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References

- [1] [The Sniper Multi-Core Simulator](#)
- [2] O. Tange (2011): [GNU Parallel](#) - The Command-Line Power Tool
- [3] S. C. Woo, M. Ohara, E. Torrie, J. P. Singh and A. Gupta, [The SPLASH-2 Programs: Characterization and Methodological Considerations](#), Proceedings 22nd Annual International Symposium on Computer Architecture, Santa Margherita Ligure, Italy, 1995, pp. 24-36
- [4] John L. Hennessy and David A. Patterson. 2017. Computer Architecture, Sixth Edition: A Quantitative Approach. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.
- [5] McFarling, Scott, 1993. [Combining Branch Predictors](#), Technical Note TN-36, Western Research Laboratory. Digital Equipment Corp., Palo Alto, CA.

Benchmark	PHT index bits (gshare)
cholesky	0 (default branch predictor)
fmm	4
lu.cont	8
radiosity	16
raytrace	

Table 1: Configuration parameters and values for PHT index bits for the gshare branch predictor swept in the experiment. The default branch predictor is pentium.

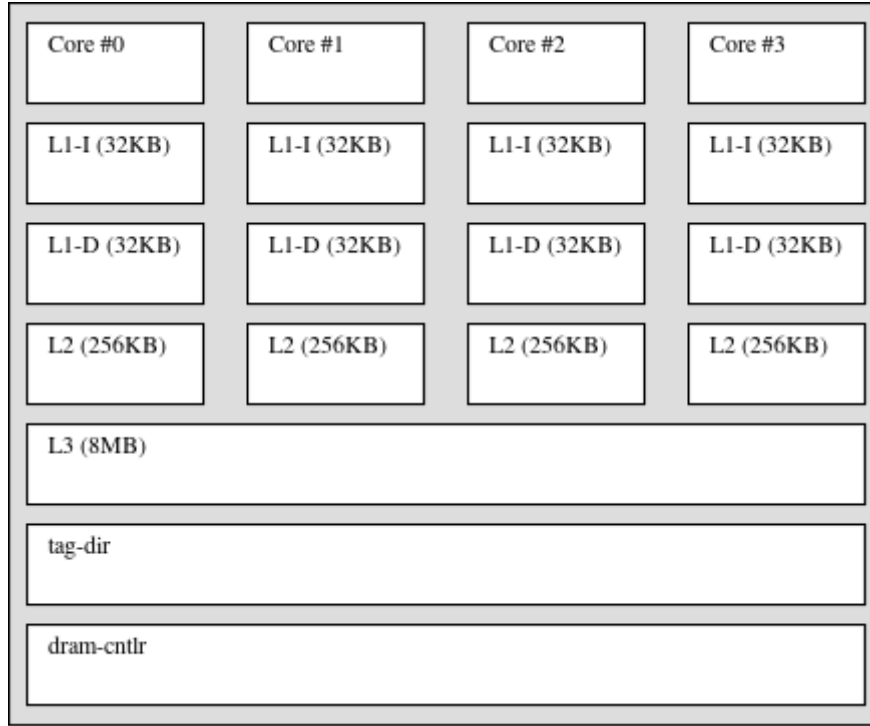


Figure 1: Topology for all five benchmark tests where only the number of PHT index bits were varied (all cache sizes remained consistent through every simulation). All benchmarks were run in `Sniper-7.3` with the `gainestown` configuration using the `--viz` and `--roi` options.

1 Intro

pattern history table (PHT)

2 Experimental Setup

Simulations ran for an x86 architecture simulator, Sniper 7.3 [1]. Since this experiment looked to sweep the `gshare` branch predictor performance through PHT sizes, each simulation was configured the same topology (Figure 1). The same default configurations were set in `gainestown.cfg`.

Three PHT sizes were swept for simulations using the `gshare` branch predictor, $2^4, 2^8, 2^{16}$. The sweep for “size” 2^0 represents simulations that ran the default branch predictor, `pentium`. `gshare` was implemented separately according to technical specifications [5] in C++, and integrated into Sniper-7.3 with gcc-7.4.0. There was a total of 26 simulations (see Table 1). The different branch predictor configurations were simulated with five `splash2` benchmarks not previously used: `cholesky`, `lu.cont`, `radiosity`, `raytrace`, and `fmm` [3].

The workloads are briefly described as follows:

cholesky : The `cholesky` factors a sparse matrix into the product of a lower triangular matrix and its transpose without globally synchronizing between steps.

fmm : The `fmm` application implements the adaptive Fast Multipole Method to simulate interactions of systems of N-bodies (particles, galaxies, etc.) in 2D with unstructured communication patterns.

suite of test studies large-scale ocean movements based on currents, and uses 4D array grids and a red-black Gauss-Seidel multigrid equation solver.

lu.cont : The `lu.cont` factors a dense matrix into the product of a lower and upper triangular matrix, exploiting temporal locality on submatrix elements. Blocks are allocated sequentially and locally to processors that own them in order to improve the spatial locality.

suite uses an iterative radix sort algorithm that generates histograms and has each processor permute array index keys, a process that depends on processors communicating in order to determine keys through writes.

radiosity : The `radiosity` application computes the equilibrium distribution of light in a scene using the iterative hierarchical diffuse radiosity method using the light transport interactions and subdivisions in polygons. This application has highly irregular computation structure and data structure accesses.

raytrace : The `raytrace` renders a 3D scene using ray tracing through each pixel in the image plane, reflecting them off objects in unpredictable and multiple ways; therefore, data structure access patterns are also unpredictable.

All the simulations ran concurrently using bash script(s) and GNU `parallel` shell tool [2], and post processing of the data were handled with python (v2.7) and bash scripts (included separately). Simulations ran on a python virtual environment and in a detached `tmux` session, due to long duration of the experiments. Sniper provided data processing tools used were: `gen_topology.py`, `cpi-stack.py`, and `mcpat.py`.

