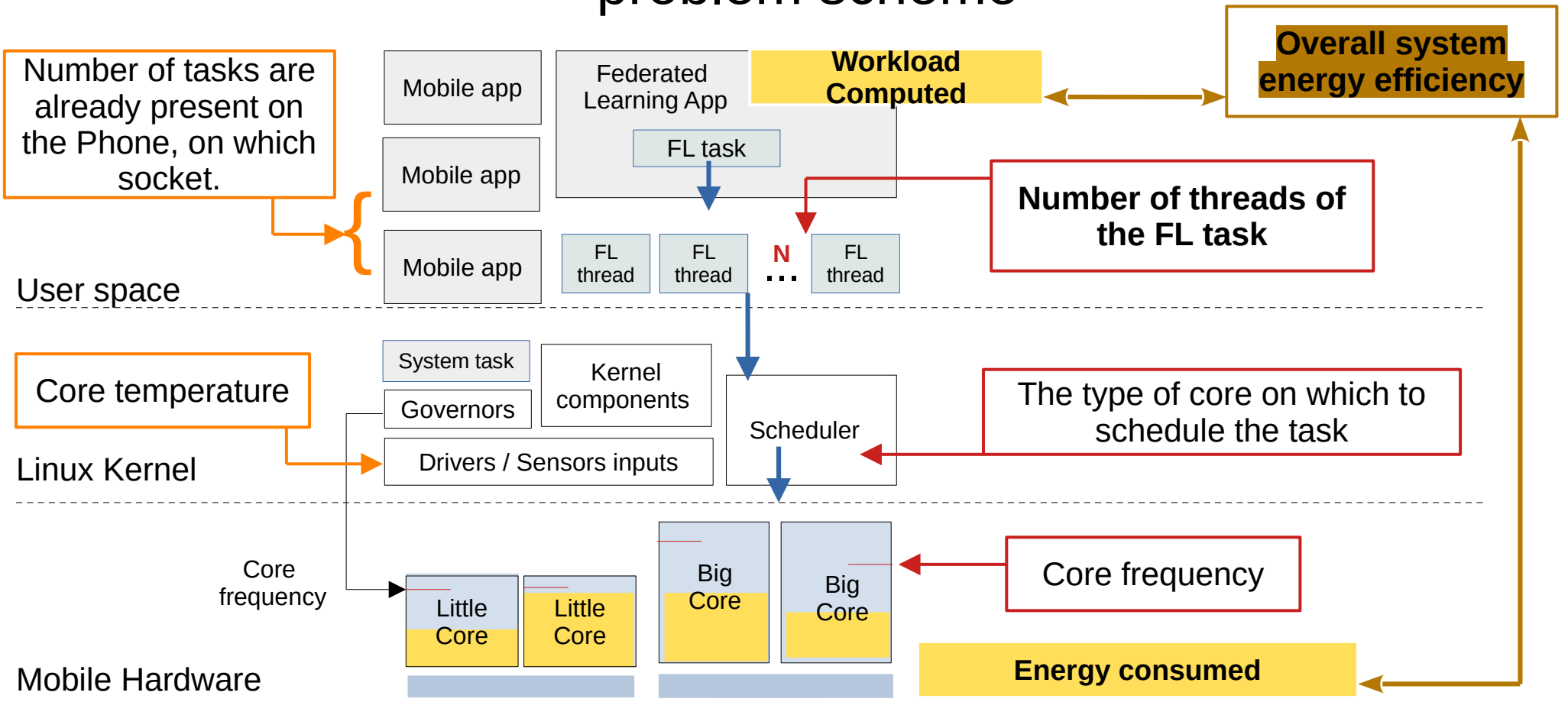

3.d Approach to resolve the problem

I. Make in-lab experiments by varying scenarios parameters:

- Number of interactive task present on phones
- Number of threads of the FL task
- Type of cores
- Core frequencies
- Temperature

II. Bringing out the lessons learned about HOW those parameters influence energy efficiency.

III. Apply these lessons learned in the FL task scheduling decision:

- At user space Level
- At kernel Level (Scheduler, governor).

3.e Workload measurement

- Benchmarks (Newly added FL task)
  - **Prime number computation** (to quickly get an overview of cores energy efficiency) [1]
  - **Tensor Flow Lite model** on Mobile Device [2] (to have ML-like task behavior)
  - **Federated Learning System called FLEET** (for FL-like experiments) [3]
- Interactive apps (Other apps)
  - **Interactive app simulation** (with interruptions to quickly get an overview) [1]
  - **Widely used mobile apps** (YouTube, Instagram, ...)

- Phone 1: Google Pixel 4A 5G:
  - 3 sockets: CPUs 0-5: 1.8048 GHz; CPU 6: 2.208 GHz;CPU7: 2.4 GHz
  - Memory: 6GB RAM
- Phone 2: Samsung galaxy S8
  - 2 sockets CPUs 0-3 : 1.69 GHz , CPUs 4-7: 2.314 GHz
  - Memory: 4GB RAM

[1] Prime number computation source code https://gitlab.liris.cnrs.fr/plwapet/benchmarking_app_to_test_big_cores/-/blob/main/app/src/main/java/com/opportunistask/scheduling/benchmarking_app_to_test_big_cores/PrimeNumberThread.java

[2] On-Device Training with TensorFlow Lite https://www.tensorflow.org/lite/examples/on_device_training/overview

[3] FLeet: Online Federated Learning via Staleness Awareness and Performance Prediction, Georgios Damaskinos, Rachid Guerraoui, Vlad Nitu et al. Source code https://github.com/gdamaskinos/fleet/

3.f Energy consumption measurement:

system API “*dumpsys batterystats*” from Android OS

- Widely used in research [1]
- We have used it for more than 7 months.
- **Confirms the influence of the above-mentioned parameters** on the energy efficiency
- But some results incompatible with reality

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Power-meter tool

- Also widely used in research [2][3]
- The common installation required is **expensive**
  - Its makes phone battery no longer usable.
- **Alternative 1: Software simulation of battery shutdown** (Google Pixel 4A, 5G).
  - Modifying internal system file : *“charge_stop_level”*, *“charge_limit”*
  - USB mode power supply
  - Retrieving data from power-meter
- **Alternative 2 : Full battery charging** (Samsung)
  - Retriving data from system file “cc_info”
  - Retrieving data form power-meter

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4. Experiments and observations (made using APIs)

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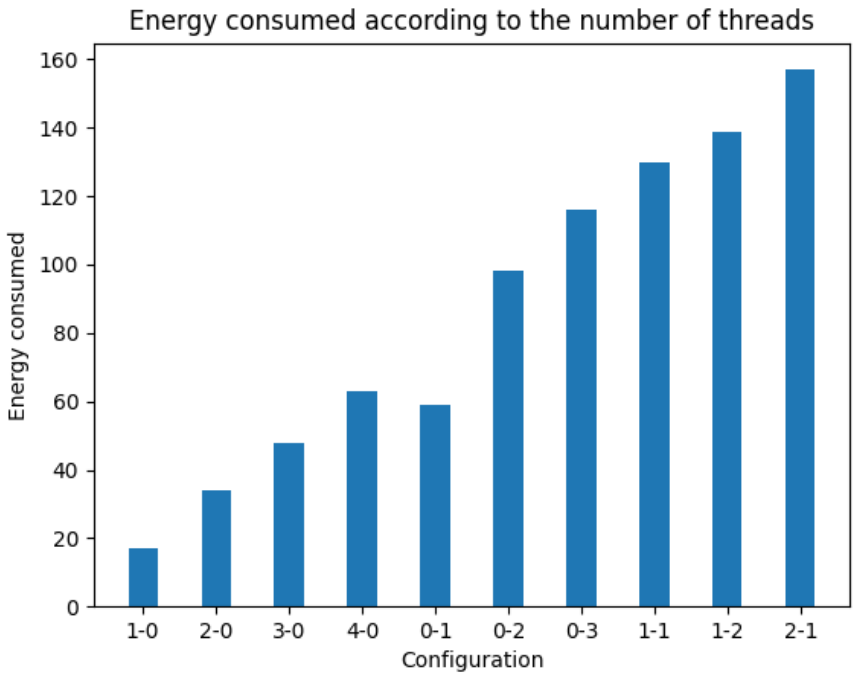
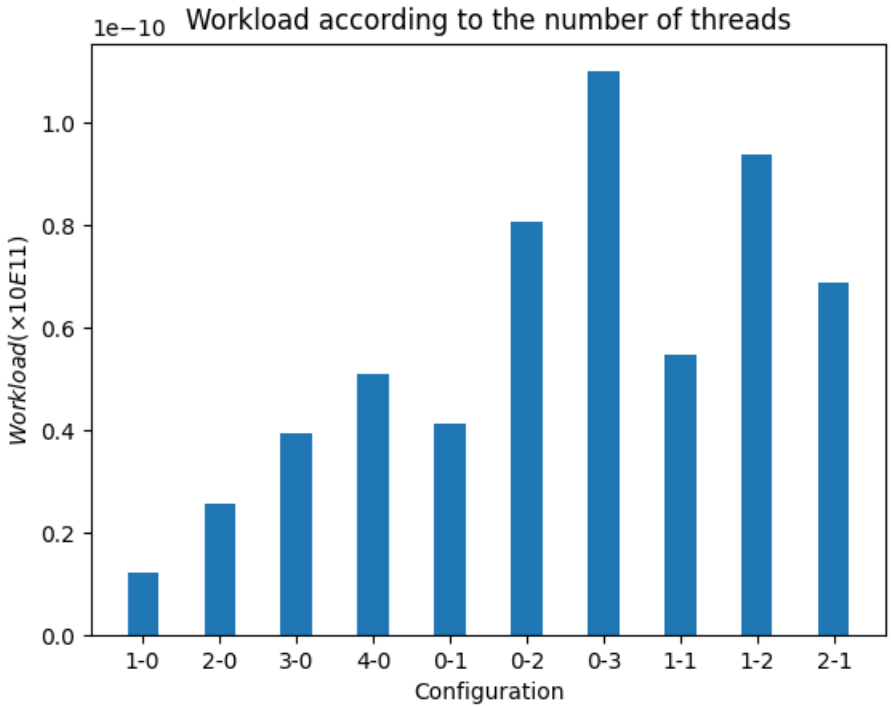
Impact of: **Type or Core**
Experiments duration: 10 min
Legend: Configuration 0-1 means

- 0 thread on Little sockets
- 1 Thread on Big Socket





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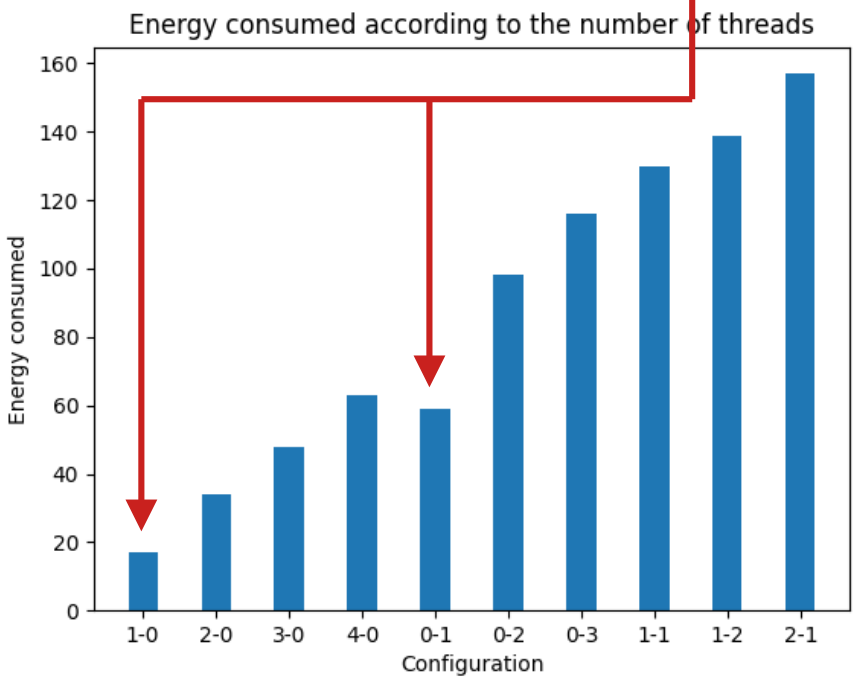
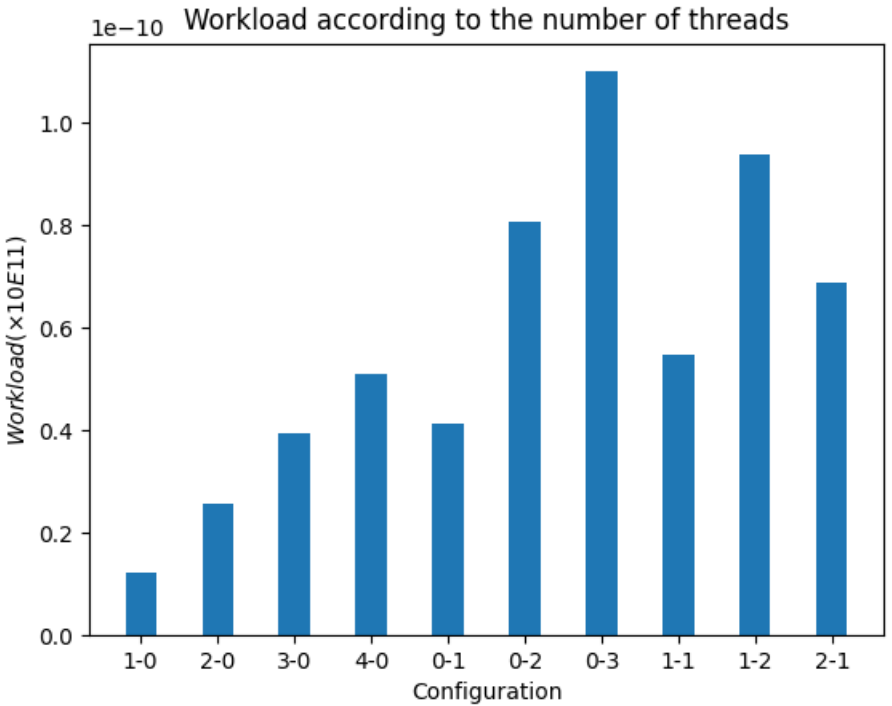
Big Cores consume a lot of energy compared to little cores





