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References

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- [2] O. Tange (2011): [GNU Parallel](#) - The Command-Line Power Tool
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Benchmark	PHT index bits
cholesky	4
fmm	8
lu.cont	16
radiosity	
raytrace	

Table 1: Configuration parameters and values swept in the experiment.

1 Intro

2 Experimental Setup

Simulations ran for an x86 architecture simulator, Sniper 7.3 [1]. Since this experiment looked to sweep instruction-level parallelism (ILP) through reservation station (RS) entries, each simulation was configured with 1 core to isolate the feature of multiple instructions simultaneously in-flight. The same default configurations were set in `gainestown.cfg` and `rob.cfg`. Those worth noting for purposes of this experiment are a window size of 128, and L1, L2 and L3 cache sizes of 64 KB, 256 KB, and 8192 KB, respectively, each using 64 byte blocks. Figure ?? visualizes the topologies for all simulations since cache sizes remained constant. Due to time constraints, commit width was set to 128 (default in `rob.cfg`). With a normal width of 4, simulations took several days and did not complete, and the large default commit width would yield results in reasonable time for the given purpose.

Nine different reservation station (RS) entries across five benchmarks were swept, for a total of 45 simulations (see Table 1). The different configurations were simulated with three `splash2` benchmarks (`barnes`, `ocean.cont` and `radix` [3]) and two NAS parallel benchmark (`npb`) (`is` and `cg` [4])¹. These were chosen for the range of simple to complex memory access patterns and parallel implementation. Two benchmarks from `npb` were also included to show the effects of increasing ILP for applications that would benefit from more thread-level parallelism (TLP).

¹These are additional changes from the original experiment design due to time constraints of running `npb-ua` and sweeping number of cores.

The workloads are briefly described as follows:

splash2-barnes : The **barnes** application implements the Barnes-Hut method to simulate interactions of systems of N-bodies (particles, galaxies, etc.) in 3D.

splash2-ocean.cont : The **ocean** 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.

splash2-radix : The **radix** 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.

npb-is : The NASA Advanced Supercomputing (NAS) Parallel Benchmarks (NPB) are a set of benchmarks tuned for highly parallel workloads. The **is** kernel performs a sorting operation that is important as “particle method” code (ex. simulations of mechanics (solid, fluid, etc.) as discrete “particles”), testing both integer computation speed and communication performance. This benchmark excludes floating point arithmetic.

npb-cg : This benchmark uses a conjugate gradient method that computes the smallest eigenvalue of a large, sparse symmetric, positive definite matrix. It tests irregular, long distance communication and employs unstructured matrix vector multiplication.