3 Results & Analysis

3.1 Performance Analysis

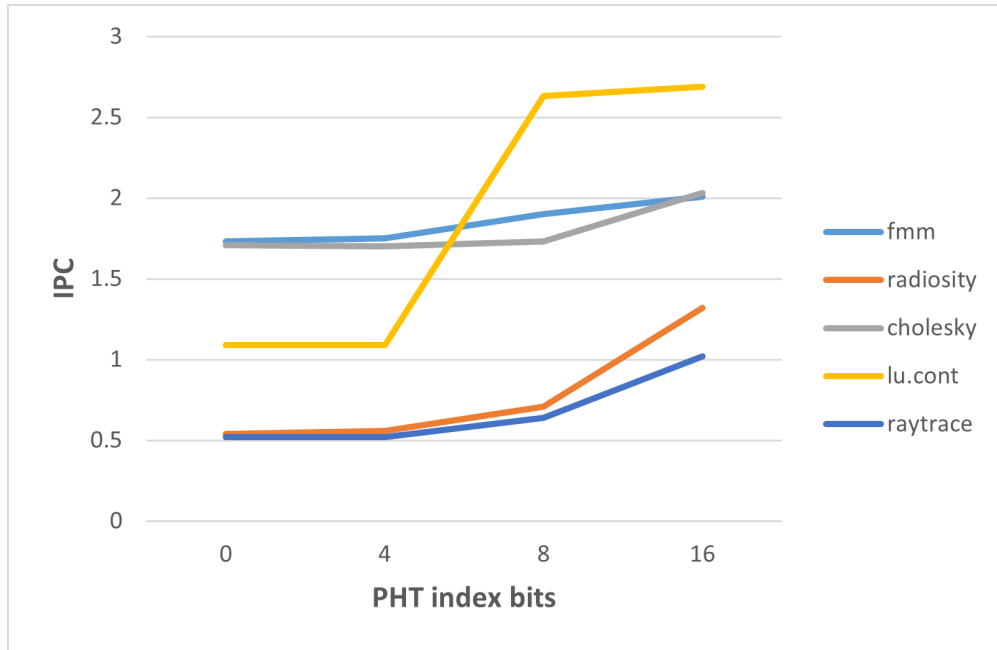


Figure 2

3.2 Energy Consumption

4 Conclusion

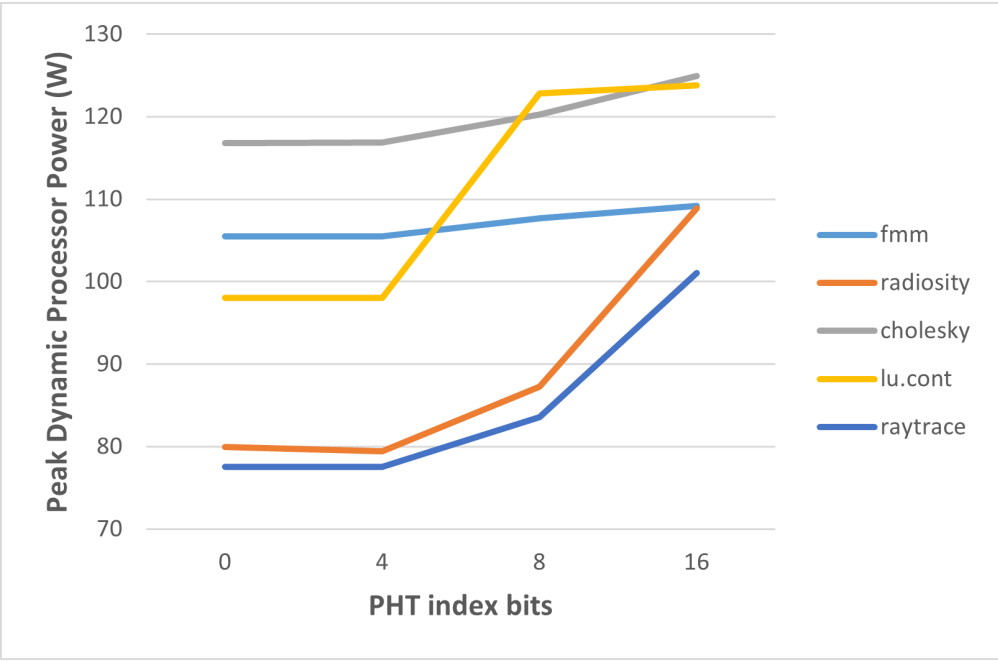


Figure 3

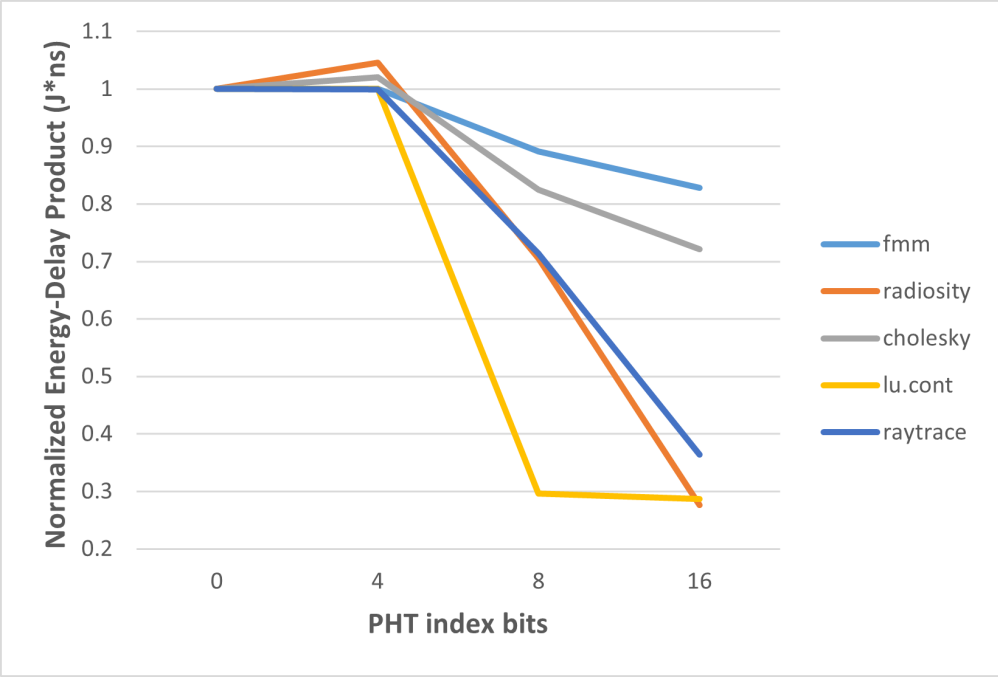


Figure 4

5 Appendix: Raw Post Processed Data

5.1 cholesky

5.1.1 Power Results

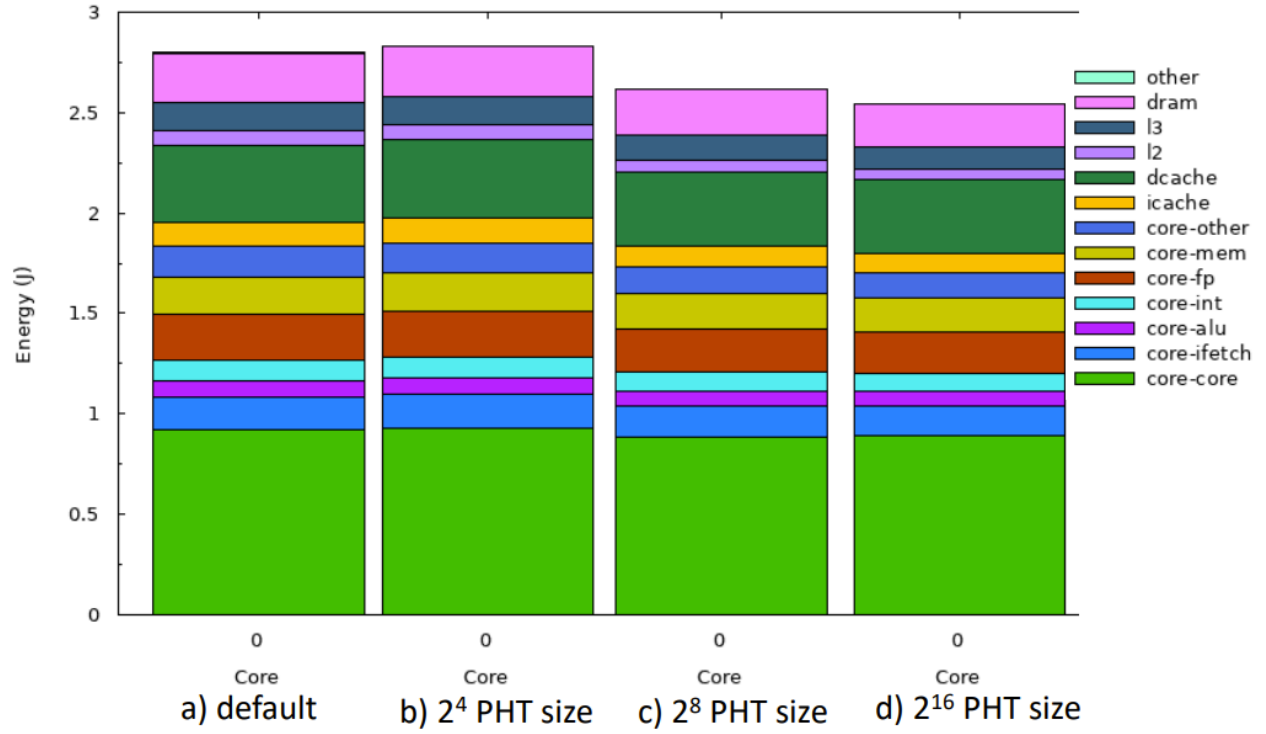


Figure 5: Processor power for various PHT sizes.

	Power	Energy	Energy %
core-core	22.91 W	0.92 J	32.89%
core-ifetch	4.04 W	0.16 J	5.79%
core-alu	2.06 W	0.08 J	2.95%
core-int	2.60 W	0.10 J	3.73%
core-fp	5.68 W	0.23 J	8.15%
core-mem	4.57 W	0.18 J	6.55%
core-other	3.79 W	0.15 J	5.45%
icache	2.90 W	0.12 J	4.16%
dcache	9.71 W	0.39 J	13.93%
l2	1.71 W	0.07 J	2.46%
l3	3.48 W	0.14 J	4.99%
dram	6.19 W	0.25 J	8.89%
other	0.03 W	1.31 mJ	0.05%
core	45.65 W	1.83 J	65.52%
cache	17.79 W	0.71 J	25.54%
total	69.67 W	2.80 J	100.00%

(a) default

	Power	Energy	Energy %
core-core	22.92 W	0.93 J	32.86%
core-ifetch	4.06 W	0.16 J	5.82%
core-alu	2.05 W	0.08 J	2.94%
core-int	2.61 W	0.11 J	3.74%
core-fp	5.65 W	0.23 J	8.10%
core-mem	4.59 W	0.19 J	6.59%
core-other	3.79 W	0.15 J	5.44%
icache	2.96 W	0.12 J	4.24%
dcache	9.75 W	0.40 J	13.97%
l2	1.71 W	0.07 J	2.45%
l3	3.48 W	0.14 J	4.99%
dram	6.15 W	0.25 J	8.82%
other	0.03 W	1.33 mJ	0.05%
core	45.68 W	1.85 J	65.49%
cache	17.89 W	0.73 J	25.65%
total	69.76 W	2.83 J	100.00%

(b) 2^4 PHT size

	Power	Energy	Energy %
core-core	25.07 W	0.89 J	33.92%
core-ifetch	4.26 W	0.15 J	5.76%
core-alu	2.18 W	0.08 J	2.95%
core-int	2.71 W	0.10 J	3.67%
core-fp	6.04 W	0.21 J	8.18%
core-mem	4.89 W	0.17 J	6.61%
core-other	3.79 W	0.13 J	5.13%
icache	2.88 W	0.10 J	3.89%
dcache	10.42 W	0.37 J	14.09%
l2	1.72 W	0.06 J	2.32%
l3	3.49 W	0.12 J	4.72%
dram	6.45 W	0.23 J	8.72%
other	0.03 W	1.16 mJ	0.04%
core	48.94 W	1.73 J	66.20%
cache	18.50 W	0.66 J	25.03%
total	73.93 W	2.62 J	100.00%

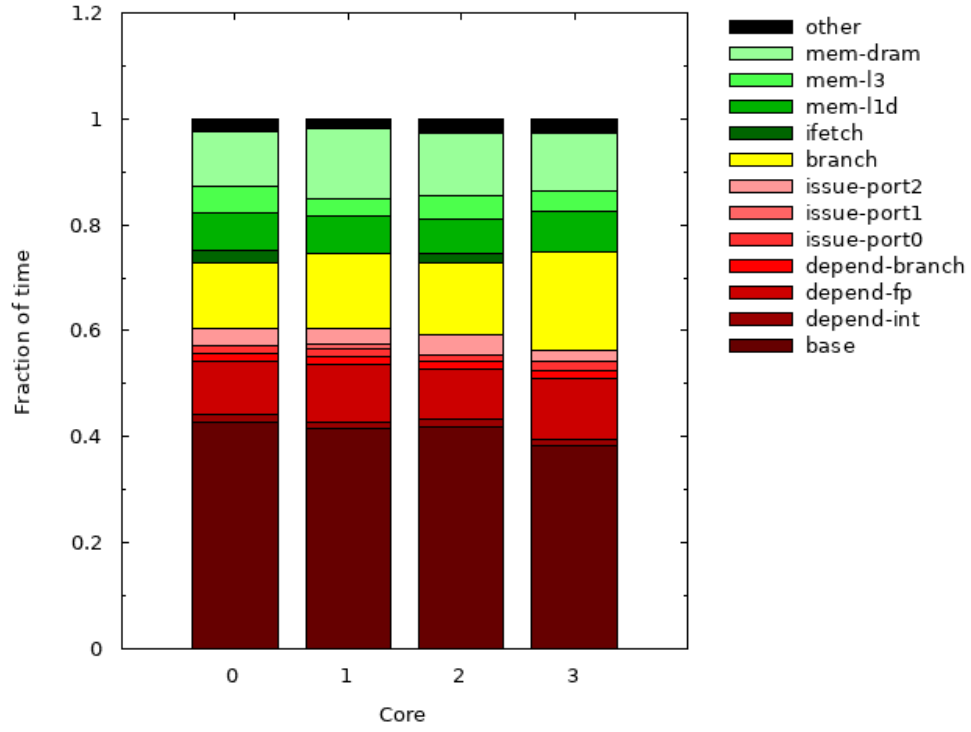
(c) 2^8 PHT size

	Power	Energy	Energy %
core-core	27.97 W	0.89 J	34.91%
core-ifetch	4.66 W	0.15 J	5.81%
core-alu	2.29 W	0.07 J	2.86%
core-int	2.90 W	0.09 J	3.62%
core-fp	6.39 W	0.20 J	7.98%
core-mem	5.44 W	0.17 J	6.79%
core-other	3.79 W	0.12 J	4.74%
icache	3.15 W	0.10 J	3.93%
dcache	11.54 W	0.37 J	14.40%
l2	1.72 W	0.05 J	2.15%
l3	3.51 W	0.11 J	4.38%
dram	6.71 W	0.21 J	8.38%
other	0.03 W	1.04 mJ	0.04%
core	53.45 W	1.70 J	66.72%
cache	19.92 W	0.63 J	24.86%
total	80.11 W	2.55 J	100.00%

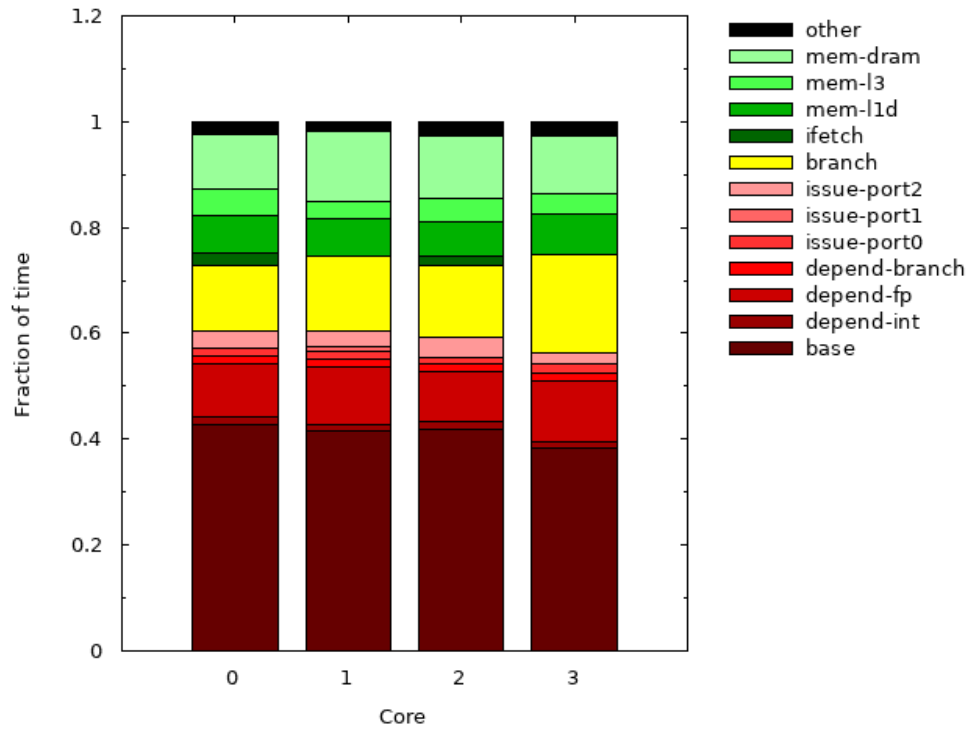
(d) 2^{16} PHT size

Figure 6: Specific values for each components' power consumption.