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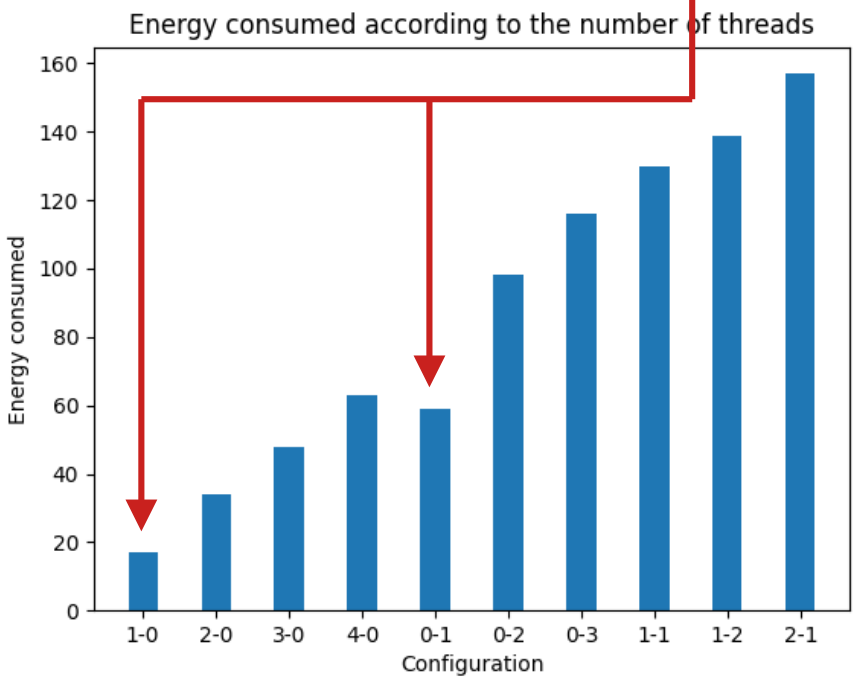
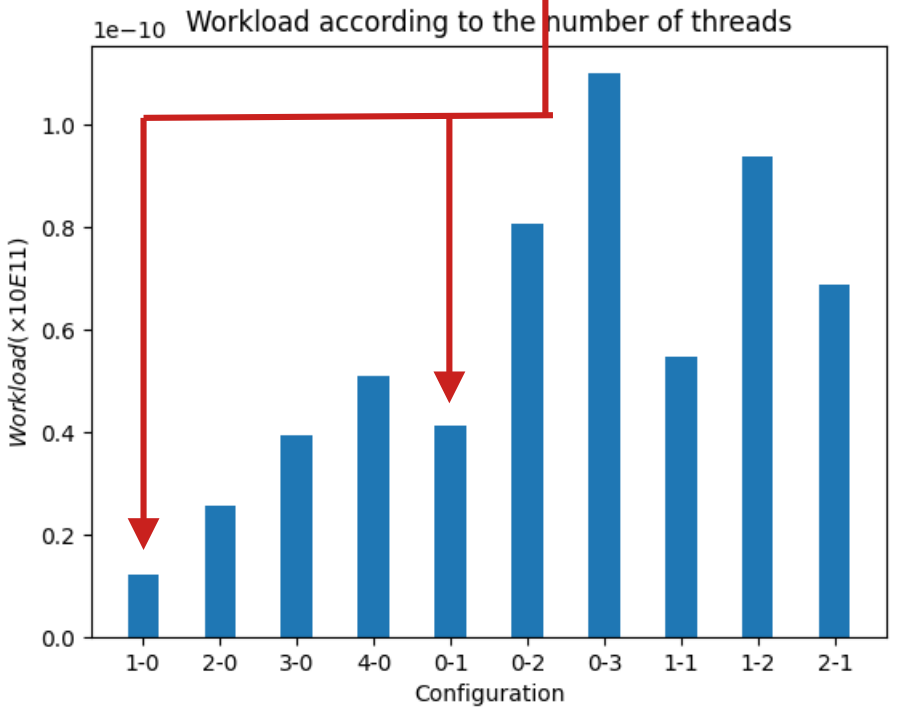
Big cores are very fast in computation





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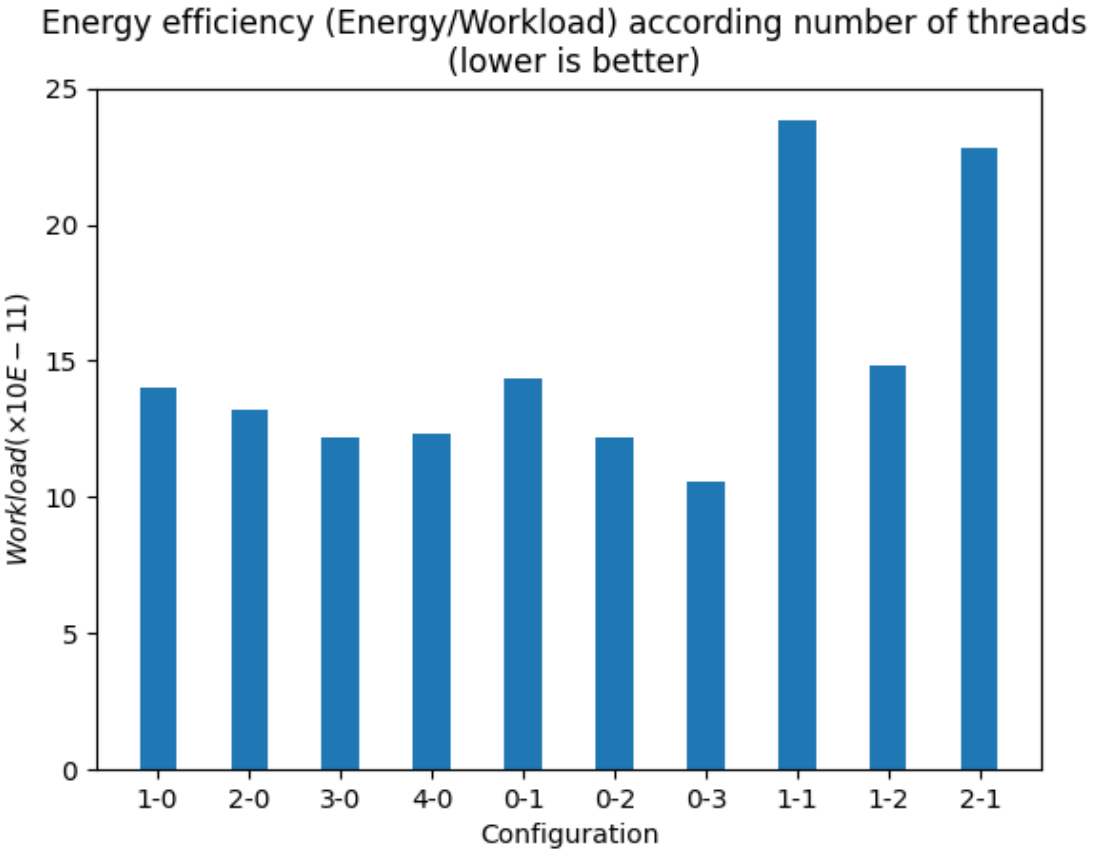

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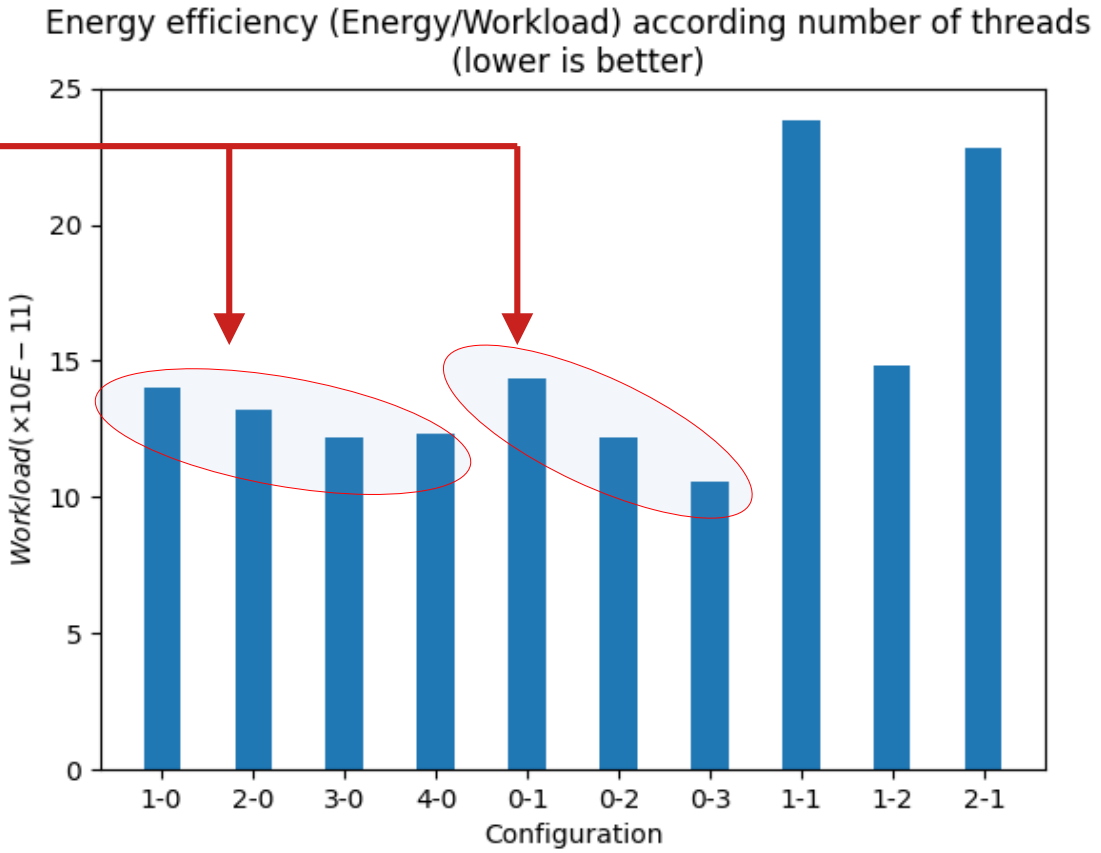
On the same socket the number of threads slightly increases with the efficiency



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Phone: Samsung S8
Impact of: **Other interactive tasks**
Experiments duration: 5 and- 10 min
Legend: Configuration 1_Int_1_BE-0 means

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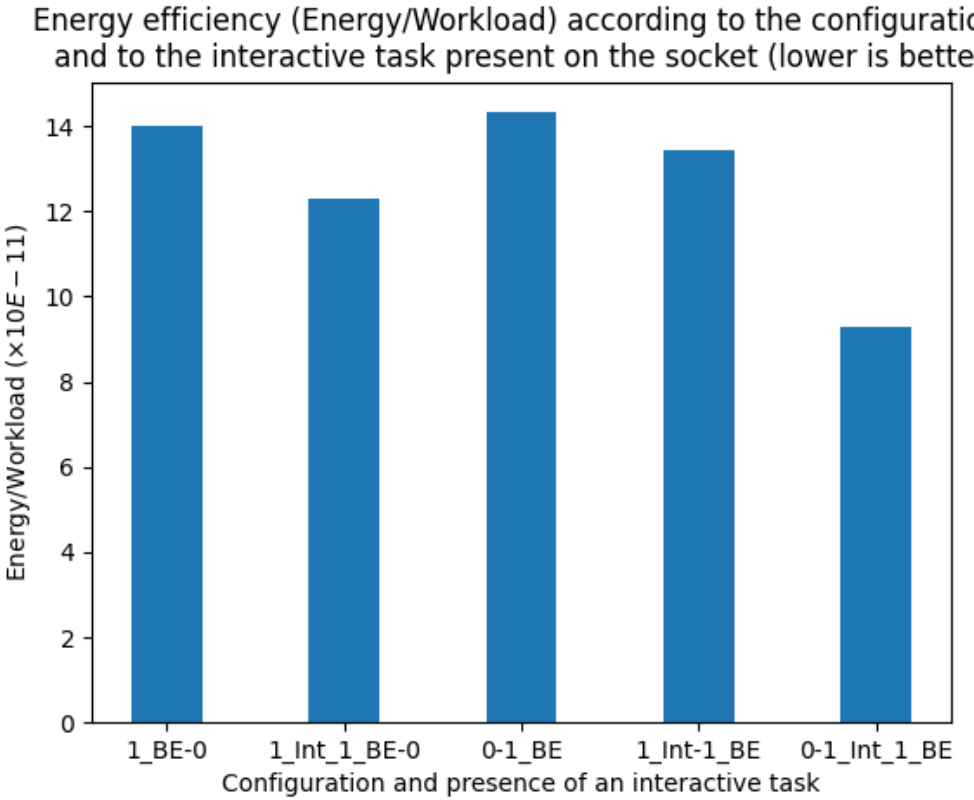
- 1 benchmarked thread on big Socket
- 0 Thread on big socket