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

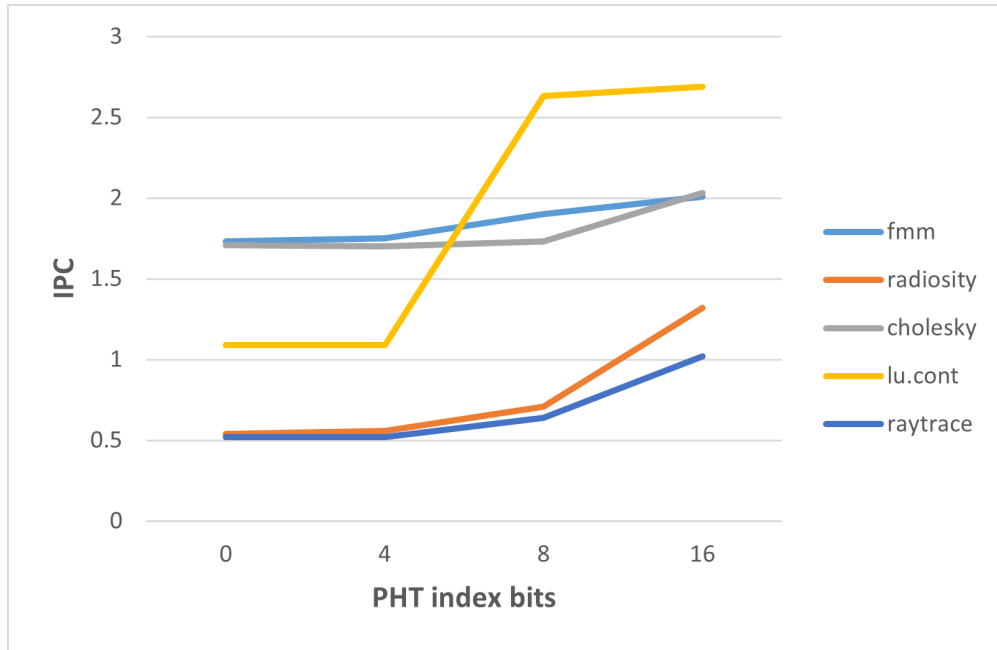


Figure 1

3.2 Energy Consumption

4 Conclusion

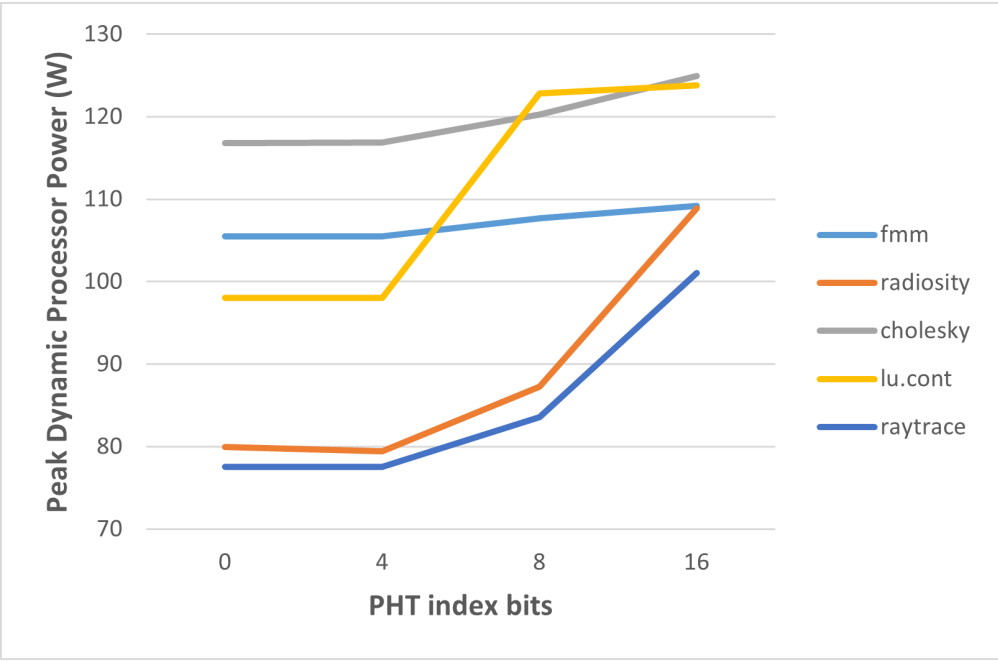


Figure 2

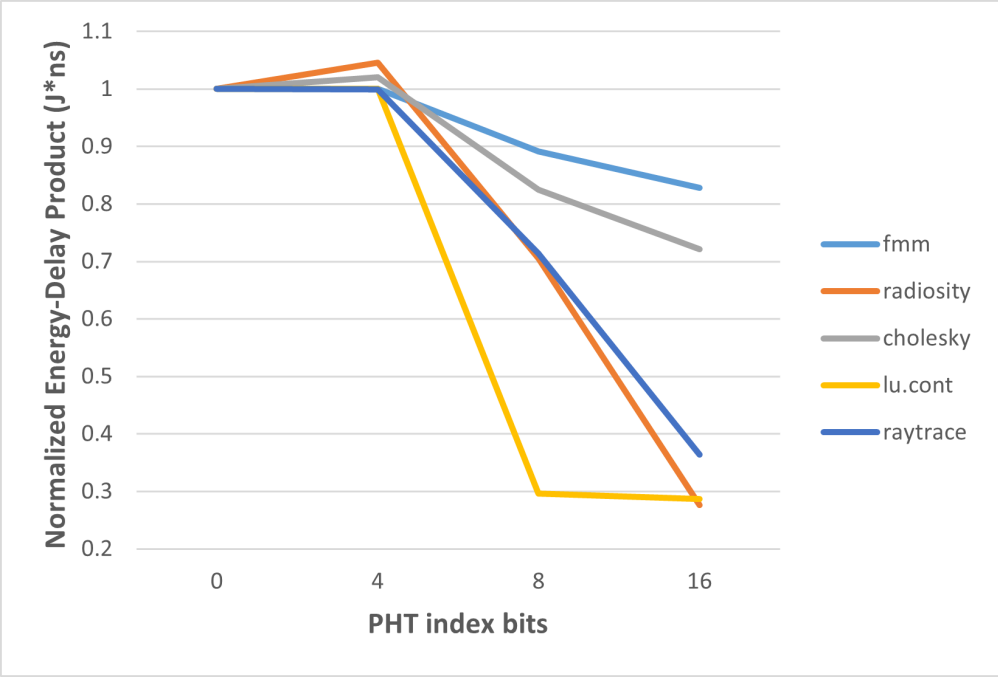


Figure 3

5 Appendix: Raw Post Processed Data

5.1 cholesky

5.1.1 Power Results

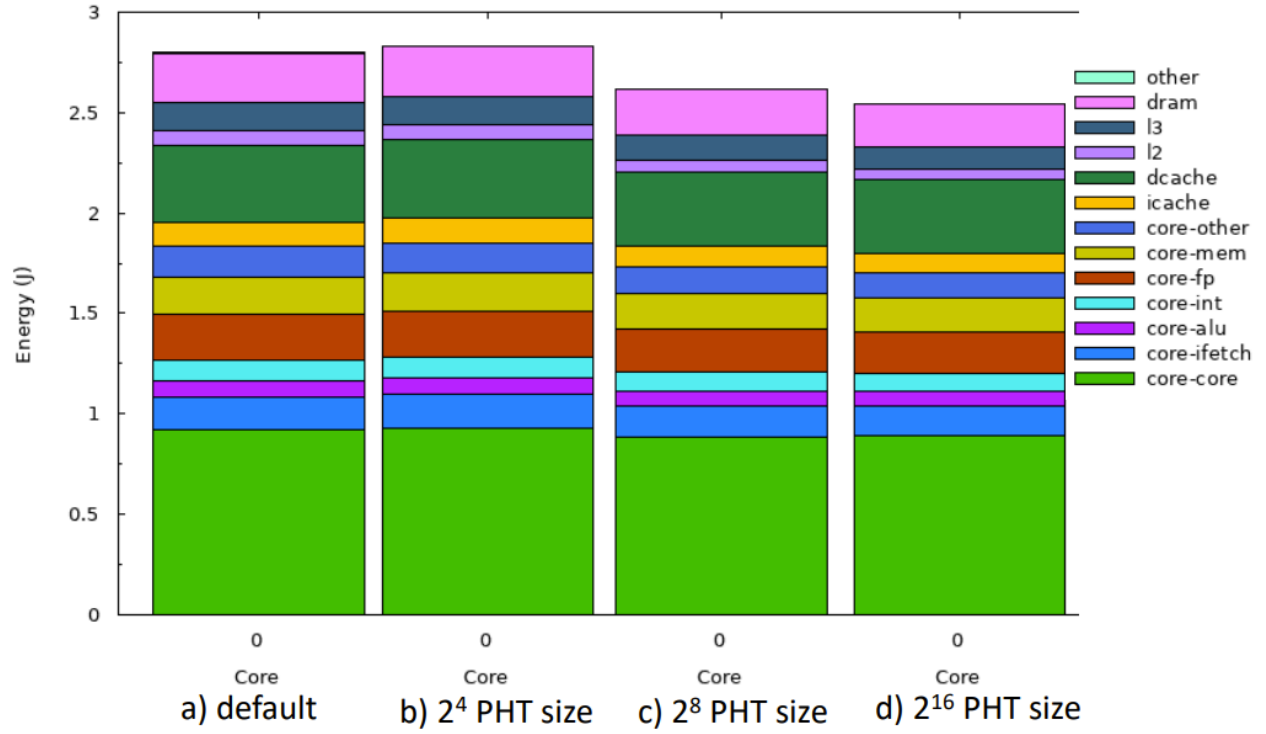


Figure 4: Processor power for various PHT sizes.

	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) 2⁴ 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%