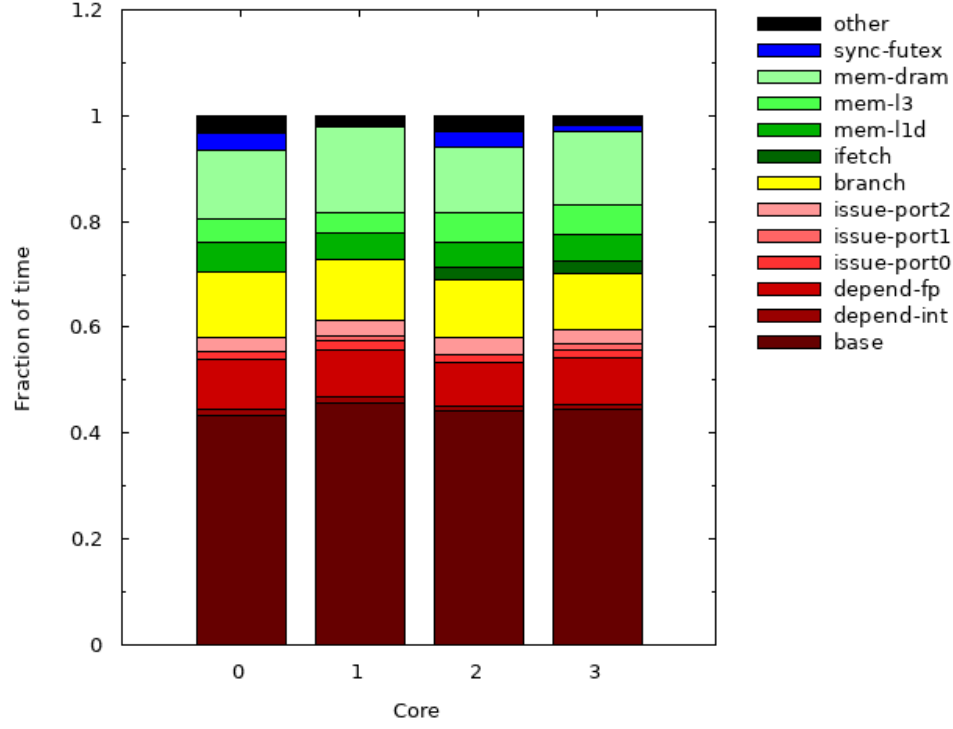
5.1.2 CPI Stacks



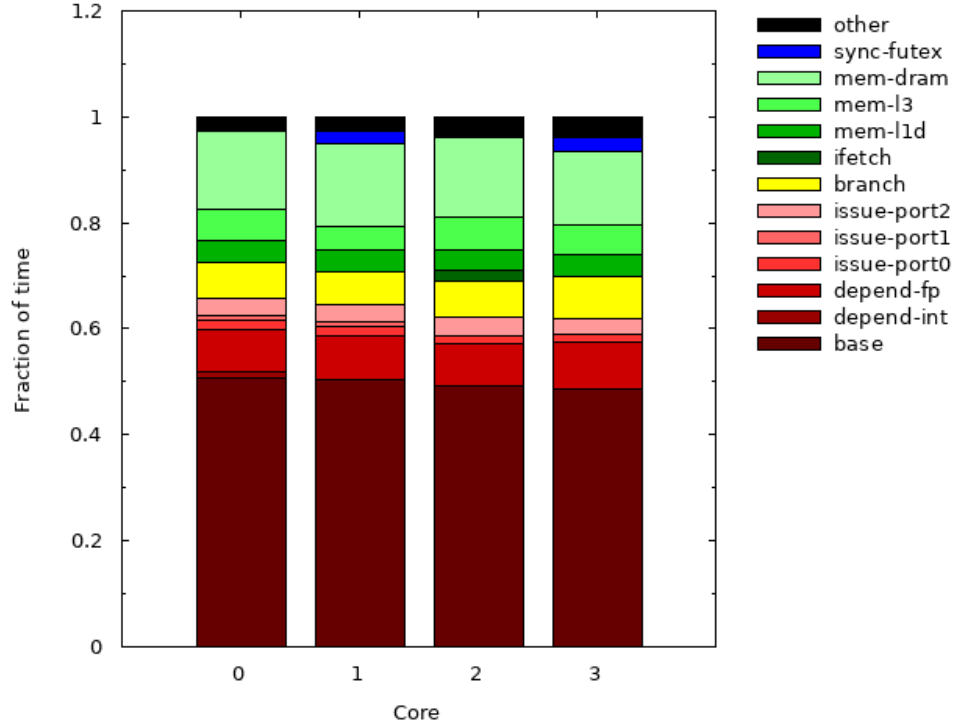
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 7: CPI stacks for various PHT sizes.

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.06	0.06	0.05	0.08
depend-branch	0.01	0.01	0.01	0.01
issue-port0	0.01	0.01	0.01	0.01
issue-port1	0.00	0.01	0.00	0.00
issue-port2	0.02	0.02	0.02	0.01
branch	0.07	0.09	0.08	0.12
ifetch	0.01	0.00	0.01	0.00
mem-l1d	0.04	0.04	0.04	0.05
mem-l3	0.03	0.02	0.03	0.03
mem-dram	0.06	0.08	0.07	0.07
other	0.01	0.01	0.02	0.02
total	0.58	0.60	0.60	0.65

(a) default

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.06	0.06	0.05	0.08
depend-branch	0.01	0.01	0.01	0.01
issue-port0	0.01	0.01	0.01	0.01
issue-port2	0.02	0.02	0.02	0.01
branch	0.07	0.07	0.08	0.11
ifetch	0.01	0.00	0.00	0.00
mem-l1d	0.04	0.04	0.04	0.05
mem-l3	0.03	0.02	0.03	0.03
mem-dram	0.06	0.07	0.06	0.07
sync-futex	0.01	0.00	0.03	0.02
other	0.01	0.02	0.02	0.02
total	0.59	0.57	0.60	0.66

(b) 2^4 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.05	0.05	0.05	0.05
issue-port0	0.01	0.01	0.01	0.01
issue-port1	0.00	0.01	0.00	0.01
issue-port2	0.02	0.02	0.02	0.01
branch	0.07	0.06	0.06	0.06
ifetch	0.00	0.00	0.01	0.01
mem-l1d	0.03	0.03	0.03	0.03
mem-l3	0.03	0.02	0.03	0.03
mem-dram	0.08	0.09	0.07	0.08
sync-futex	0.02	0.00	0.02	0.01
other	0.02	0.01	0.02	0.01
total	0.58	0.55	0.57	0.56

(c) 2^8 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.00	0.00	0.00
depend-fp	0.04	0.04	0.04	0.05
issue-port0	0.01	0.01	0.01	0.01
issue-port1	0.01	0.00	0.00	0.00
issue-port2	0.01	0.01	0.02	0.02
branch	0.03	0.03	0.03	0.04
ifetch	0.00	0.00	0.01	0.00
mem-l1d	0.02	0.02	0.02	0.02
mem-l3	0.03	0.02	0.03	0.03
mem-dram	0.07	0.08	0.08	0.07
sync-futex	0.00	0.01	0.00	0.01
other	0.01	0.01	0.02	0.02
total	0.49	0.50	0.51	0.51

(d) 2^{16} PHT size

Figure 8: Specific values for each components' CPI stack.

5.2 fmm

5.2.1 Power Results

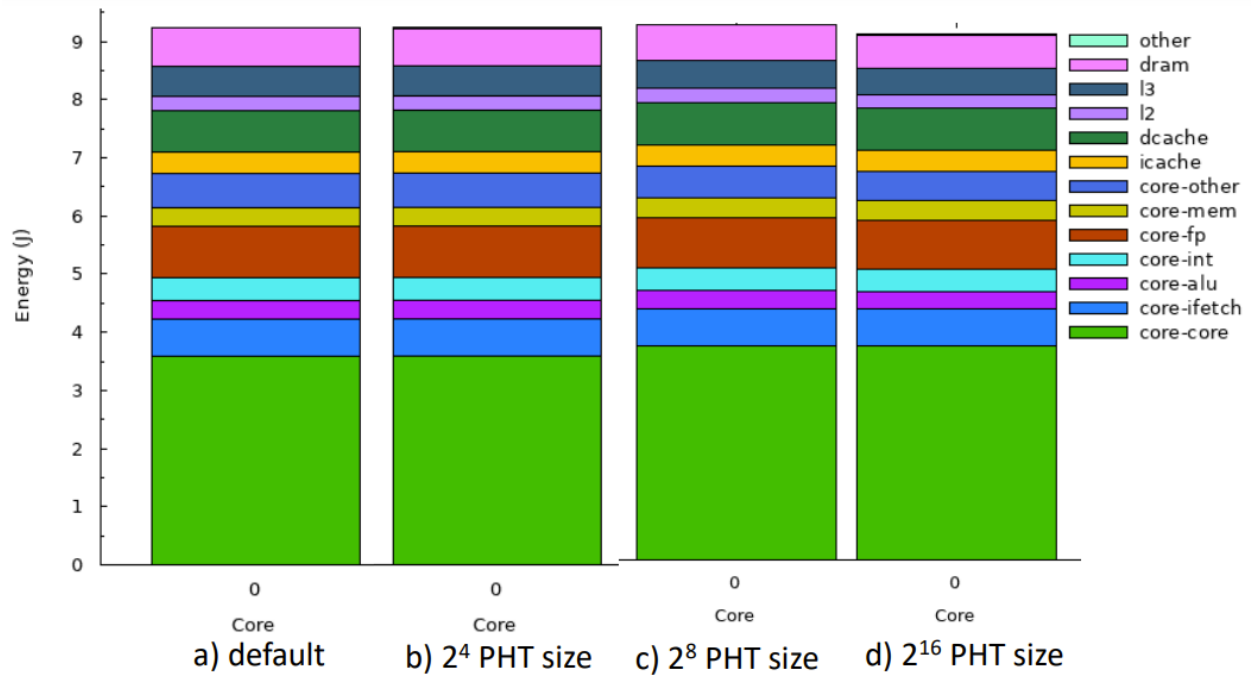


Figure 9: Processor power for various PHT sizes.

	Power	Energy	Energy %
core-core	24.12 W	3.60 J	38.99%
core-ifetch	4.22 W	0.63 J	6.83%
core-alu	2.18 W	0.33 J	3.52%
core-int	2.62 W	0.39 J	4.23%
core-fp	5.84 W	0.87 J	9.44%
core-mem	2.26 W	0.34 J	3.66%
core-other	3.79 W	0.57 J	6.13%
icache	2.54 W	0.38 J	4.11%
dcache	4.78 W	0.71 J	7.73%
l2	1.68 W	0.25 J	2.71%
l3	3.41 W	0.51 J	5.51%
dram	4.38 W	0.65 J	7.08%
other	0.03 W	4.88 mJ	0.05%
core	45.04 W	6.72 J	72.81%
cache	12.41 W	1.85 J	20.06%
total	61.87 W	9.23 J	100.00%

(a) default

	Power	Energy	Energy %
core-core	24.13 W	3.60 J	38.99%
core-ifetch	4.22 W	0.63 J	6.83%
core-alu	2.18 W	0.33 J	3.52%
core-int	2.62 W	0.39 J	4.23%
core-fp	5.84 W	0.87 J	9.44%
core-mem	2.26 W	0.34 J	3.66%
core-other	3.79 W	0.57 J	6.13%
icache	2.54 W	0.38 J	4.11%
dcache	4.78 W	0.71 J	7.73%
l2	1.68 W	0.25 J	2.71%
l3	3.41 W	0.51 J	5.51%
dram	4.38 W	0.65 J	7.08%
other	0.03 W	4.88 mJ	0.05%
core	45.05 W	6.72 J	72.81%
cache	12.41 W	1.85 J	20.06%
total	61.88 W	9.23 J	100.00%

(b) 2⁴ PHT size

	Power	Energy	Energy %
core-core	26.20 W	3.59 J	40.08%
core-ifetch	4.51 W	0.62 J	6.90%
core-alu	2.27 W	0.31 J	3.47%
core-int	2.75 W	0.38 J	4.20%
core-fp	6.10 W	0.84 J	9.33%
core-mem	2.43 W	0.33 J	3.73%
core-other	3.79 W	0.52 J	5.81%
icache	2.70 W	0.37 J	4.12%
dcache	5.10 W	0.70 J	7.81%
l2	1.68 W	0.23 J	2.57%
l3	3.41 W	0.47 J	5.22%
dram	4.39 W	0.60 J	6.72%
other	0.03 W	4.48 mJ	0.05%
core	48.05 W	6.58 J	73.51%
cache	12.89 W	1.77 J	19.72%
total	65.36 W	8.96 J	100.00%

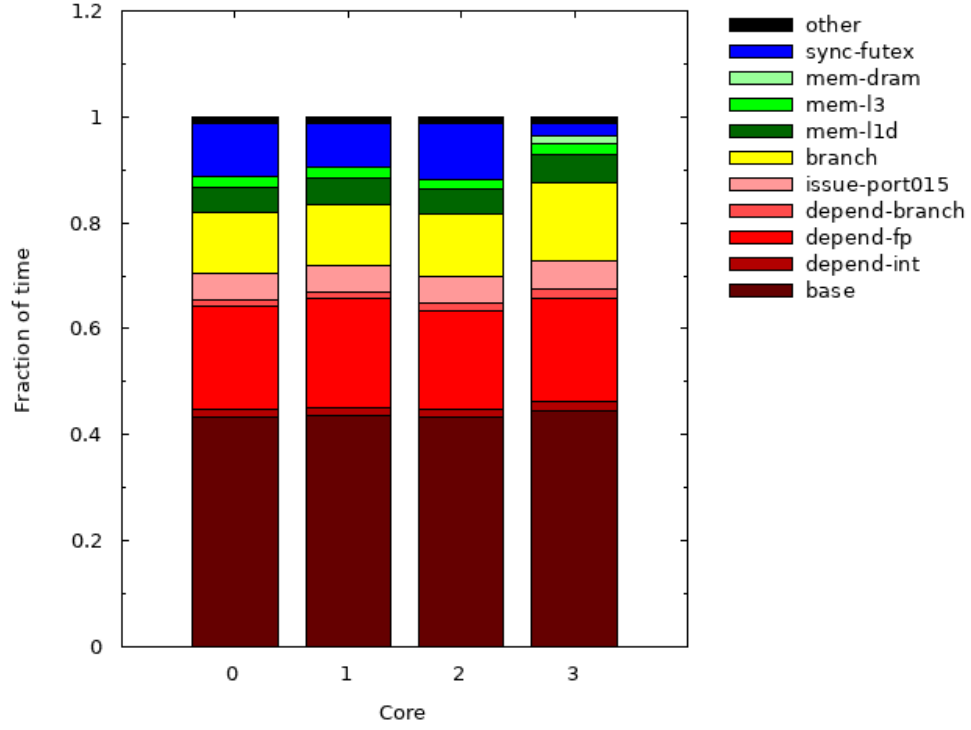
(c) 2^8 PHT size

	Power	Energy	Energy %
core-core	27.61 W	3.58 J	40.76%
core-ifetch	4.70 W	0.61 J	6.94%
core-alu	2.33 W	0.30 J	3.44%
core-int	2.84 W	0.37 J	4.19%
core-fp	6.27 W	0.81 J	9.26%
core-mem	2.55 W	0.33 J	3.76%
core-other	3.79 W	0.49 J	5.60%
icache	2.80 W	0.36 J	4.13%
dcache	5.32 W	0.69 J	7.85%
l2	1.68 W	0.22 J	2.48%
l3	3.41 W	0.44 J	5.04%
dram	4.40 W	0.57 J	6.49%
other	0.03 W	4.24 mJ	0.05%
core	50.09 W	6.50 J	73.96%
cache	13.21 W	1.71 J	19.50%
total	67.74 W	8.79 J	100.00%