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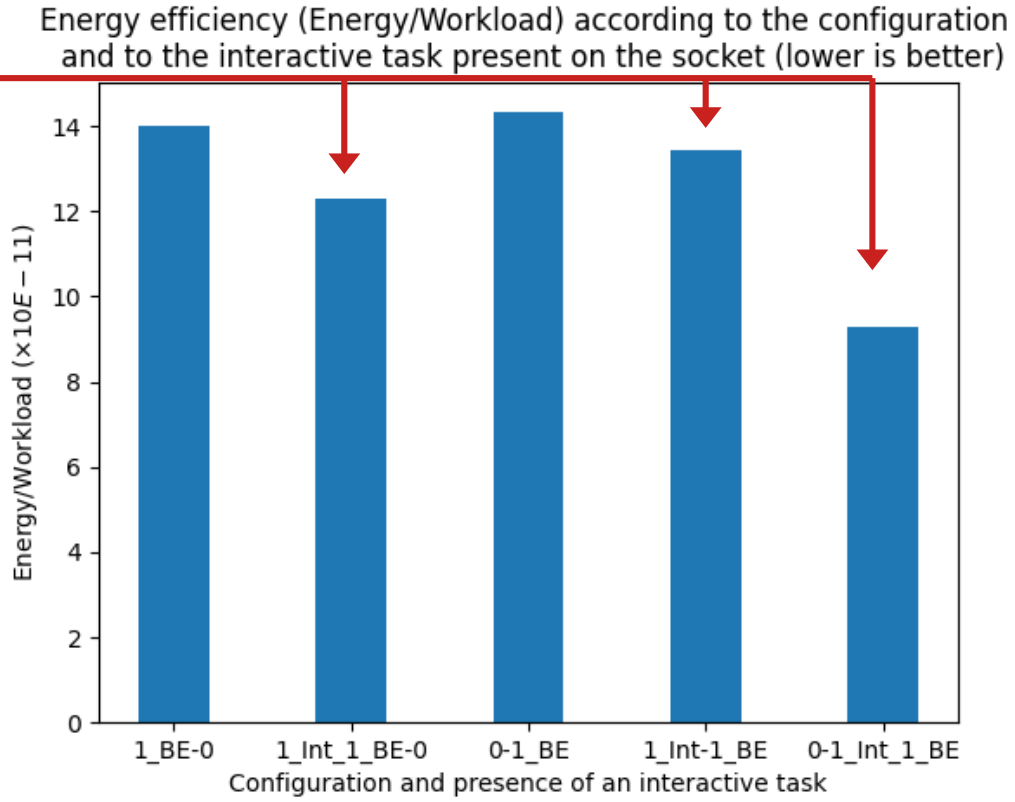

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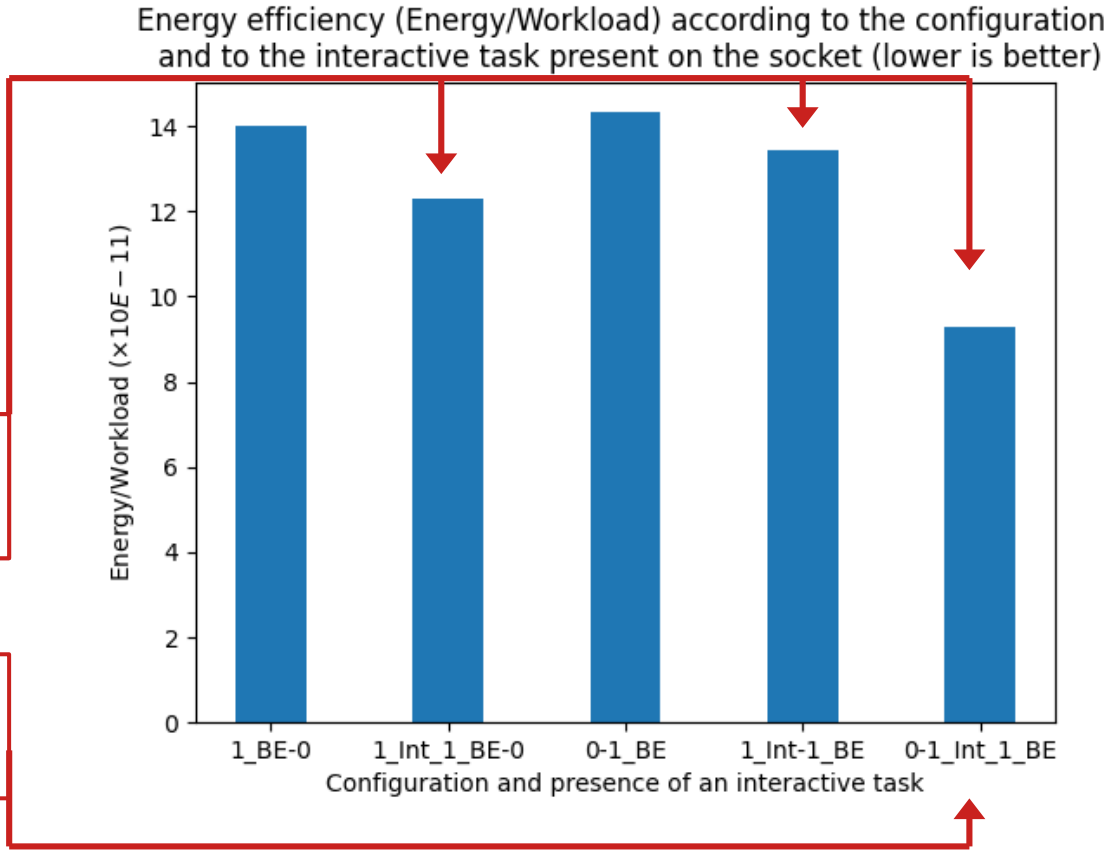
Co-location is more efficient on Big Sockets



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Phone: Samsung S8
Impact of: **Frequency**
Experiments duration: 5 min
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- 0 thread on Little sockets
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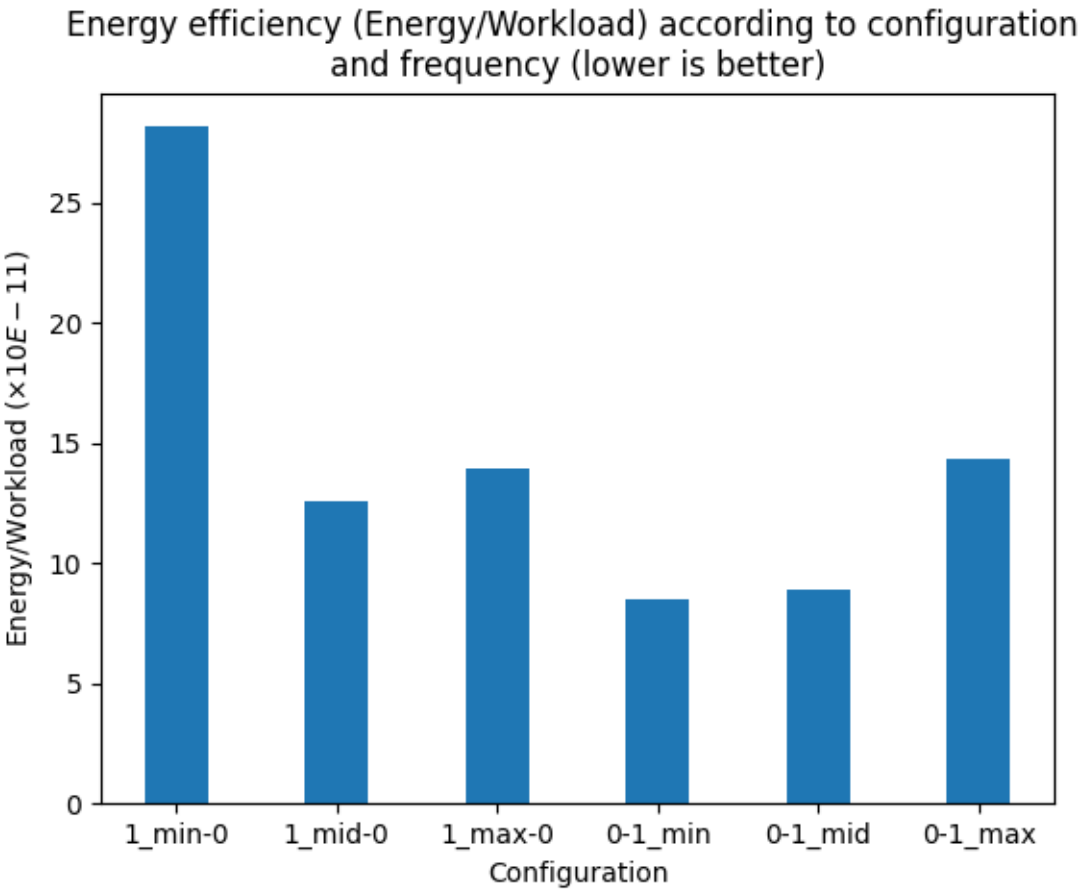
- Big socket runs with frequency at middle level.
- Mid = middle level, min = minimum level
  - Max = maximum frequency



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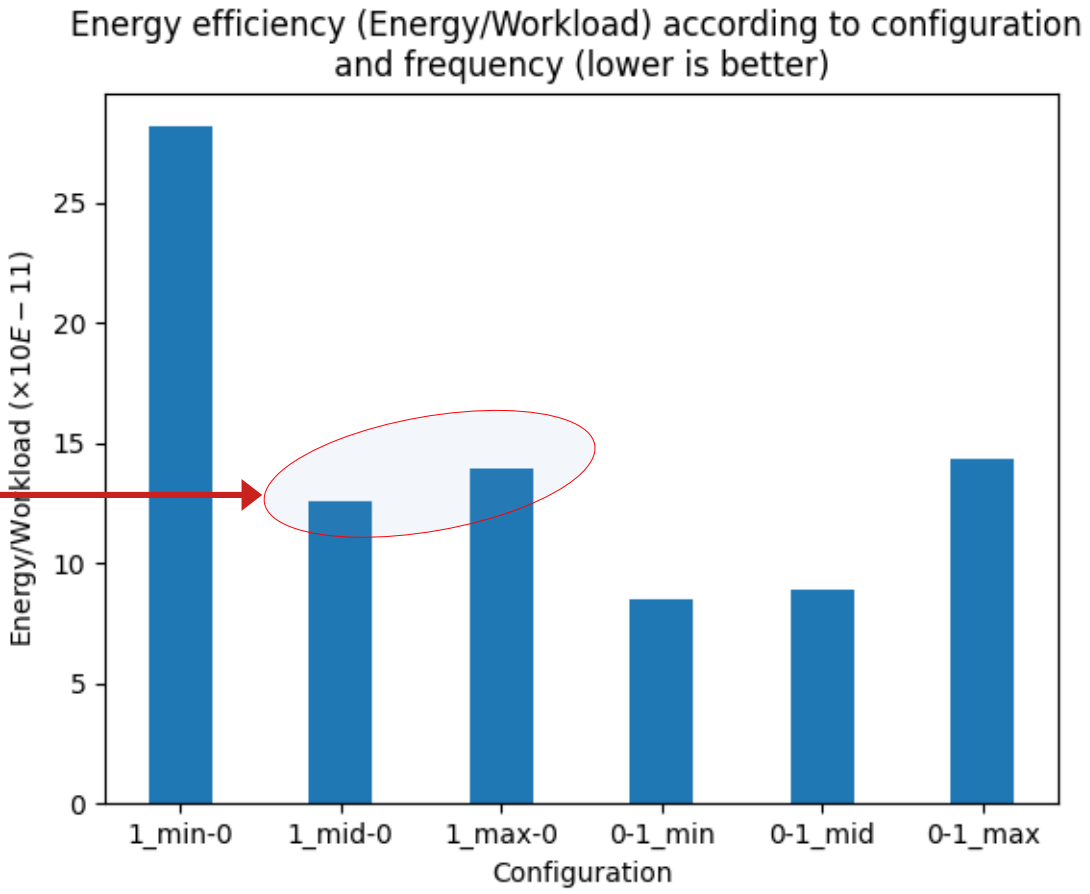

