Combining Uncore Frequency and Dynamic Power Capping to Improve Power Savings

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Uncore frequency scaling (UFS)

- Frequency of the L3 cache, the memory controllers, ...
- The default UFS does not always adapt to the application needs
DUF: Dynamic uncore frequency scaling

- Adapts to the application characteristics (computations, memory accesses)
- Allows for a user-defined tolerated slowdown
- Improvements compared to the default UFS:
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  - Power savings: by up to 7.46 % with less than 5 % performance loss
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In collaboration with: Étienne André, Rémi Dulong and François Trahay
Power capping

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- One can reduce the power budget:
  - Per processor
  - Per DRAM (not available on the used platform)
Impact of power capping on application performance and power consumption

- Applying power cap throughout the execution of an application introduces an overhead

Impact of power capping on the power consumption and execution time of CG (from the NAS Parallel Benchmarks) on a 4x16 cores Intel Xeon Gold. Default budget is 125 W.
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- Applying power capping only on the beginning of the application provides power savings
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• Applying power capping only on the beginning of the application provides power savings with no impact on performance

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Dynamic power capping

• Basic algorithm:
  • Decrease power cap as long as the flops are within the tolerated slowdown (increase otherwise)
  • Reset the power cap whenever when the behavior of the application changes

• Goals:
  • Respect the user-defined tolerated slowdown
  △ We may not be able to save energy (since power capping impacts performance). As a consequence, the goal is to save power without impact on energy consumption.
Target architecture and measurement framework

- Grid’5000 Grenoble Yeti: Intel Xeon Gold 6130 (Skylake)
  - 4 Processors
  - 16 cores/ Processor
  - Default power cap 125 W

- Measurement framework:
  - PAPI library for all measurements (FLOPS/s, memory bandwidth, processor power consumption, memory power consumption)
  - Powercap library to set the power cap
Target applications and configurations

- **Target applications**
  - Nas Parallel Benchmarks BT, CG, EP, FT, LU, MG, SP, UA
  - HPL
  - lammps

- **Configurations:**
  - Period = 200ms
  - Tolerated slowdown: 0 %, 5 %, 10 % and 20 %
  - Measurement error: 2 %
  - Uncore frequency scaling is also handled
Impact on execution time, power and energy consumption
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- Performance loss (%)
- Processor power savings (%)
- Processor + Memory energy savings (%)

Up to 3.1%
1.17%
0.4%
1.98%
1.17%
Impact on execution time, power and energy consumption

Performance loss (%):
- hpl: Up to 3.1%
- lammps: 1.17%
- bt: 0.4%
- cg: 1.98%
- ep: 24%
- ft: 13.98%
- lu: 4.70%

Processor power savings (%):
- hpl: 9
- lammps: 13
- bt: 17
- cg: 5
- ep: 10
- ft: 20
- lu: 10
- mg: 5
- sp: 10
- ua: 10

Processor + memory energy savings (%):
- hpl: -10
- lammps: -10
- bt: -10
- cg: 0
- ep: 5
- ft: 10
- lu: 10
- mg: 5
- sp: 10
- ua: 10

Legend:
- Yellow (0)
- Green (5)
- Blue (10)
- Dark green (20)
Impact on execution time, power and energy consumption

DUF: Dynamic Uncore Frequency Scaling

DUFP: Dynamic power capping

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1.17 %
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9 / 13
Impact on execution time, power and energy consumption

- **DUF**: Dynamic Uncore Frequency Scaling
- **DUFP**: Dynamic power capping

- **Impact on execution time, power and energy consumption**

- **Graphs**
  - Performance loss (%)
  - Processor power savings (%)
  - Processor + Memory energy savings (%)

- **Data Points**
  - Percentage changes across different benchmarks:
    - hpl, lammps, bt, cg, ep, ft, lu, mg, sp, ua
  - Specific values:
    - Up to 3.1%
    - 1.17%
    - 0.4%
    - 1.98%
    - 24%
    - 13.98%
    - 4.70%
Impact on execution time, power and energy consumption

- Performance loss (%)
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### Performance Results

- hpl
- lammps
- bt
- cg
- ep
- ft
- lu
- mg
- sp
- ua

**Performance Loss**
- hpl: Up to 3.1%
- lammps: 1.17%
- bt: 0.4%
- cg: 1.98%
- ep: 24%
- ft: 13.98%
- lu: 4.70%

**Processor Power Savings**
- hpl: 0%
- lammps: 5%
- bt: 10%
- cg: 20%
- ep: 10%
- ft: 5%
- lu: 0%
- mg: 0%
- sp: 0%
- ua: 0%

**Processor + Memory Energy Savings**
- hpl: 0%
- lammps: 5%
- bt: 10%
- cg: 10%
- ep: 5%
- ft: 0%
- lu: 0%
- mg: 0%
- sp: 0%
- ua: 0%
Impact on execution time, power and energy consumption

![Graph showing performance loss, processor power savings, and processor + memory energy savings for various benchmarks under DUF and DUFP settings.](image)
Impact on execution time, power and energy consumption
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performance loss (%)

processor power savings (%)

processor + memory energy savings (%)
Impact on execution time, power and energy consumption

![Chart showing performance loss, processor power savings, and processor + memory energy savings across different benchmarks.]
Impact on execution time, power and energy consumption

The diagram above illustrates the impact of DUF (Dynamic Uncore Frequency Scaling) and DUFP (Dynamic power capping) on performance loss, processor power savings, and processor + memory energy savings across various applications. The X-axis represents different applications, while the Y-axis shows the percentage changes in these metrics. The bars indicate the data points with error bars representing the variability. The legend at the right side of the diagram categorizes the applications based on performance loss, processor power savings, and processor + memory energy savings.
Impact on execution time, power and energy consumption
Impact on memory power consumption

The graph shows the impact of Dynamic Uncore Frequency Scaling (DUF) and Dynamic Power Capping (DUFP) on memory power consumption. The x-axis represents different benchmarks (hpl, lammps, bt, cg, ep, ft, lu, mg, sp, ua), and the y-axis represents the DRAM power savings in percent (%). The color legend indicates the tolerated slowdown in percent (%): 0, 5, 10, 20. The graph compares the performance of DUF and DUFP versions.
Summary of the results

• Up to 5.56 % power savings with less than 1 % performance loss (0.85 % slowdown)

• Up to 8.76 % power savings with less than 5 % performance loss (2.32 % slowdown)

• Best energy savings with 0 % tolerated slowdown

• Best power savings with no energy loss with 10 % tolerated slowdown

• Additional power savings with DUFP compared to DUF
Current work

- Use dynamic power capping for dynamic CPU/GPU scheduling

\[ \text{CPU + GPU consumption} \leq \text{Imposed power budget} \]

\[ \text{GPU consumption} \]

\[ \text{CPU consumption} \]
Current work

- Use dynamic power capping for dynamic CPU/GPU scheduling

![Diagram showing CPU + GPU consumption and imposed power budget]

- Impose power budget
- GPU consumption
- CPU consumption