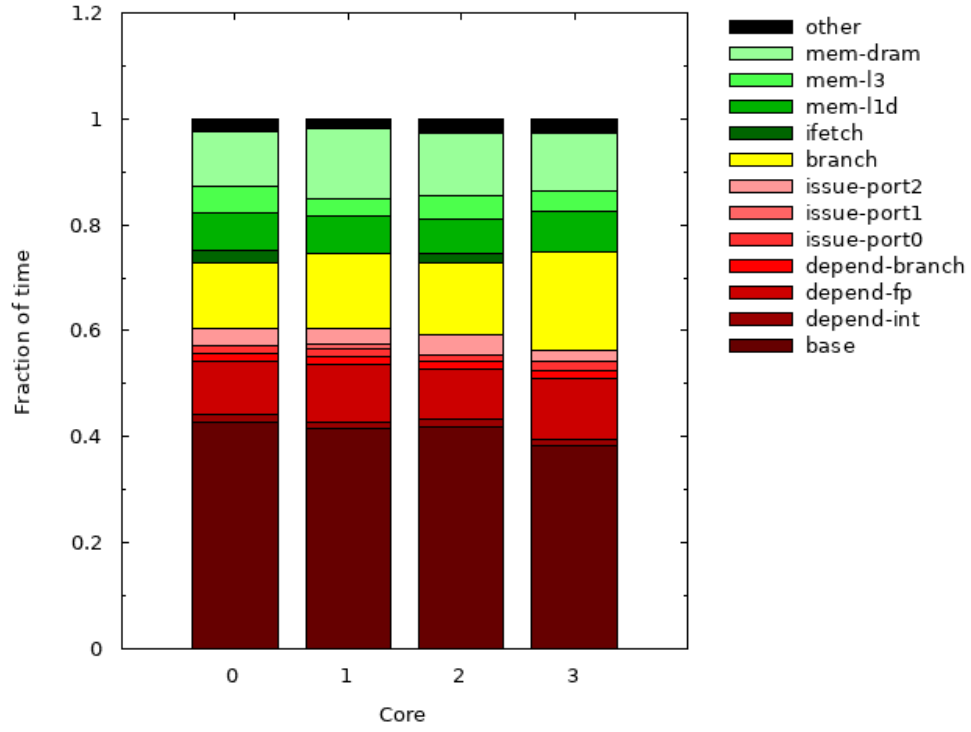
(c) 2^8 PHT size

	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%

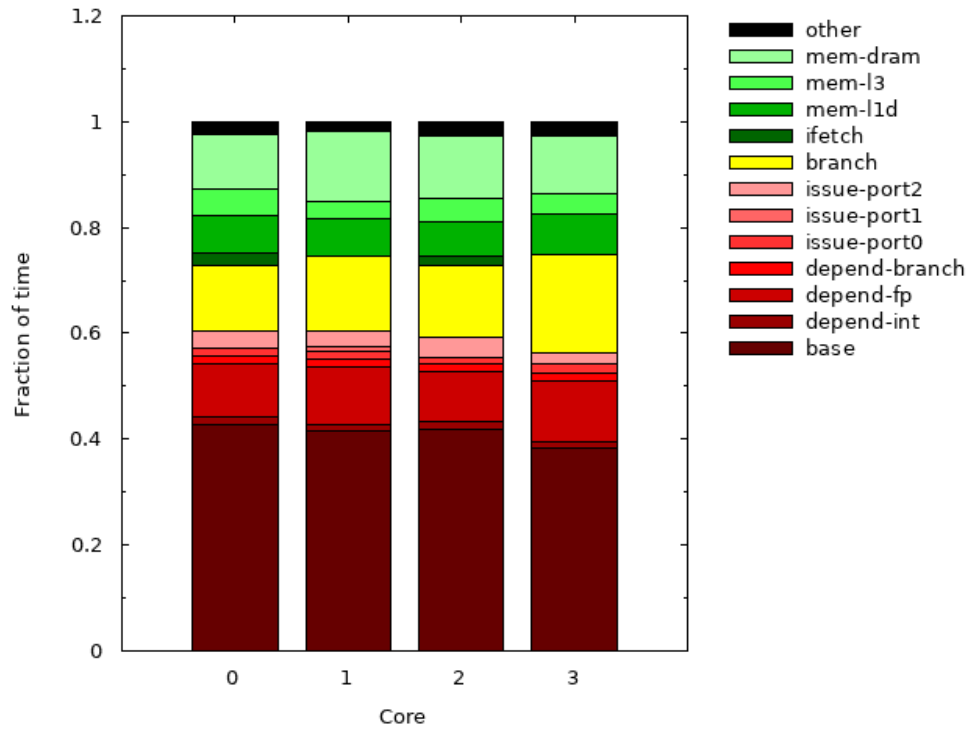
(d) 2^{16} PHT size

Figure 5: Specific values for each components' power consumption.

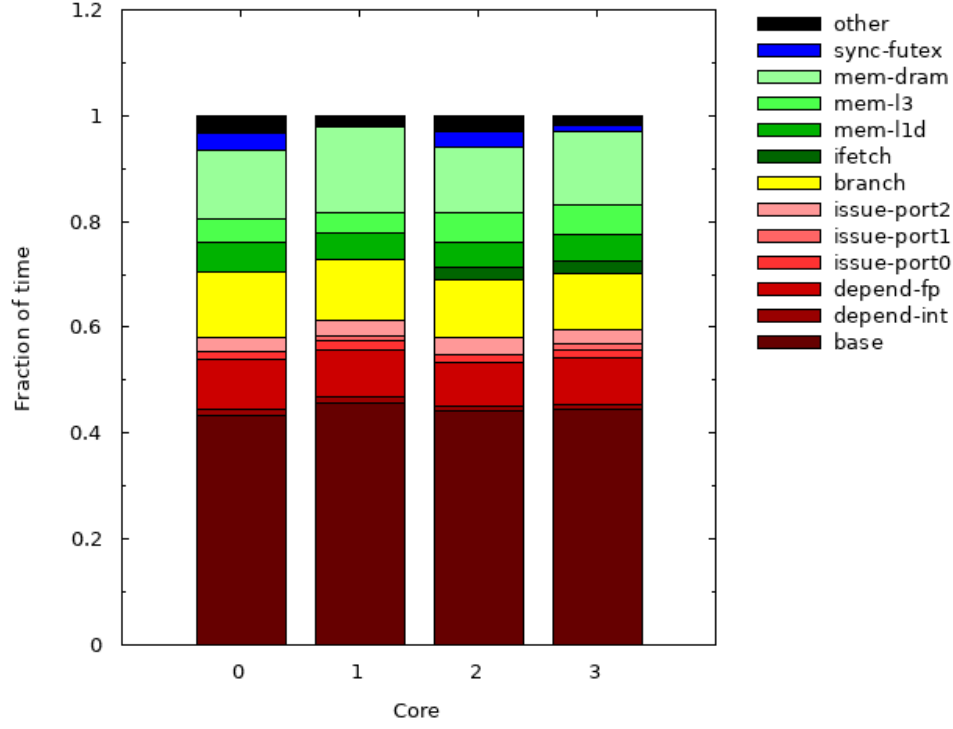
5.1.2 CPI Stacks



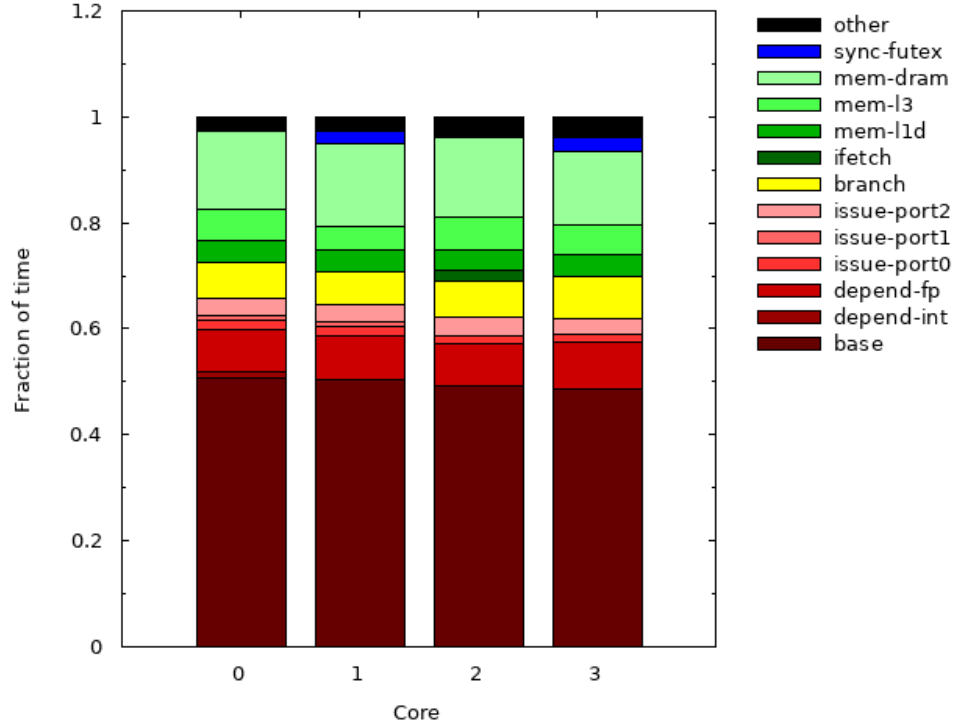
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 6: 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 7: Specific values for each components' CPI stack.

