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

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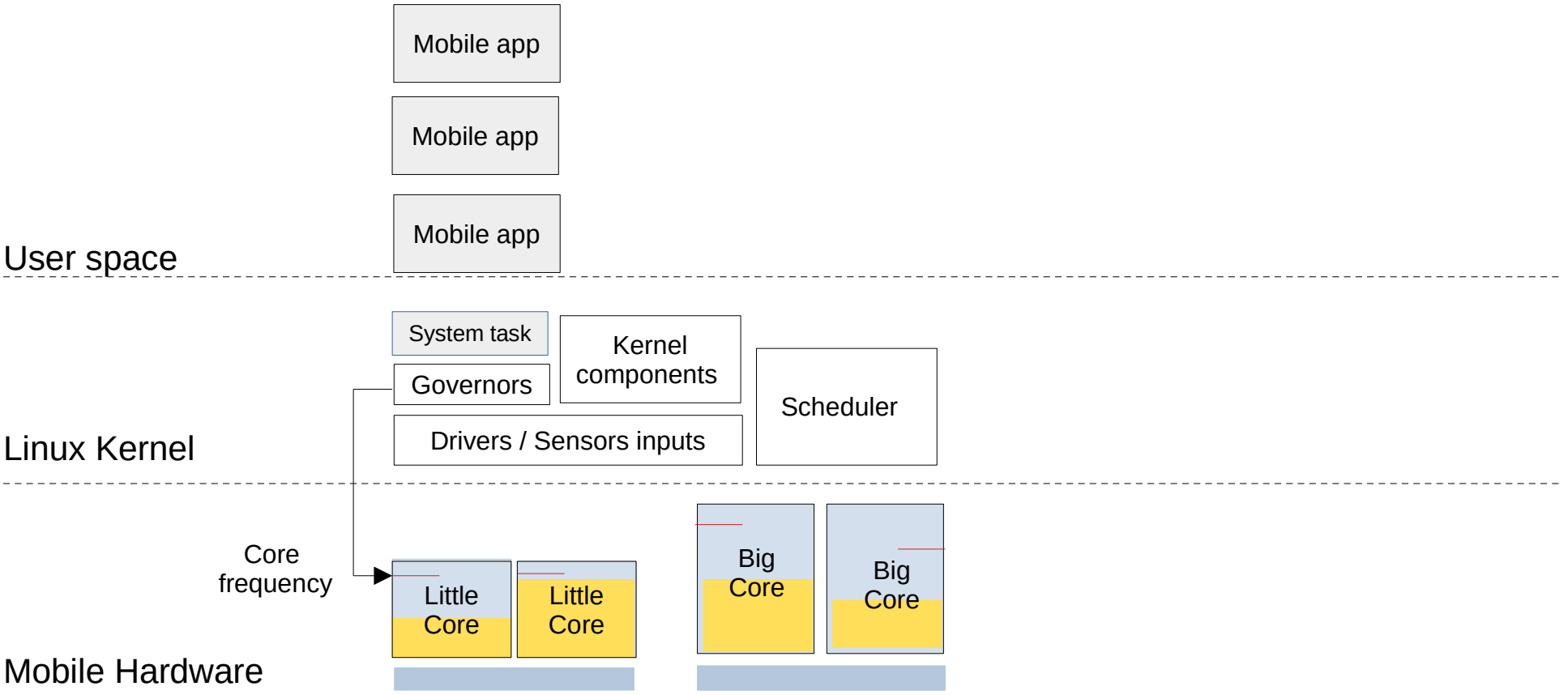
Summary

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 state the problem: general scheme



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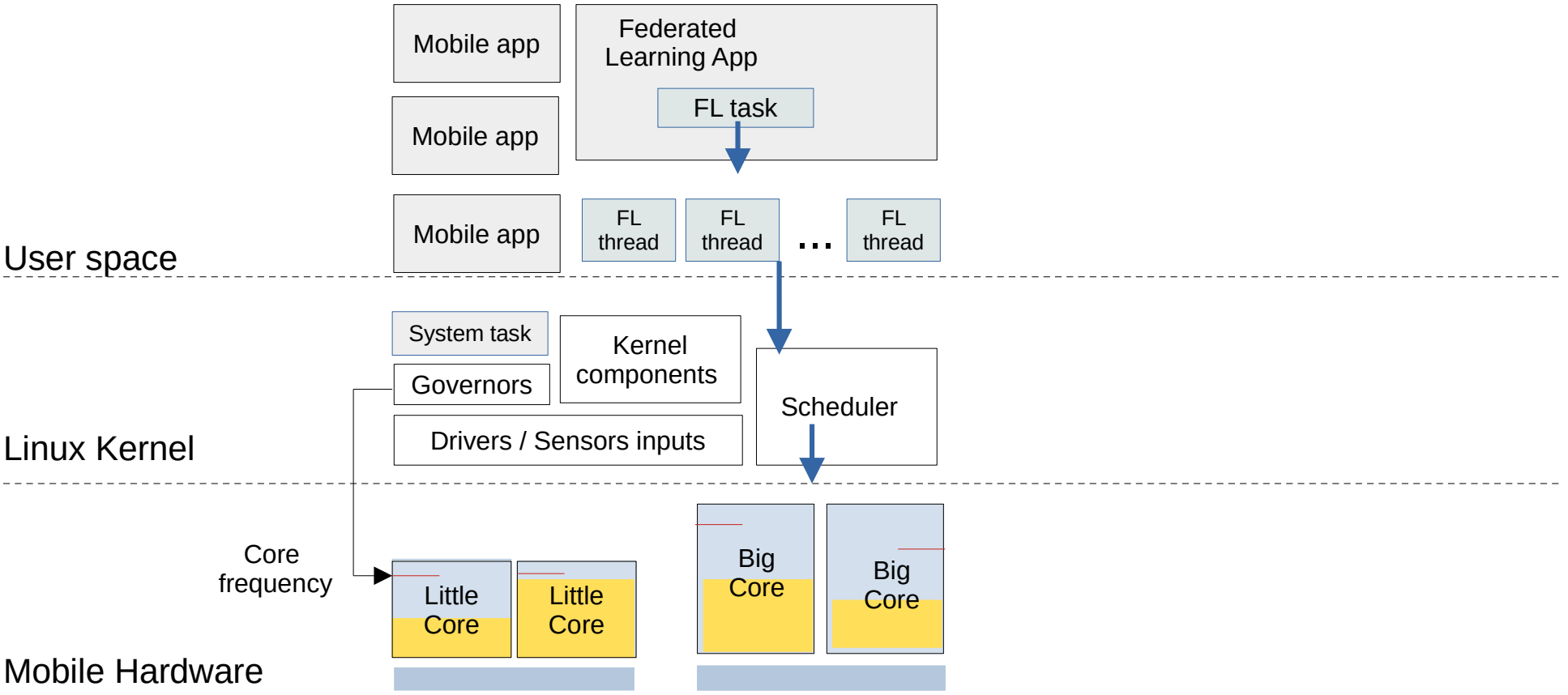

3.a. Let us define the **metric** to optimize

- 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 total energy consumed: obtained by measurements.
- Metric adopted for the project: **energy efficiency**

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

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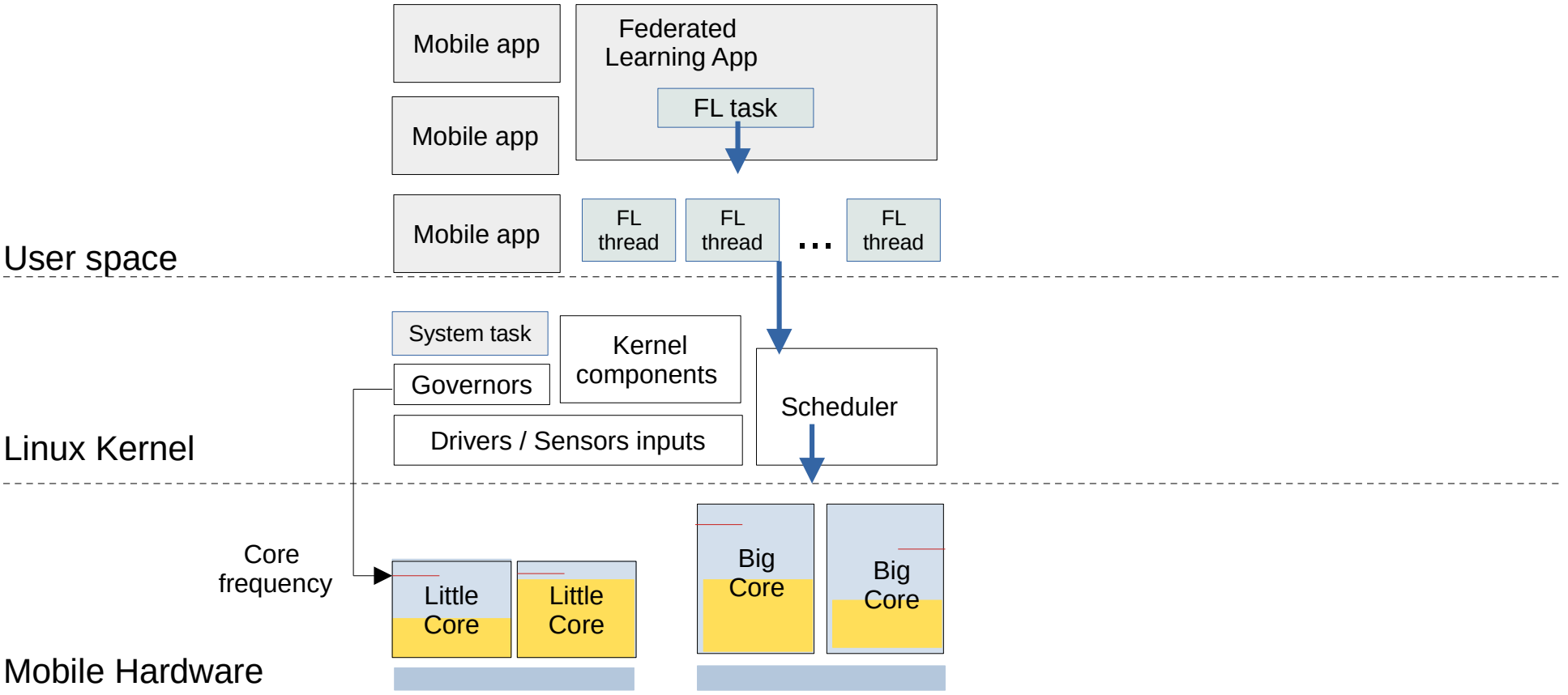

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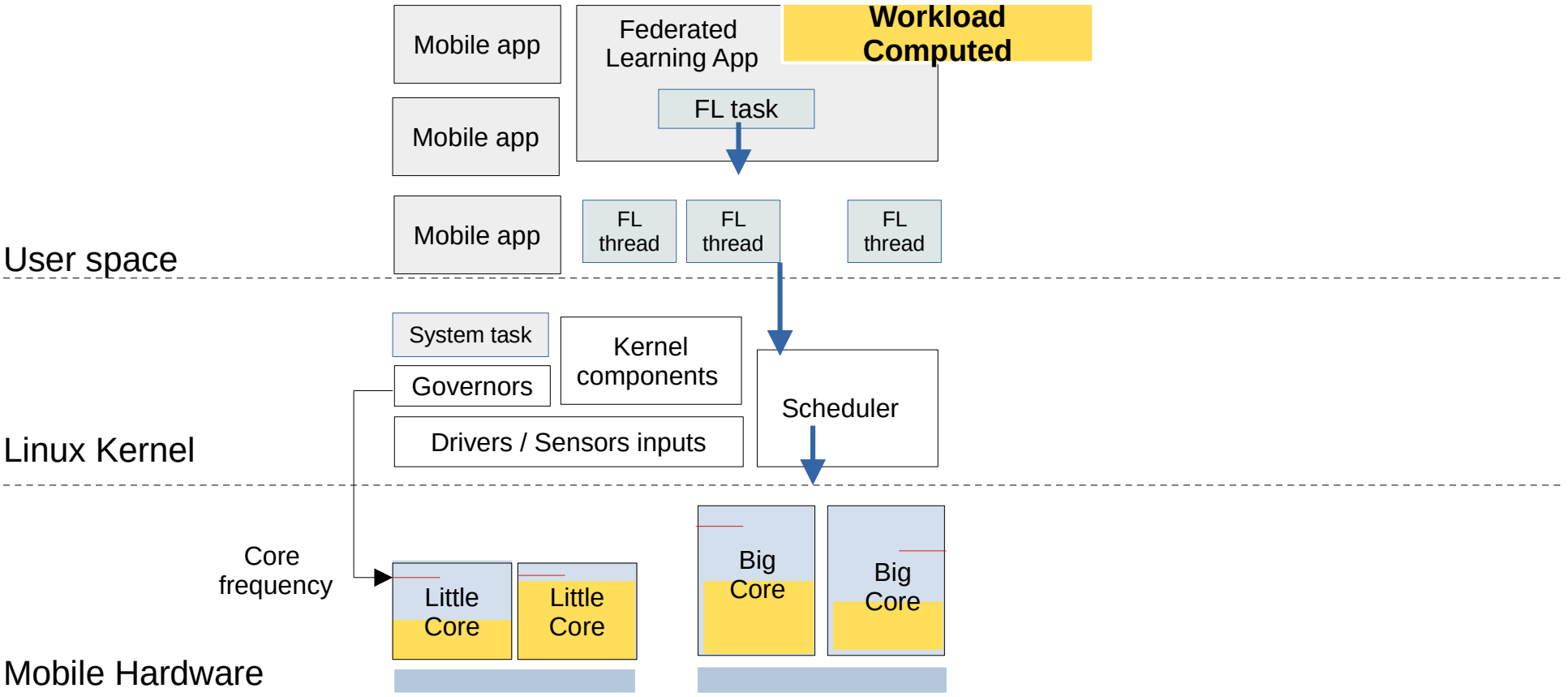

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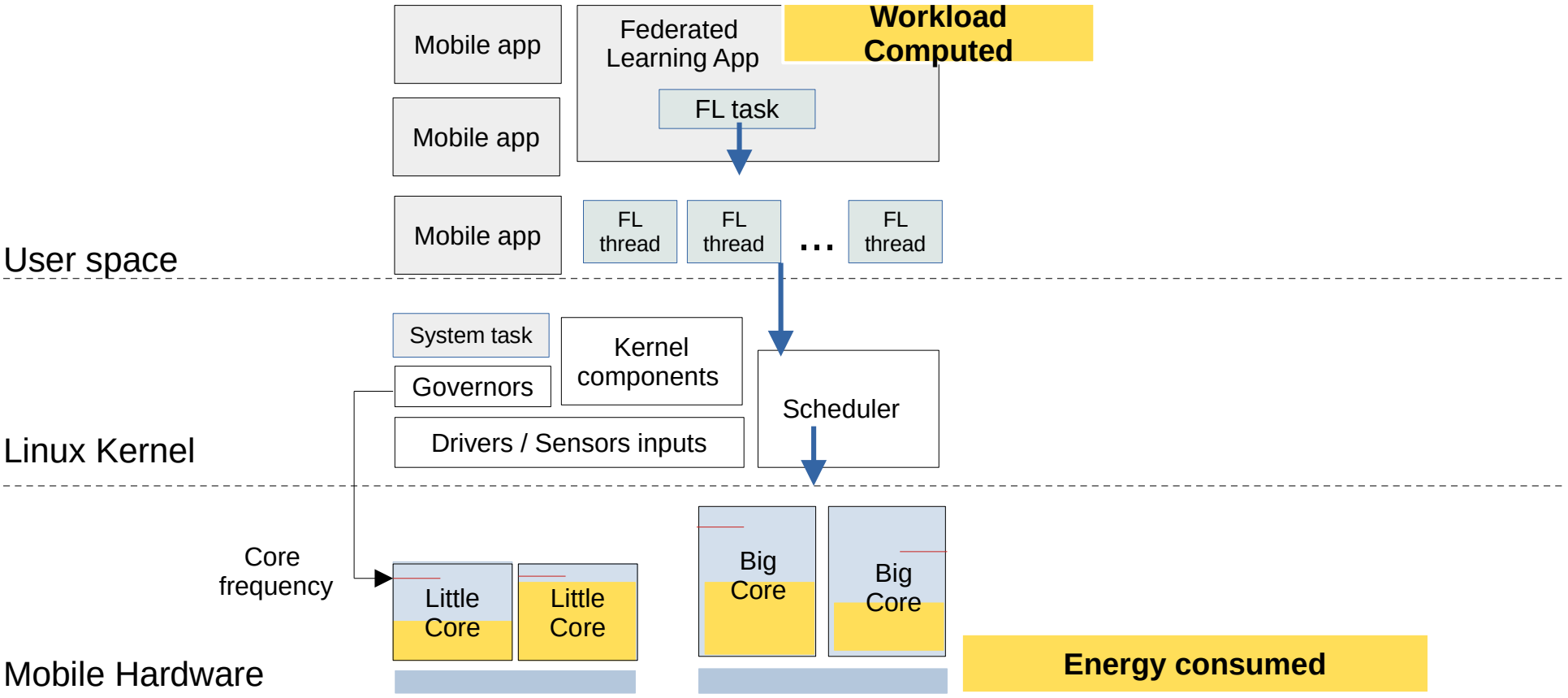

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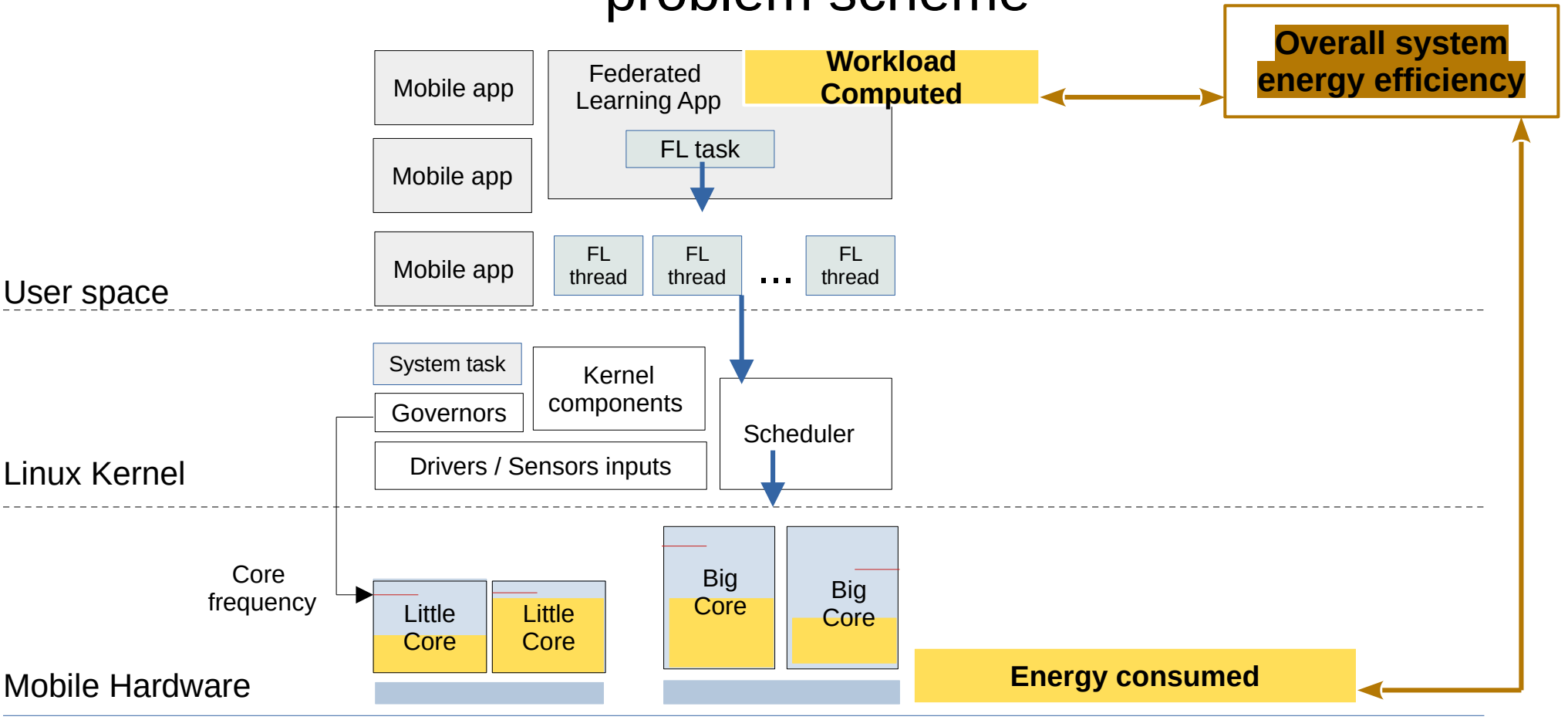

3.b. What influences the energy efficiency

- 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
  - Mentioned In research [3].
- Core temperature [4].