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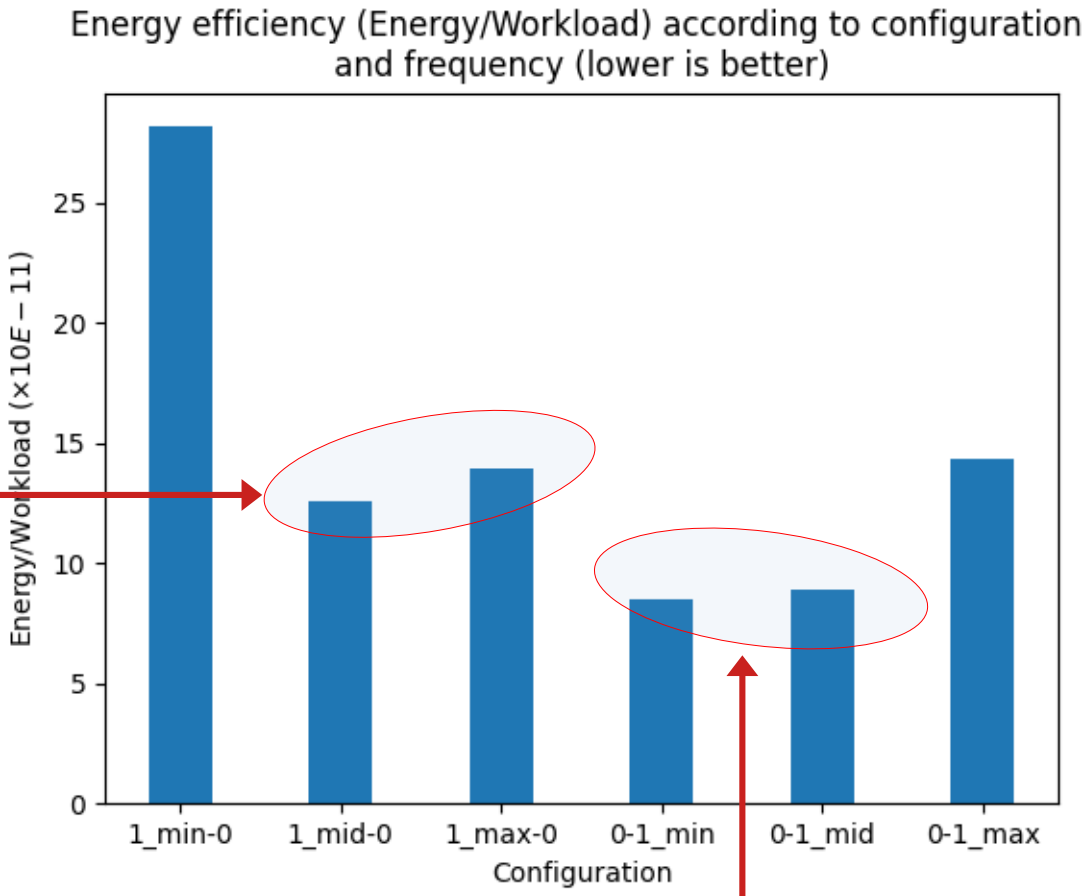


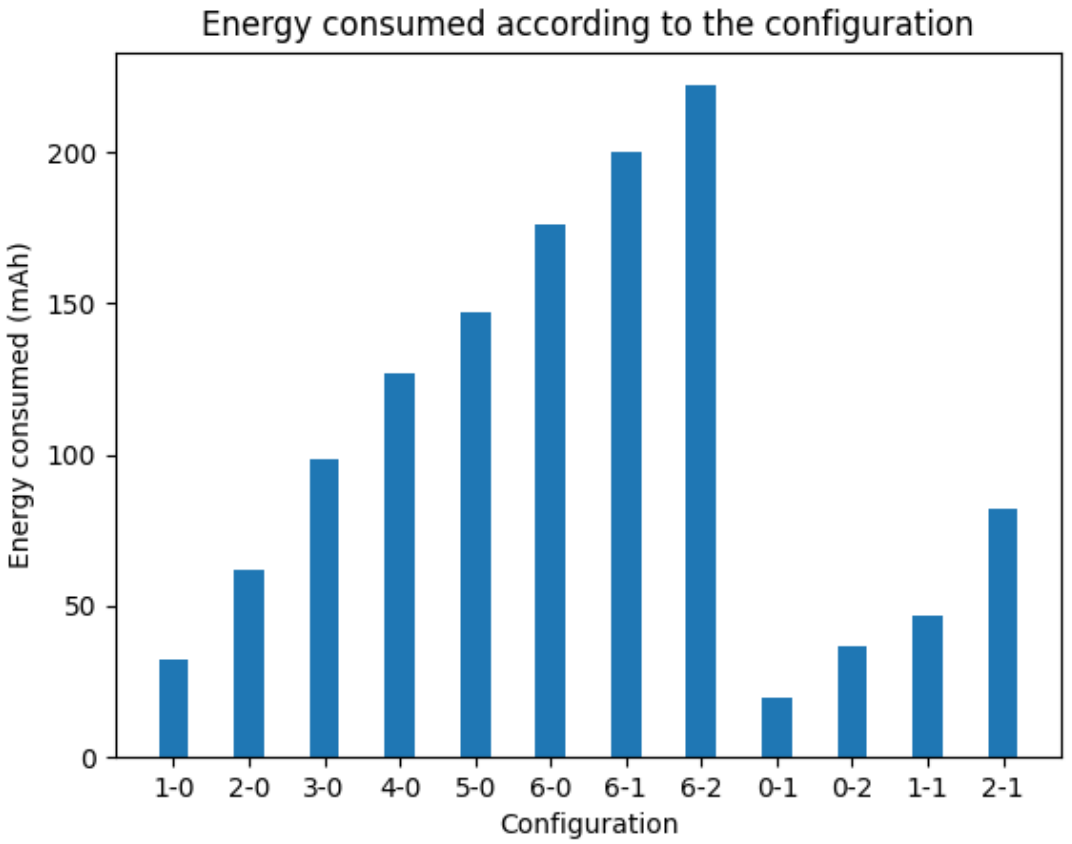
At slightly reduced frequency the Little cores are efficient

It is more efficient to reduced frequency on the Big cores as much as possible for one task.

4. Strange observations made using APIs on google Pixel

Phone: Google Pixel
Impact of: **Measurement method !!!**
Experiments duration: 10 min
Legend: Configuration 0-1 means:

- 0 thread on Little core
- 1 thread on Big core



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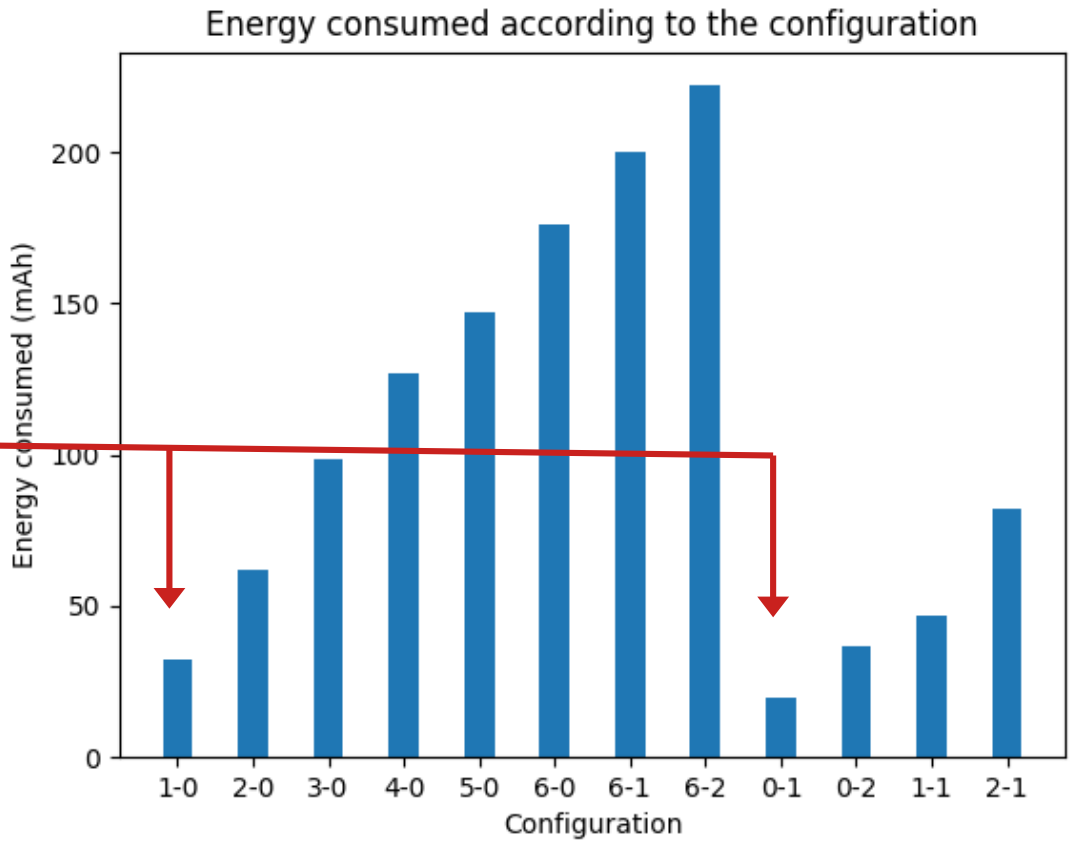

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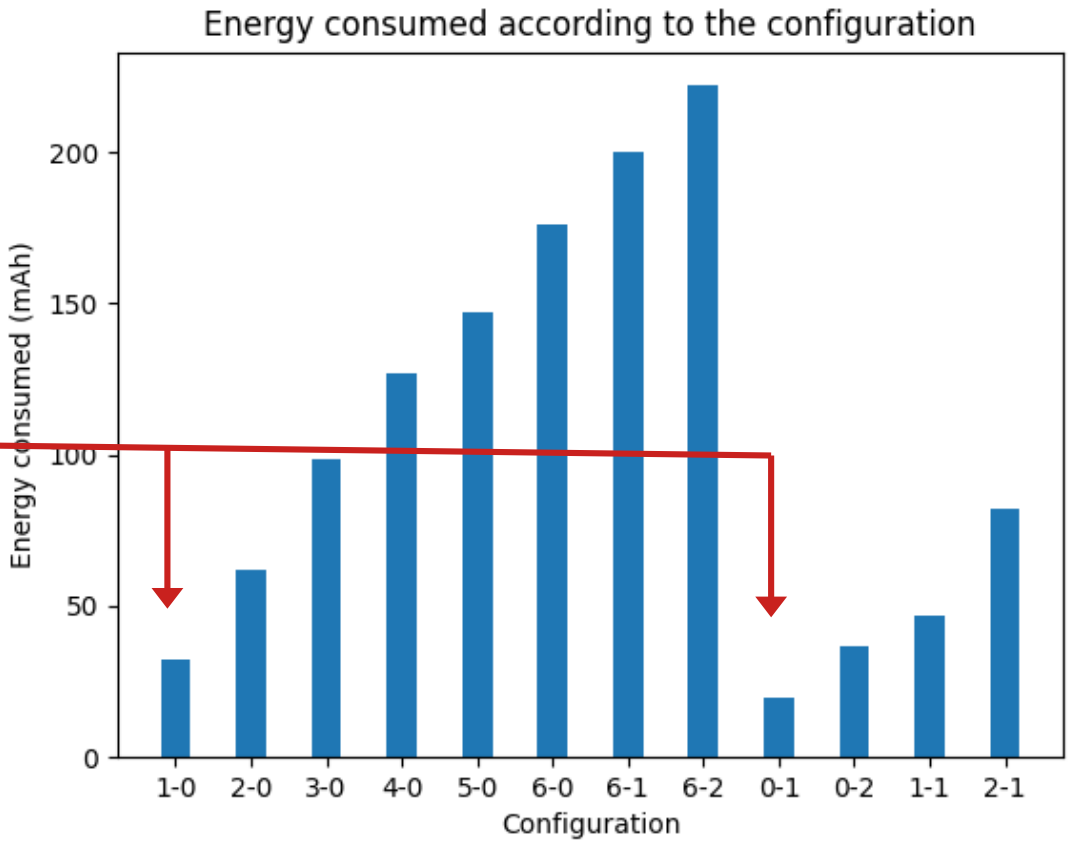
We had to restart experiments to validate previous observations (Missing submission death-lines)



4. Experiments and observations (made using the power-meter)

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Impact of: **Measurement method !!!**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file
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Legend: Configuration 0-1_BM means:

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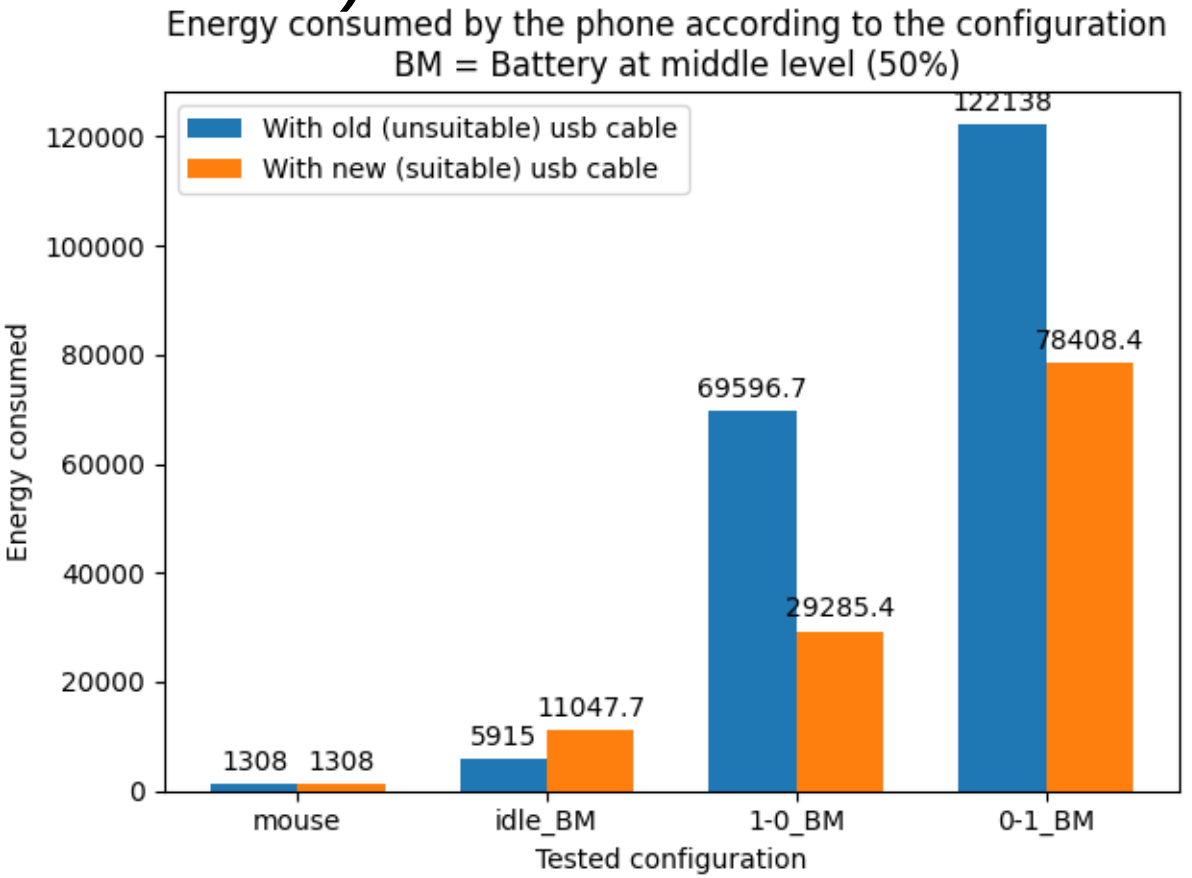
- Battery at Middle level
- Idle = phone is idle



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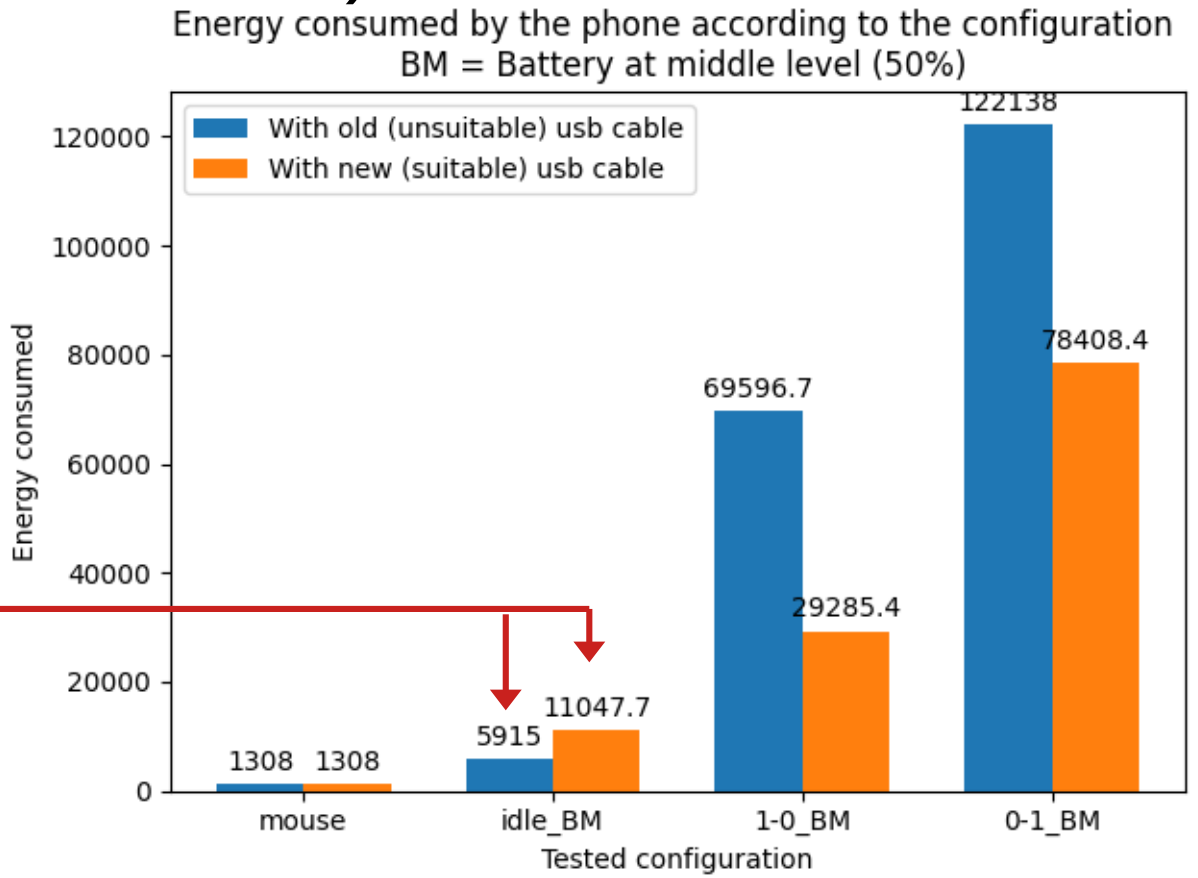
- Idle = phone is idle

The quality of the equipment (USB cable) impact results



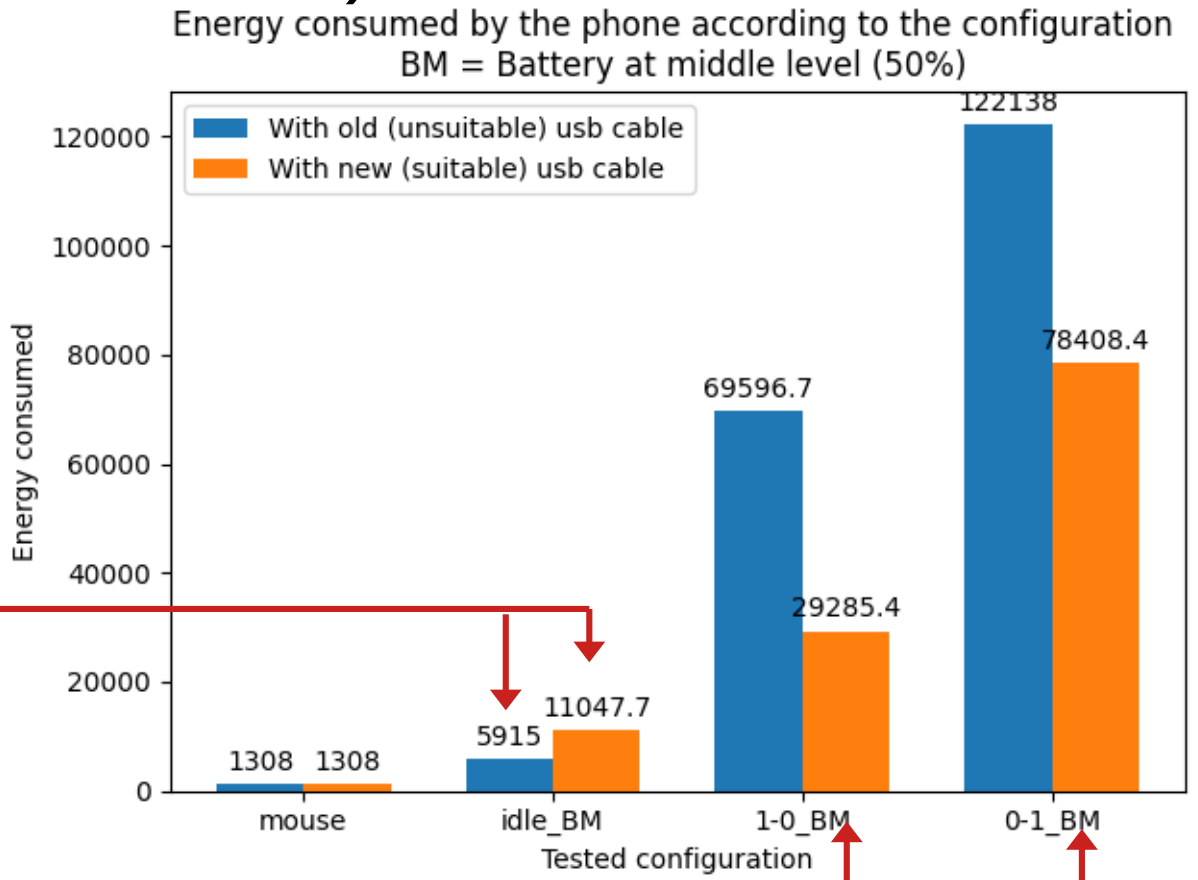
4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Measurement method !!!**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file
charge_stop_level
Legend: Configuration 0-1_BM means:

- 0 thread on Little core
- 1 thread on Big core
- Battery at Middle level
- Idle = phone is idle

The quality of the equipment (USB cable) impact results

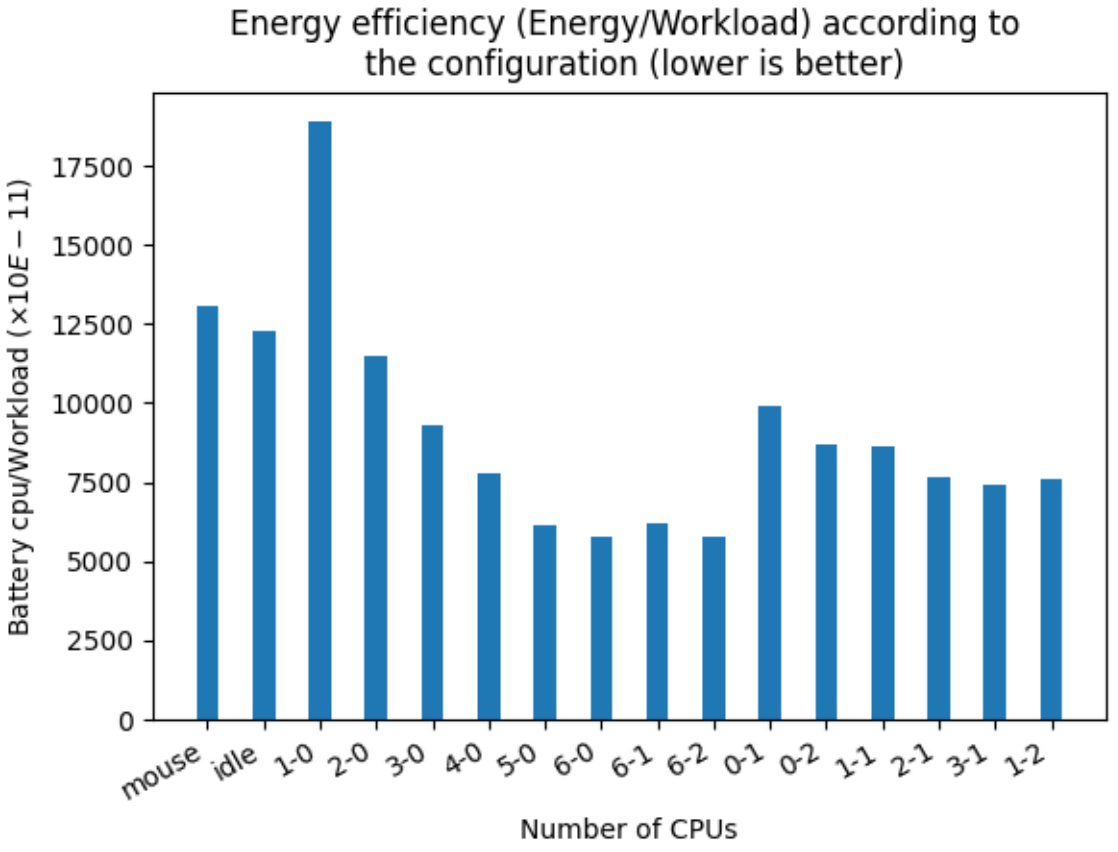
With the power-meter, results seem consistent with reality



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Number of threads**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1 means:

- 0 thread on Little core
- 1 thread on Big core

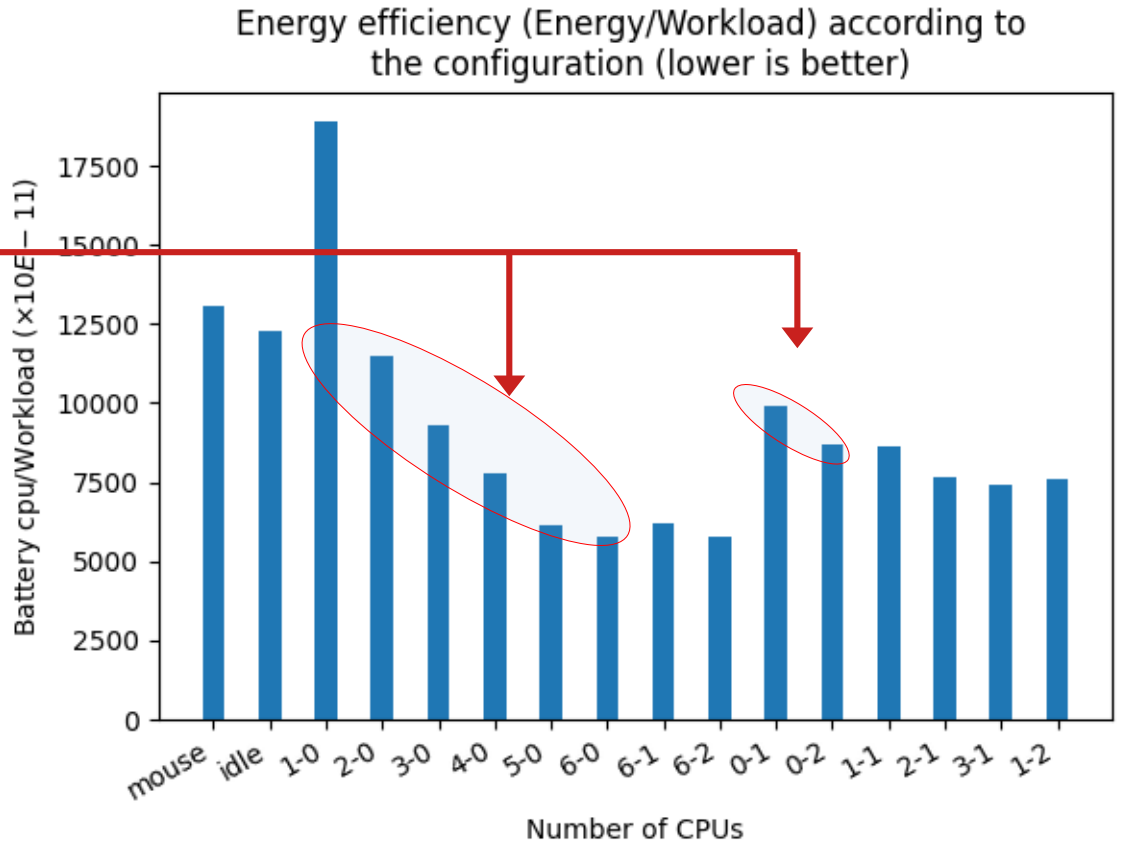


4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Number of threads**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1 means:

- 0 thread on Little core
- 1 thread on Big core

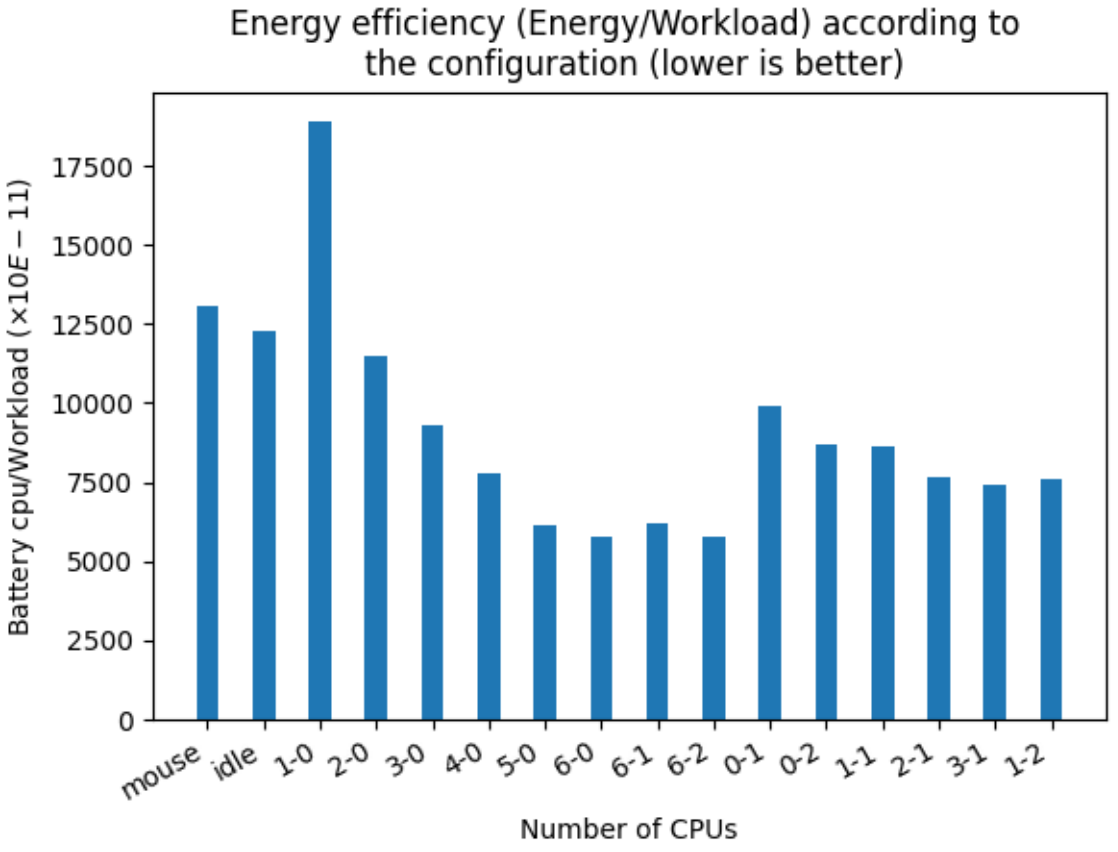
On the same socket the number of threads slightly increases with the efficiency



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Type of Cores**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file
charge_stop_level
Legend: Configuration 0-1 means:

- 0 thread on Little core
- 1 thread on Big core

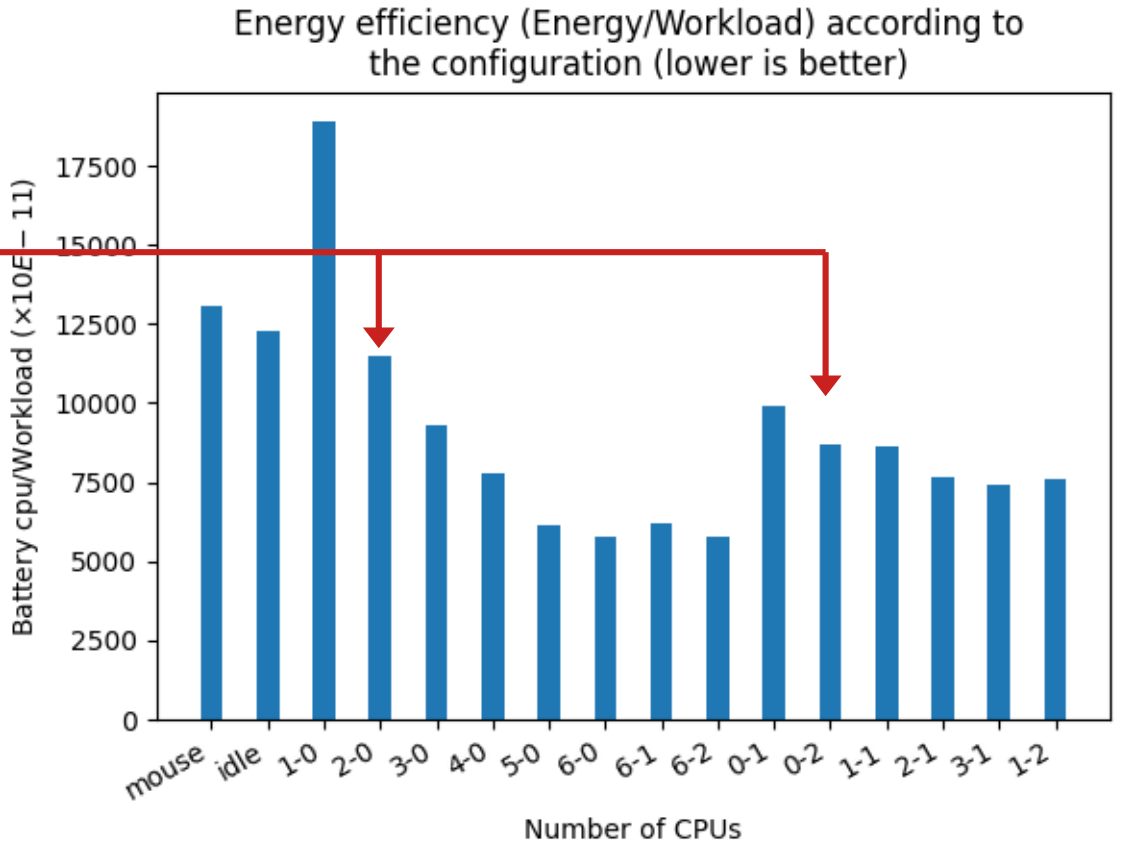


4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Type of Cores**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1 means:

- 0 thread on Little core
- 1 thread on Big core

Big cores are much more efficient than little cores



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Type of Cores**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1 means:

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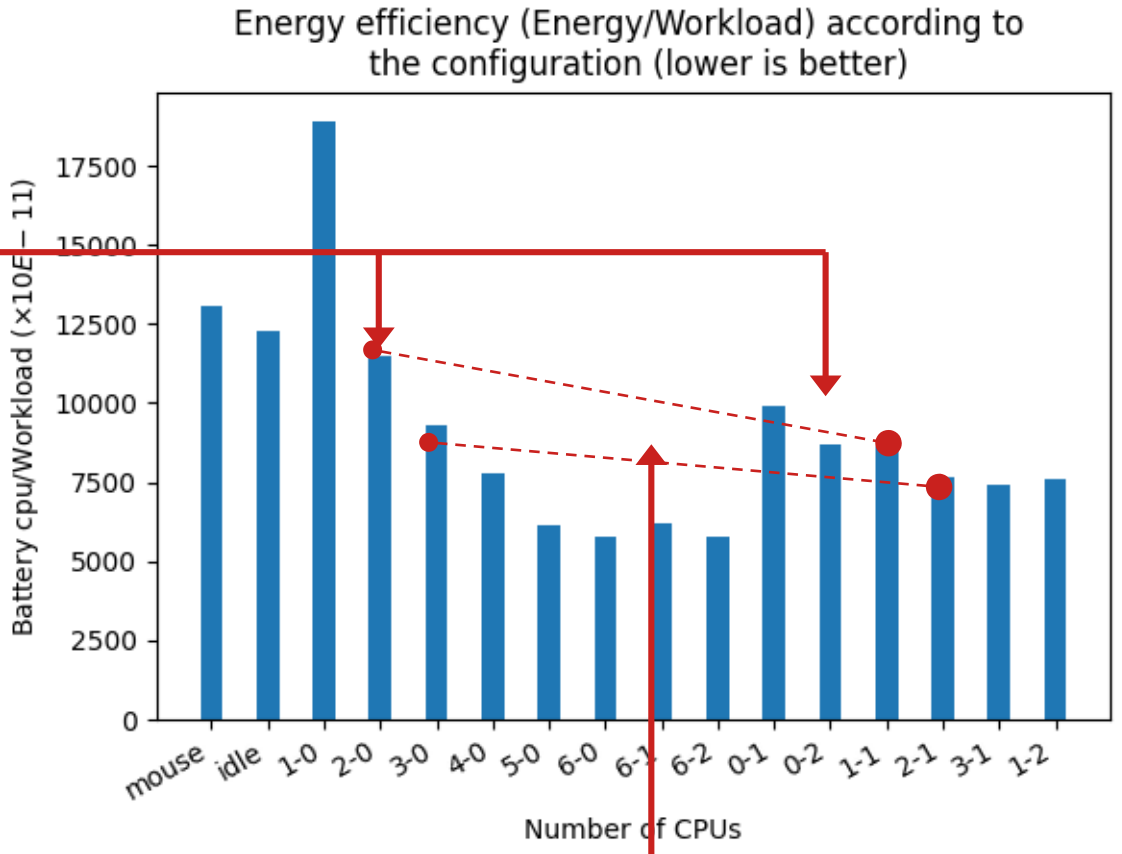
Big cores are much more efficient than little cores