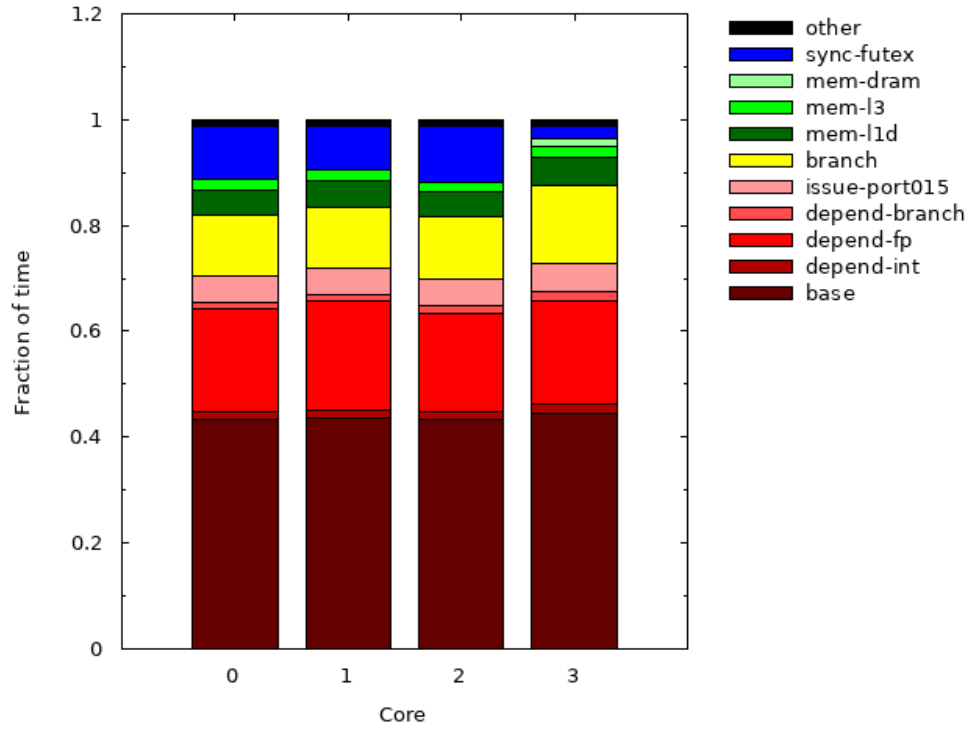
(d) 2^{16} PHT size

Figure 10: Specific values for each components' power consumption.

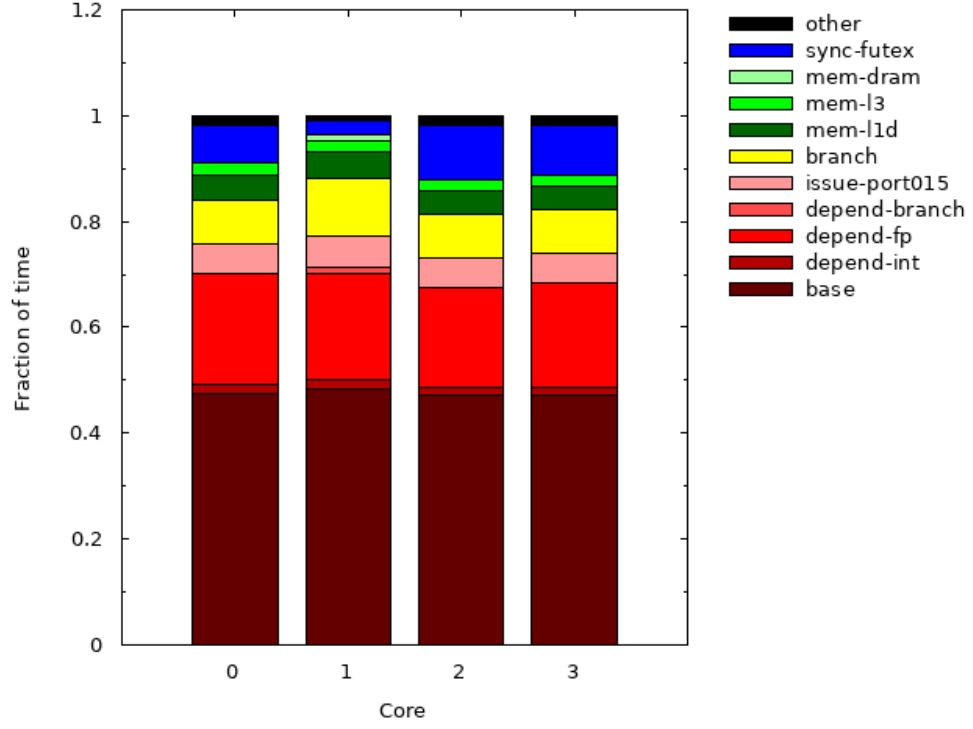
5.2.2 CPI Stacks



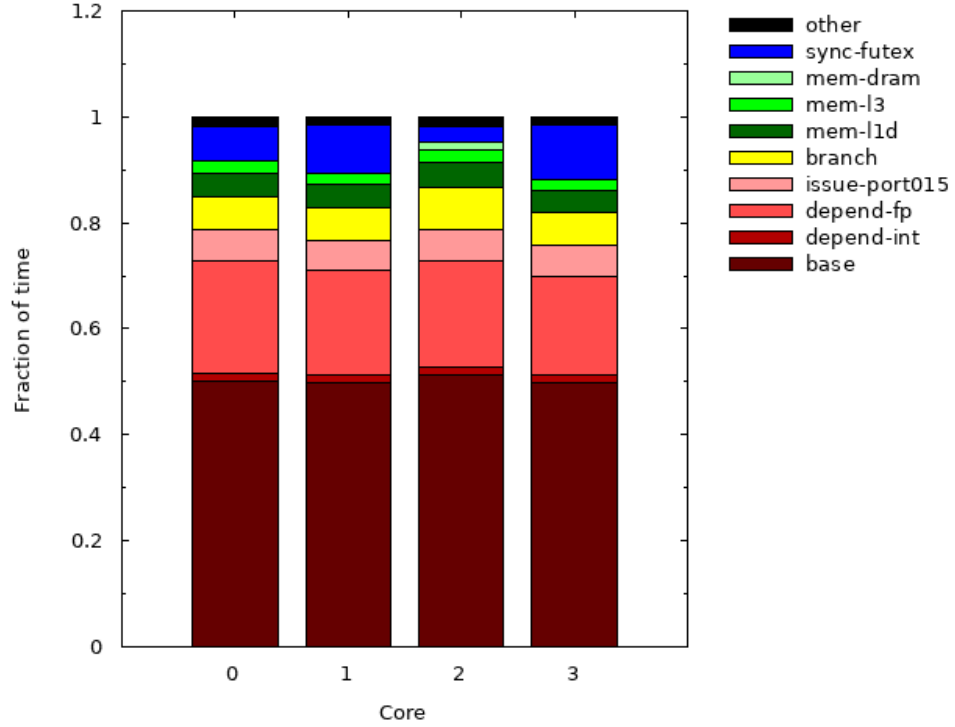
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 11: CPI stacks for various PHT sizes.

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.11	0.12	0.11	0.11
depend-branch	0.01	0.01	0.01	0.01
issue-port015	0.03	0.03	0.03	0.03
branch	0.07	0.07	0.07	0.08
mem-l1d	0.03	0.03	0.03	0.03
mem-l3	0.01	0.01	0.01	0.01
mem-dram	0.00	0.00	0.00	0.01
sync-futex	0.06	0.05	0.06	0.01
other	0.01	0.01	0.01	0.01
total	0.58	0.57	0.58	0.56

(a) default

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.12	0.11	0.11	0.11
depend-branch	0.01	0.01	0.01	0.01
issue-port015	0.03	0.03	0.03	0.03
branch	0.07	0.08	0.07	0.07
mem-l1d	0.03	0.03	0.03	0.03
mem-l3	0.01	0.01	0.01	0.01
mem-dram	0.00	0.01	0.00	0.00
sync-futex	0.05	0.01	0.06	0.06
other	0.01	0.01	0.01	0.01
total	0.57	0.56	0.58	0.58

(b) 2^4 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.11	0.10	0.10	0.10
depend-branch	0.00	0.01	0.00	0.00
issue-port015	0.03	0.03	0.03	0.03
branch	0.04	0.06	0.04	0.04
mem-l1d	0.03	0.03	0.02	0.02
mem-l3	0.01	0.01	0.01	0.01
mem-dram	0.00	0.01	0.00	0.00
sync-futex	0.04	0.01	0.06	0.05
other	0.01	0.00	0.01	0.01
total	0.53	0.52	0.53	0.53

(c) 2^8 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.01	0.01	0.01	0.01
depend-fp	0.11	0.10	0.10	0.09
issue-port015	0.03	0.03	0.03	0.03
branch	0.03	0.03	0.04	0.03
mem-l1d	0.02	0.02	0.02	0.02
mem-l3	0.01	0.01	0.01	0.01
mem-dram	0.00	0.00	0.01	0.00
sync-futex	0.03	0.05	0.01	0.05
other	0.01	0.01	0.01	0.01
total	0.50	0.50	0.49	0.50

(d) 2^{16} PHT size

Figure 12: Specific values for each components' CPI stack.

5.3 lu.cont

5.3.1 Power Results

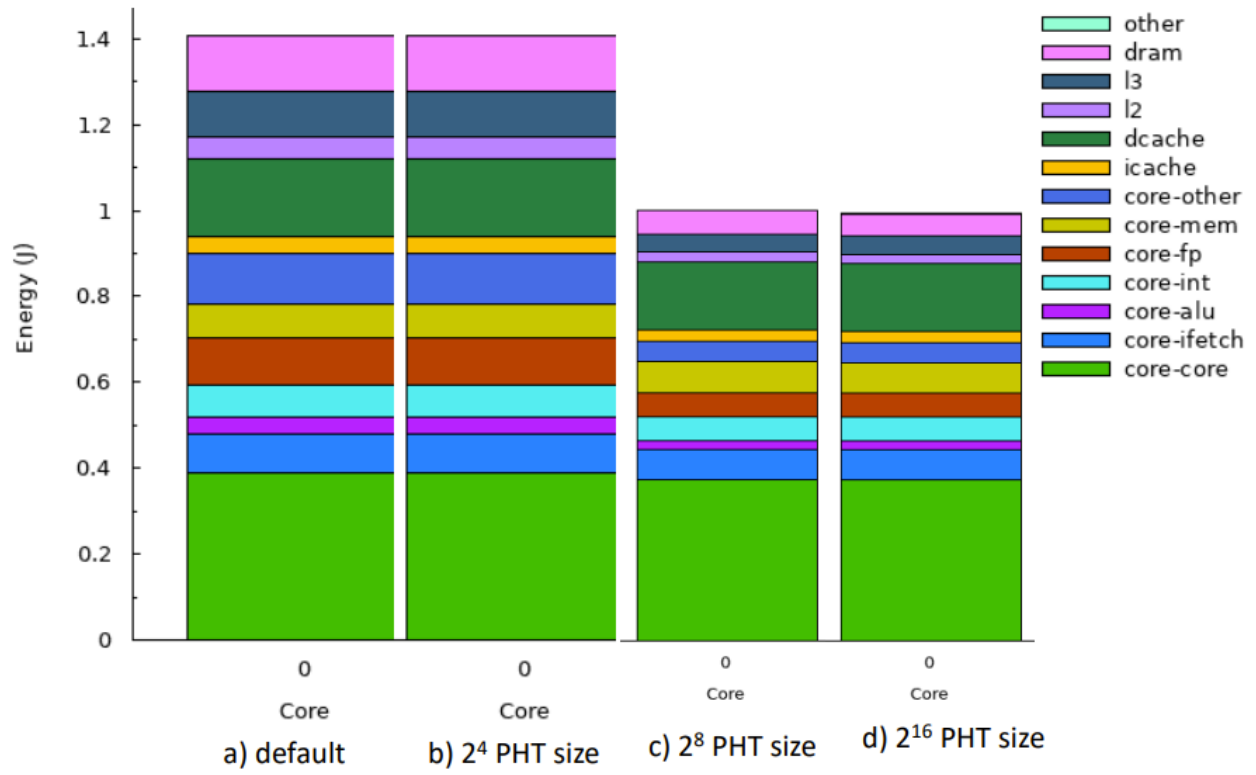


Figure 13: Processor power for various PHT sizes.