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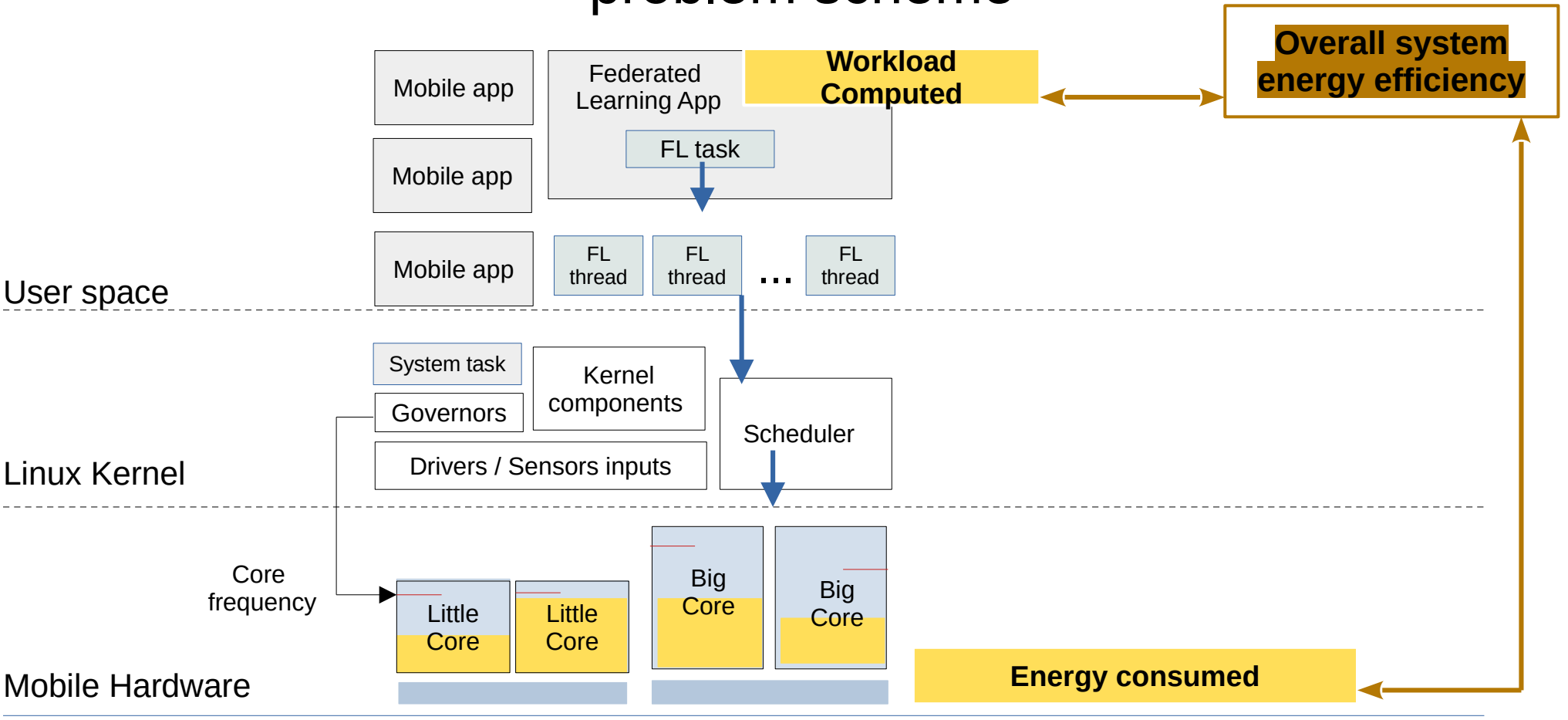

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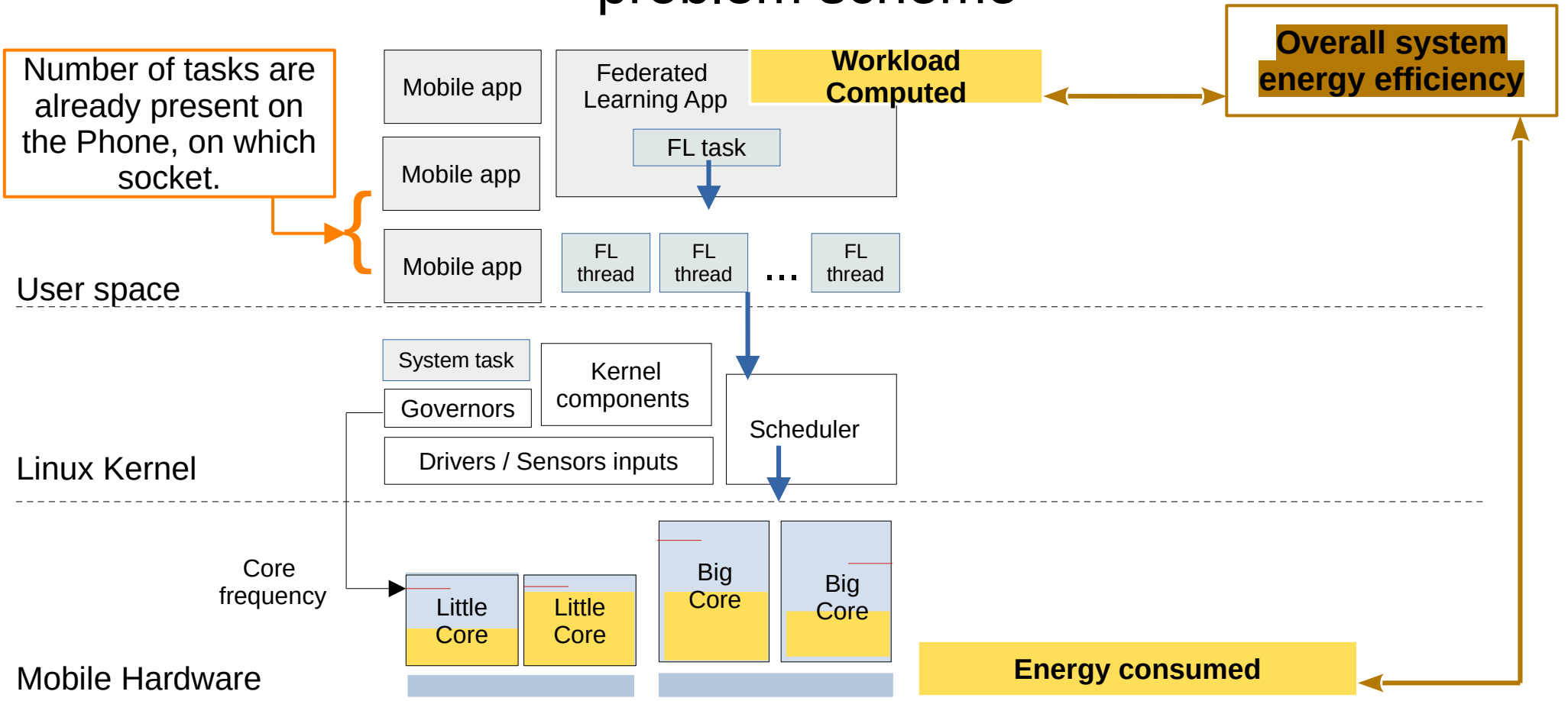

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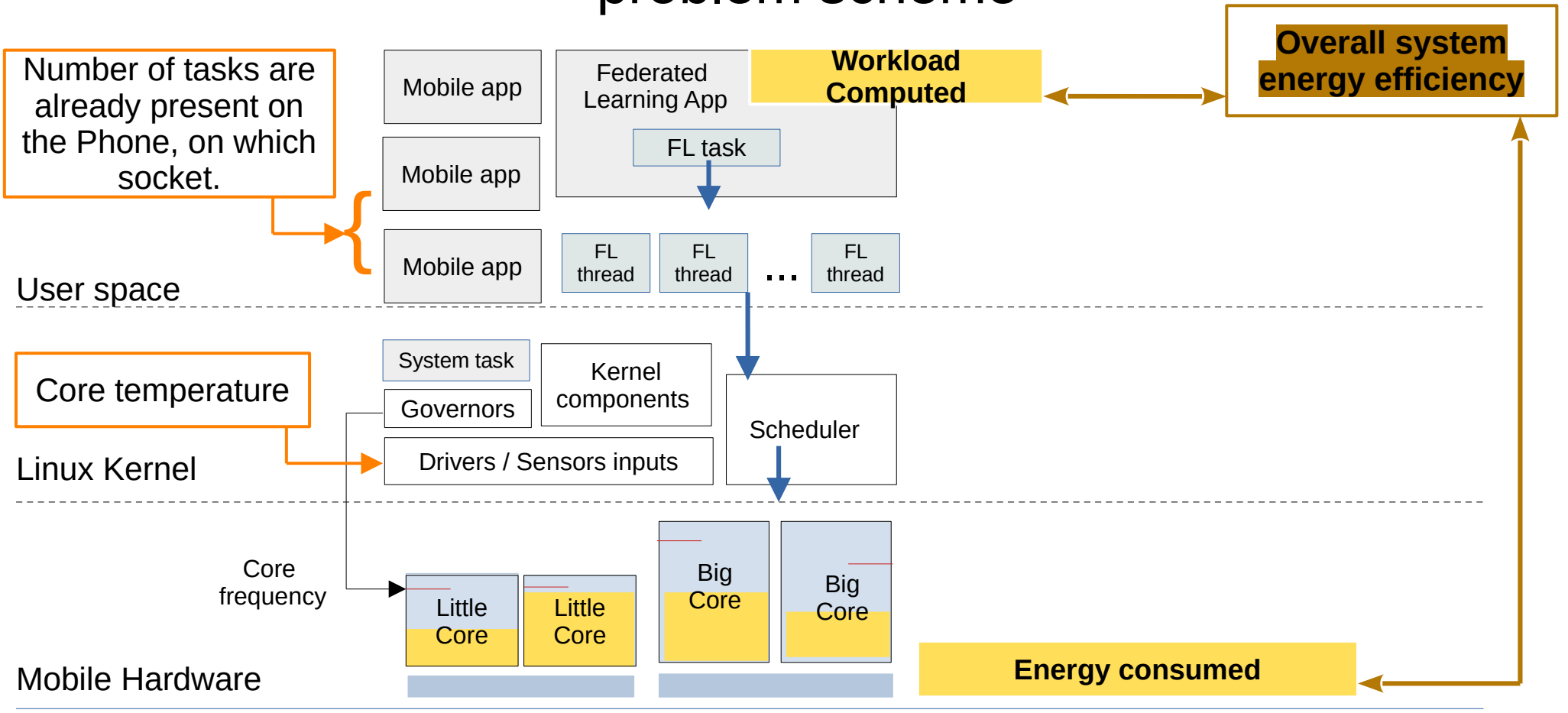

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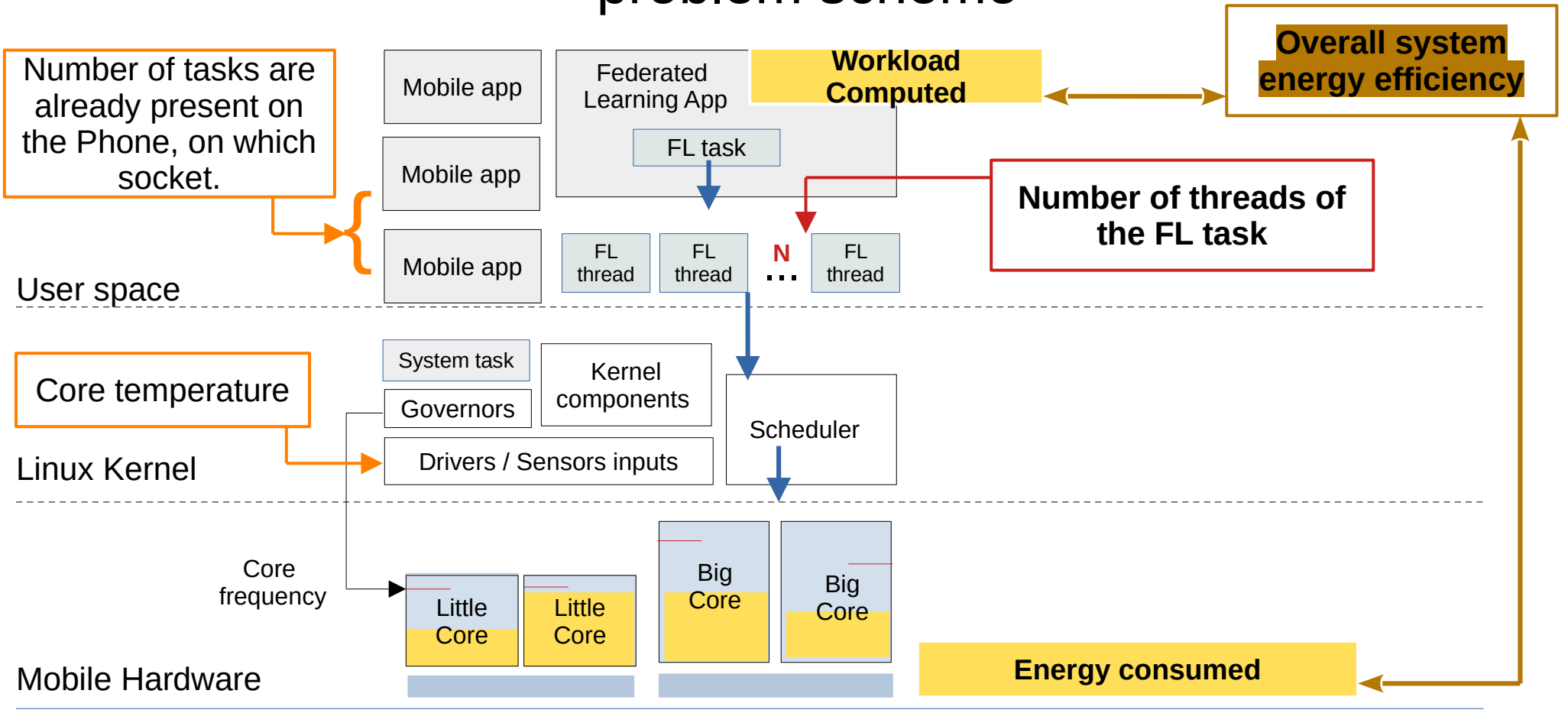

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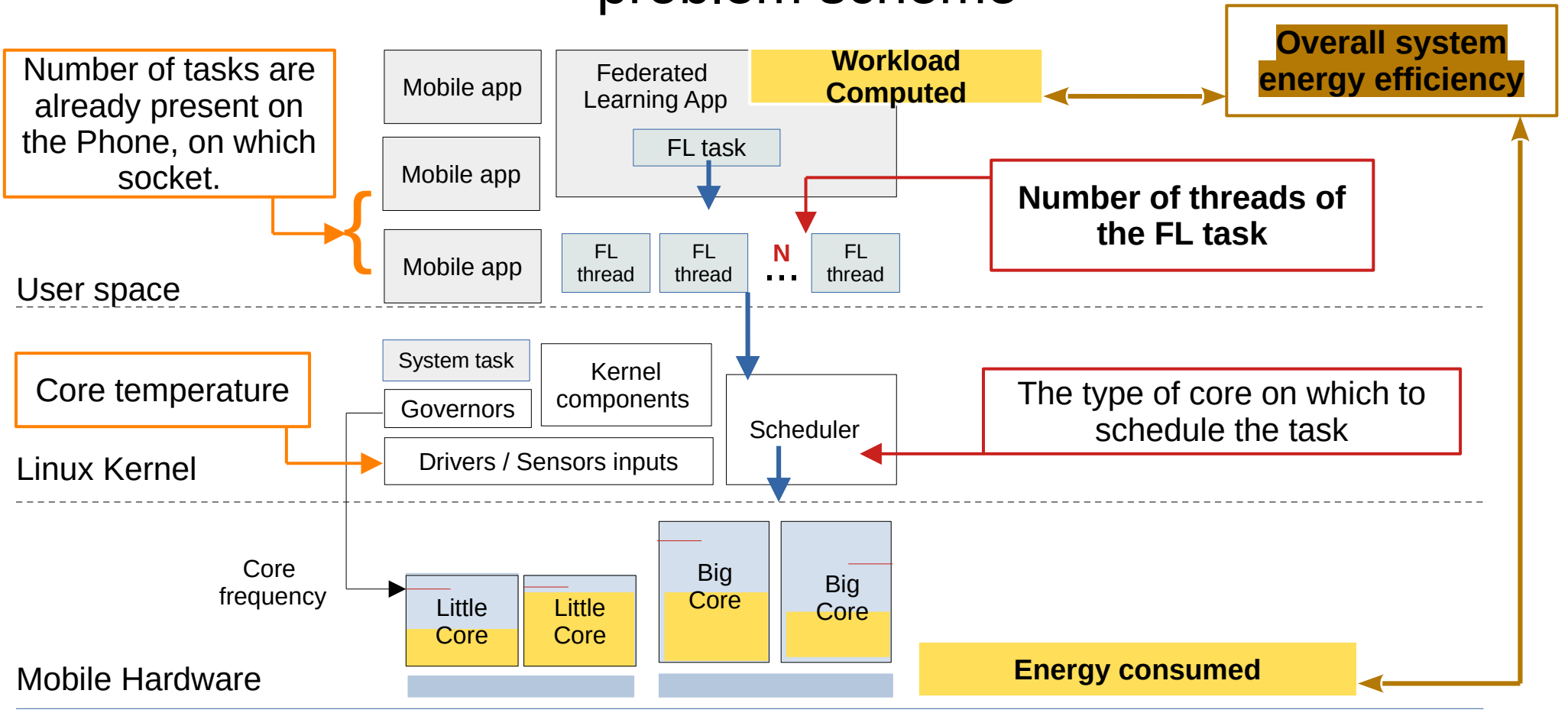

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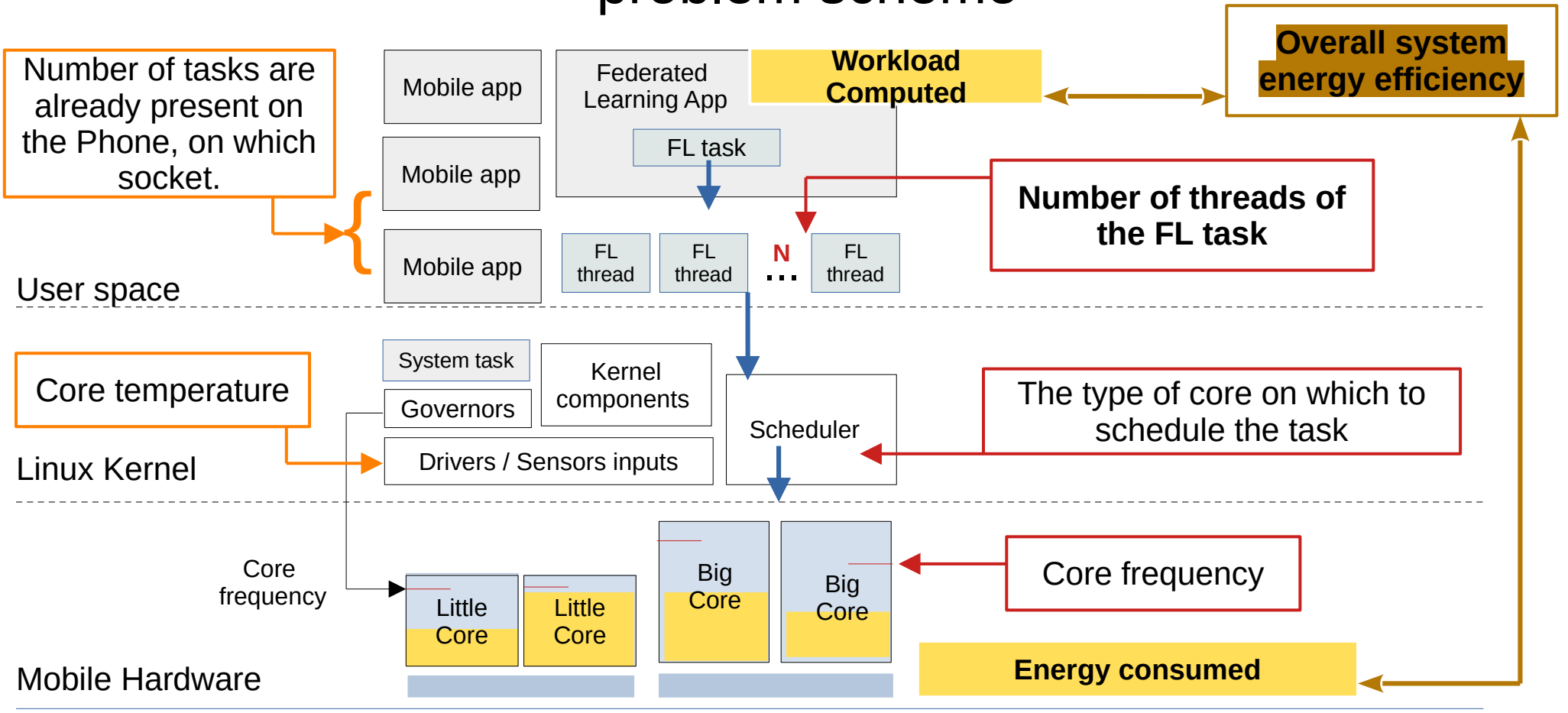


3.d Approach to resolve the problem

- 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 (when possible)
- Bringing out the lessons learned about HOW those parameters influence energy efficiency.
- Apply these lessons learned in the FL task scheduling decision:
  - At user space Level
  - At kernel Level (Scheduler, governor).