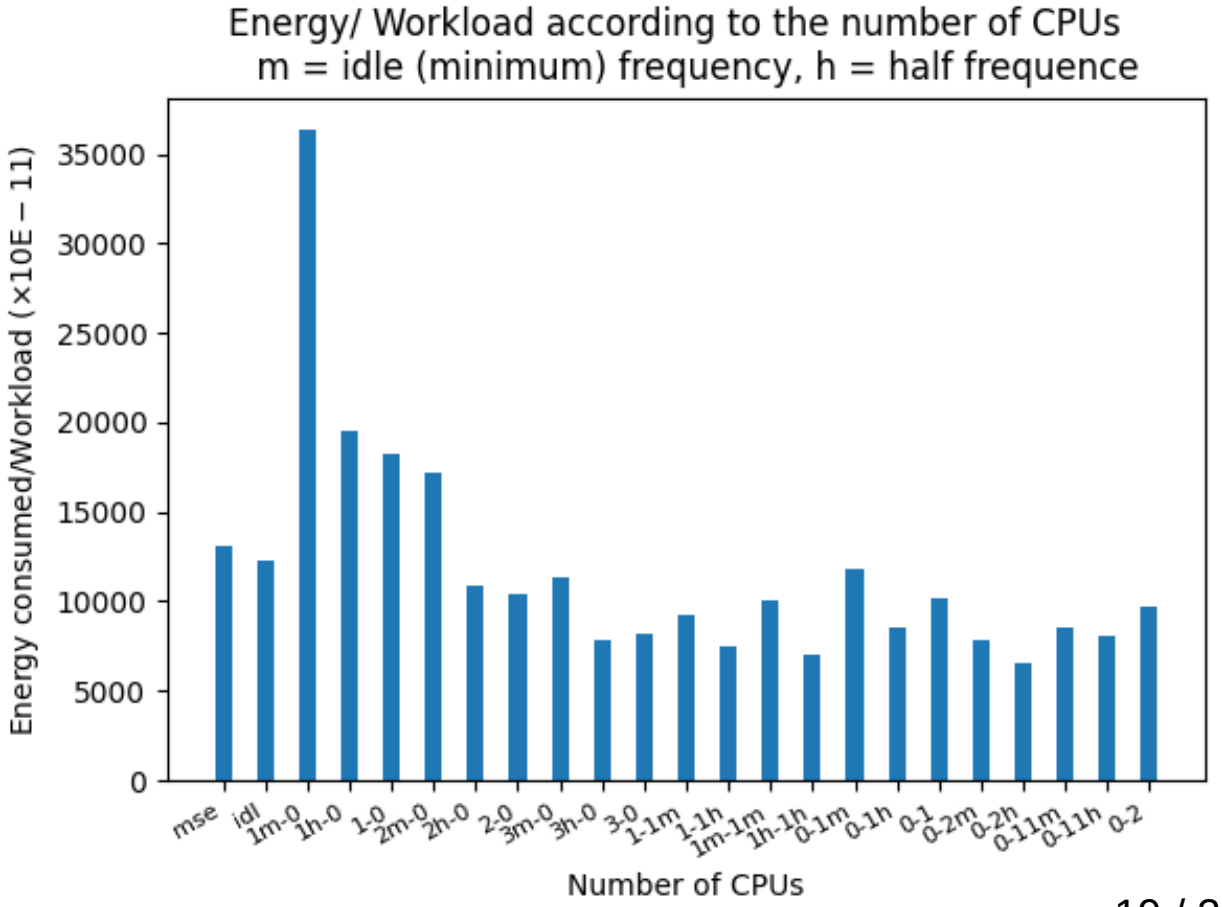
The efficiency of the big cores influences the overall efficiency of the configuration



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Frequency**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file
charge_stop_level
Legend: Configuration 0-1m means:

- 0 thread on Little core
- 1 thread on Big core
- The Big core has the min frequency
- H = half frequency, nothing = max frequency

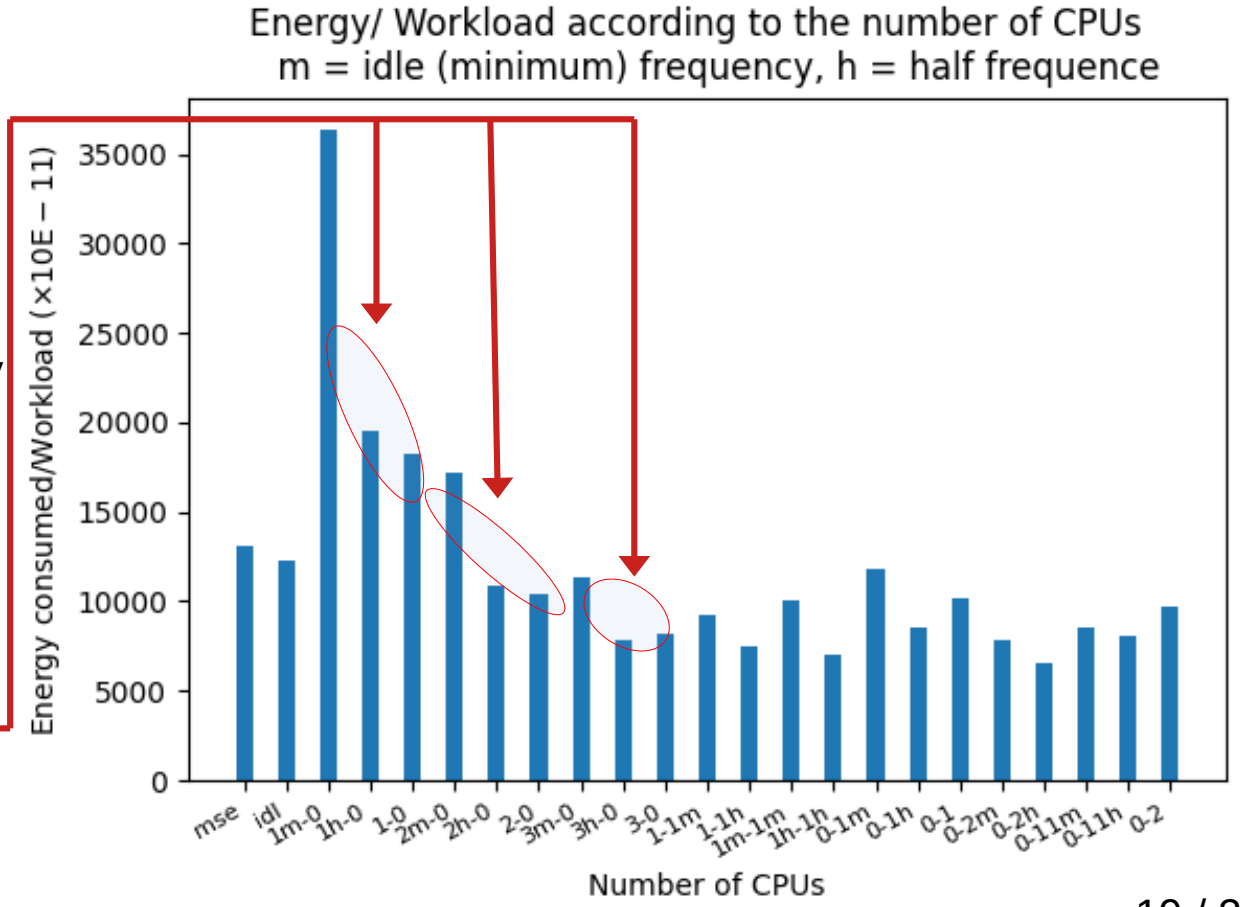


4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Frequency**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1m means:

- 0 thread on Little core
- 1 thread on Big core
- The Big core has the min frequency
- H = half frequency, nothing = max frequency

On the Little cores we are much more efficient with the maximum frequency



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Frequency**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1m means:

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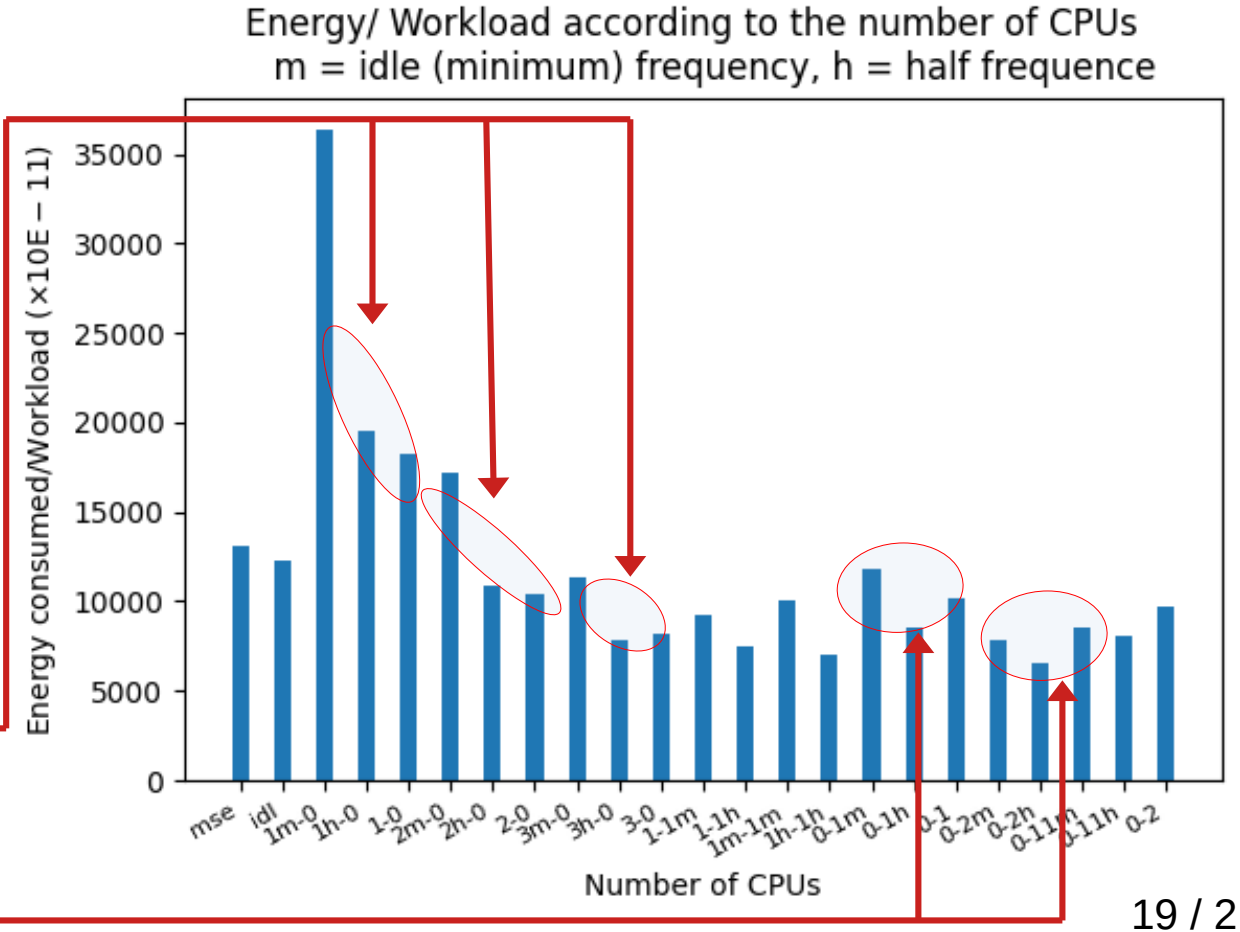


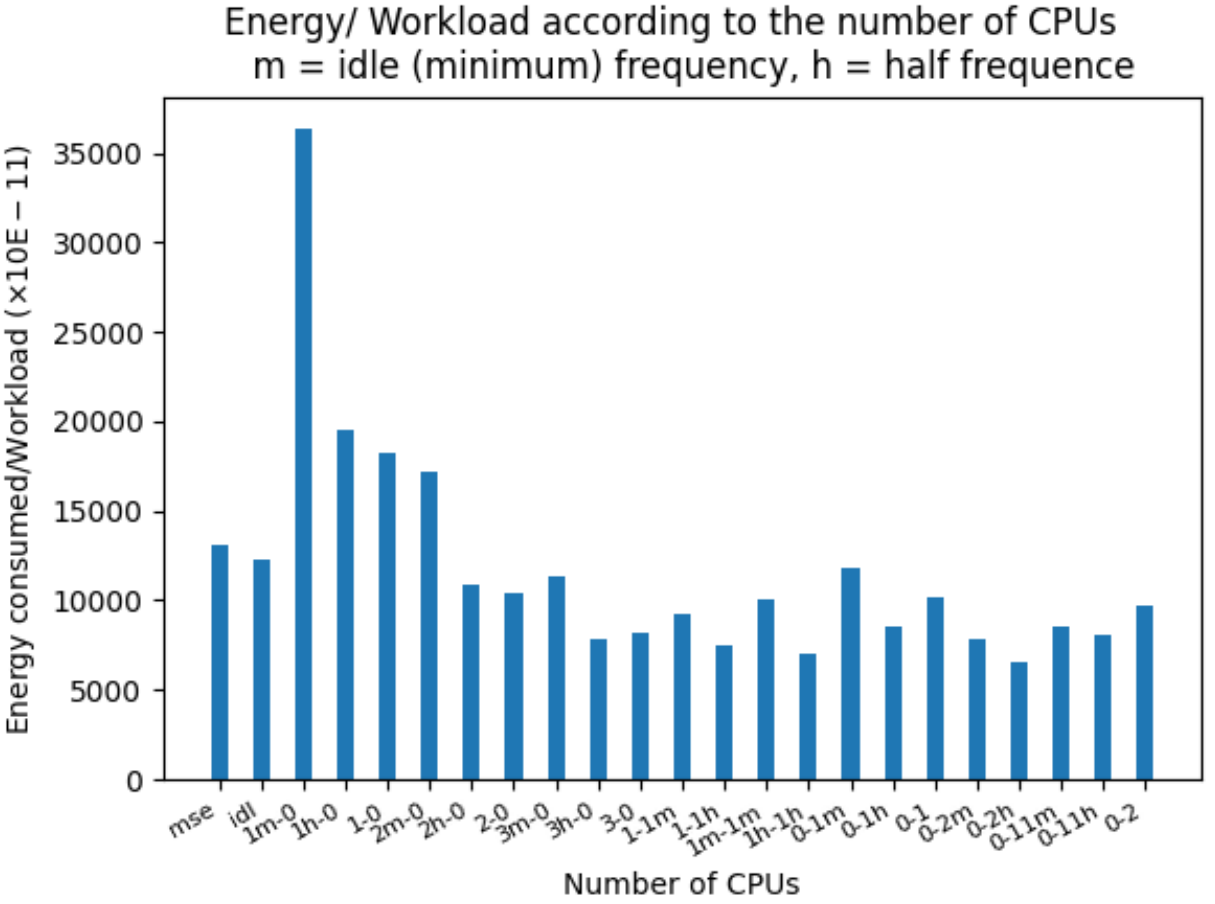
On the Little cores we are much more efficient with the maximum frequency