	Power	Energy	Energy %
core-core	12.70 W	0.39 J	27.60%
core-ifetch	2.95 W	0.09 J	6.42%
core-alu	1.37 W	0.04 J	2.98%
core-int	2.45 W	0.08 J	5.33%
core-fp	3.59 W	0.11 J	7.79%
core-mem	2.58 W	0.08 J	5.60%
core-other	3.79 W	0.12 J	8.24%
icache	1.34 W	0.04 J	2.92%
dcache	5.88 W	0.18 J	12.78%
l2	1.67 W	0.05 J	3.63%
l3	3.40 W	0.10 J	7.40%
dram	4.25 W	0.13 J	9.24%
other	0.03 W	1.00 mJ	0.07%
core	29.44 W	0.90 J	63.97%
cache	12.30 W	0.38 J	26.72%
total	46.03 W	1.41 J	100.00%

(a) default

	Power	Energy	Energy %
core-core	12.70 W	0.39 J	27.60%
core-ifetch	2.95 W	0.09 J	6.42%
core-alu	1.37 W	0.04 J	2.98%
core-int	2.46 W	0.08 J	5.33%
core-fp	3.59 W	0.11 J	7.79%
core-mem	2.58 W	0.08 J	5.60%
core-other	3.79 W	0.12 J	8.24%
icache	1.34 W	0.04 J	2.92%
dcache	5.88 W	0.18 J	12.78%
l2	1.67 W	0.05 J	3.63%
l3	3.40 W	0.10 J	7.39%
dram	4.25 W	0.13 J	9.24%
other	0.03 W	1.00 mJ	0.07%
core	29.45 W	0.90 J	63.97%
cache	12.30 W	0.38 J	26.72%
total	46.03 W	1.41 J	100.00%

(b) 2⁴ PHT size

	Power	Energy	Energy %
core-core	29.83 W	0.38 J	37.39%
core-ifetch	5.74 W	0.07 J	7.20%
core-alu	1.66 W	0.02 J	2.09%
core-int	4.36 W	0.06 J	5.46%
core-fp	4.46 W	0.06 J	5.60%
core-mem	5.80 W	0.07 J	7.27%
core-other	3.79 W	0.05 J	4.76%
icache	2.06 W	0.03 J	2.58%
dcache	12.65 W	0.16 J	15.86%
l2	1.68 W	0.02 J	2.10%
l3	3.45 W	0.04 J	4.32%
dram	4.25 W	0.05 J	5.33%
other	0.03 W	0.41 mJ	0.04%
core	55.65 W	0.70 J	69.76%
cache	19.84 W	0.25 J	24.86%
total	79.77 W	1.01 J	100.00%

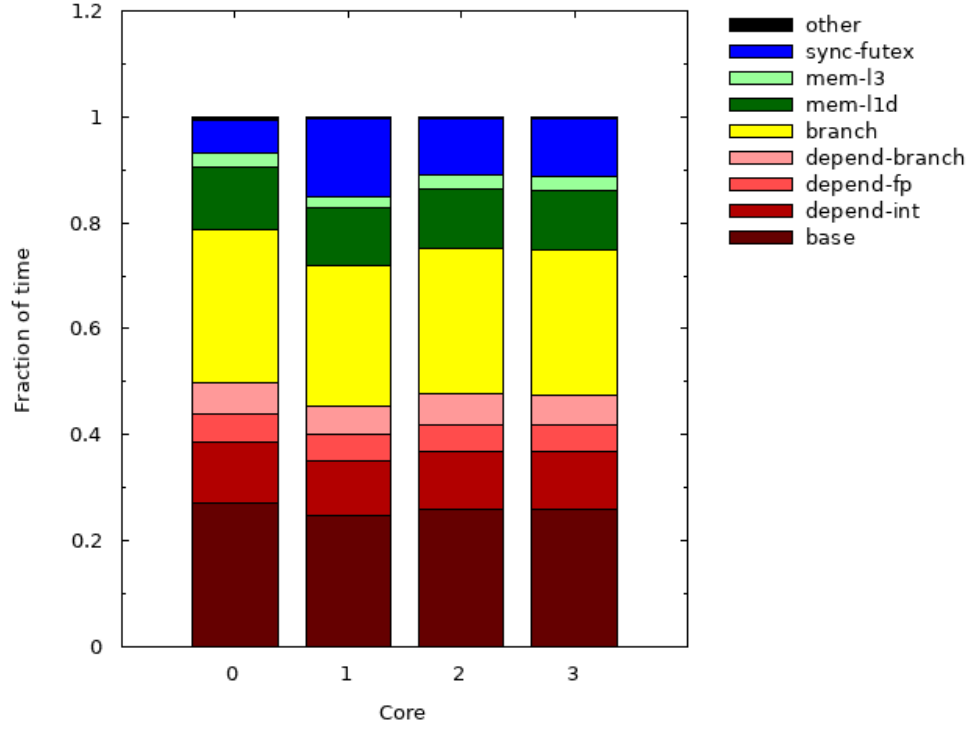
(c) 2^8 PHT size

	Power	Energy	Energy %
core-core	30.48 W	0.38 J	37.60%
core-ifetch	5.85 W	0.07 J	7.22%
core-alu	1.68 W	0.02 J	2.07%
core-int	4.43 W	0.05 J	5.47%
core-fp	4.50 W	0.06 J	5.55%
core-mem	5.92 W	0.07 J	7.31%
core-other	3.79 W	0.05 J	4.68%
icache	2.08 W	0.03 J	2.57%
dcache	12.91 W	0.16 J	15.93%
l2	1.68 W	0.02 J	2.07%
l3	3.45 W	0.04 J	4.26%
dram	4.25 W	0.05 J	5.25%
other	0.03 W	0.40 mJ	0.04%
core	56.65 W	0.70 J	69.89%
cache	20.12 W	0.25 J	24.82%
total	81.06 W	1.00 J	100.00%

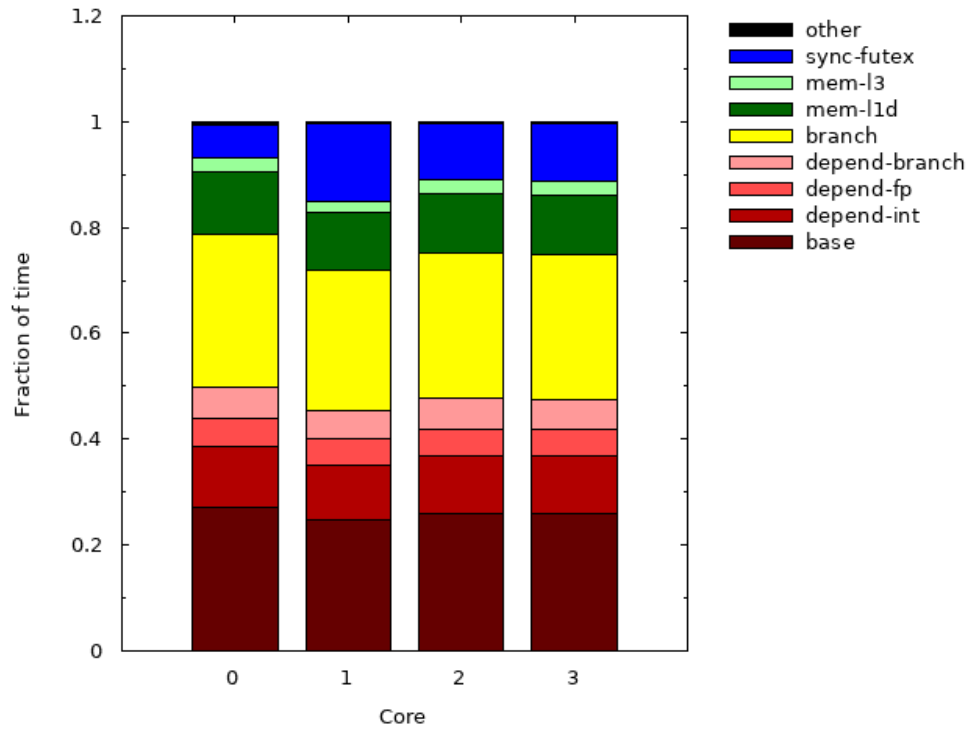
(d) 2^{16} PHT size

Figure 14: Specific values for each components' power consumption.

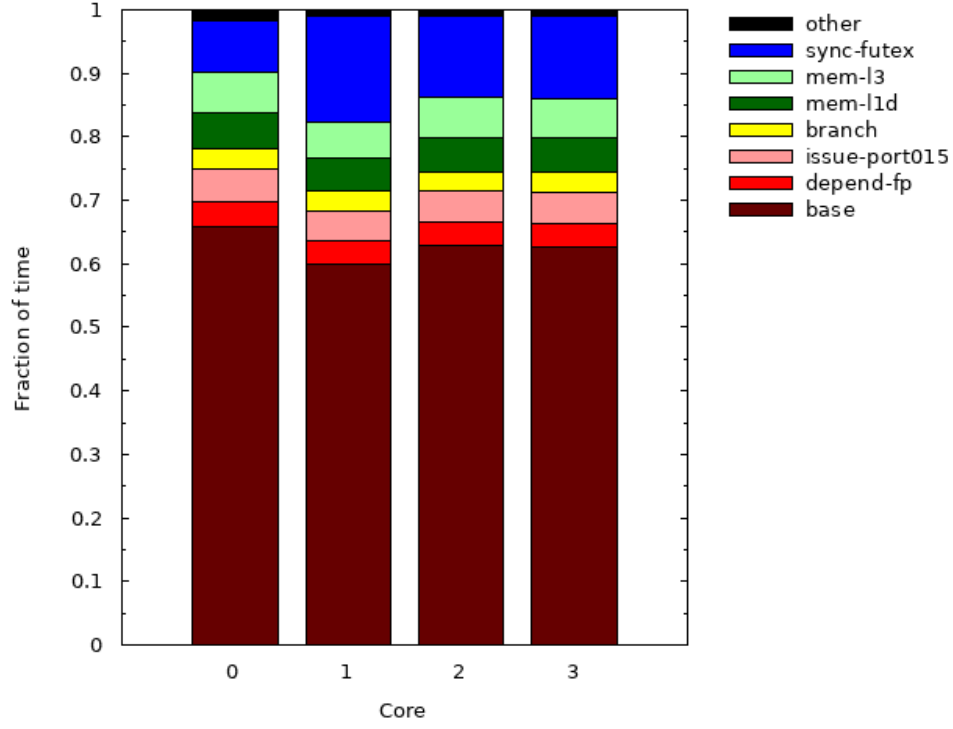
5.3.2 CPI Stacks



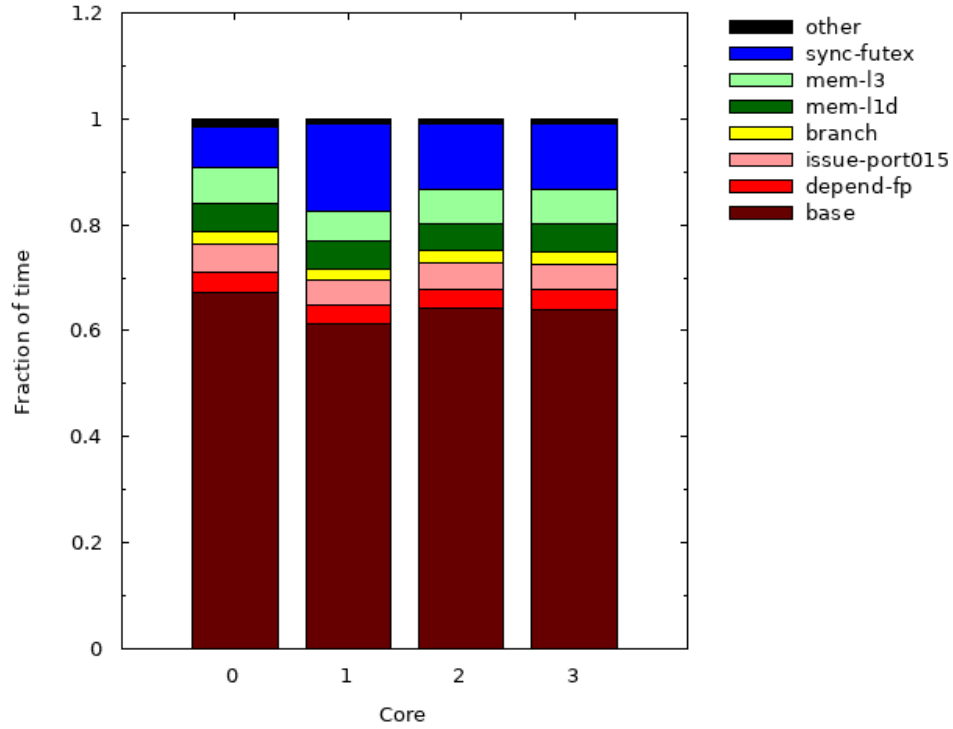
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 15: CPI stacks for various PHT sizes.