3.e Workload measurement

- Benchmark (In lab Mobile Apps)
  - **Prime number computation** (to quickly get an overview of energy efficiency) [1]
  - Tensor Flow Lite model on Mobile Device [2] (to have ML-like task behavior)
  - Federated Learning Tool from FLEET (for real time experiments) [3]
- Phones used for experiments:
  - Google Pixel 4A 5G:
    - Chipset : Qualcomm SM7250 Snapdragon 765G 5G (7 nm)
    - 3 sockets: CPUs 0-5: 1.8048 GHz CPU 6: 2.208 GHz CPU7: 2.4 GHz
    - Memory: 6GB RAM
  - Samsung galaxy S8 :
    - Chipset: Exynos 8895 (10 nm) – EMEA, Qualcomm MSM8998 Snapdragon 835 (10 nm) - USA & China
    - 2 sockets CPUs 0-3 : 1.69 GHz , CPUs 4-7: 2.314 GHz
    - Memory: 4GB RAM

3.f Energy consumption measurement: Phone APIs

- API name : “*dumpsys batterystats*” from Android OS
- Works in almost all phones
  - except in some configurations
- 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

[1] Resource utilization and per formance, A comparative study on mobile crossplatform tools, Lucas Arvidsson, Max Bekkhus

3.f Energy consumption measurement: Power-meter

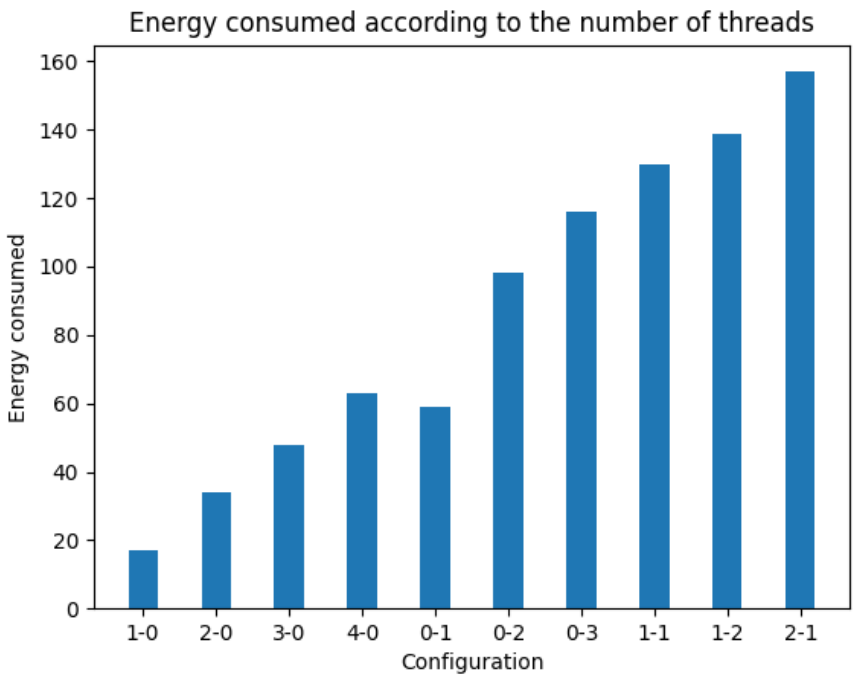
- Also widely used in research [1][2]
- The common installation required is expensive
  - Its makes phone battery no longer usable.
- Alternative 1: Software simulation of battery shutdown (Google Pixel 4A, 5G).
  - Modifying internal system file : “charge_stop_level”, “charge_limit”
  - USB mode power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

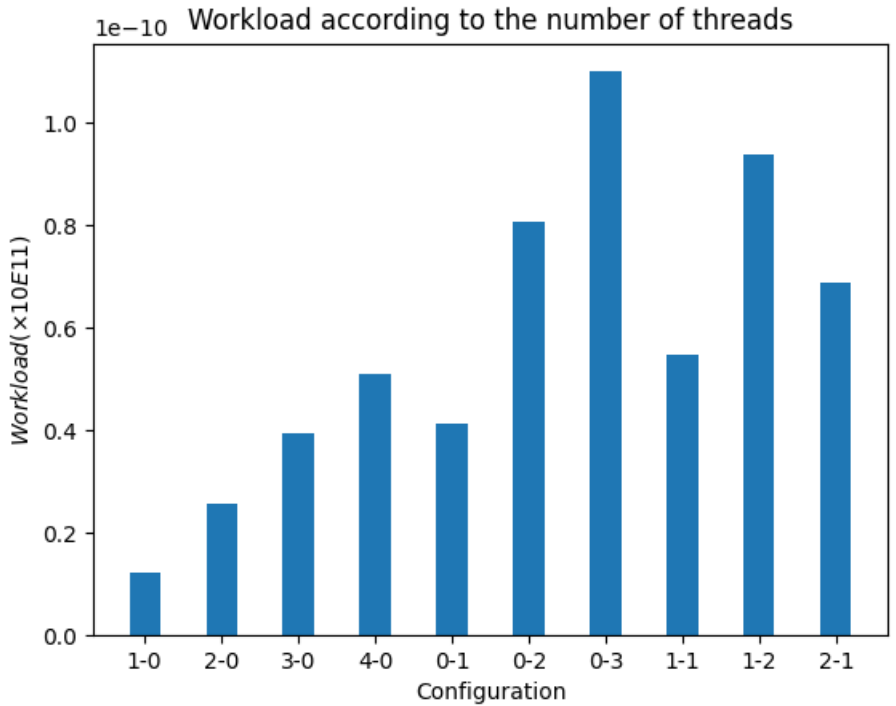
[1]"Energy Consumption and Conservation in WiFi Based Phones: A Measurement-Based Study By Ashima Gupta and Prasant Mohapatra"
[2] Energy-Efficient Collaborative Sensing with Mobile Phones Xiang Sheng ∗

4. Experiments and observations (made using APIs)

Phone: Samsung S8
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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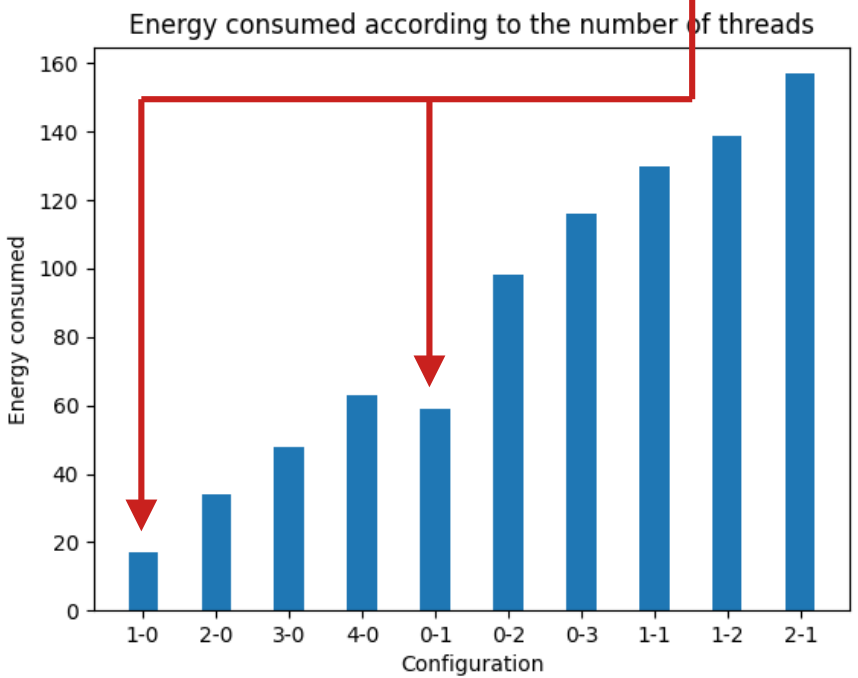
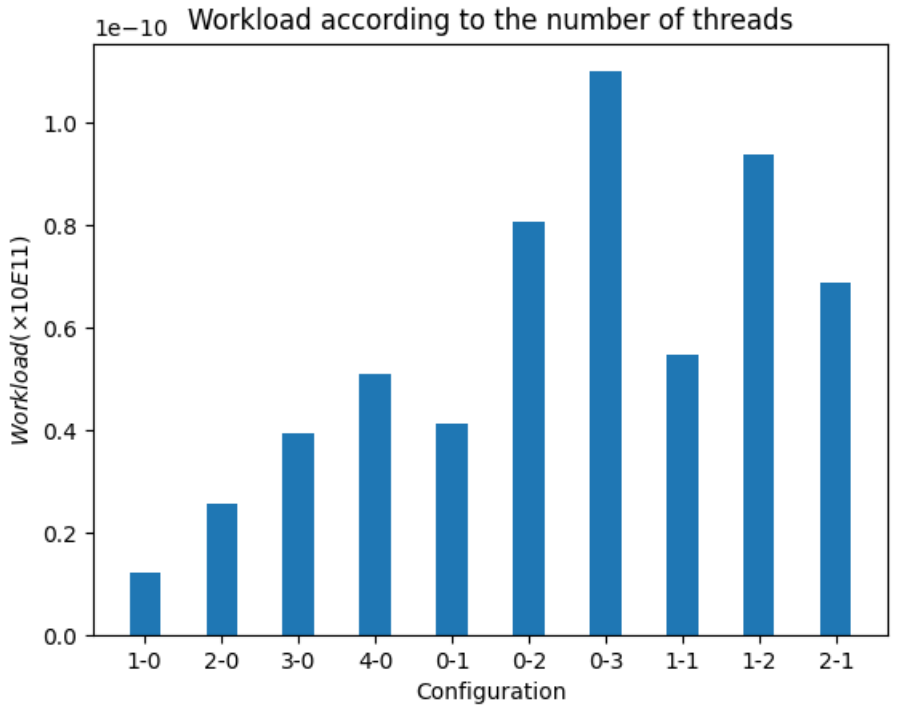
Big Cores consume a lot of energy compared to little cores





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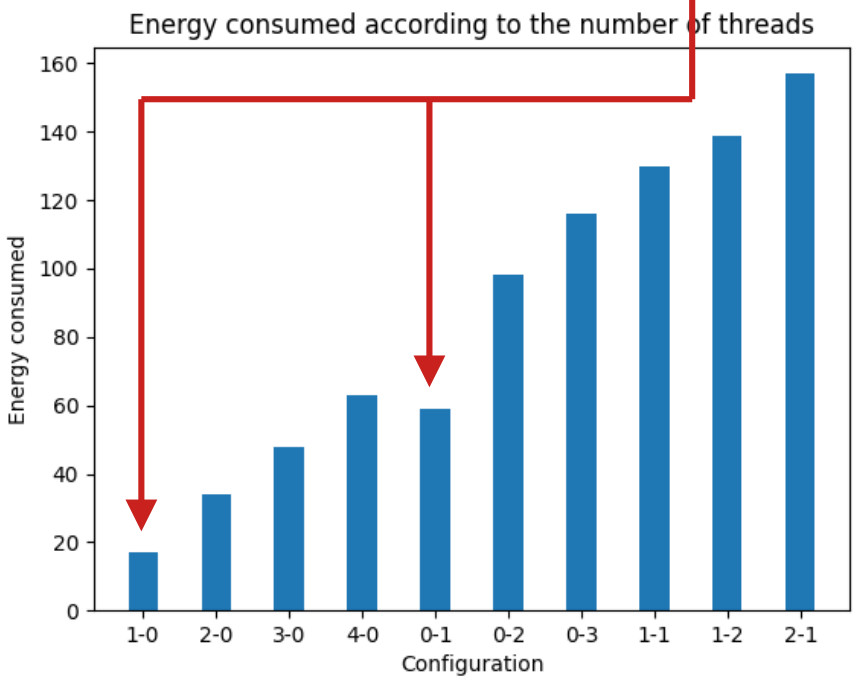
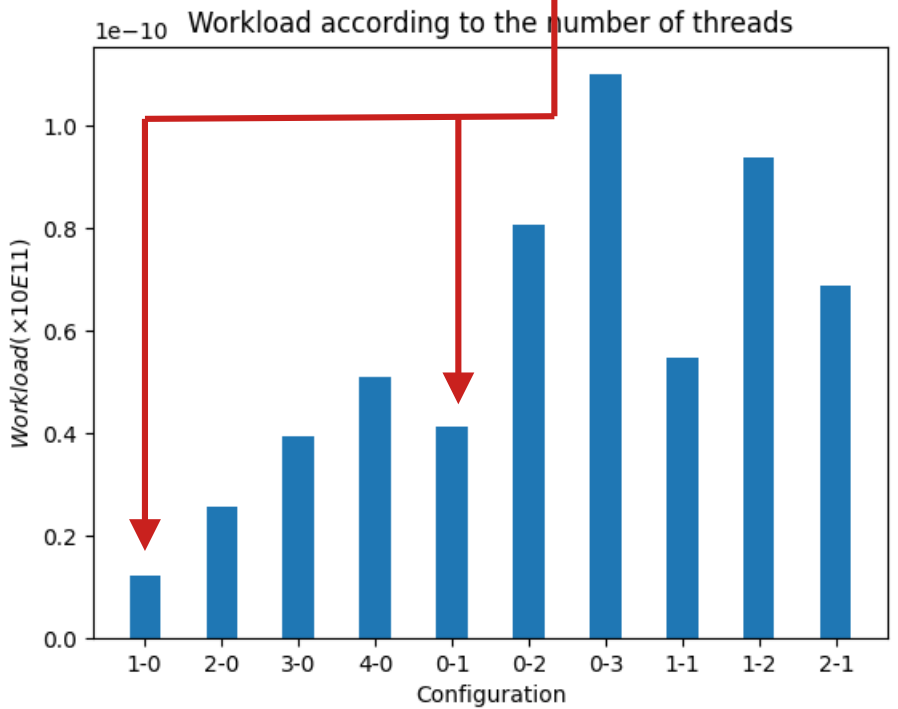
Big cores are very fast in computation





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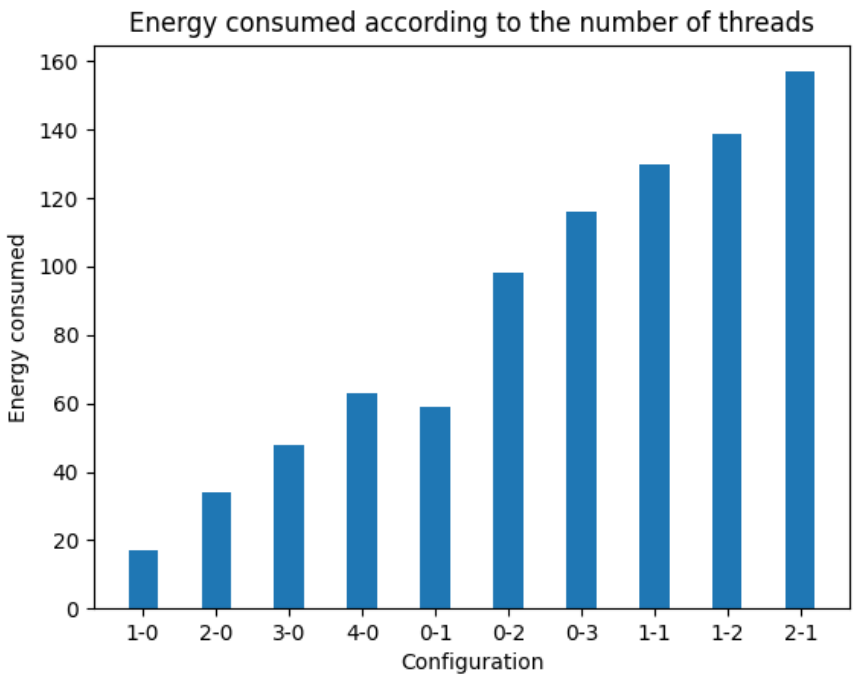

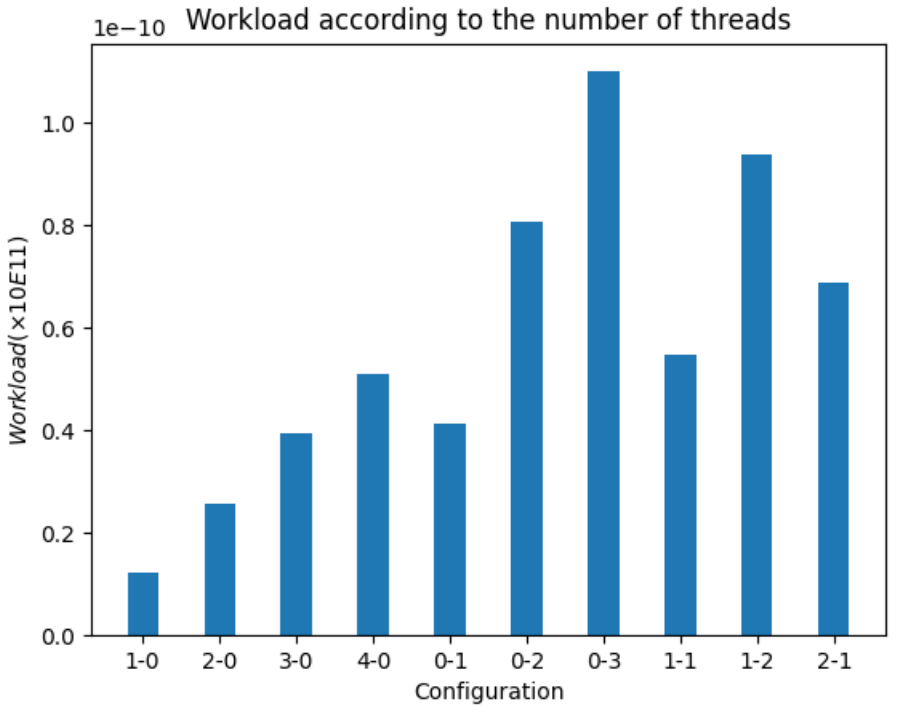

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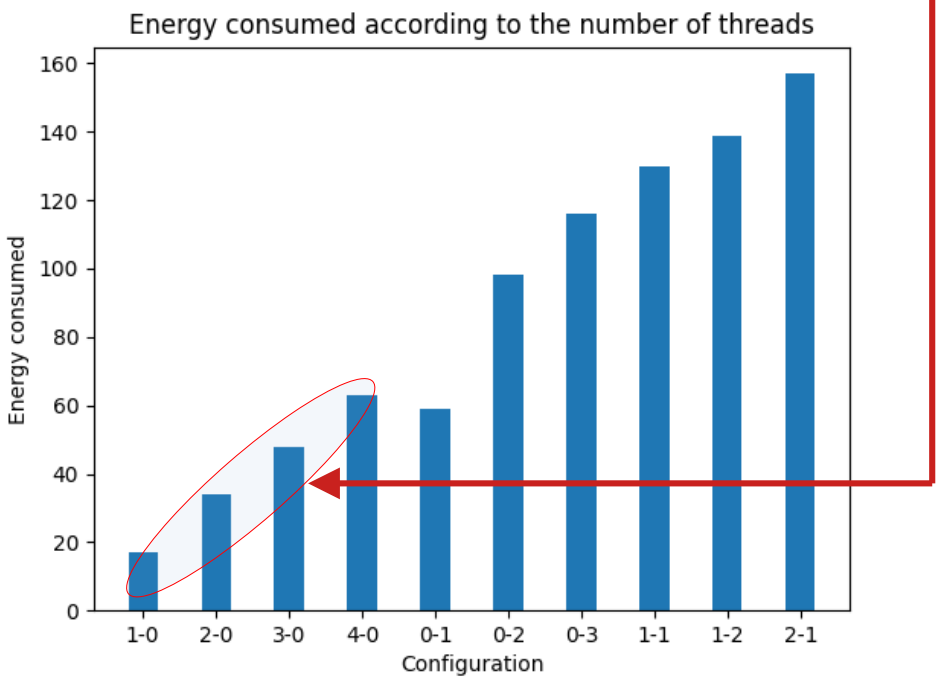

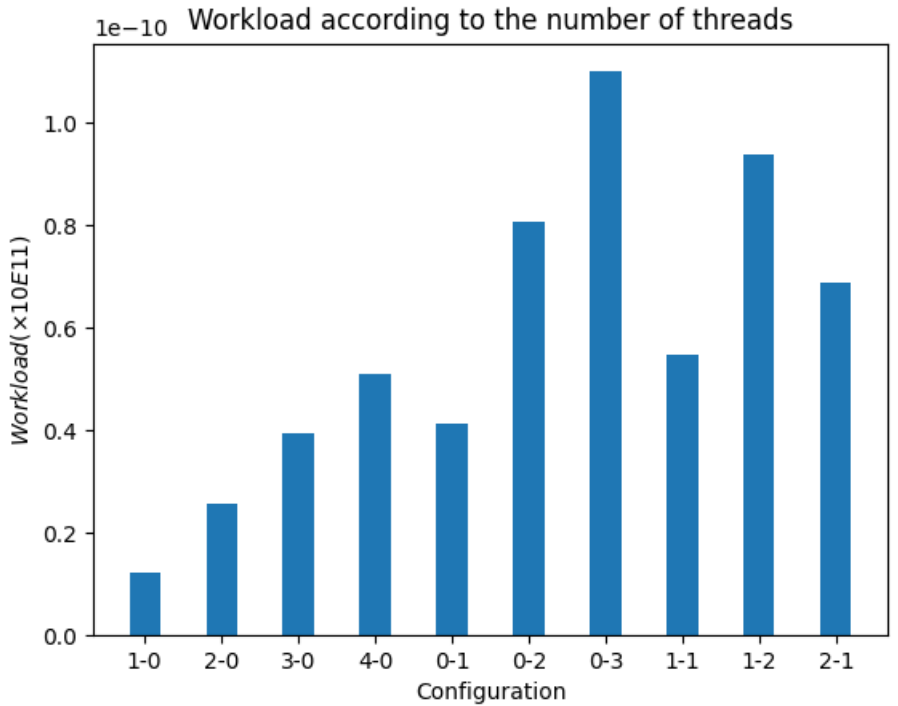

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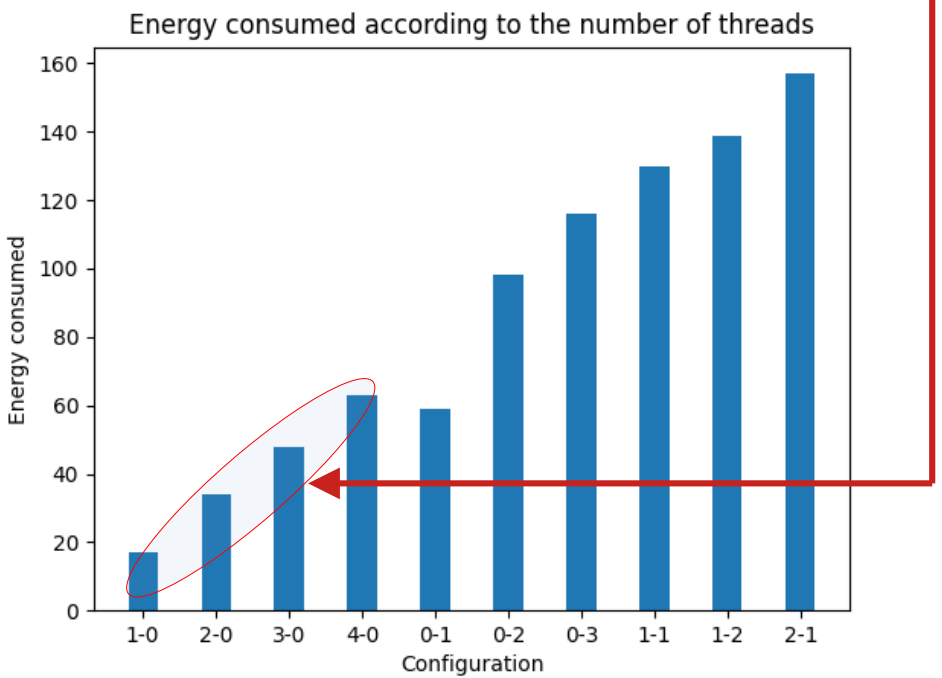
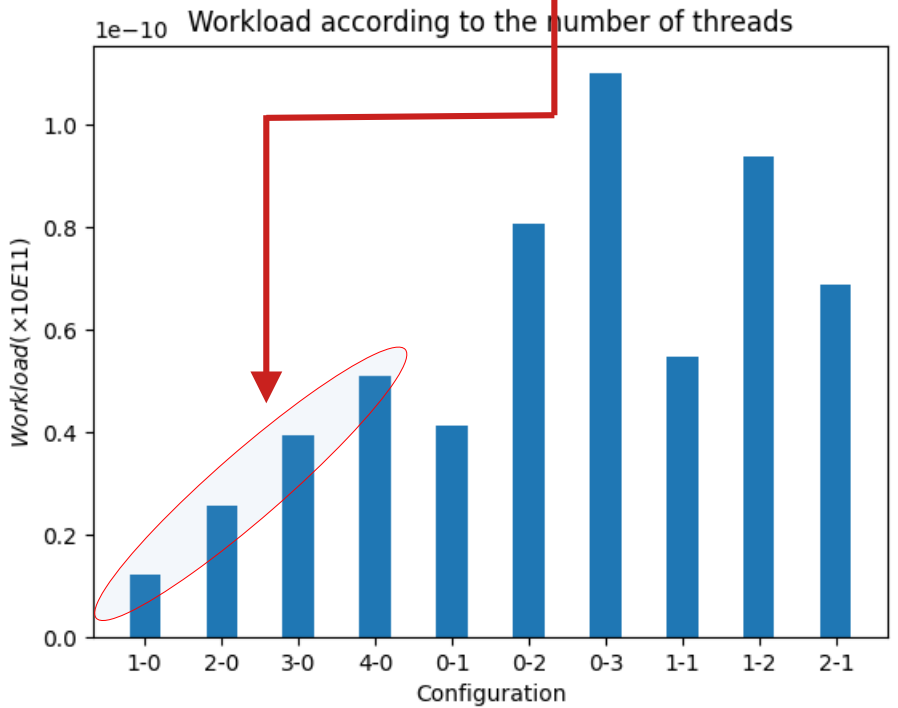
The energy consumed always grows linearly with the number of threads