5.2 fmm

5.2.1 Power Results

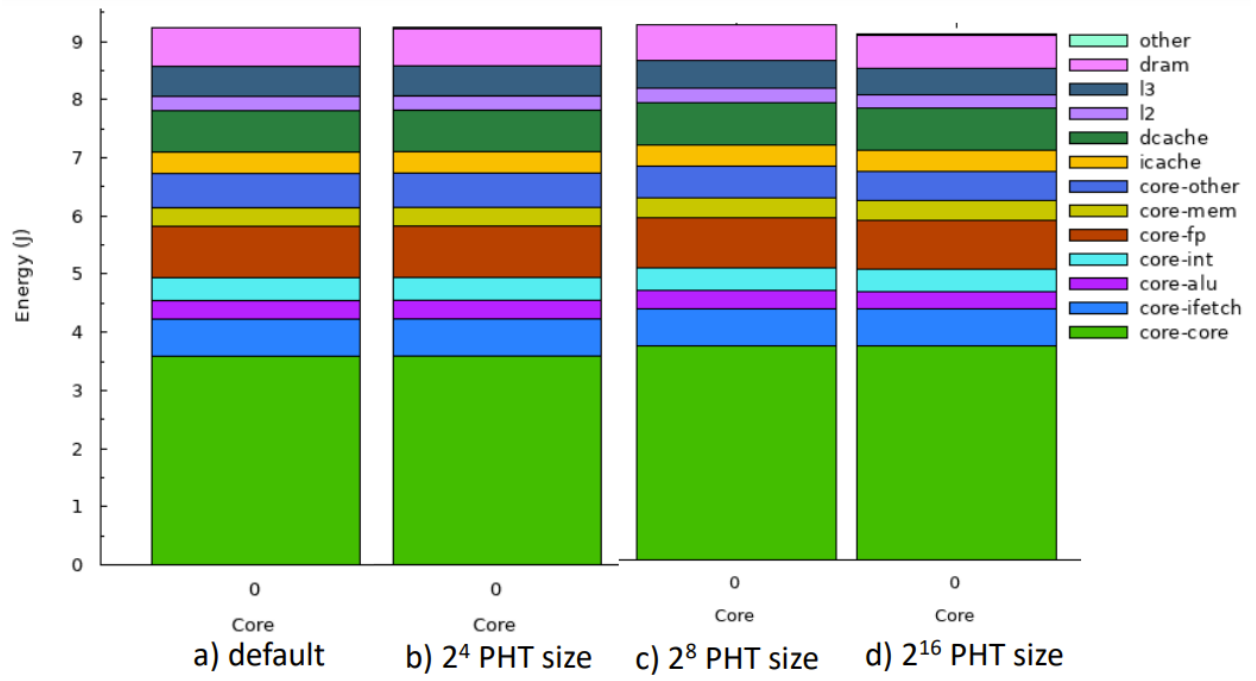


Figure 8: Processor power for various PHT sizes.

	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%

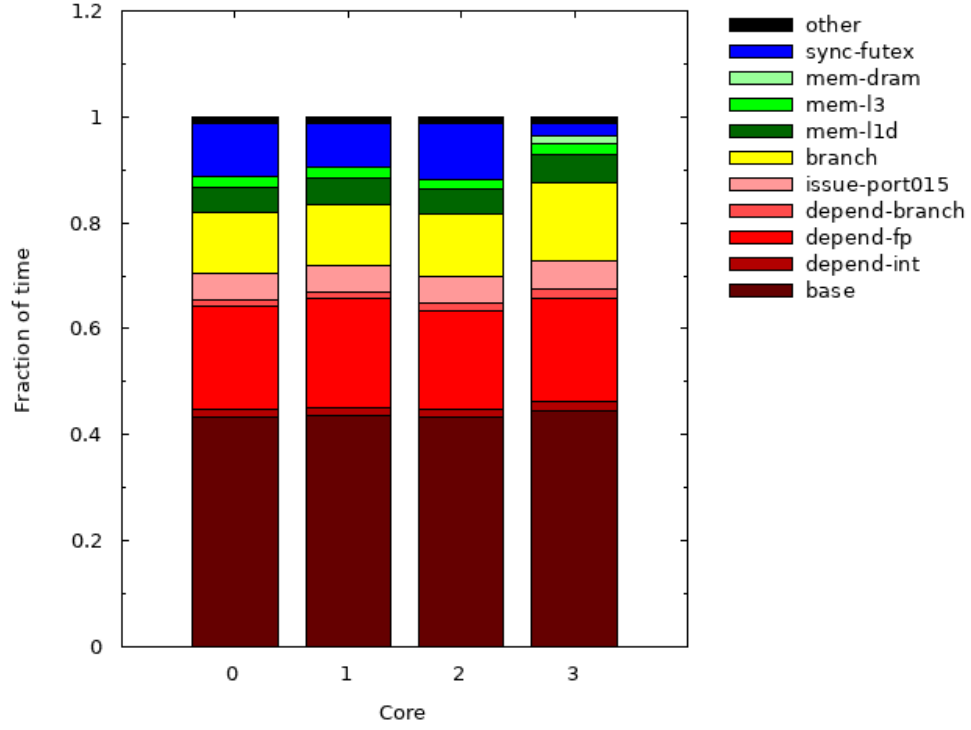
(c) 2^8 PHT size

	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%

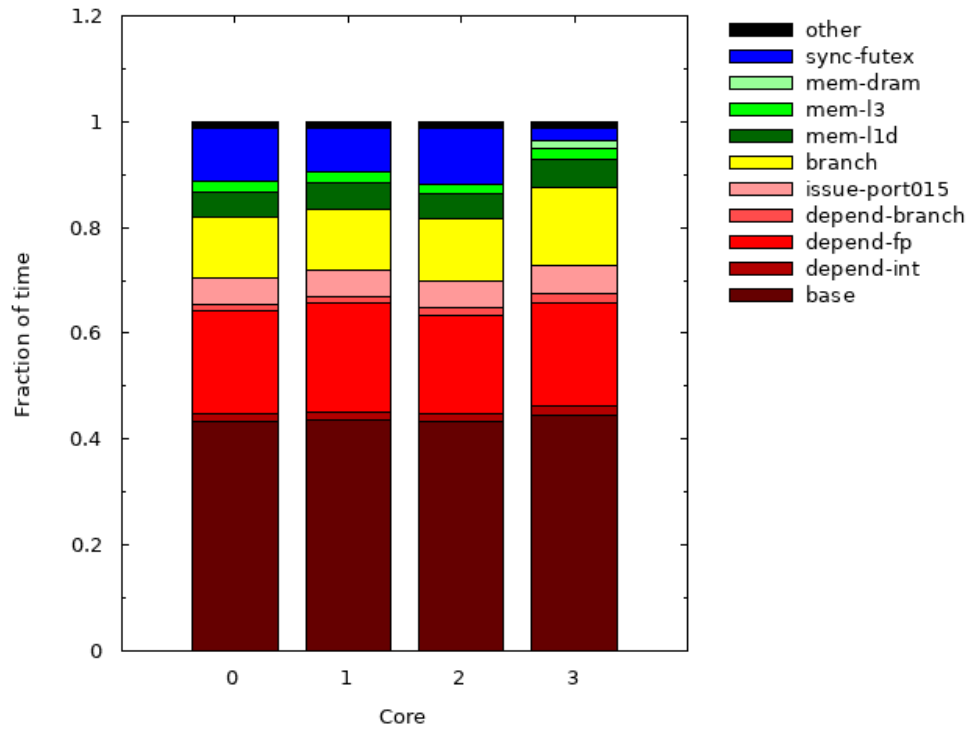
(d) 2^{16} PHT size

Figure 9: Specific values for each components' power consumption.