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.10	0.10	0.10	0.10
depend-fp	0.05	0.05	0.05	0.05
depend-branch	0.05	0.05	0.05	0.05
branch	0.27	0.27	0.27	0.26
mem-l1d	0.11	0.11	0.11	0.11
mem-l3	0.02	0.02	0.03	0.03
sync-futex	0.06	0.15	0.10	0.10
other	0.01	0.00	0.00	0.00
total	0.92	1.01	0.96	0.97

(a) default

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.10	0.10	0.10	0.10
depend-fp	0.05	0.05	0.05	0.05
depend-branch	0.05	0.05	0.05	0.05
branch	0.27	0.27	0.27	0.27
mem-l1d	0.11	0.11	0.11	0.11
mem-l3	0.02	0.02	0.03	0.03
sync-futex	0.06	0.15	0.10	0.10
other	0.01	0.00	0.00	0.00
total	0.92	1.01	0.96	0.96

(b) 2^4 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-fp	0.01	0.02	0.01	0.01
issue-port015	0.02	0.02	0.02	0.02
branch	0.01	0.01	0.01	0.01
mem-l1d	0.02	0.02	0.02	0.02
mem-l3	0.02	0.02	0.02	0.03
sync-futex	0.03	0.07	0.05	0.05
other	0.01	0.00	0.00	0.00
total	0.38	0.42	0.40	0.40

(c) 2^8 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-fp	0.01	0.01	0.01	0.01
issue-port015	0.02	0.02	0.02	0.02
branch	0.01	0.01	0.01	0.01
mem-l1d	0.02	0.02	0.02	0.02
mem-l3	0.02	0.02	0.03	0.02
sync-futex	0.03	0.07	0.05	0.05
other	0.01	0.00	0.00	0.00
total	0.37	0.41	0.39	0.39

(d) 2^{16} PHT size

Figure 16: Specific values for each components' CPI stack.

5.4 radiosity

5.4.1 Power Results

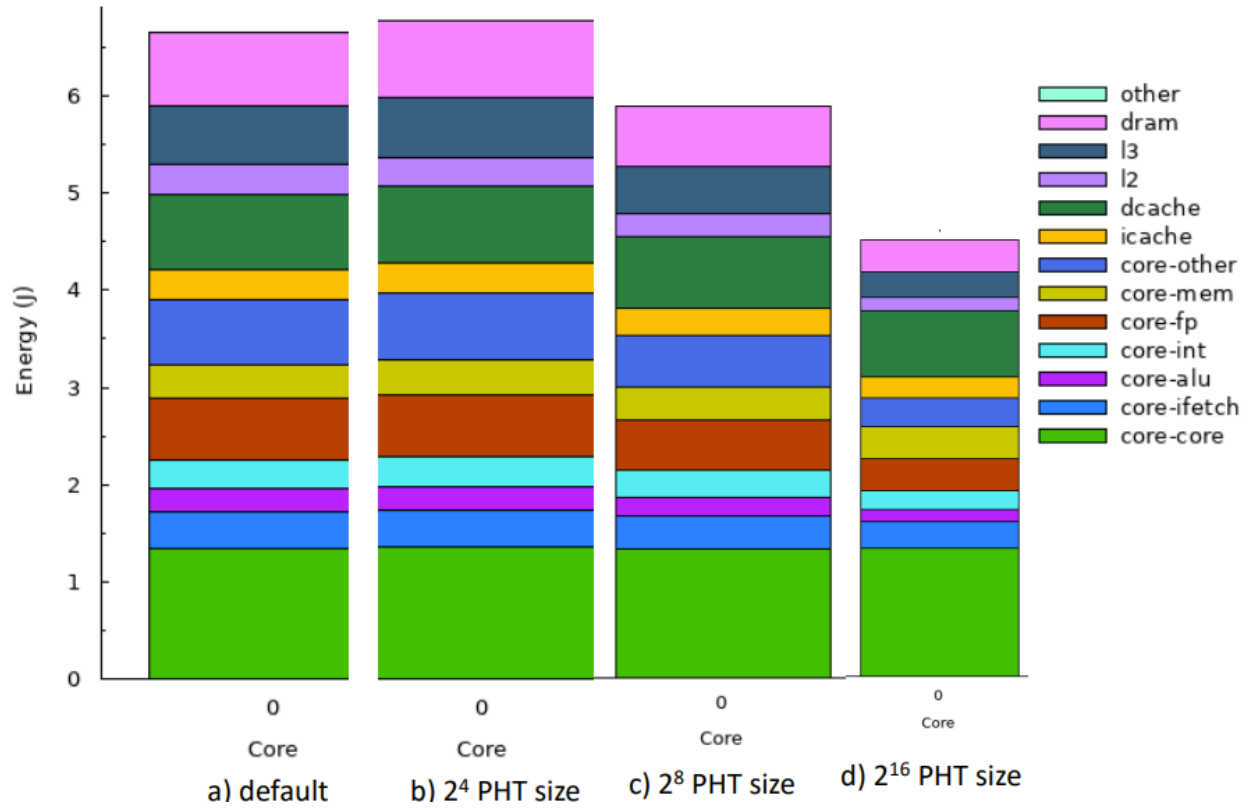


Figure 17: Processor power for various PHT sizes.

	Power	Energy	Energy %
core-core	7.53 W	1.34 J	20.14%
core-ifetch	2.08 W	0.37 J	5.56%
core-alu	1.35 W	0.24 J	3.60%
core-int	1.72 W	0.31 J	4.61%
core-fp	3.53 W	0.63 J	9.44%
core-mem	1.94 W	0.35 J	5.18%
core-other	3.79 W	0.68 J	10.15%
icache	1.70 W	0.30 J	4.56%
dcache	4.36 W	0.78 J	11.67%
l2	1.67 W	0.30 J	4.47%
l3	3.38 W	0.60 J	9.05%
dram	4.29 W	0.76 J	11.48%
other	0.03 W	5.83 mJ	0.09%
core	21.94 W	3.91 J	58.69%
cache	11.12 W	1.98 J	29.74%
total	37.38 W	6.66 J	100.00%

(a) default

	Power	Energy	Energy %
core-core	7.39 W	1.35 J	19.93%
core-ifetch	2.06 W	0.38 J	5.55%
core-alu	1.34 W	0.25 J	3.62%
core-int	1.71 W	0.31 J	4.62%
core-fp	3.52 W	0.64 J	9.49%
core-mem	1.90 W	0.35 J	5.13%
core-other	3.79 W	0.69 J	10.24%
icache	1.68 W	0.31 J	4.54%
dcache	4.29 W	0.79 J	11.57%
l2	1.67 W	0.31 J	4.51%
l3	3.38 W	0.62 J	9.13%
dram	4.29 W	0.79 J	11.58%
other	0.03 W	5.99 mJ	0.09%
core	21.71 W	3.97 J	58.58%
cache	11.03 W	2.02 J	29.75%
total	37.06 W	6.78 J	100.00%

(b) 2⁴ PHT size

	Power	Energy	Energy %
core-core	9.32 W	1.33 J	22.57%
core-ifetch	2.36 W	0.34 J	5.72%
core-alu	1.39 W	0.20 J	3.37%
core-int	1.88 W	0.27 J	4.56%
core-fp	3.67 W	0.52 J	8.89%
core-mem	2.36 W	0.34 J	5.71%
core-other	3.79 W	0.54 J	9.19%
icache	1.93 W	0.27 J	4.66%
dcache	5.20 W	0.74 J	12.59%
l2	1.67 W	0.24 J	4.05%
l3	3.39 W	0.48 J	8.20%
dram	4.30 W	0.61 J	10.42%
other	0.03 W	4.66 mJ	0.08%
core	24.78 W	3.53 J	60.01%
cache	12.18 W	1.73 J	29.49%
total	41.30 W	5.88 J	100.00%

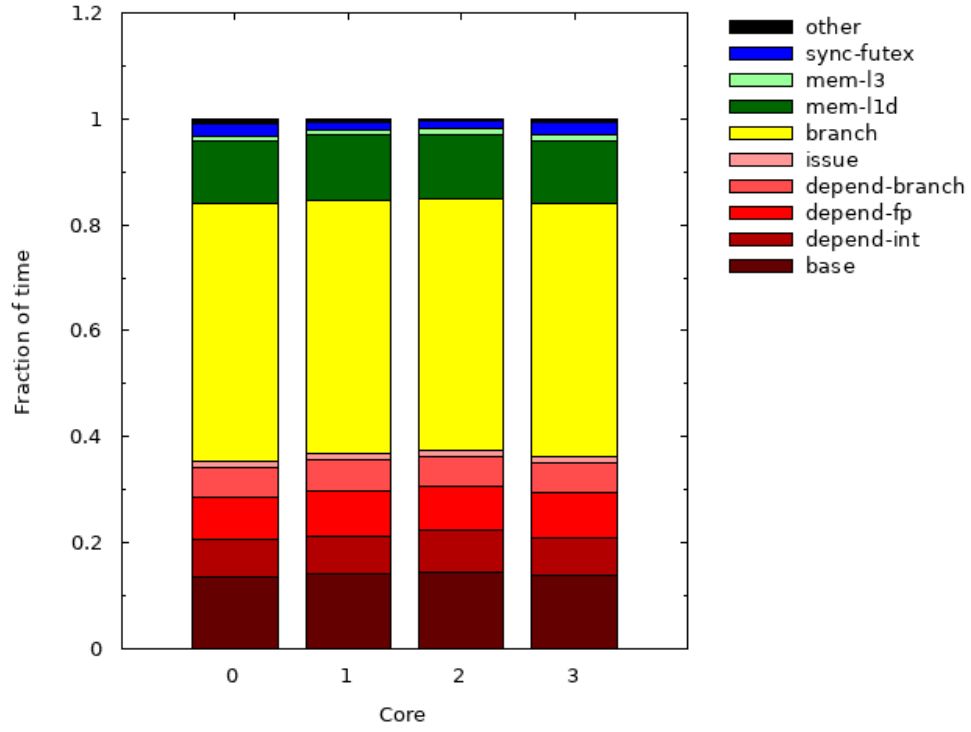
(c) 2^8 PHT size

	Power	Energy	Energy %
core-core	17.07 W	1.28 J	29.27%
core-ifetch	3.59 W	0.27 J	6.15%
core-alu	1.60 W	0.12 J	2.74%
core-int	2.57 W	0.19 J	4.41%
core-fp	4.31 W	0.32 J	7.38%
core-mem	4.20 W	0.31 J	7.19%
core-other	3.79 W	0.28 J	6.51%
icache	2.90 W	0.22 J	4.98%
dcache	8.86 W	0.66 J	15.19%
l2	1.68 W	0.13 J	2.87%
l3	3.40 W	0.25 J	5.82%
dram	4.34 W	0.33 J	7.44%
other	0.03 W	2.45 mJ	0.06%
core	37.12 W	2.78 J	63.64%
cache	16.84 W	1.26 J	28.86%
total	58.33 W	4.37 J	100.00%

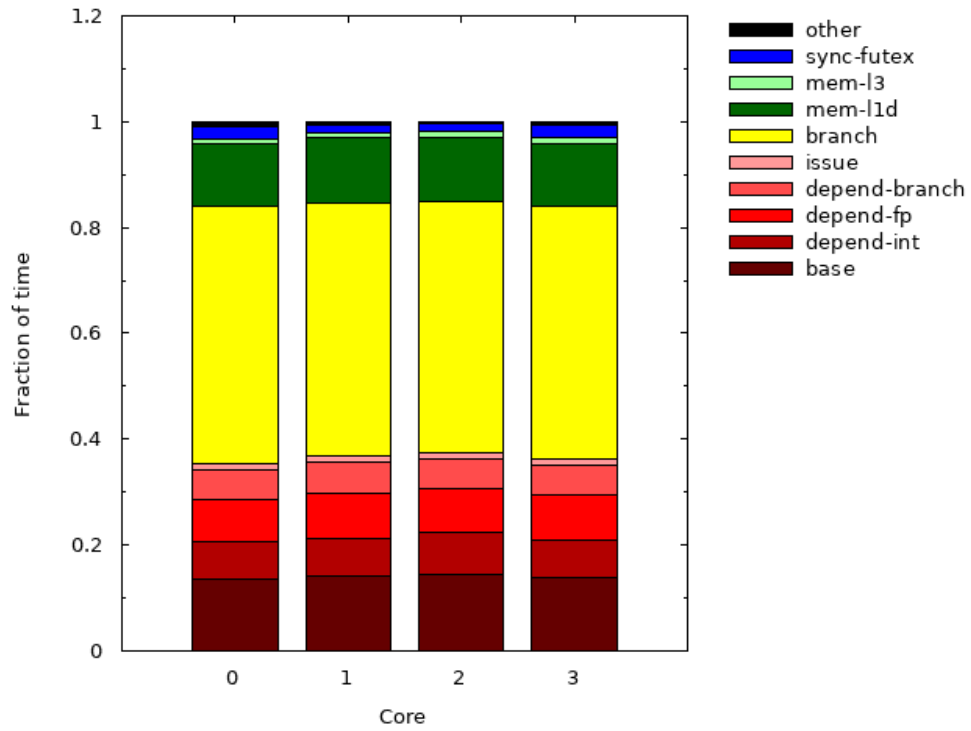
(d) 2^{16} PHT size

Figure 18: Specific values for each components' power consumption.