The workload computed grows linearly with the number of threads





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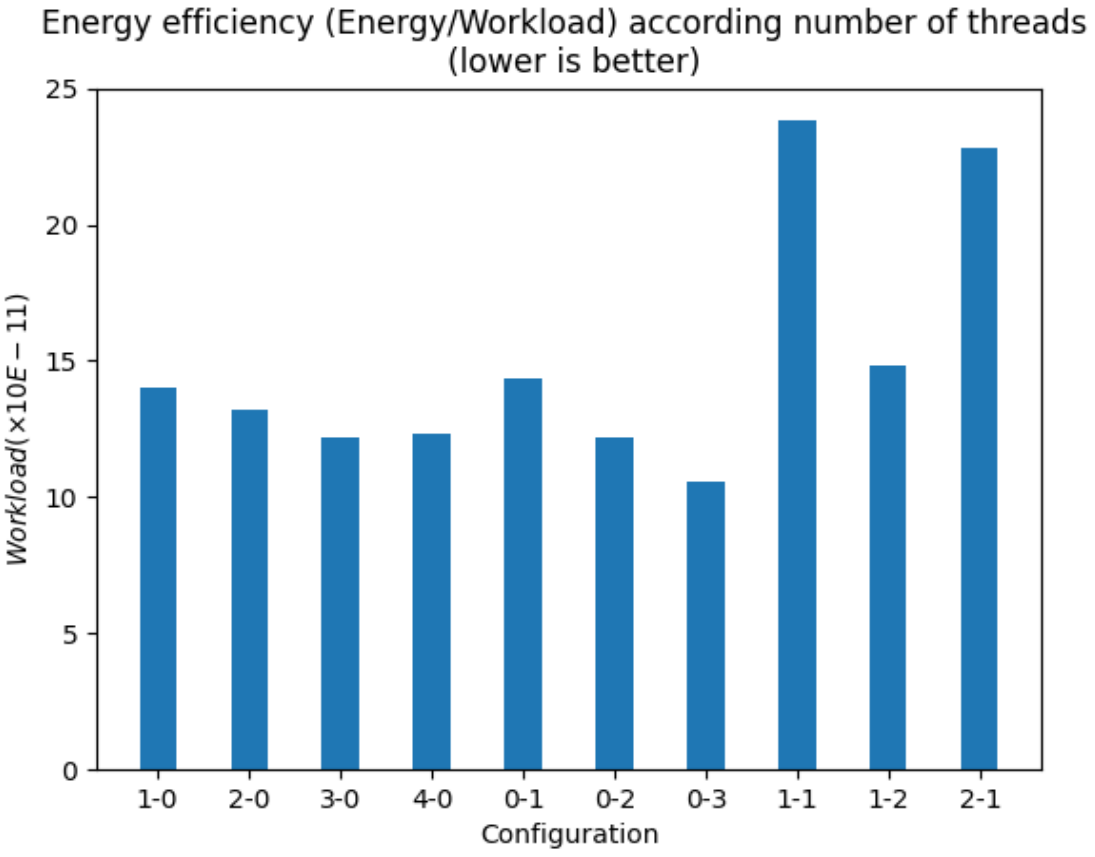

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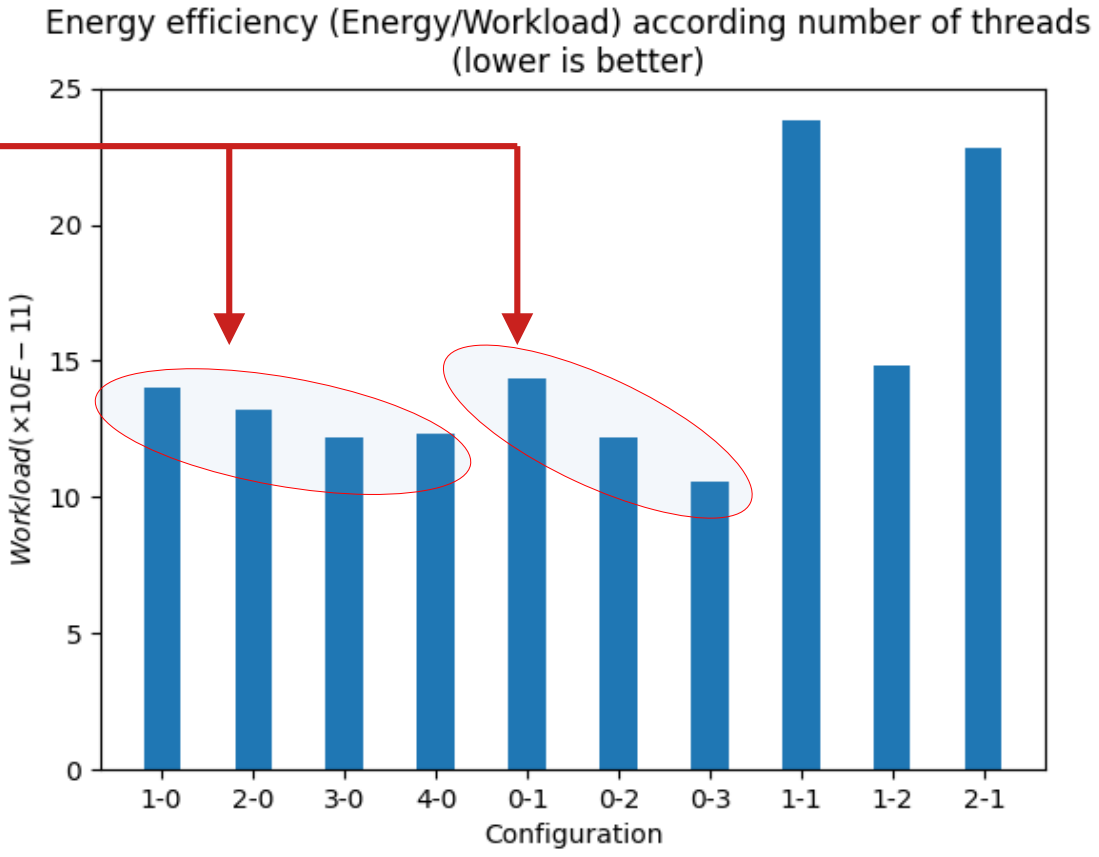
On the same socket the number of threads slightly increases with the efficiency



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Phone: Samsung S8
Impact of: **Other CPU intensive tasks**
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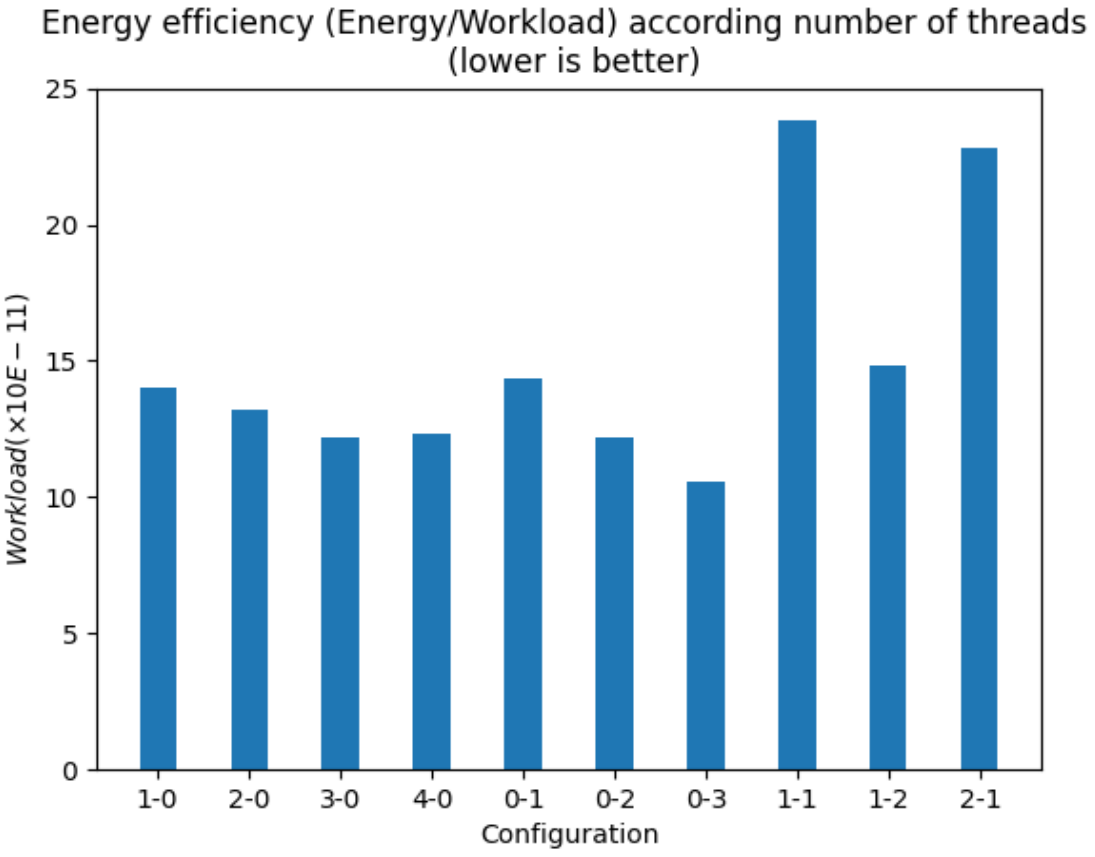

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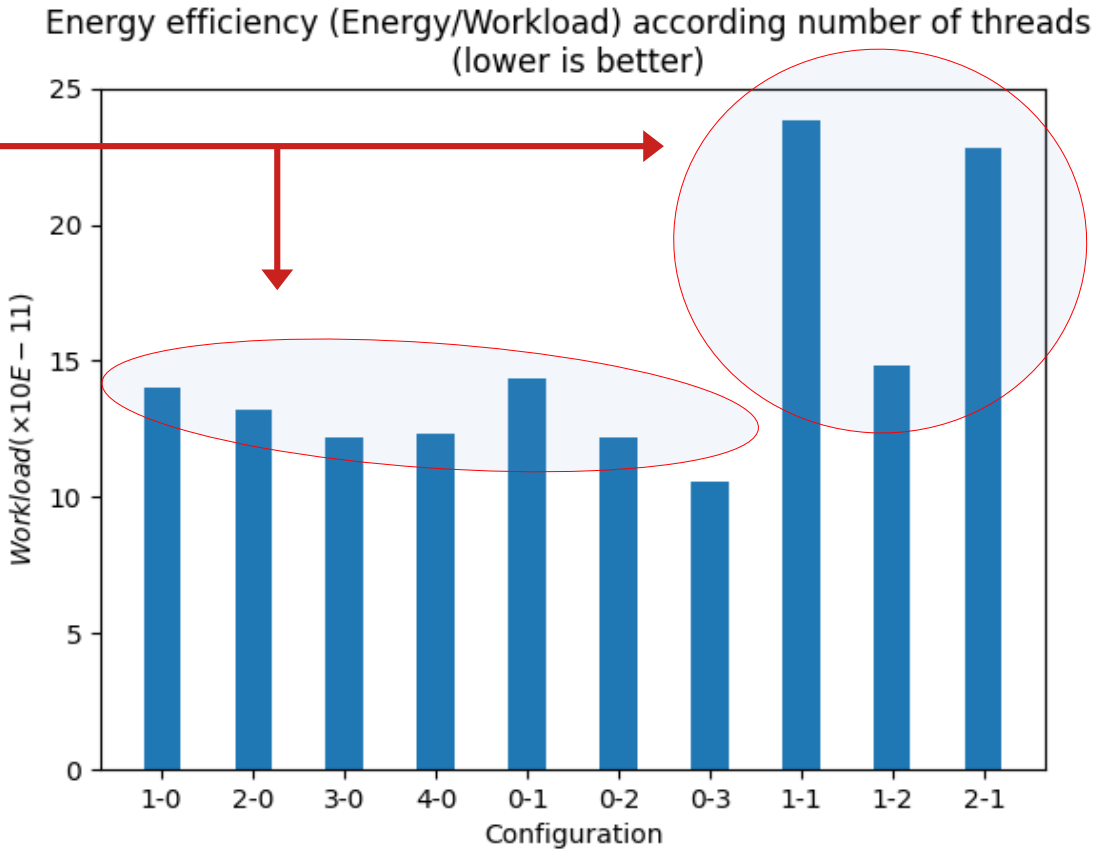
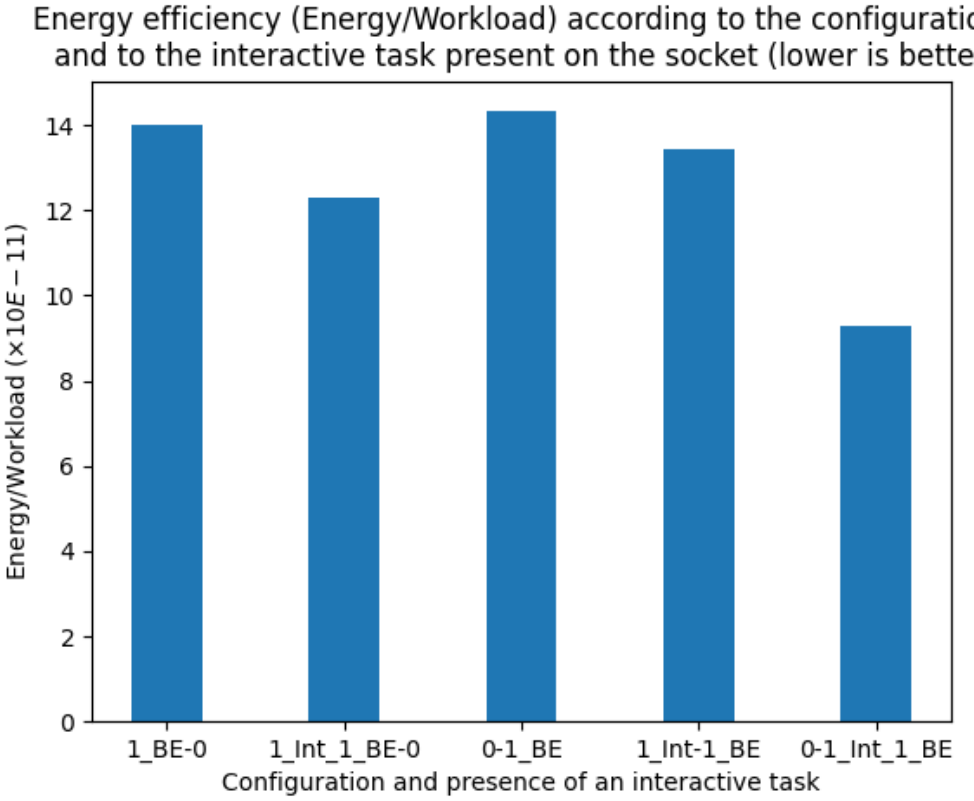
Generally we are more efficient when threads are on the same socket



4. Experiments and observations (made using APIs)

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

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



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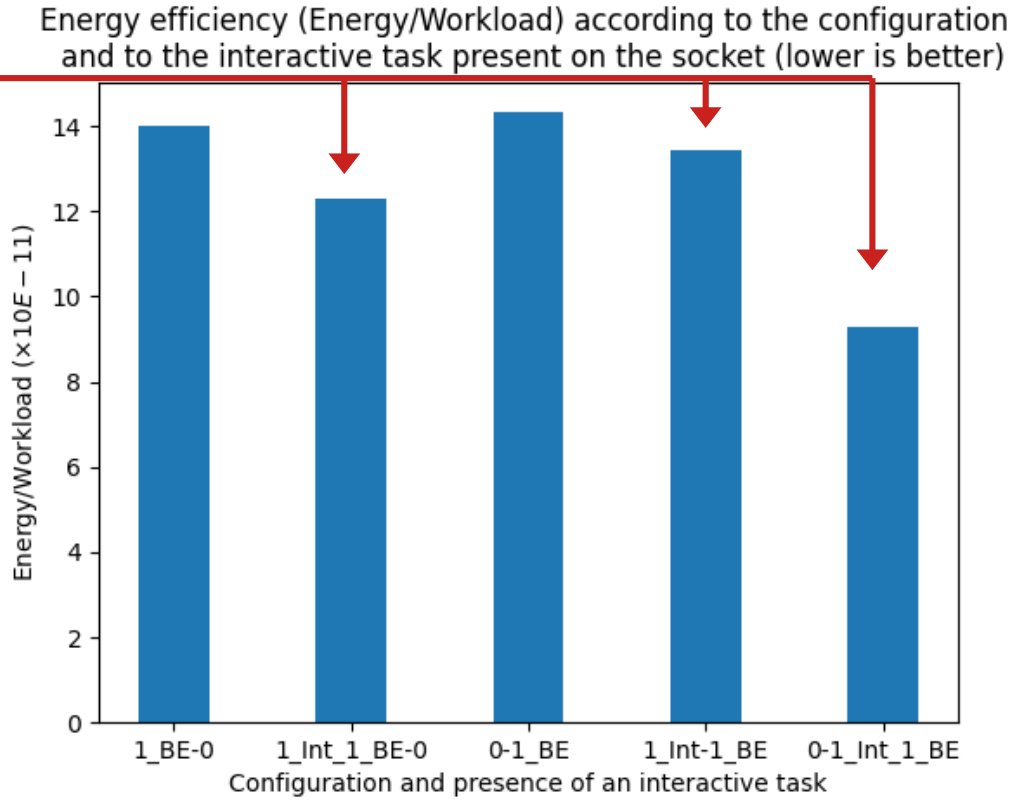
Generally we are more efficient when running thread with other interactive tasks on the same socket.