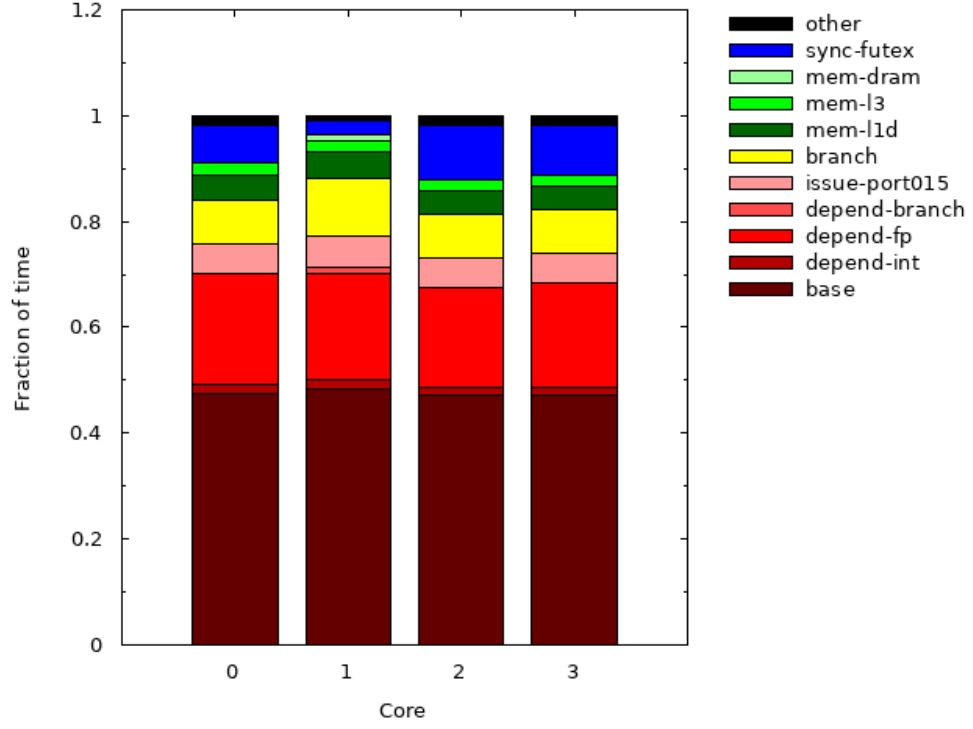
5.2.2 CPI Stacks



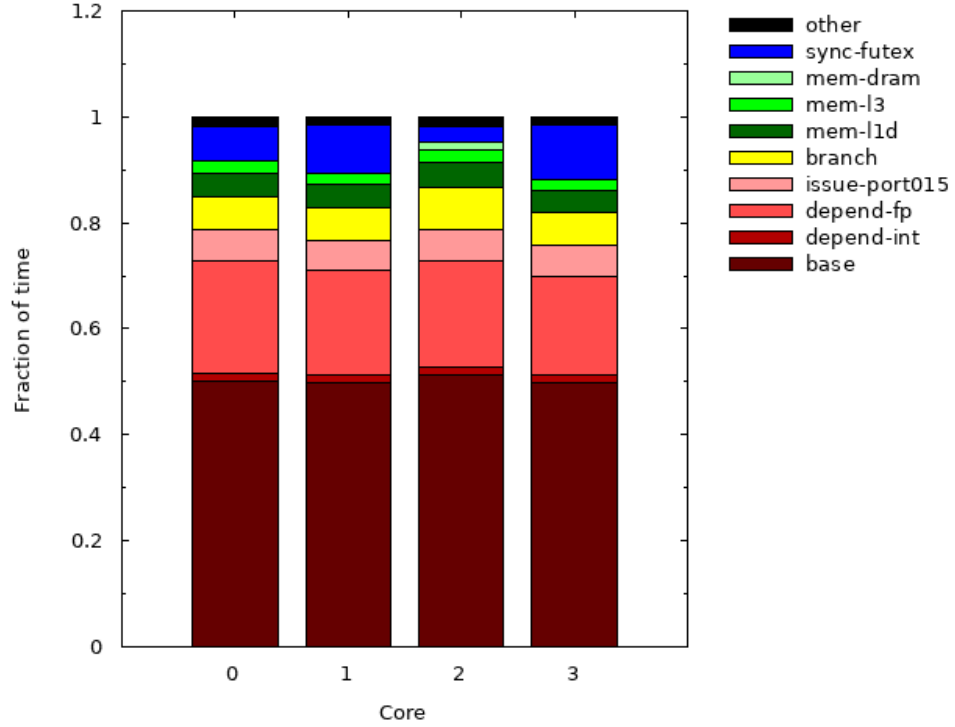
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 10: 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 11: Specific values for each components' CPI stack.