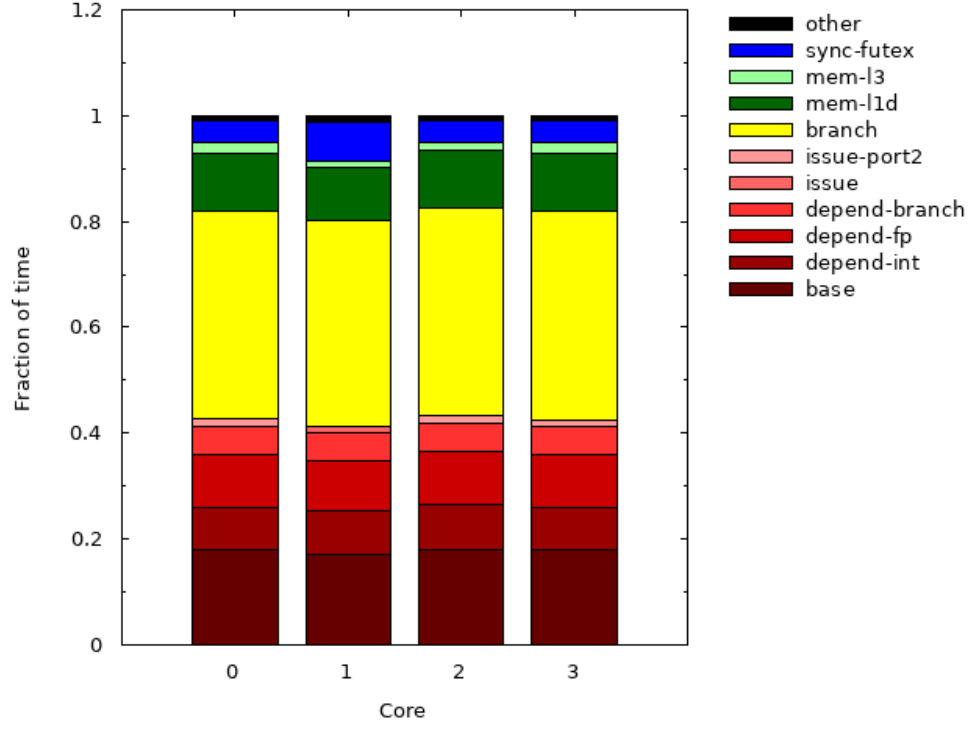
5.4.2 CPI Stacks



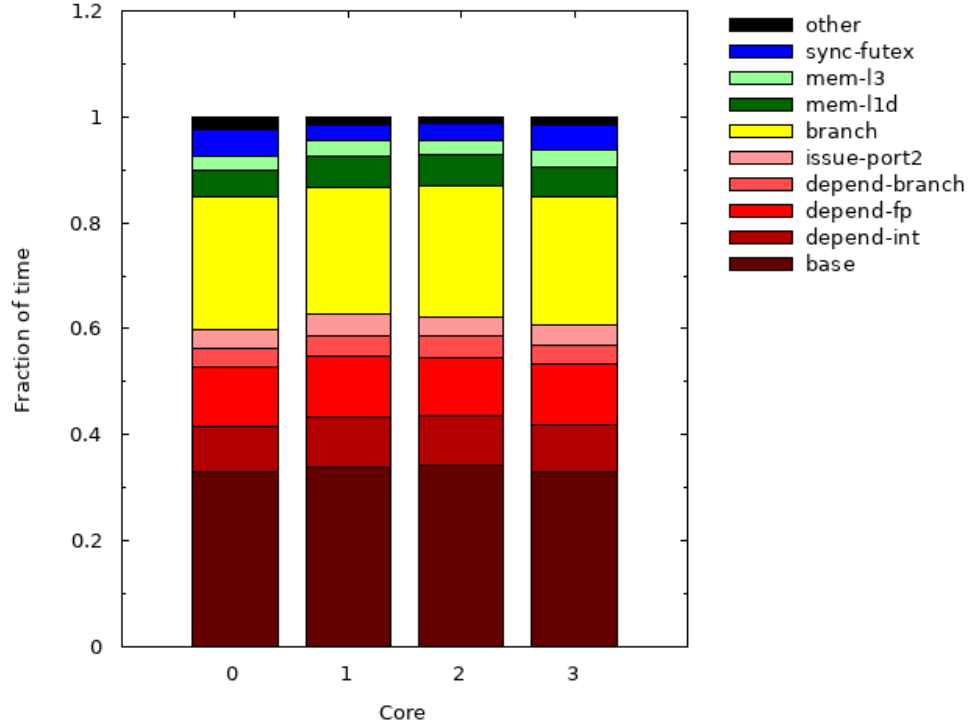
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 19: CPI stacks for various PHT sizes.

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.13	0.13	0.13	0.13
depend-fp	0.15	0.15	0.14	0.15
depend-branch	0.10	0.10	0.10	0.10
issue	0.02	0.02	0.02	0.02
branch	0.90	0.85	0.81	0.85
mem-l1d	0.22	0.21	0.21	0.21
mem-l3	0.02	0.02	0.02	0.02
sync-futex	0.04	0.03	0.03	0.04
other	0.02	0.01	0.01	0.01
total	1.85	1.77	1.72	1.79

(a) default

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.13	0.13	0.14	0.13
depend-fp	0.15	0.15	0.14	0.15
depend-branch	0.10	0.10	0.10	0.10
issue	0.02	0.02	0.02	0.02
branch	0.84	0.83	0.87	0.84
mem-l1d	0.21	0.21	0.21	0.21
mem-l3	0.03	0.02	0.00	0.03
sync-futex	0.06	0.06	0.11	0.06
other	0.01	0.01	0.03	0.01
total	1.80	1.78	1.87	1.80

(b) 2^4 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.11	0.12	0.11	0.11
depend-fp	0.14	0.14	0.14	0.14
depend-branch	0.07	0.08	0.07	0.07
issue	0.00	0.02	0.00	0.00
issue-port2	0.02	0.00	0.02	0.02
branch	0.55	0.57	0.54	0.55
mem-l1d	0.15	0.15	0.15	0.15
mem-l3	0.03	0.02	0.02	0.03
sync-futex	0.06	0.11	0.06	0.06
other	0.01	0.02	0.01	0.01
total	1.40	1.46	1.38	1.40

(c) 2^8 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.07	0.07	0.07	0.07
depend-fp	0.08	0.09	0.08	0.09
depend-branch	0.03	0.03	0.03	0.03
issue-port2	0.03	0.03	0.03	0.03
branch	0.19	0.18	0.18	0.18
mem-l1d	0.04	0.04	0.04	0.04
mem-l3	0.02	0.02	0.02	0.02
sync-futex	0.04	0.02	0.02	0.04
other	0.02	0.01	0.01	0.01
total	0.76	0.73	0.73	0.76

(d) 2^{16} PHT size

Figure 20: Specific values for each components' CPI stack.

5.5 raytrace

5.5.1 Power Results

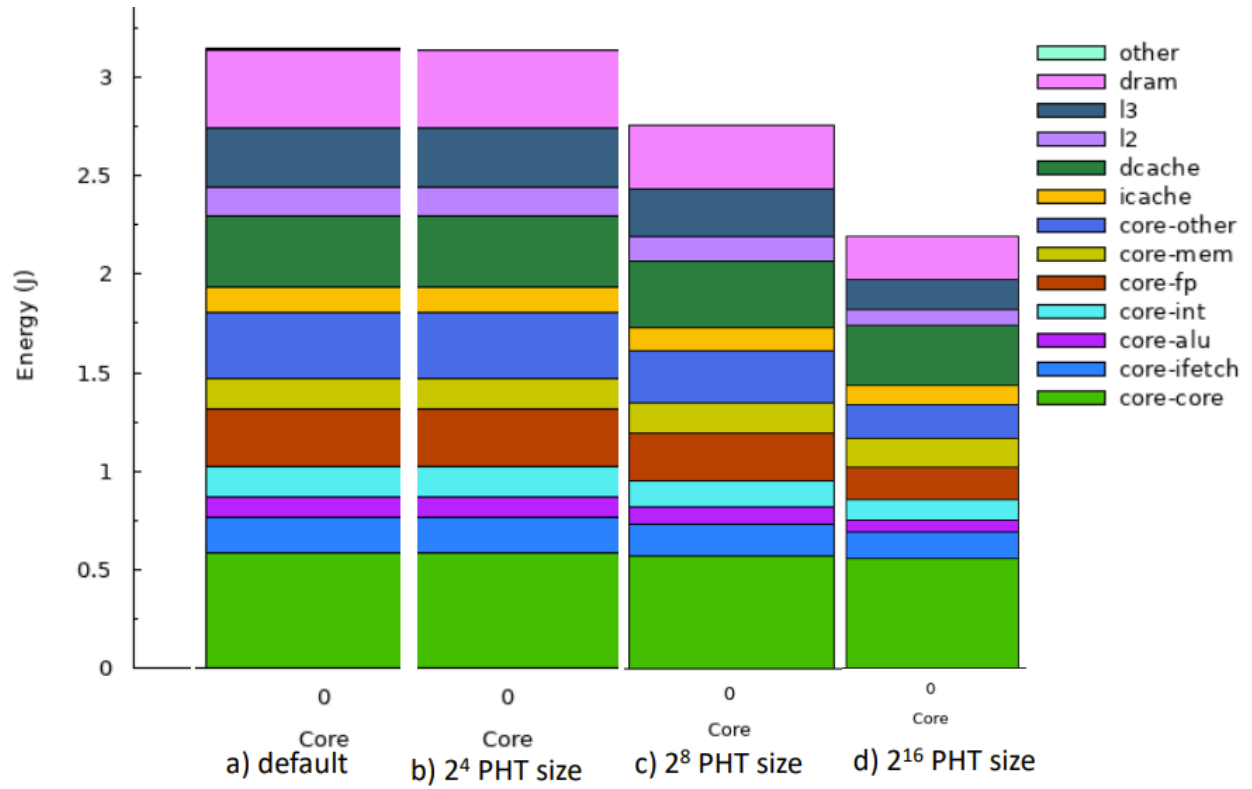


Figure 21: Processor power for various PHT sizes.

	Power	Energy	Energy %
core-core	6.74 W	0.59 J	18.71%
core-ifetch	1.99 W	0.17 J	5.51%
core-alu	1.27 W	0.11 J	3.53%
core-int	1.72 W	0.15 J	4.78%
core-fp	3.37 W	0.29 J	9.34%
core-mem	1.79 W	0.16 J	4.98%
core-other	3.79 W	0.33 J	10.53%
icache	1.54 W	0.13 J	4.27%
dcache	4.11 W	0.36 J	11.41%
l2	1.69 W	0.15 J	4.69%
l3	3.42 W	0.30 J	9.48%
dram	4.57 W	0.40 J	12.68%
other	0.03 W	2.85 mJ	0.09%
core	20.68 W	1.80 J	57.38%
cache	10.76 W	0.94 J	29.85%
total	36.03 W	3.14 J	100.00%

(a) default

	Power	Energy	Energy %
core-core	6.74 W	0.59 J	18.71%
core-ifetch	1.99 W	0.17 J	5.51%
core-alu	1.27 W	0.11 J	3.53%
core-int	1.72 W	0.15 J	4.78%
core-fp	3.37 W	0.29 J	9.34%
core-mem	1.79 W	0.16 J	4.98%
core-other	3.79 W	0.33 J	10.53%
icache	1.54 W	0.13 J	4.27%
dcache	4.11 W	0.36 J	11.41%
l2	1.69 W	0.15 J	4.69%
l3	3.42 W	0.30 J	9.48%
dram	4.57 W	0.40 J	12.68%
other	0.03 W	2.85 mJ	0.09%
core	20.68 W	1.80 J	57.38%
cache	10.76 W	0.94 J	29.85%
total	36.04 W	3.14 J	100.00%

(b) 2^4 PHT size

	Power	Energy	Energy %
core-core	8.18 W	0.58 J	20.83%
core-ifetch	2.22 W	0.16 J	5.65%
core-alu	1.30 W	0.09 J	3.31%
core-int	1.86 W	0.13 J	4.75%
core-fp	3.46 W	0.24 J	8.81%
core-mem	2.14 W	0.15 J	5.46%
core-other	3.79 W	0.27 J	9.66%
icache	1.70 W	0.12 J	4.34%
dcache	4.82 W	0.34 J	12.27%
l2	1.69 W	0.12 J	4.31%
l3	3.43 W	0.24 J	8.72%
dram	4.65 W	0.33 J	11.82%
other	0.03 W	2.31 mJ	0.08%
core	22.97 W	1.62 J	58.46%
cache	11.64 W	0.82 J	29.64%
total	39.29 W	2.77 J	100.00%