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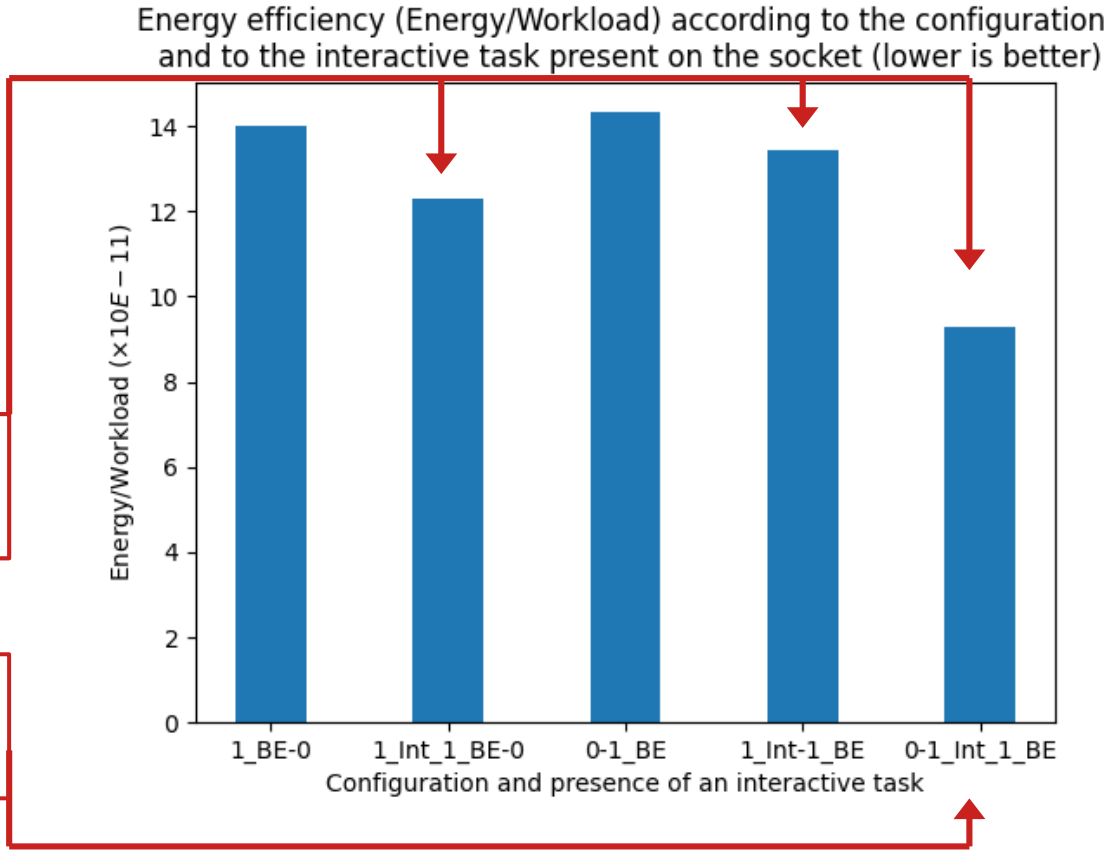
Co-location is more efficient on Big Sockets



4. Experiments and observations (made using APIs)

Phone: Samsung S8
Impact of: **Frequency**
Experiments duration: 5 min
Legend: Configuration 0-1_mid means

- 0 thread on Little sockets
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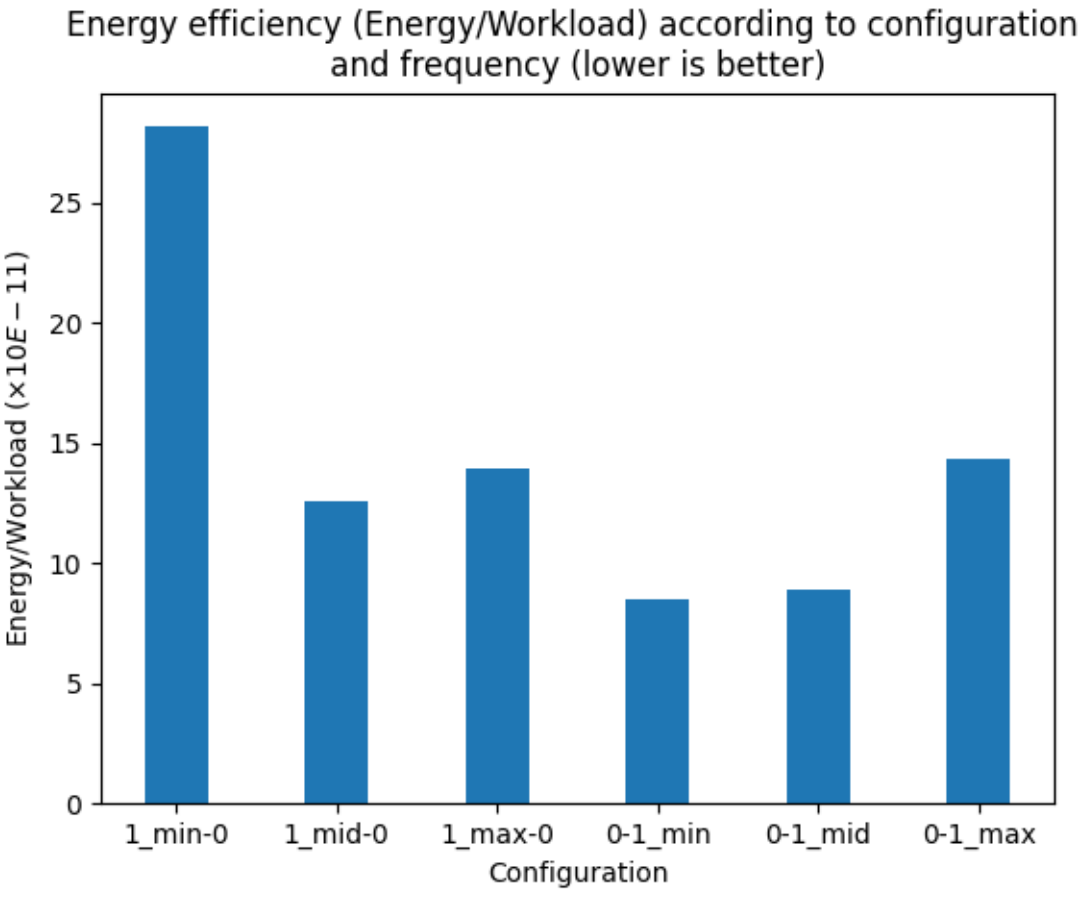
- Big socket runs with frequency at middle level.
- Mid = middle level, min = minimum level
  - Max = maximum frequency



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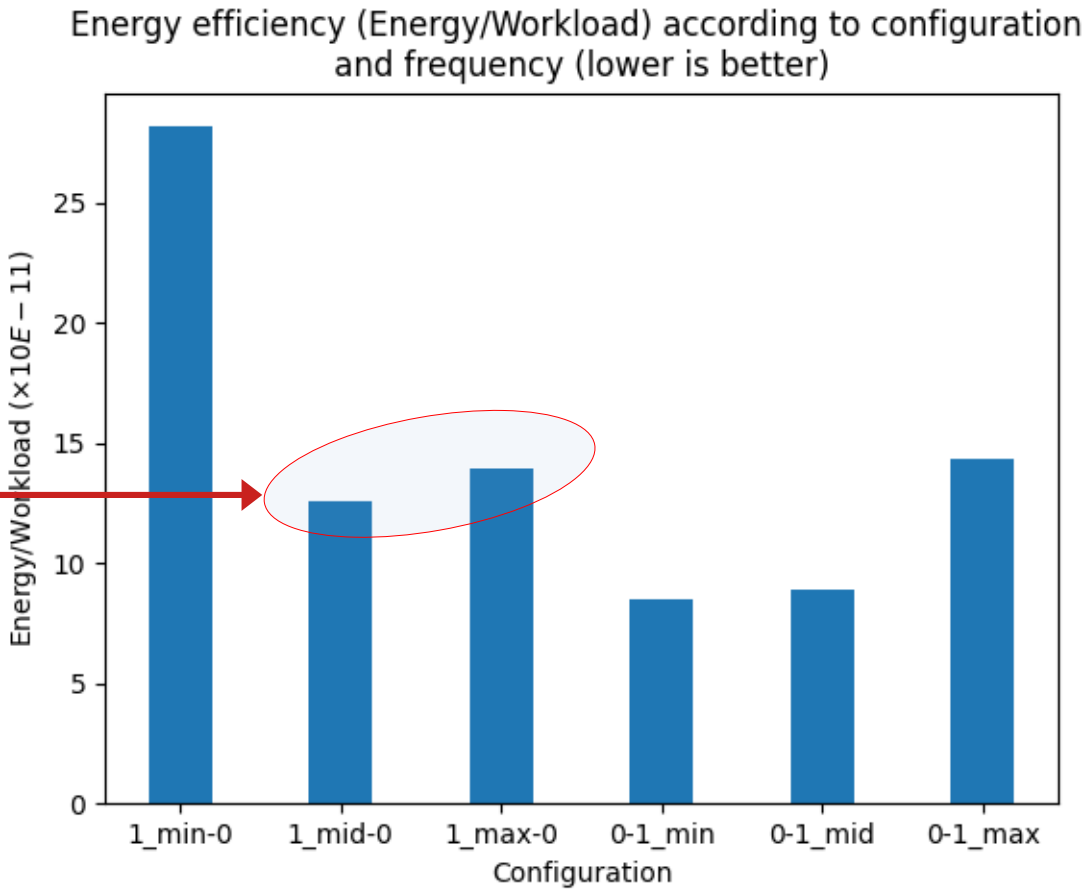

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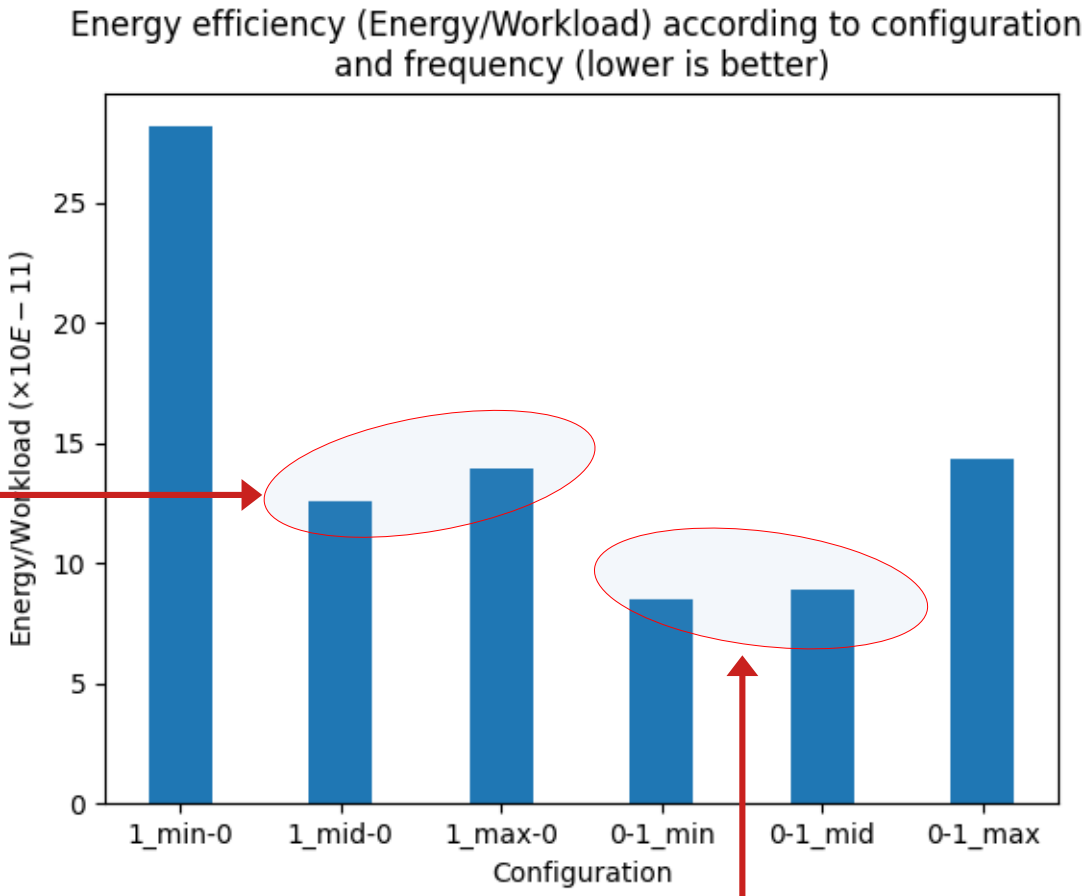

At slightly reduced frequency the Little cores are efficient

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

4. Experiments and observations (made using APIs)

Phone: Samsung S8
Impact of: **Frequency and other tasks**
Experiments duration: 5 min
Legend: Configuration 1_Inter_1BE_mid-0 means

- 1 Interactive thread on Big Socket
- 1 benchmarked thread on big Socket
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- Little socket runs with frequency at middle level.
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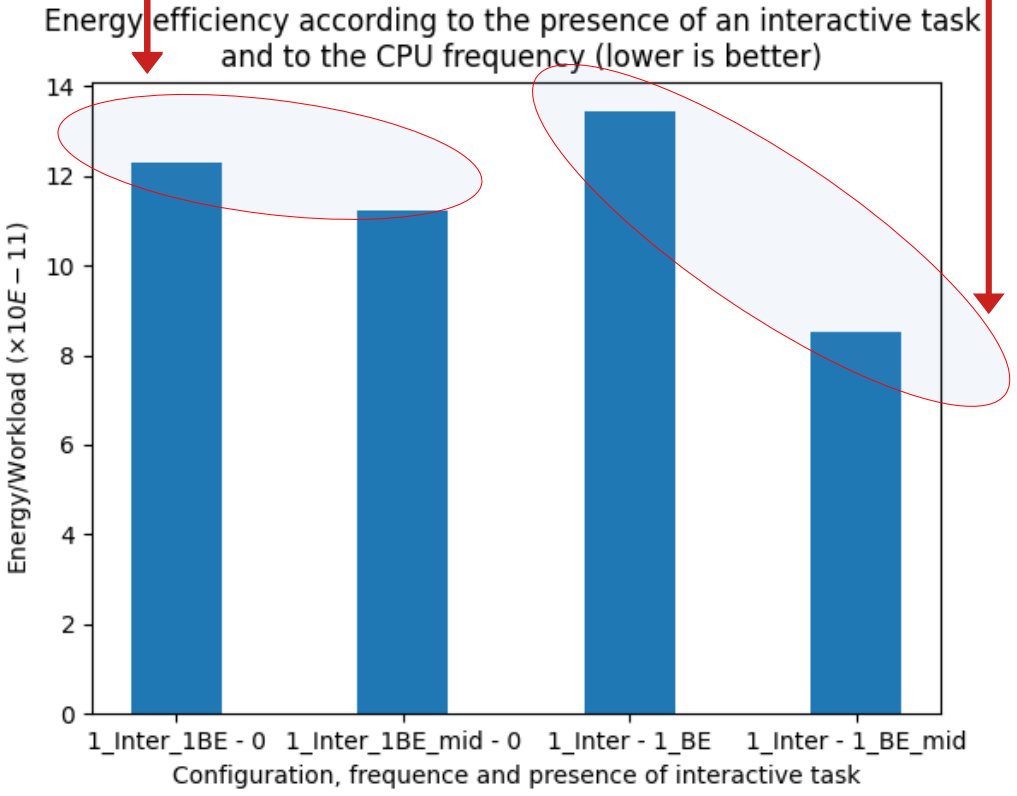
The presence of other tasks does not influence the impact of frequency on efficiency



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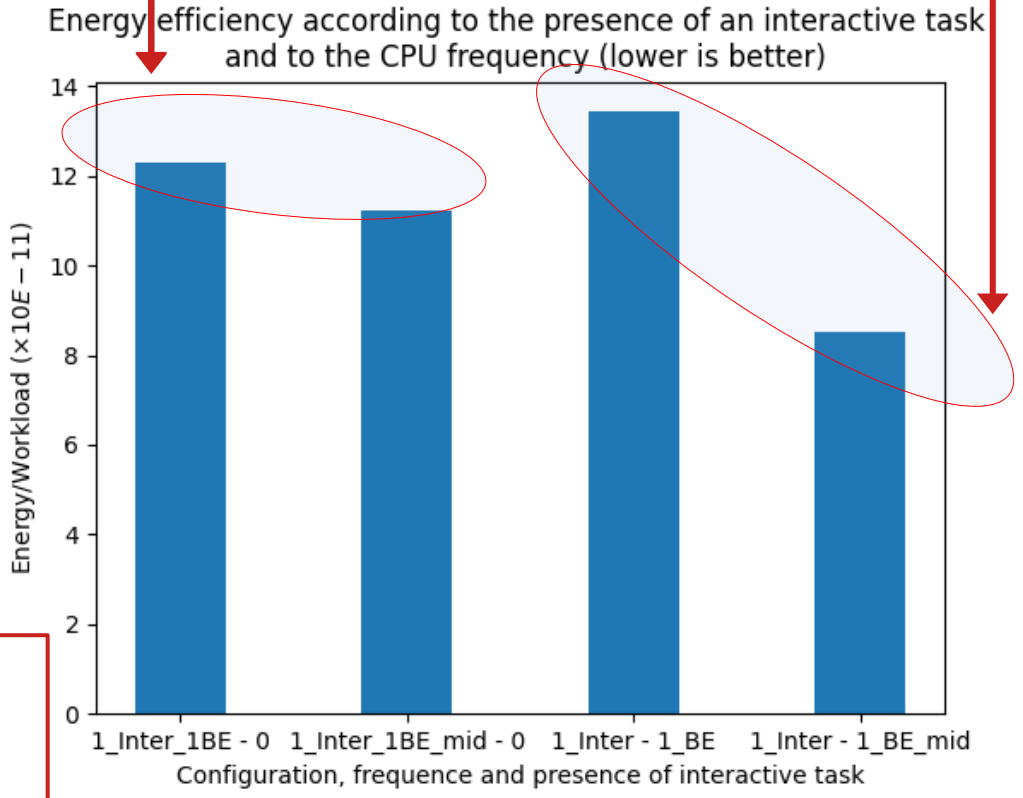
The presence of other tasks does not influence the impact of frequency on efficiency

Type of Core: It is more efficient to reduced frequency

- **slightly on Little cores**
- as much as possible **on the Big cores.**



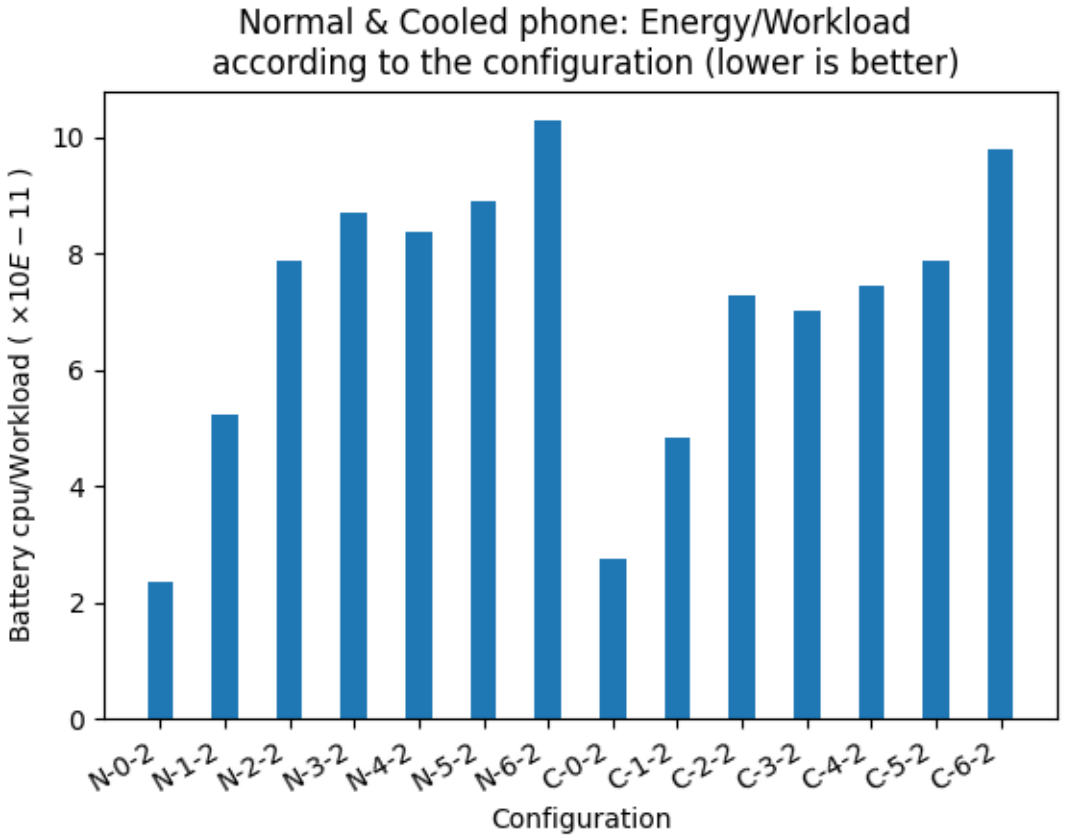
4. Experiments and observations (made using APIs)

Phone: Google Pixel
Impact of: **Temperature**
Experiments duration: 10 min
Legend: Configuration N-0-1 means:

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

Configuration C-0-1 means:

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



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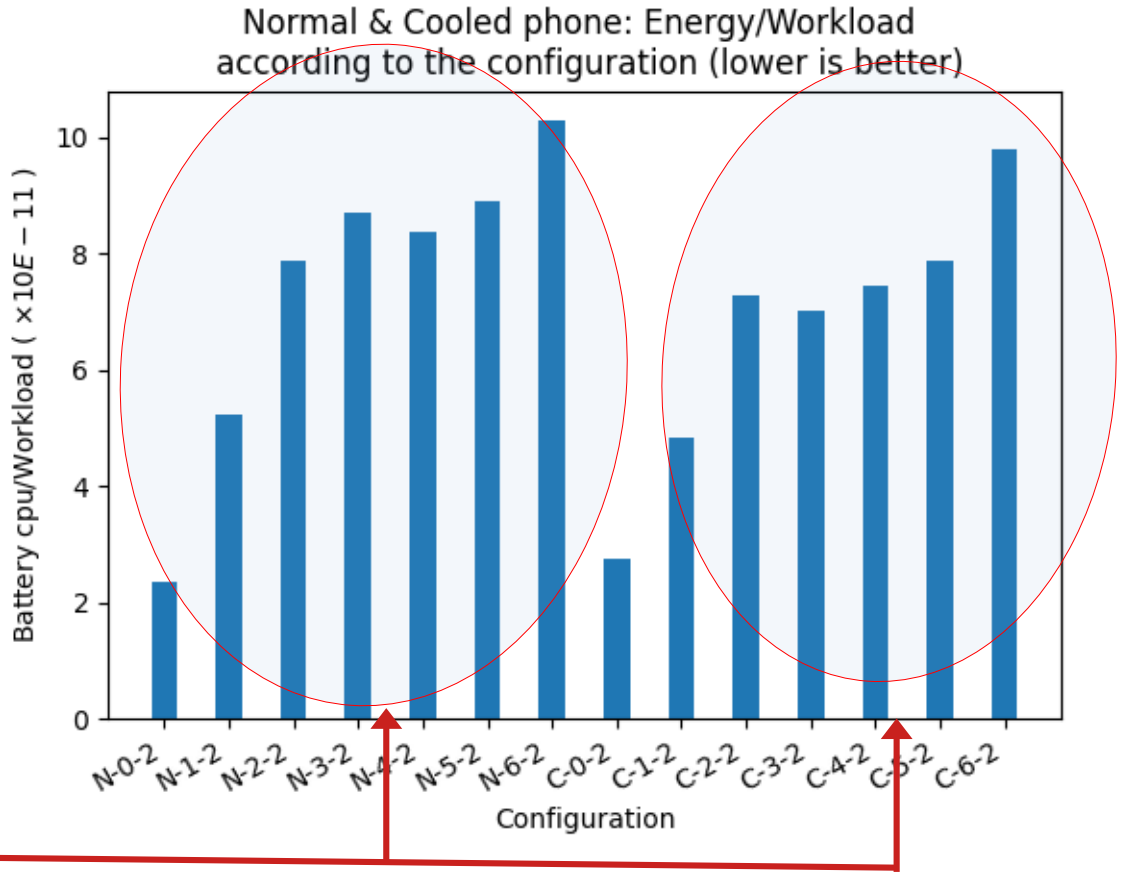
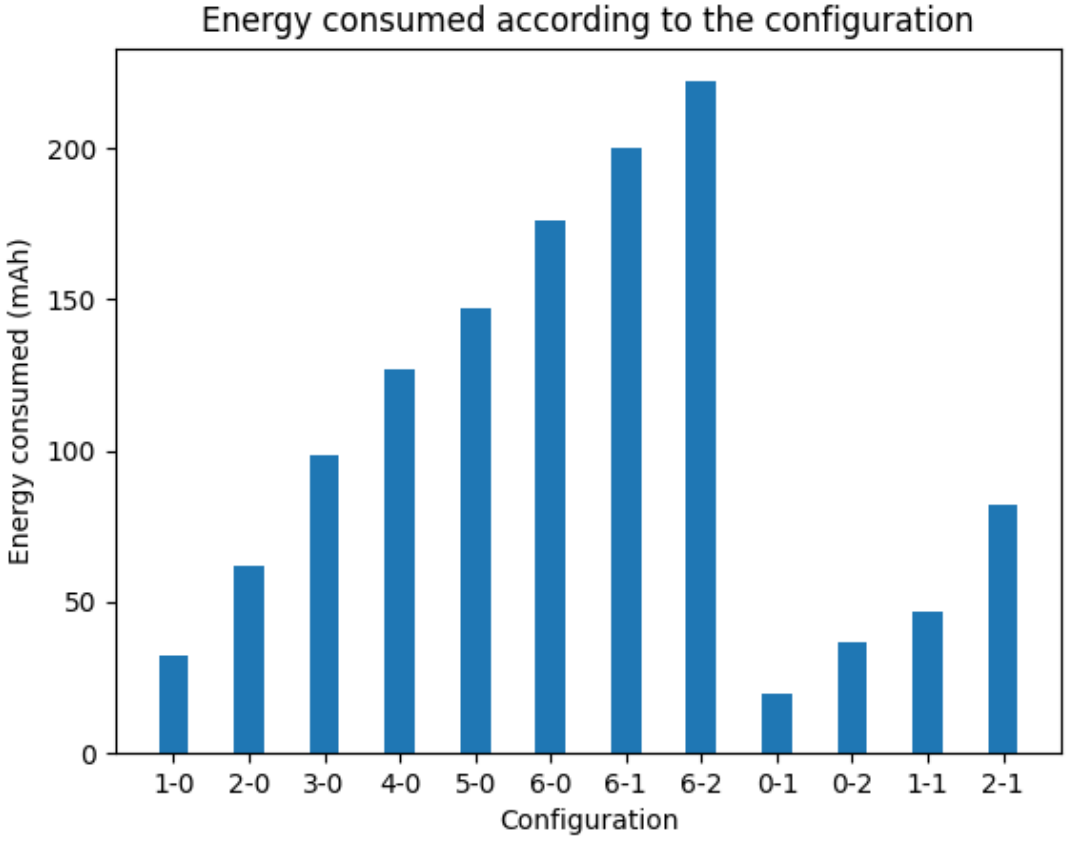


Low temperature cores seem much more efficient than high temperature ones

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

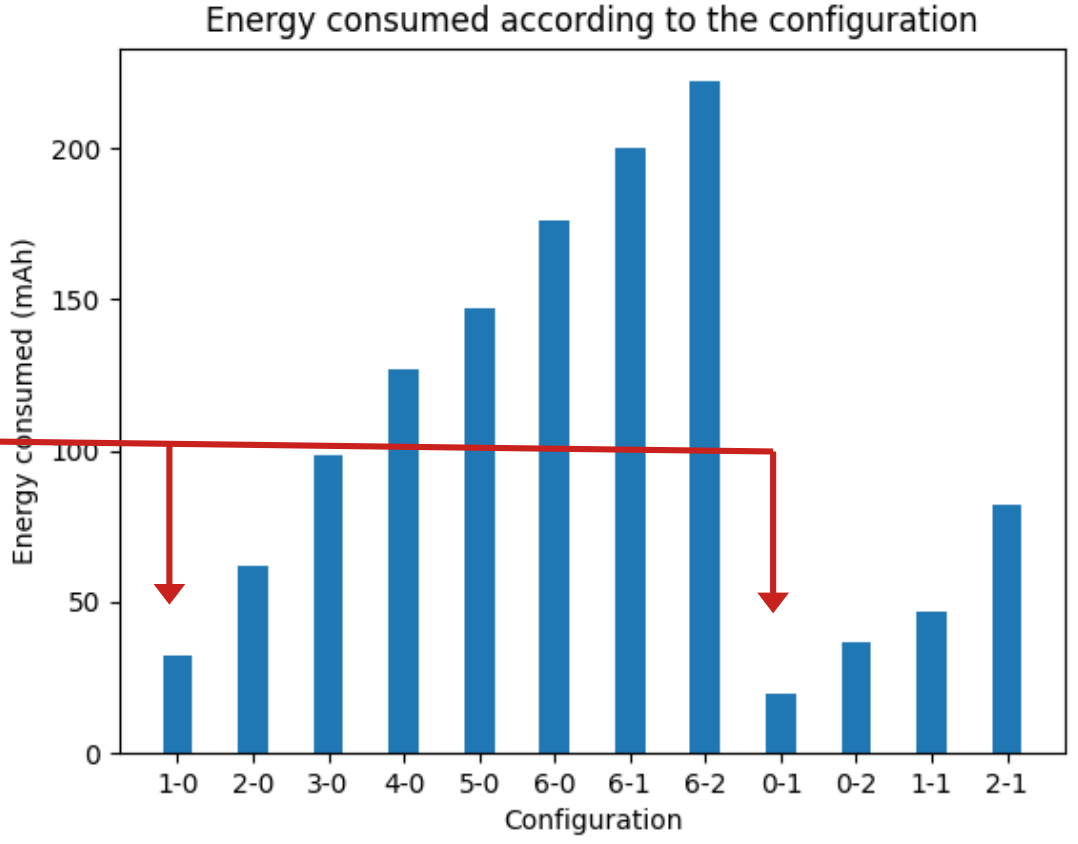


4. Strange observations made using APIs on google Pixel

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

Little core seems to consume more energy than Big core.



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Impact of: **Measurement method !!!**
Experiments duration: 10 min
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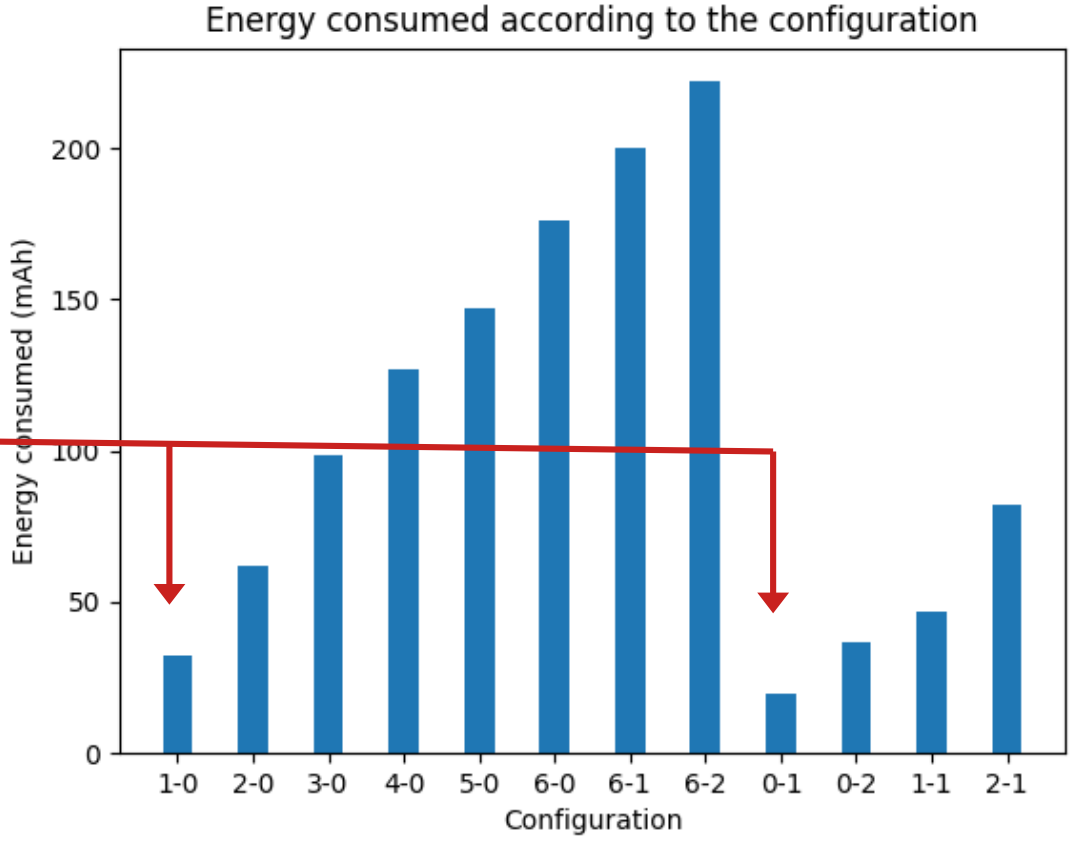
Little core seems to consume more energy than Big core.

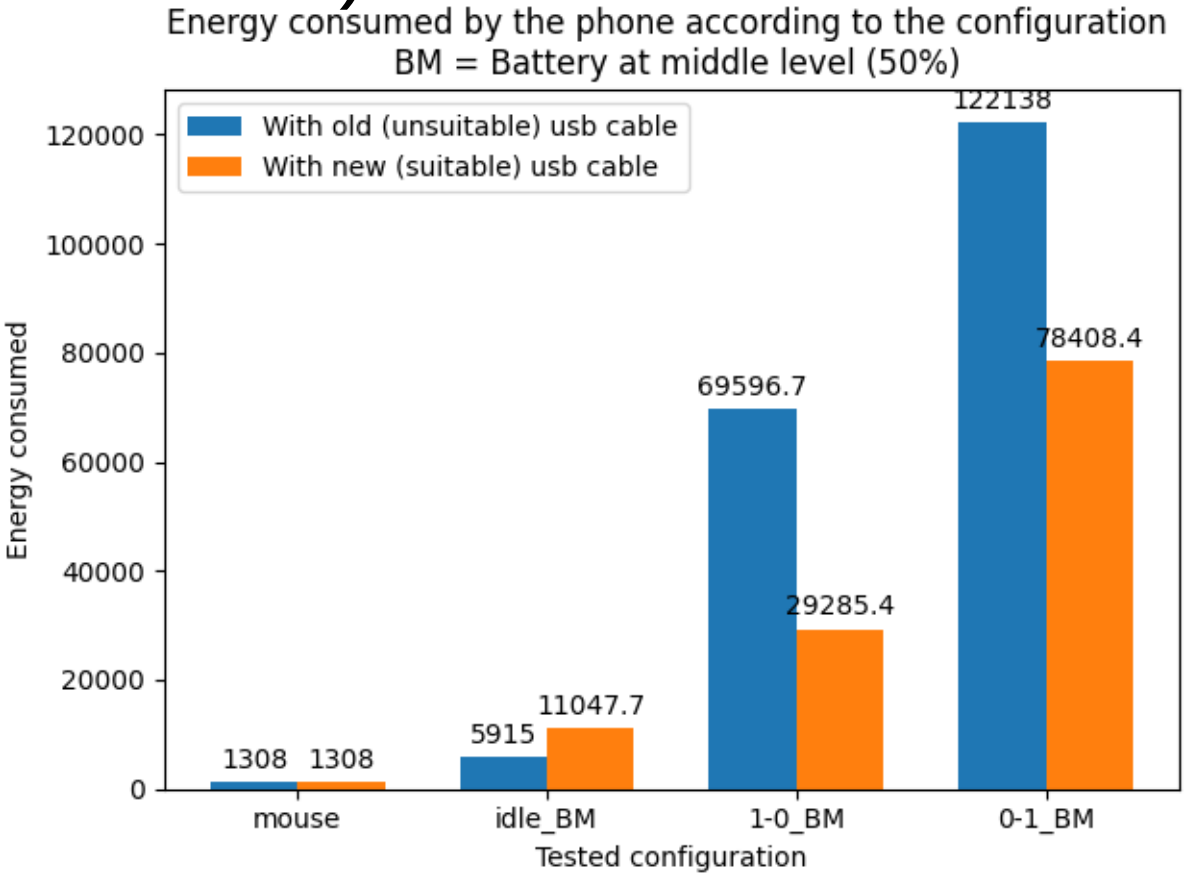
We had to restart experiments to validate previous observations (Missing submission death-lines)



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



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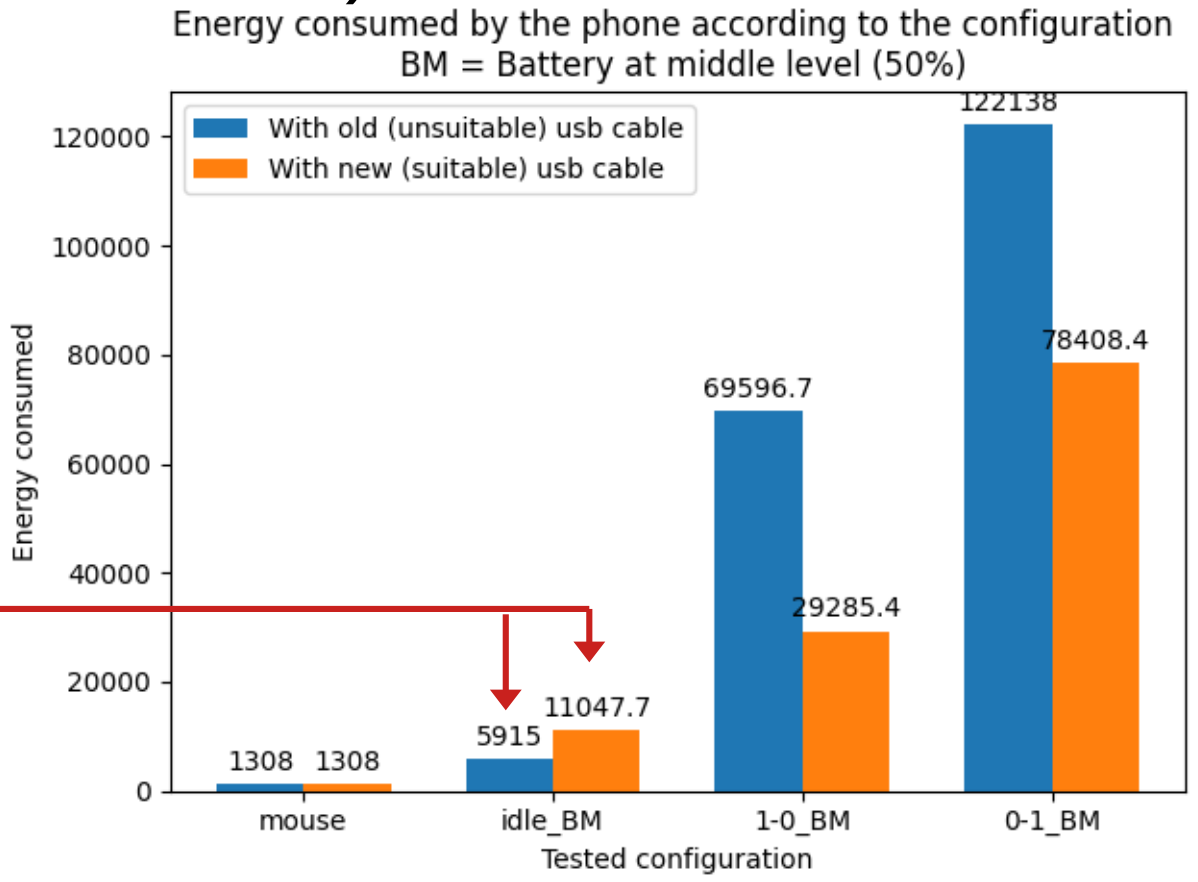
The quality of the equipment (USB cable) impact results



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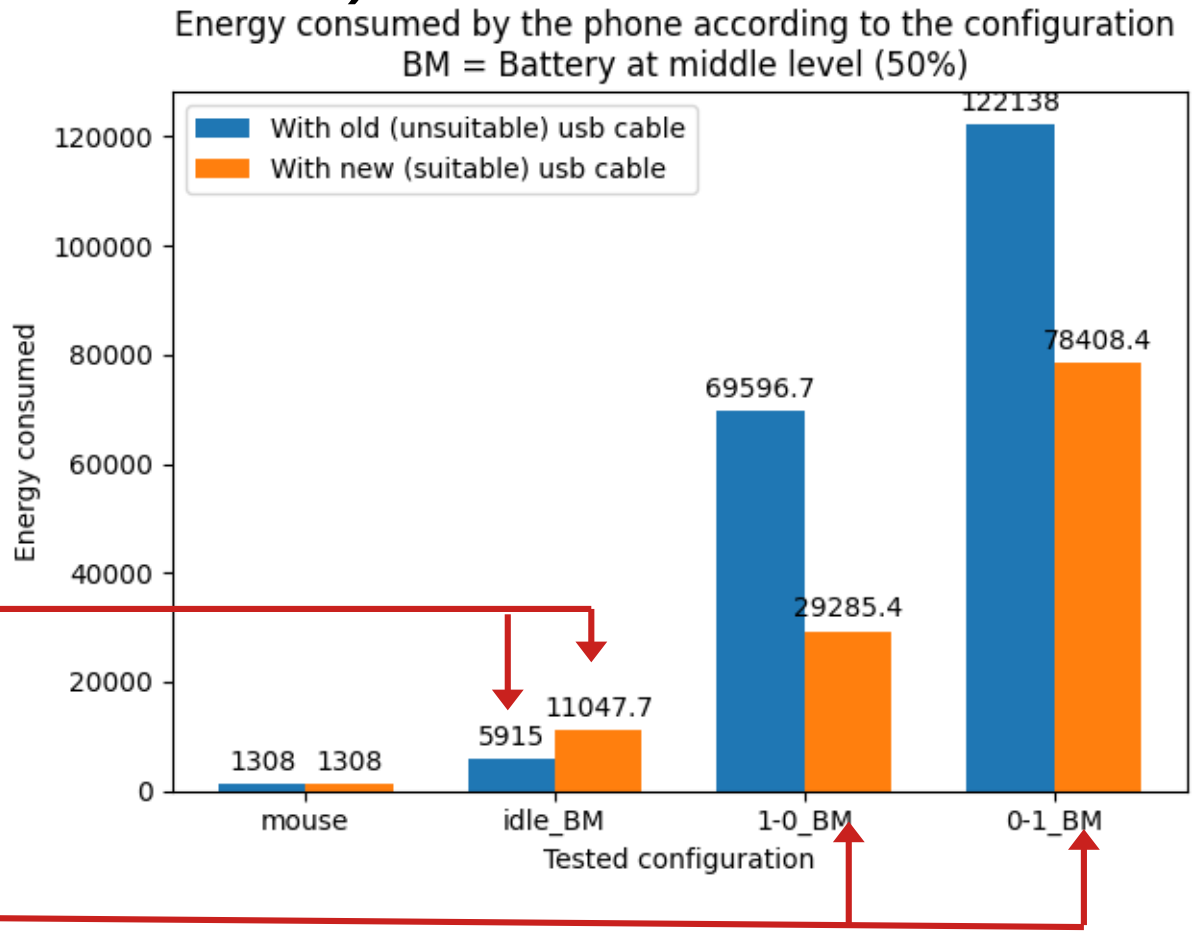
The quality of the equipment (USB cable) impact results