5.3 lu.cont

5.3.1 Power Results

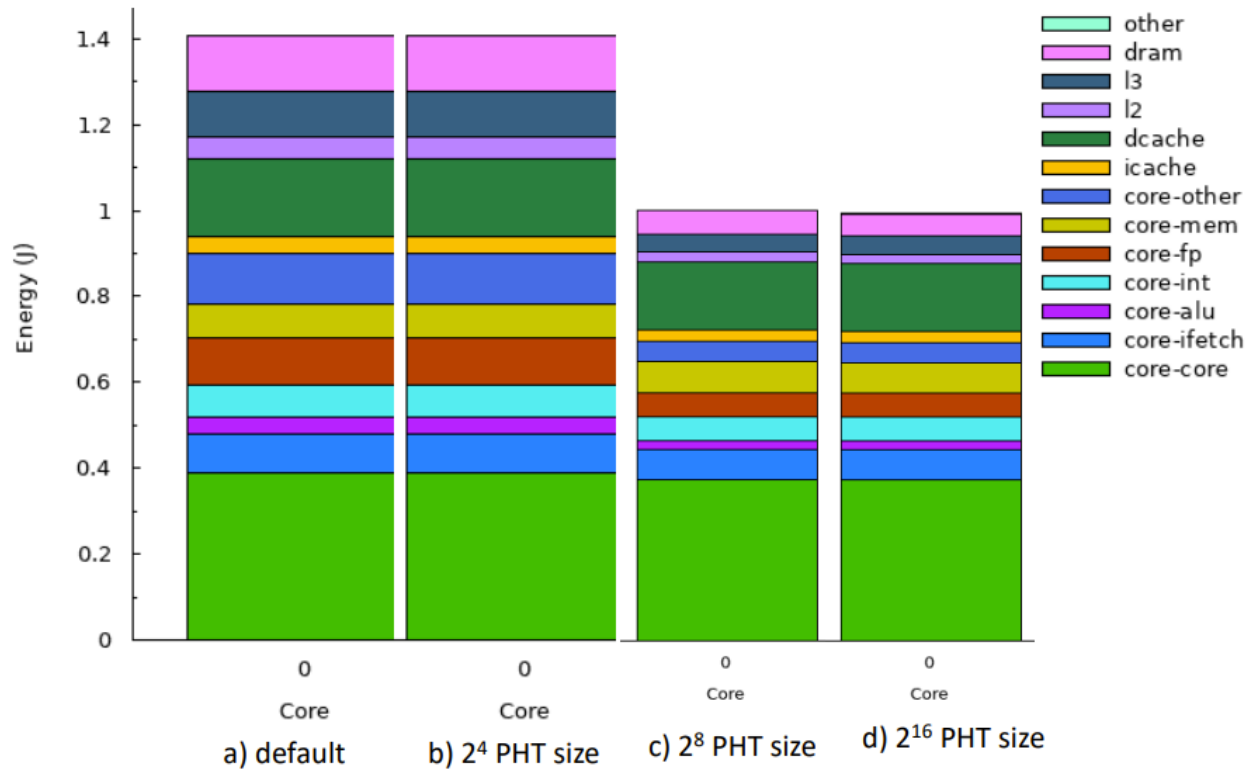


Figure 12: Processor power for various PHT sizes.

	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%

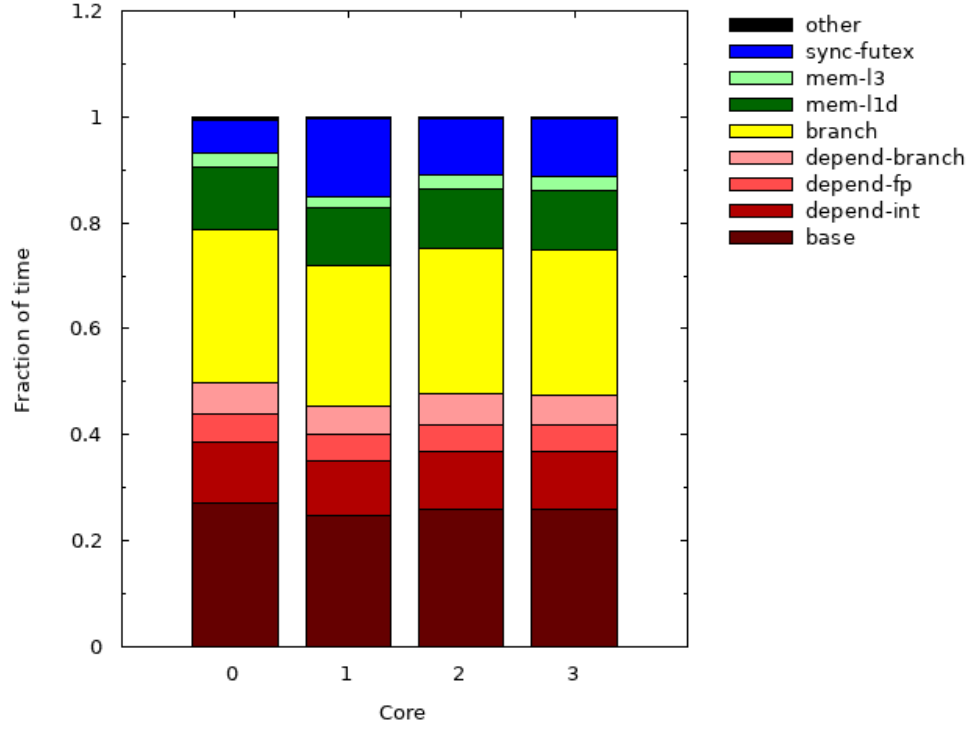
(c) 2^8 PHT size

	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%

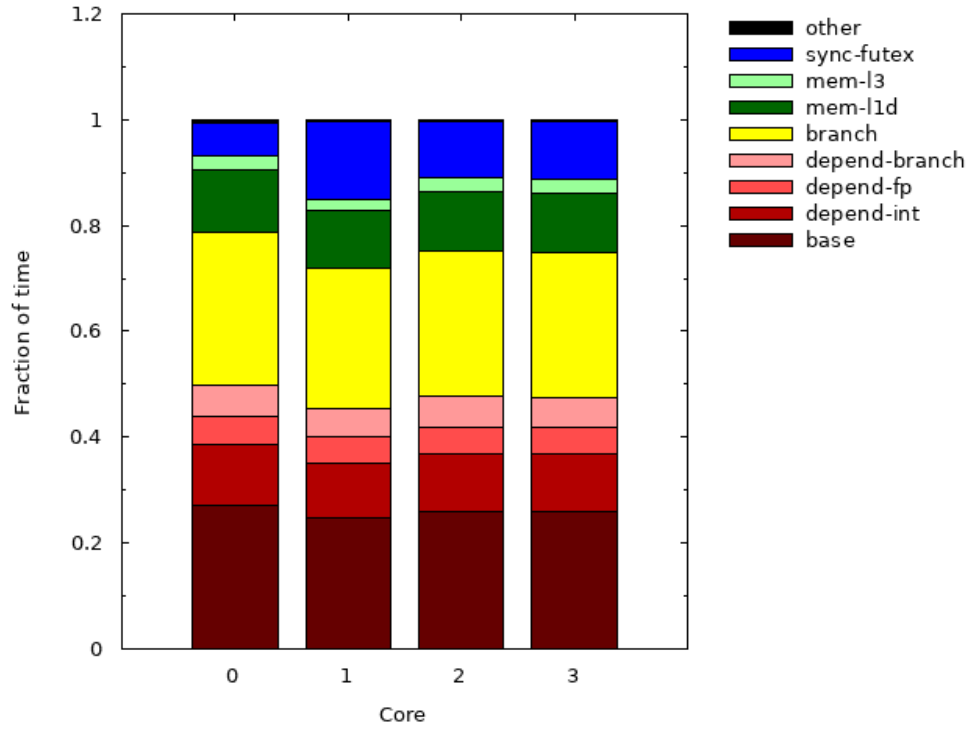
(d) 2^{16} PHT size

Figure 13: Specific values for each components' power consumption.