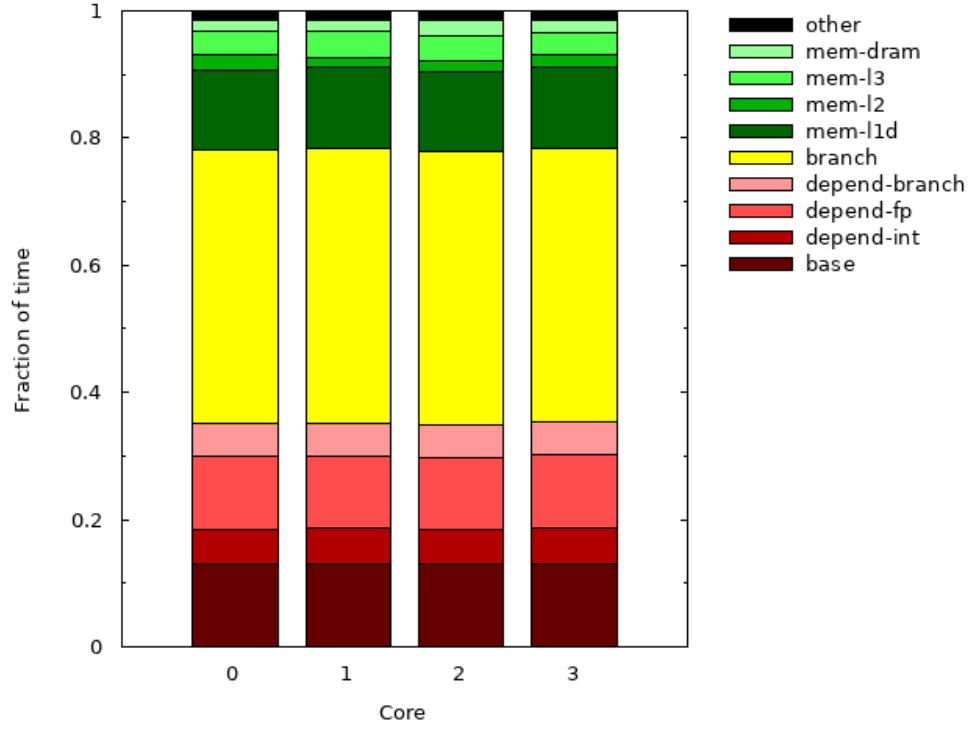
(c) 2^8 PHT size

	Power	Energy	Energy %
core-core	12.45 W	0.56 J	25.45%
core-ifetch	2.92 W	0.13 J	5.96%
core-alu	1.37 W	0.06 J	2.81%
core-int	2.29 W	0.10 J	4.68%
core-fp	3.74 W	0.17 J	7.64%
core-mem	3.18 W	0.14 J	6.51%
core-other	3.79 W	0.17 J	7.76%
icache	2.19 W	0.10 J	4.48%
dcache	6.92 W	0.31 J	14.14%
l2	1.71 W	0.08 J	3.50%
l3	3.46 W	0.16 J	7.06%
dram	4.87 W	0.22 J	9.95%
other	0.03 W	1.48 mJ	0.07%
core	29.75 W	1.34 J	60.80%
cache	14.28 W	0.64 J	29.18%
total	48.92 W	2.21 J	100.00%

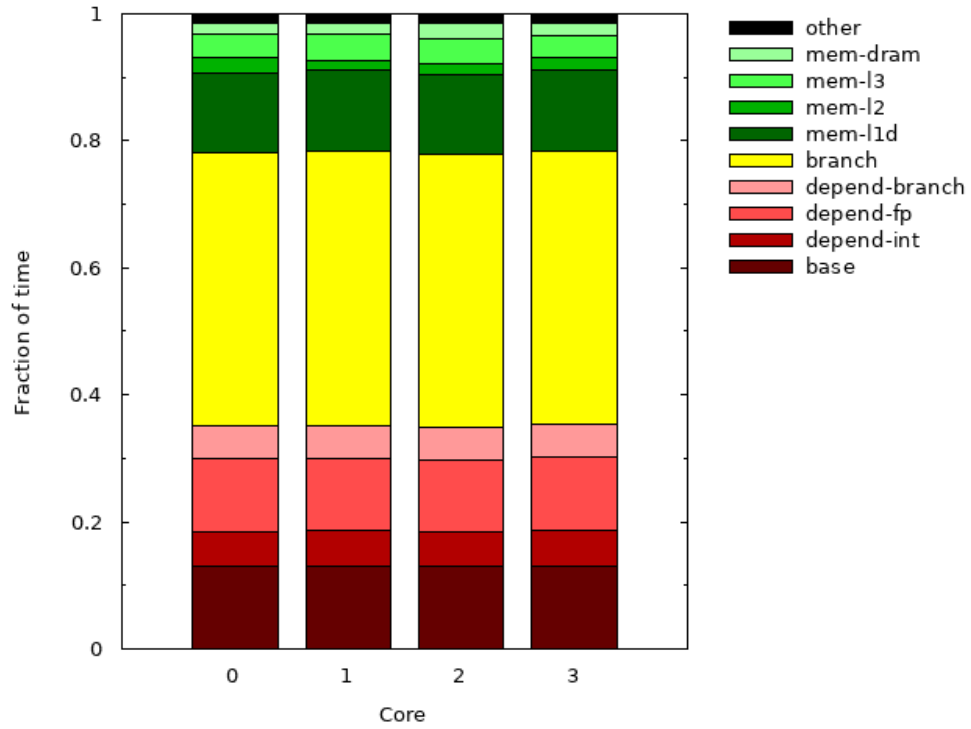
(d) 2^{16} PHT size

Figure 22: Specific values for each components' power consumption.

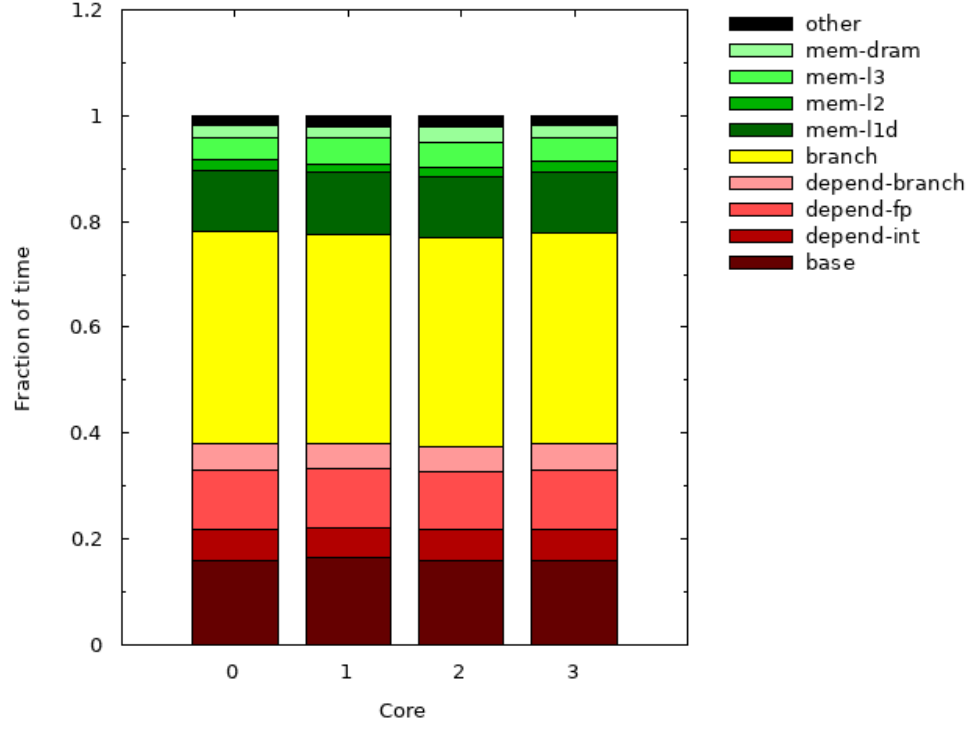
5.5.2 CPI Stacks



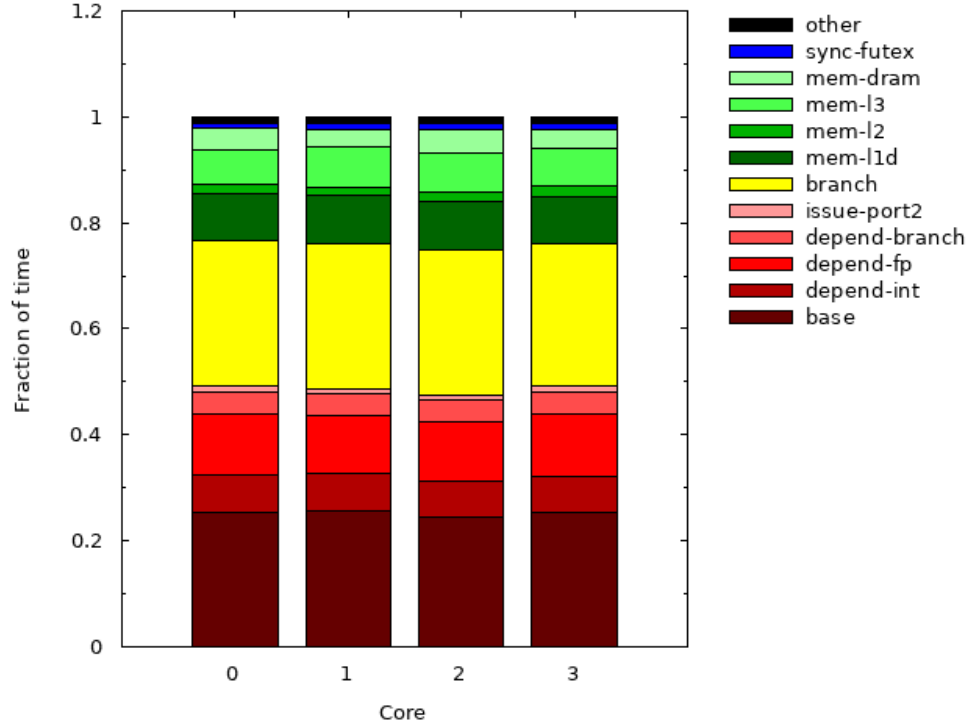
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 23: CPI stacks for various PHT sizes.

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.11	0.11	0.11	0.11
depend-fp	0.22	0.22	0.22	0.22
depend-branch	0.10	0.10	0.10	0.10
branch	0.83	0.83	0.83	0.82
mem-l1d	0.24	0.24	0.24	0.25
mem-l2	0.05	0.03	0.04	0.04
mem-l3	0.07	0.08	0.07	0.06
mem-dram	0.04	0.03	0.05	0.04
other	0.03	0.03	0.03	0.03
total	1.94	1.91	1.93	1.92

(a) default

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.11	0.11	0.11	0.11
depend-fp	0.22	0.21	0.22	0.22
depend-branch	0.10	0.10	0.10	0.10
branch	0.82	0.83	0.83	0.83
mem-l1d	0.25	0.24	0.24	0.24
mem-l2	0.04	0.03	0.04	0.05
mem-l3	0.06	0.07	0.08	0.07
mem-dram	0.04	0.03	0.05	0.04
other	0.03	0.03	0.03	0.03
total	1.92	1.91	1.93	1.93

(b) 2^4 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.09	0.09	0.09	0.09
depend-fp	0.18	0.17	0.17	0.18
depend-branch	0.08	0.07	0.08	0.08
branch	0.63	0.60	0.62	0.63
mem-l1d	0.18	0.18	0.18	0.18
mem-l2	0.03	0.02	0.03	0.03
mem-l3	0.06	0.08	0.08	0.07
mem-dram	0.04	0.03	0.05	0.04
other	0.03	0.03	0.03	0.03
total	1.56	1.52	1.56	1.57

(c) 2^8 PHT size

CPI	Core 0	Core 1	Core 2	Core 3
base	0.25	0.25	0.25	0.25
depend-int	0.07	0.07	0.07	0.07
depend-fp	0.11	0.11	0.11	0.12
depend-branch	0.04	0.04	0.04	0.04
issue-port2	0.01	0.01	0.01	0.01
branch	0.27	0.27	0.28	0.27
mem-l1d	0.09	0.09	0.09	0.09
mem-l2	0.02	0.01	0.02	0.02
mem-l3	0.06	0.07	0.08	0.07
mem-dram	0.04	0.03	0.05	0.04
sync-futex	0.01	0.01	0.01	0.01
other	0.01	0.01	0.01	0.01
total	0.98	0.98	1.02	0.99

(d) 2^{16} PHT size

Figure 24: Specific values for each components' CPI stack.