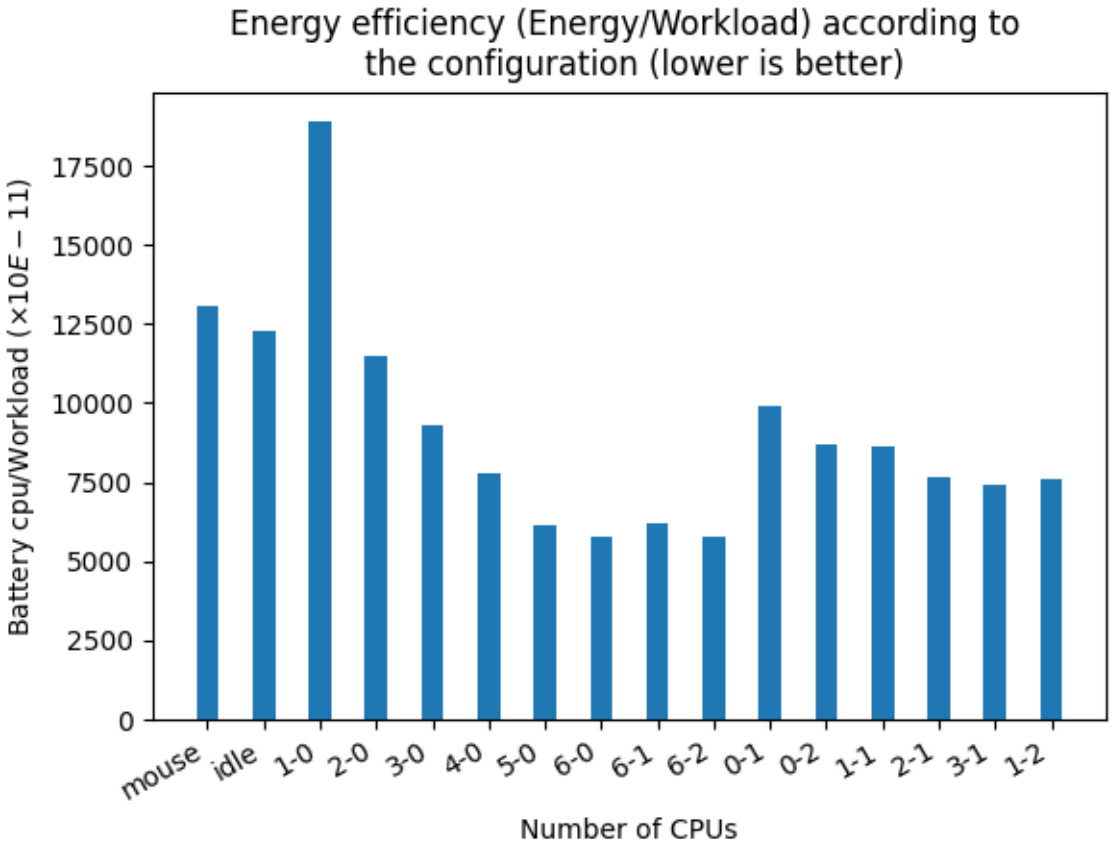
With the power-meter, results seem consistent with reality



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

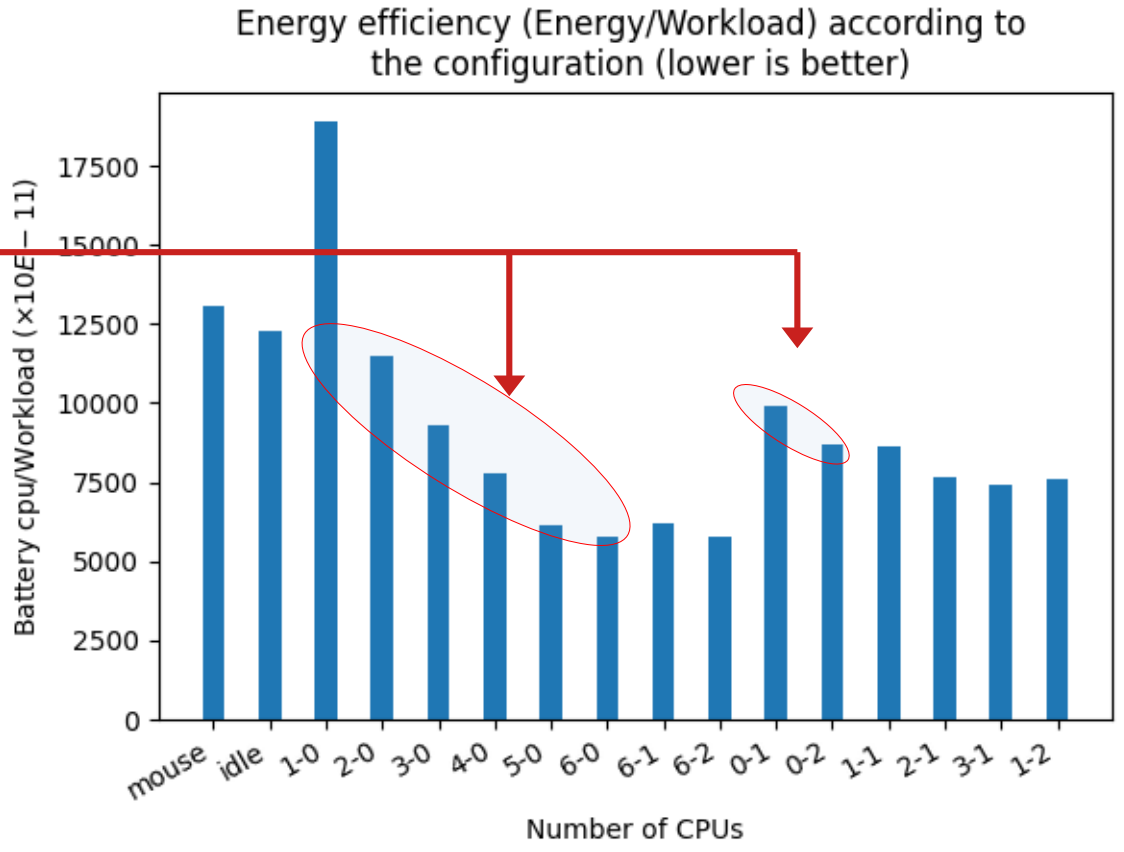


4. Experiments and observations (made using the power-meter)

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

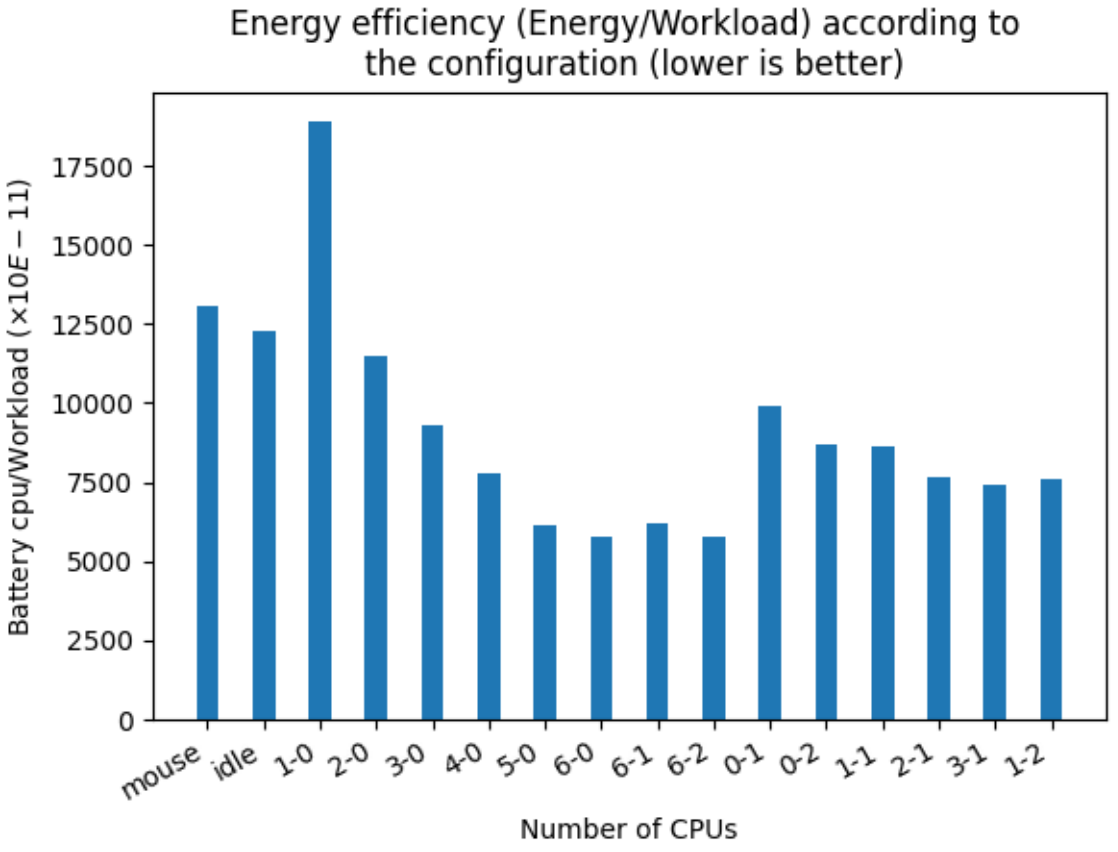
On the same socket the number of threads slightly increases with the efficiency



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



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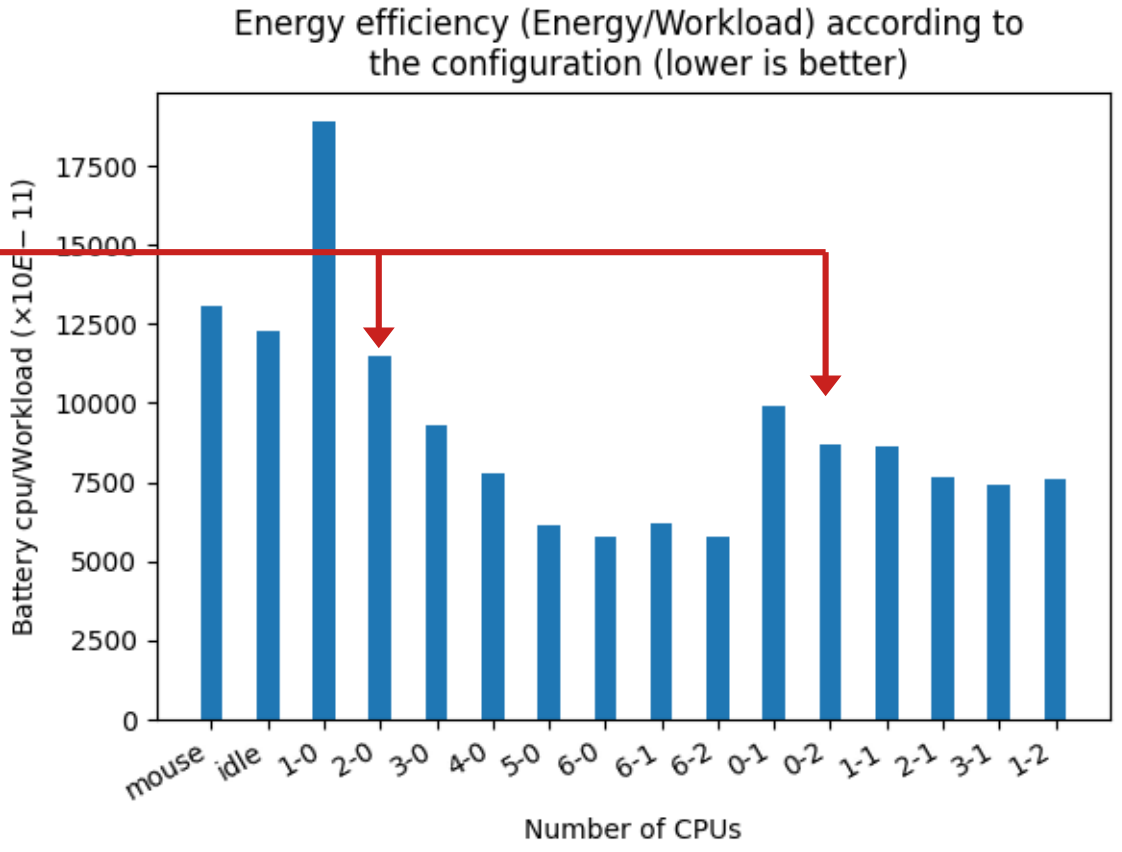
Big cores are much more efficient than little cores (for about …%)



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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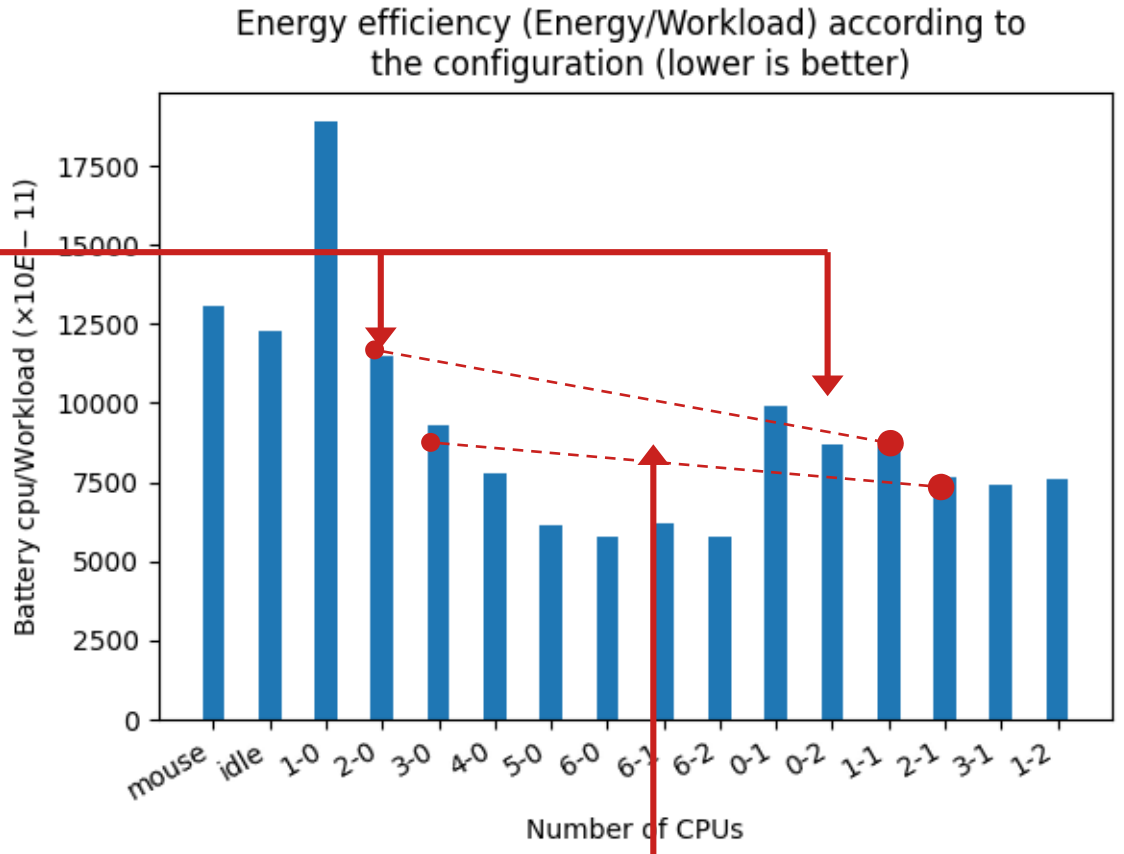
Big cores are much more efficient than little cores (for about …%)

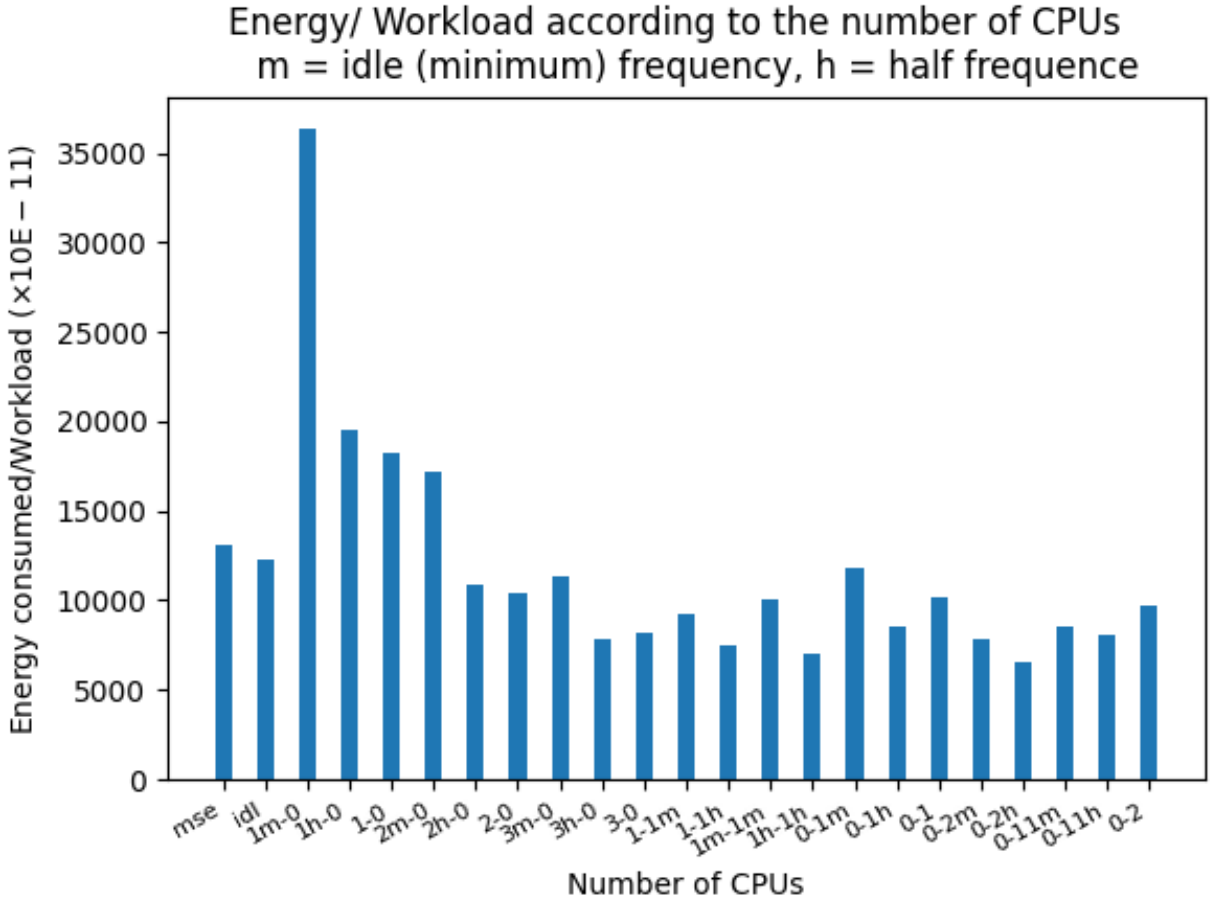
The efficiency of the big cores influences the overall efficiency of the configuration



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:

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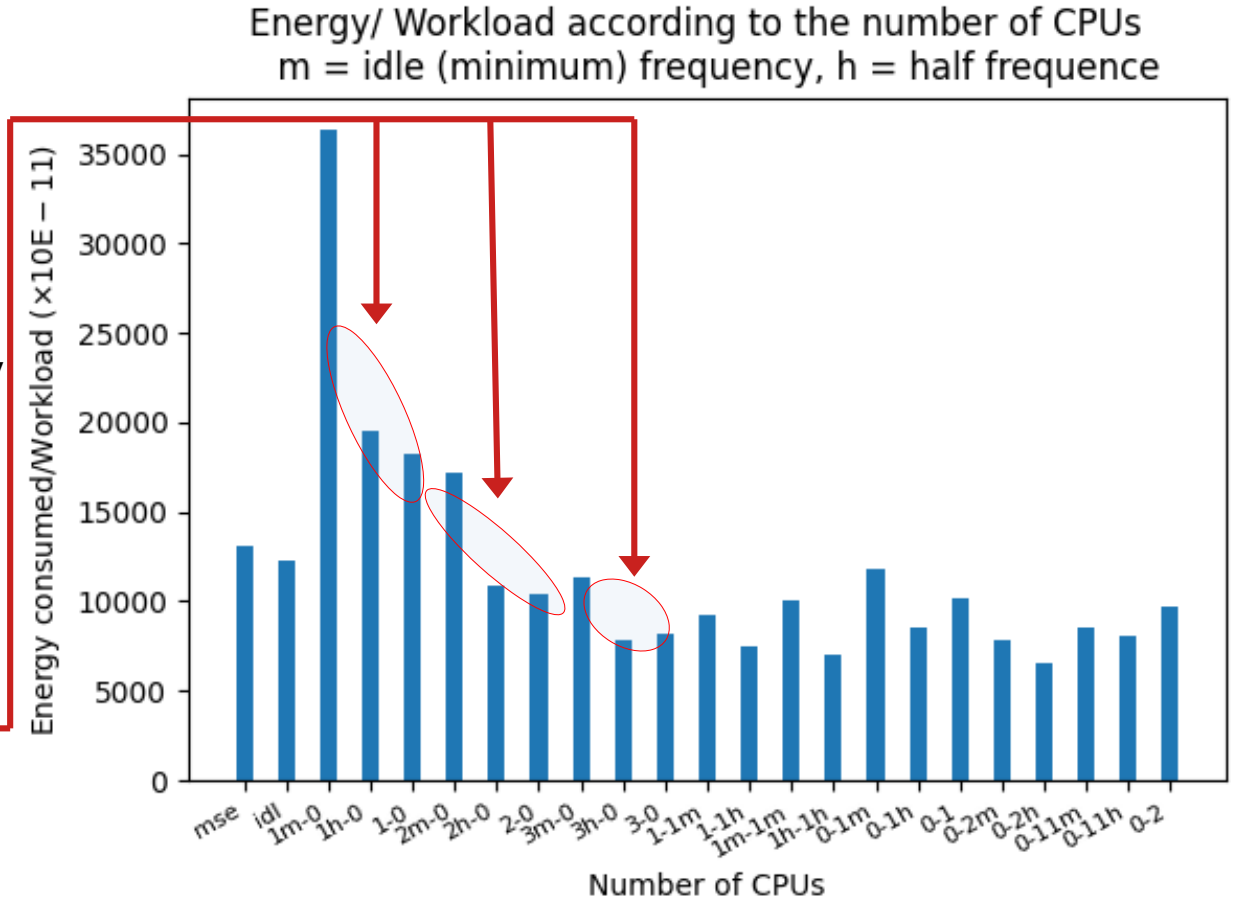
On the Little cores we are much more efficient with the maximum frequency