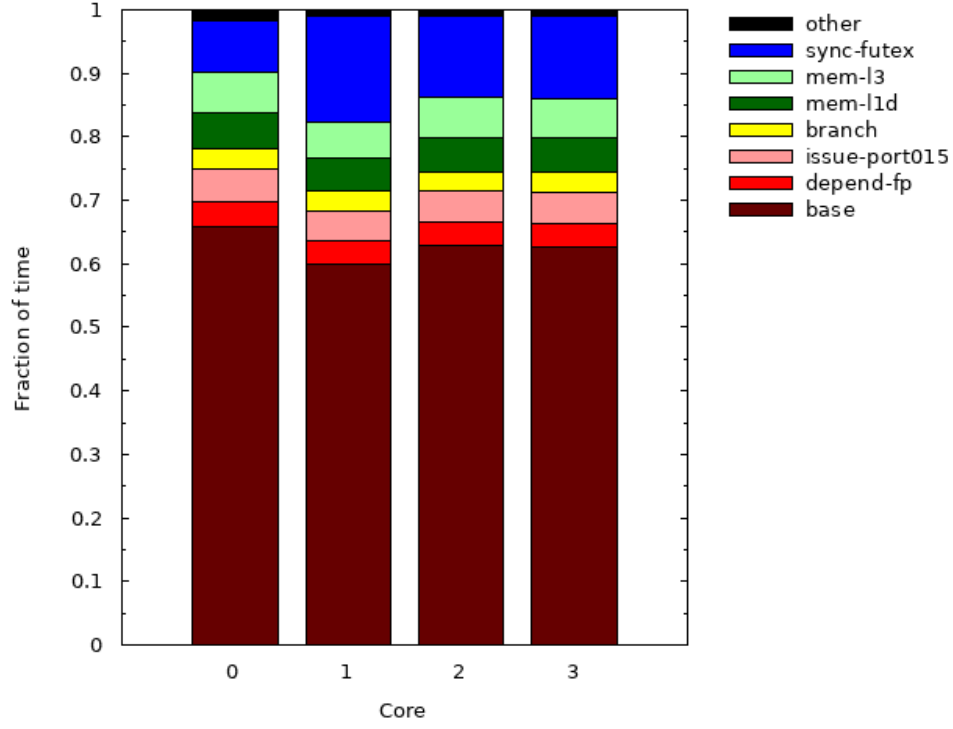
5.3.2 CPI Stacks



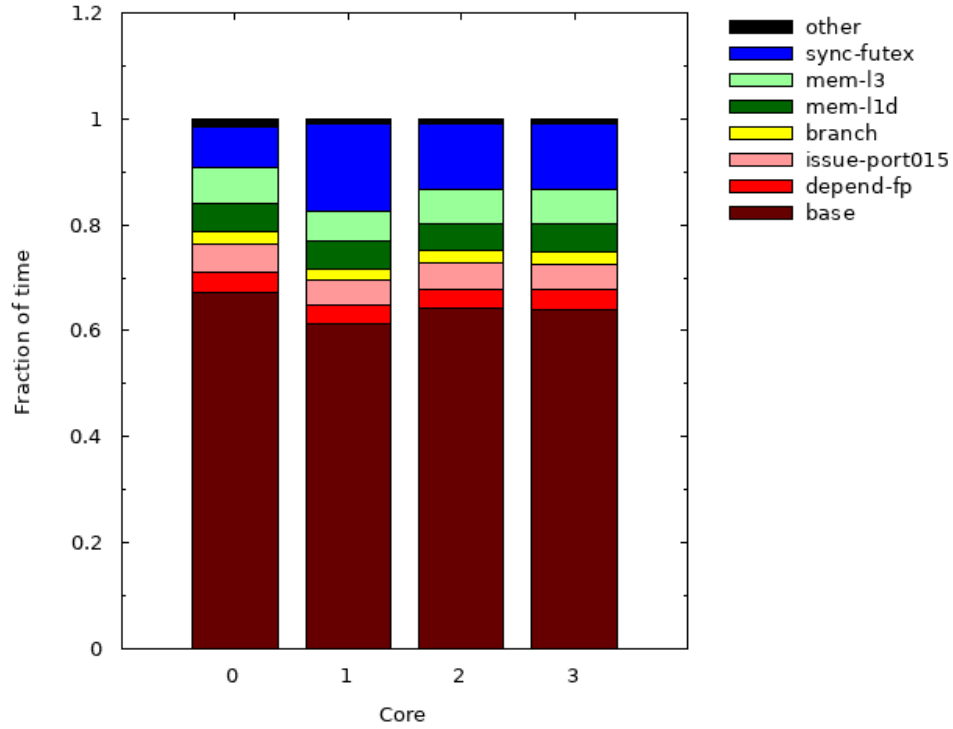
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 14: 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 15: Specific values for each components' CPI stack.

5.4 radiosity

5.4.1 Power Results

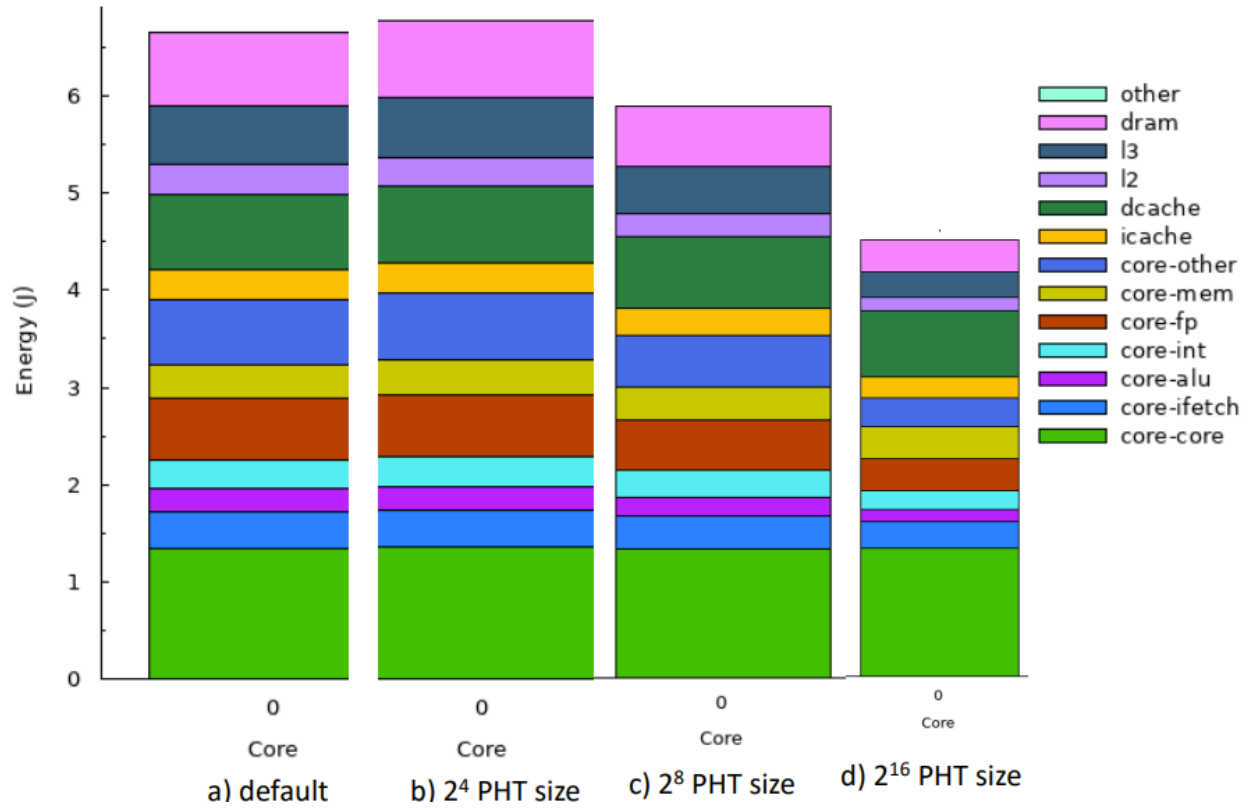


Figure 16: Processor power for various PHT sizes.