On the Big cores we are much more efficient with the mid frequency

4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Frequency and number of Threads**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1m means:

- 0 thread on Little core
- 1 thread on Big core
- The Big core has the min frequency
- H = half frequency, nothing = max frequency



4. Experiments and observations (made using the power-meter)

Phone: Google Pixel
Impact of: **Frequency and number of Threads**
Experiments duration: 10 min
Battery level: 50
No charging: Yes by the file *charge_stop_level*
Legend: Configuration 0-1m means:

- 0 thread on Little core
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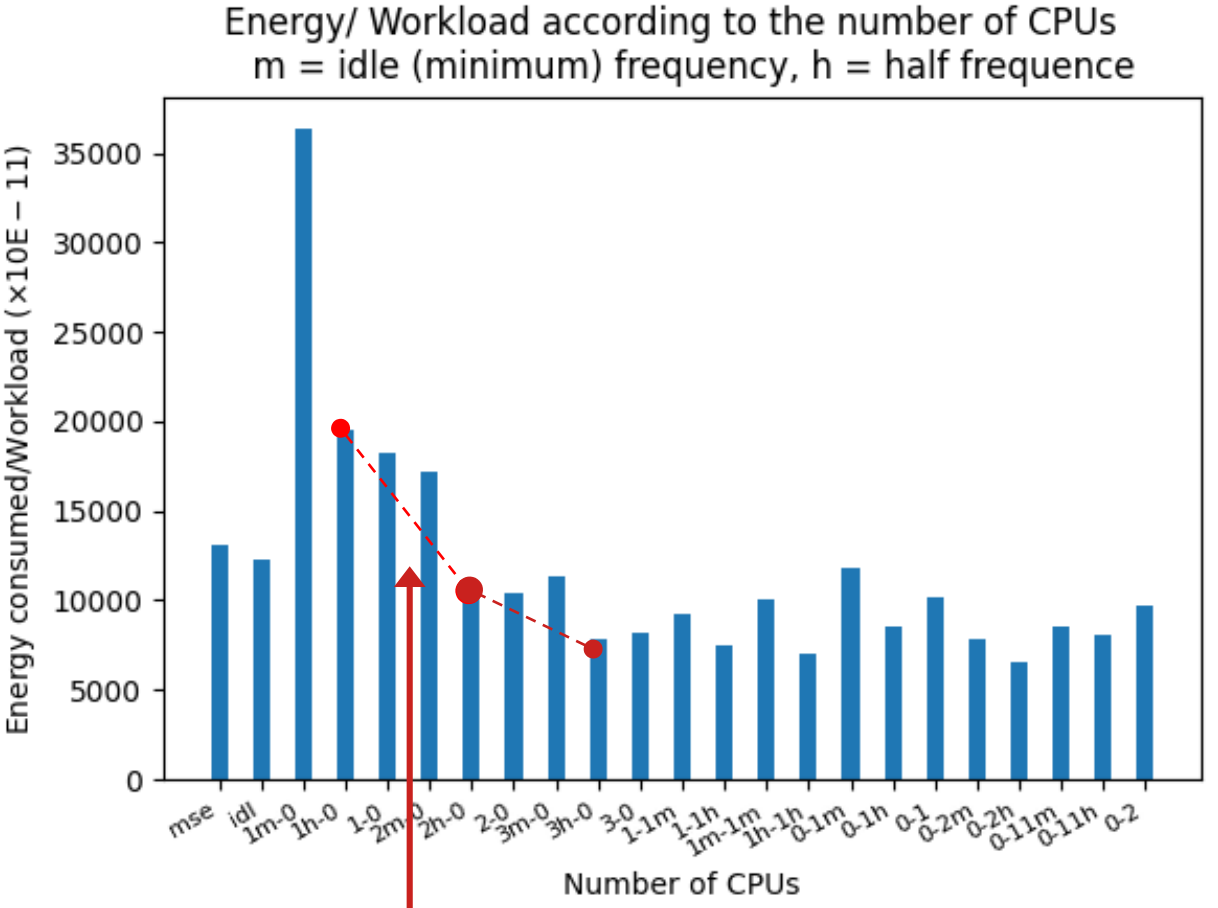
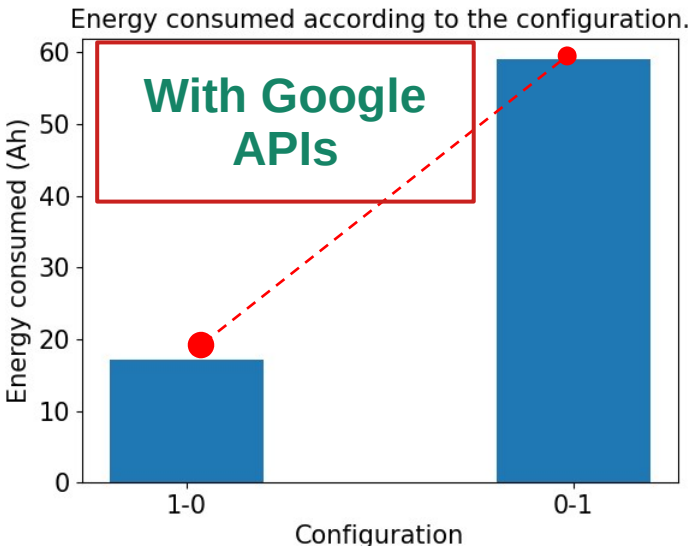
- The Big core has the min frequency
- H = half frequency, nothing = max frequency

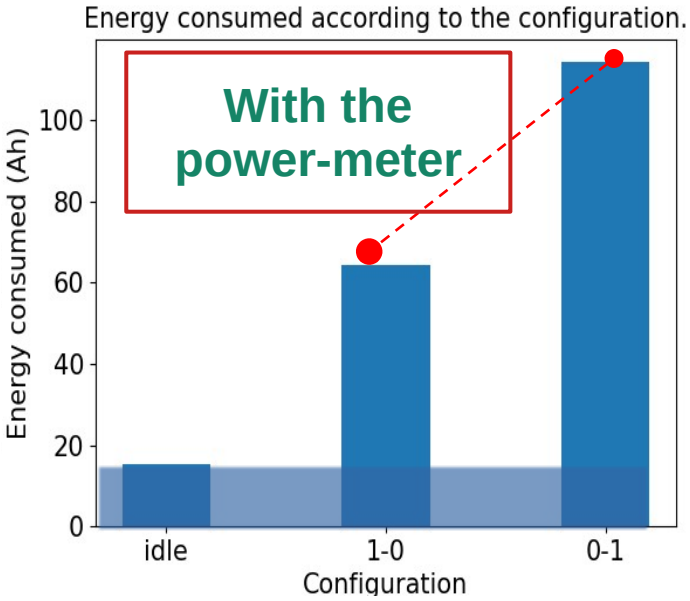
Fixing the frequency at mid level and increasing the number of threads increases the efficiency drastically (59.76 %) ~ 60%



4. Next steps

- Same experiments on Samsung
  - Good news: No limitations on the number of configurations as with APIs.
    We use *cc_info* file and the *power-meter*
  - We suspect that APIs on samsung was not far from reality in term of energy ratio.





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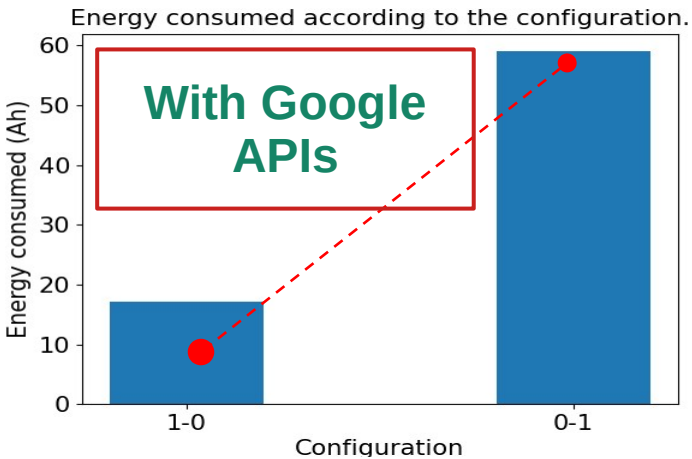

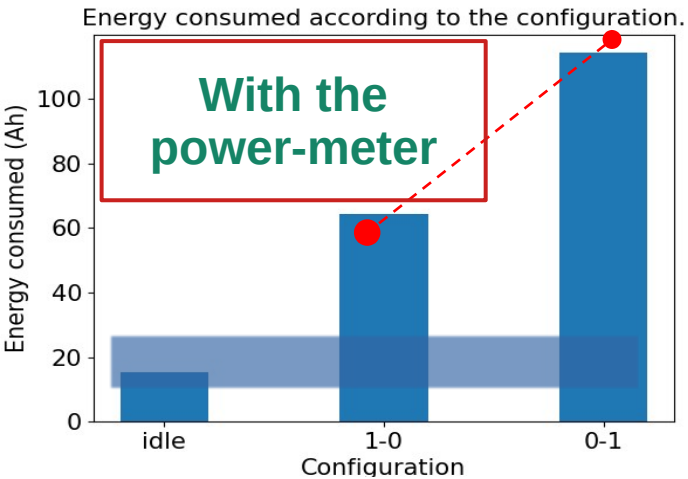

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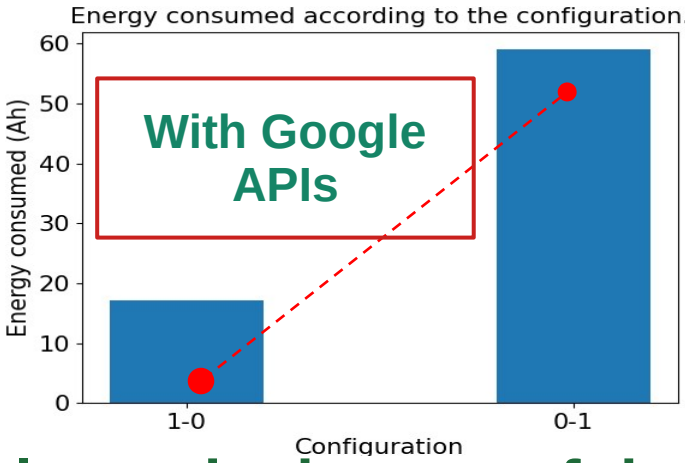

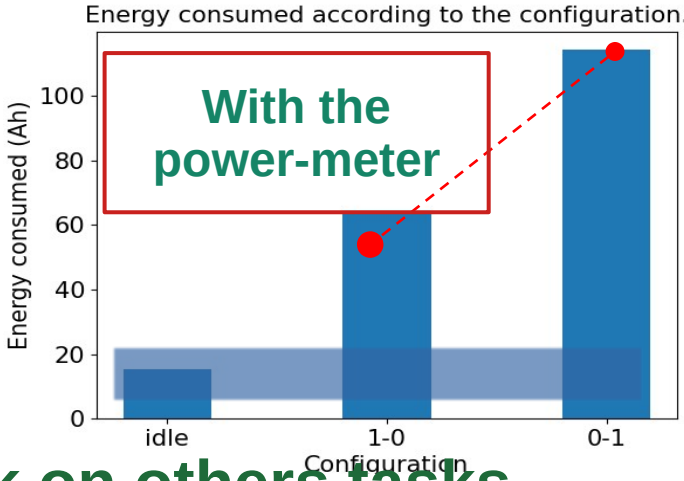

- **Evaluate the impact of the FL task on others tasks.**
- **Validate observations made with other Benchmaks.**
- **Identify underlying reasons behind lessons learned (at OS level).**
- **Valorise lessons learned and observations (publication, ...).**

Tank you for your attention.

General Problem Scheme