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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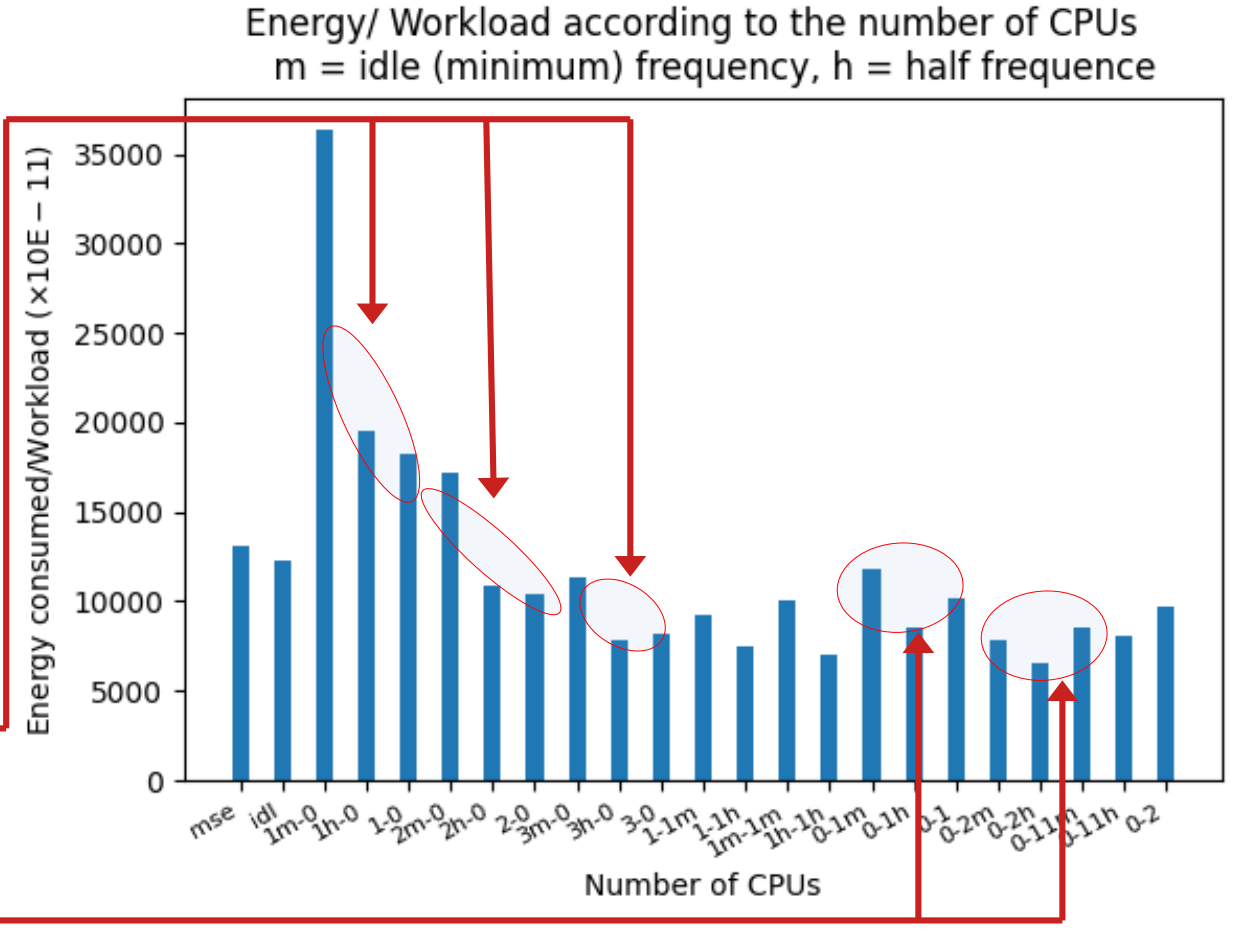

On the Little cores we are much more efficient with the maximum frequency

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:

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- 1 thread on Big core
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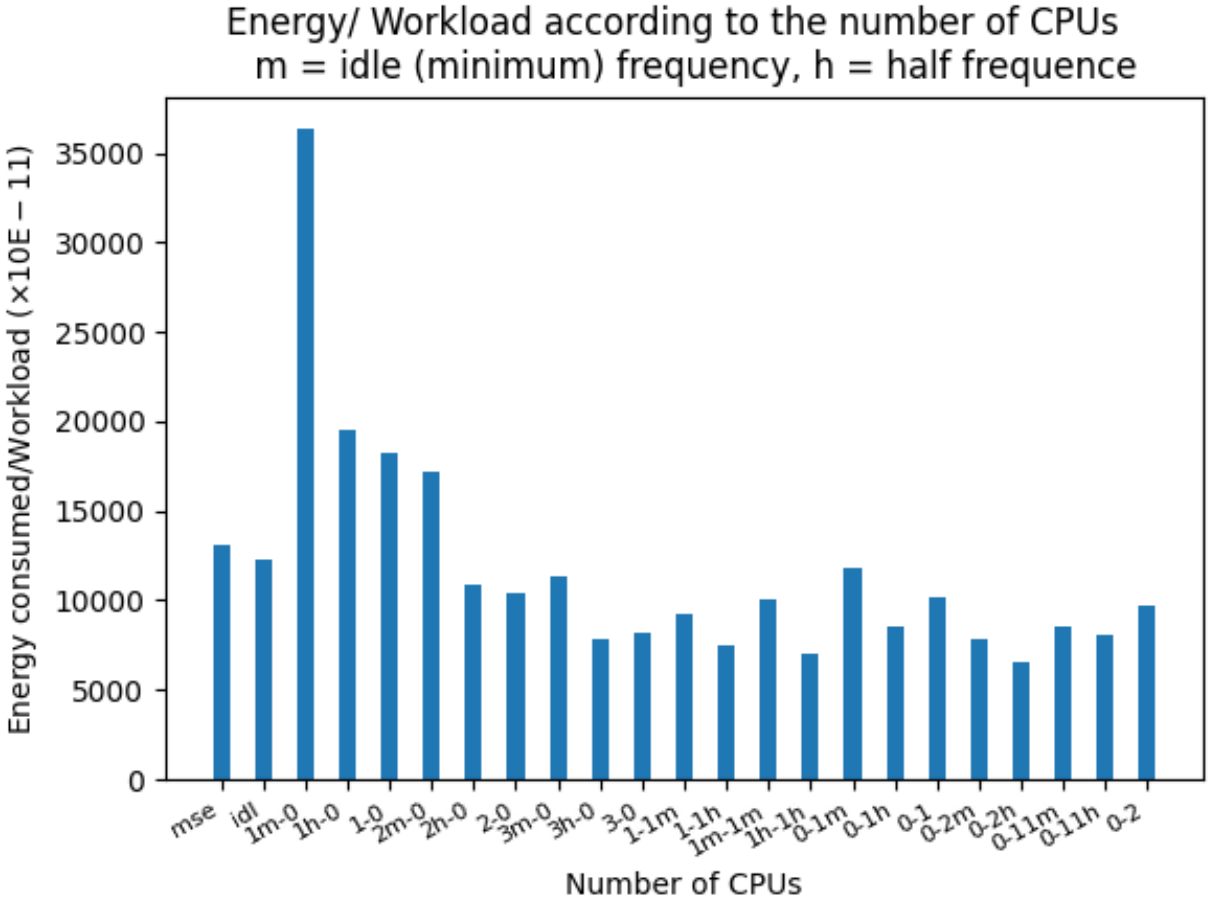

4. Experiments and observations (made using the power-meter)

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:

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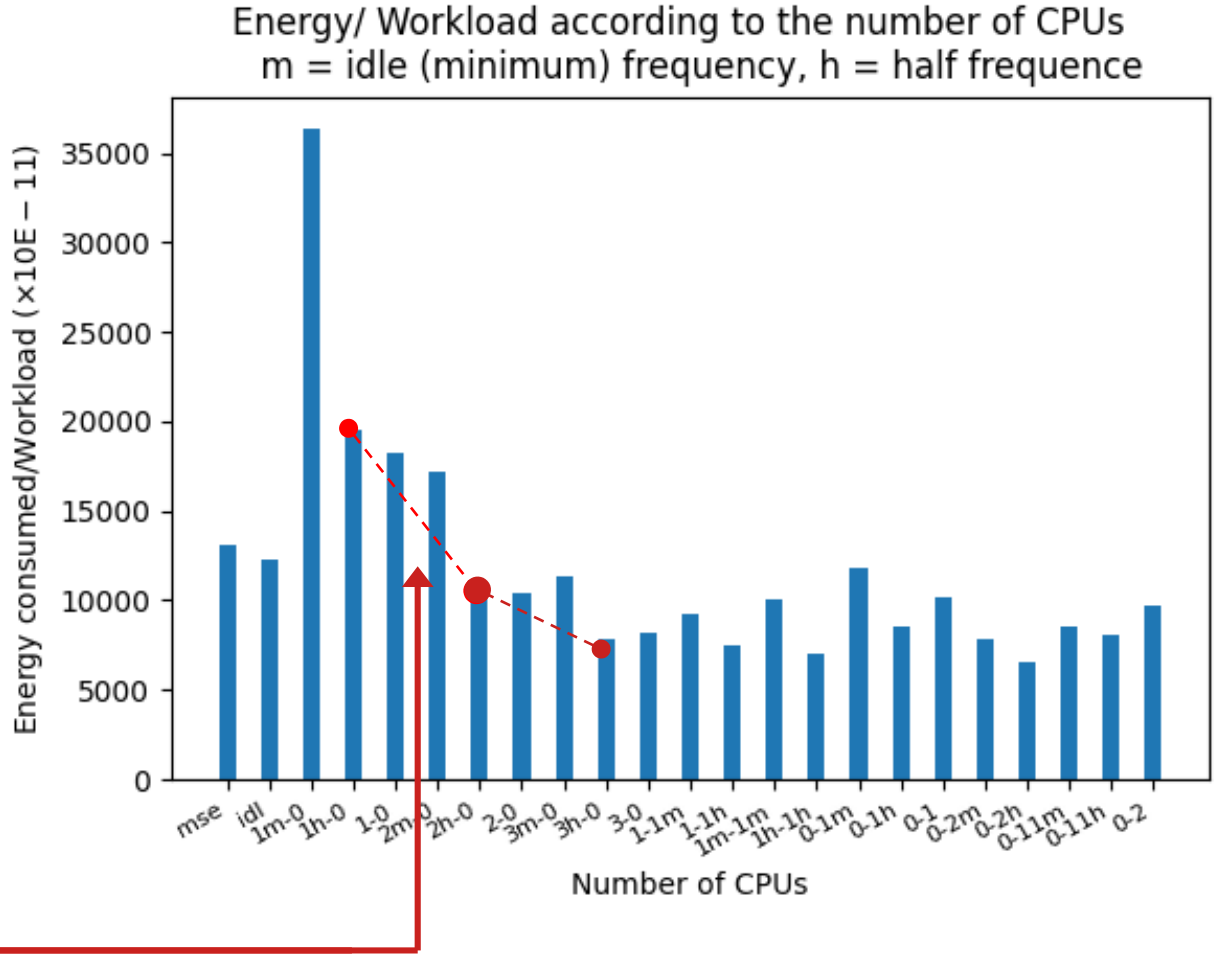
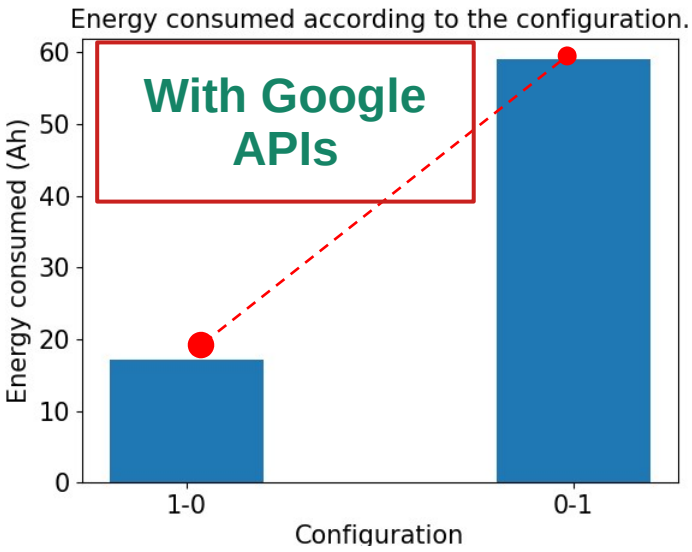
- H = half frequency, nothing = max frequency

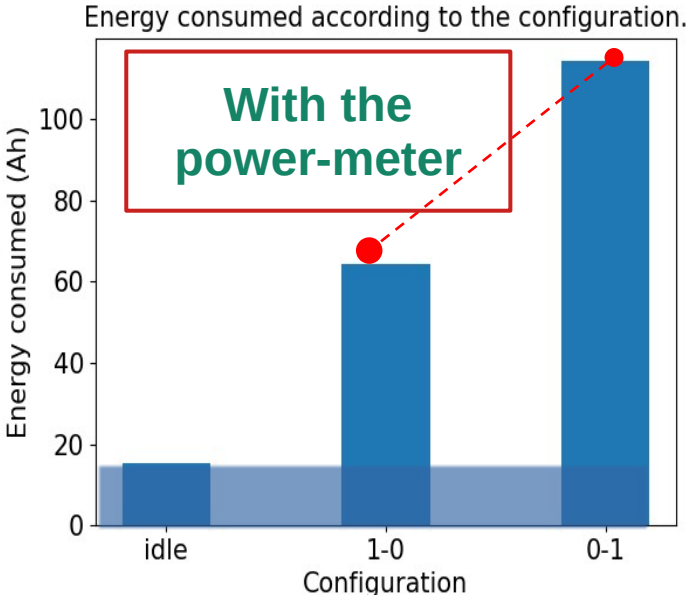
Fixing the frequency at mid level and increasing the number of threads increases the efficiency drastically



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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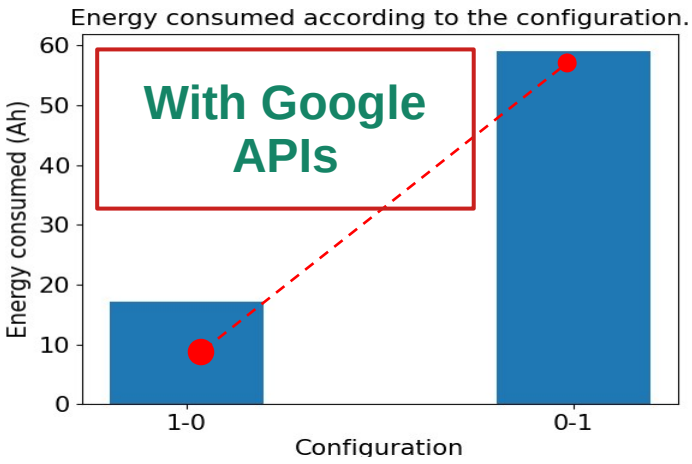

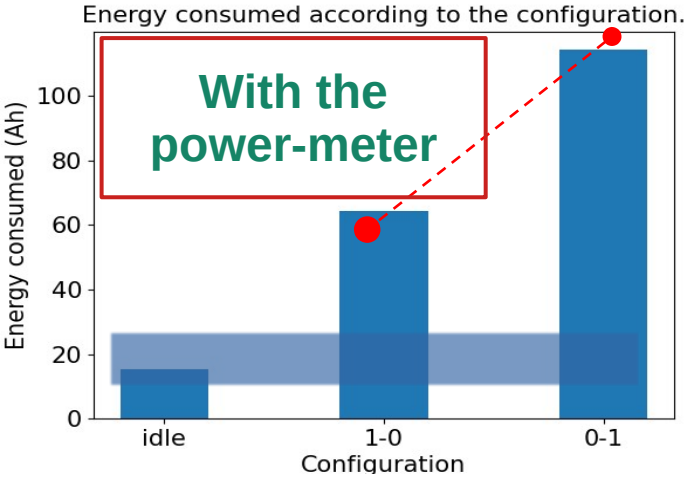

- **Validate observations made with other Benchmaks**

4. Next steps

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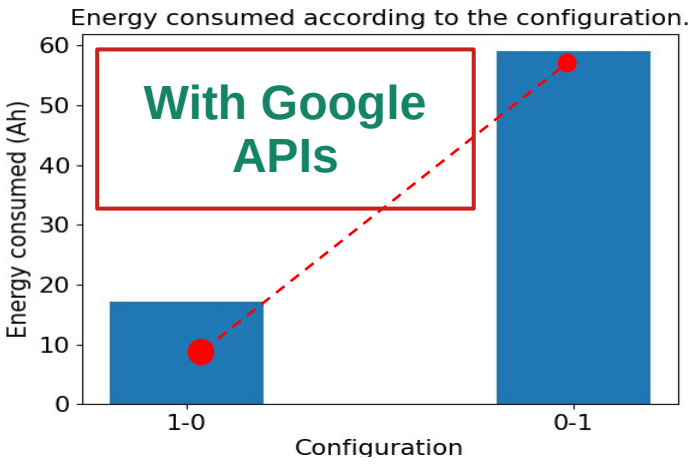
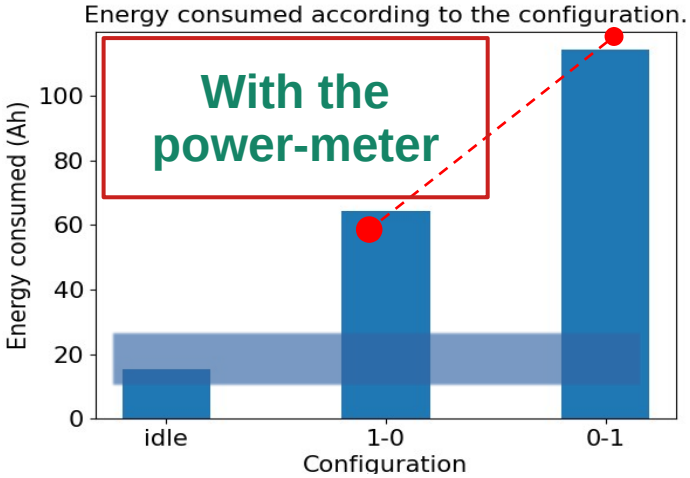


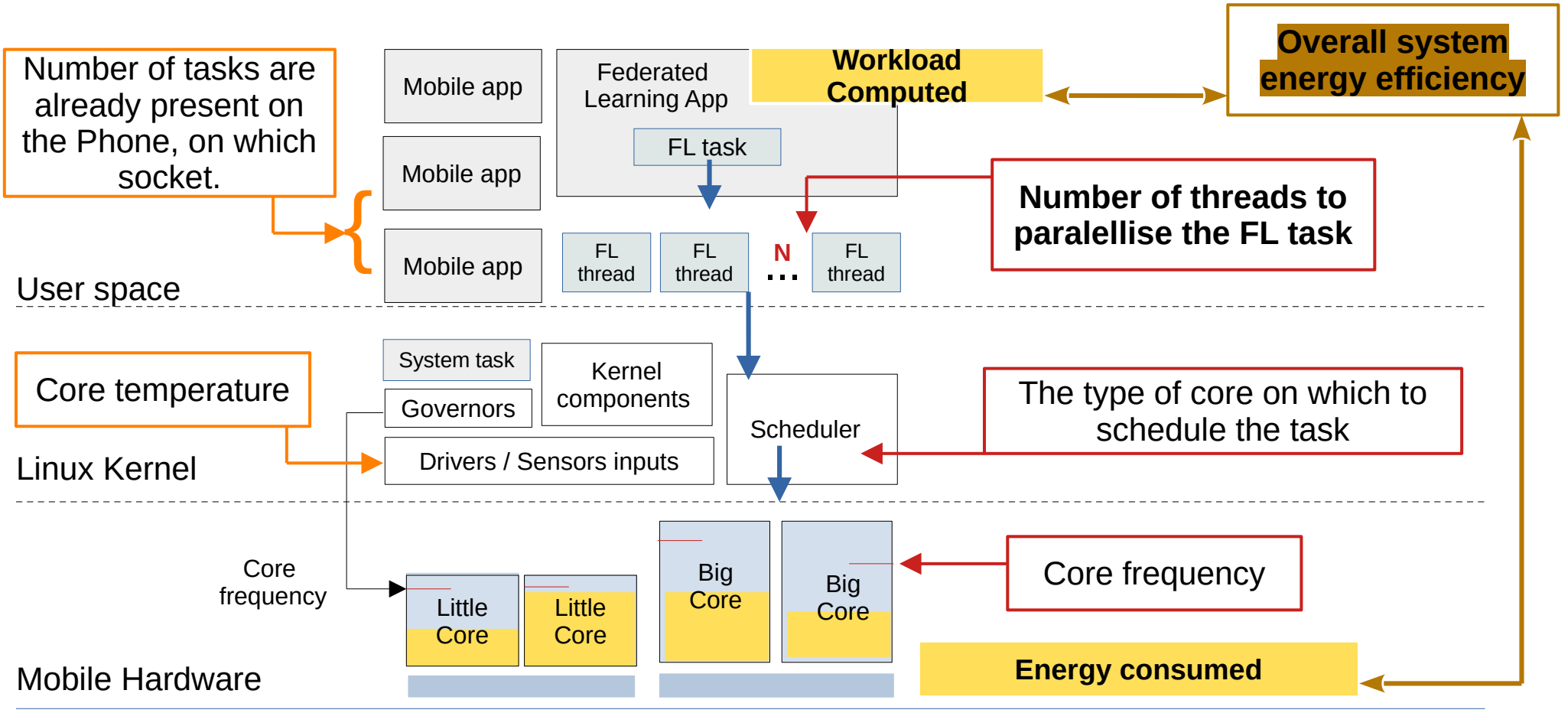


- **Validate observations made with other Benchmaks**

- **Valorise lesson learned and observations (publication, solution..).**

Tank you for your attention.

General Problem Scheme



2. template slide

- Manually make experiments by varying scenarios parameters:
  - Number of interactive task present on phones
  - Number of threads to paralellise the FL task
  - Type of cores
  - Core frequencies
- Bringing out the lessons learned
- Apply these lessons learned in the FL task scheduling process:
  - At user space Level
  - At kernel Level (Scheduler, governor).