	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%

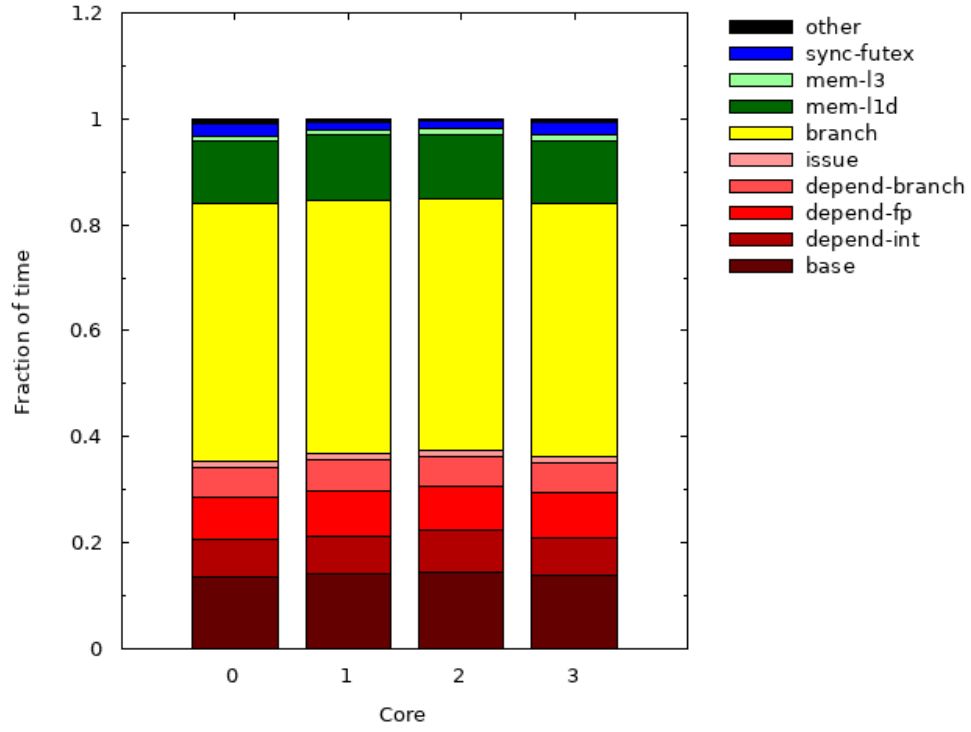
(c) 2^8 PHT size

	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%

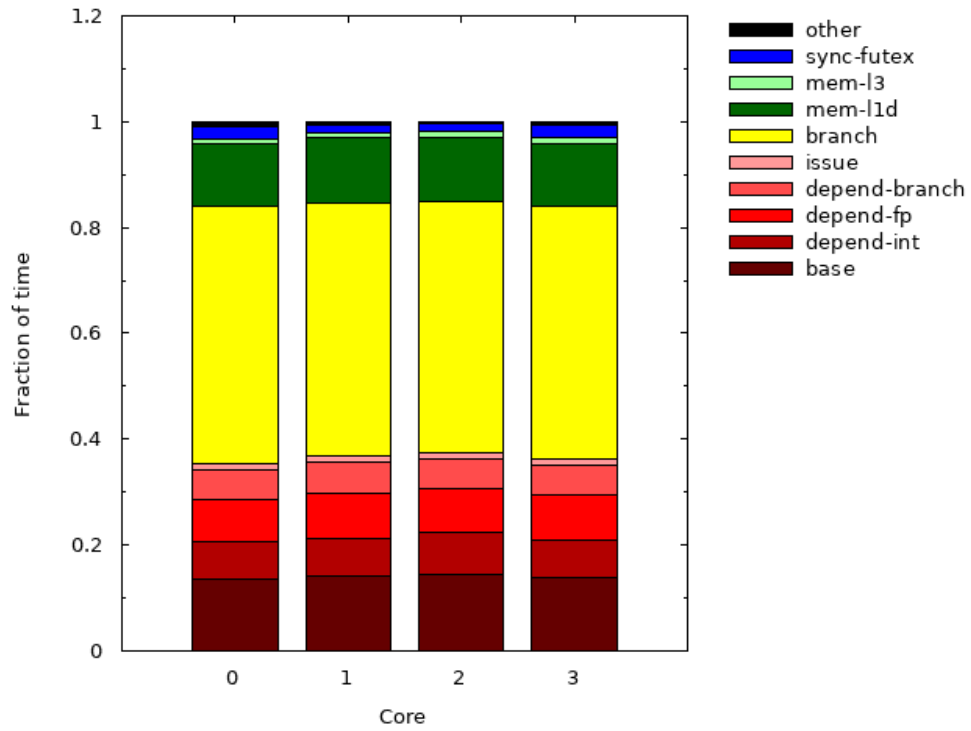
(d) 2^{16} PHT size

Figure 17: Specific values for each components' power consumption.

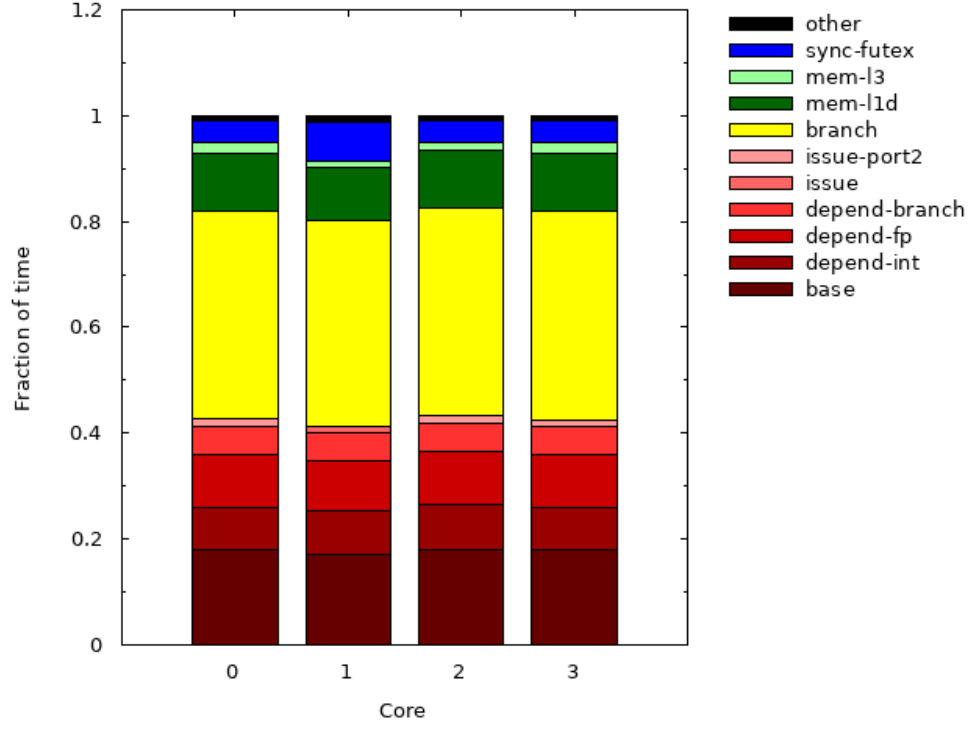
5.4.2 CPI Stacks



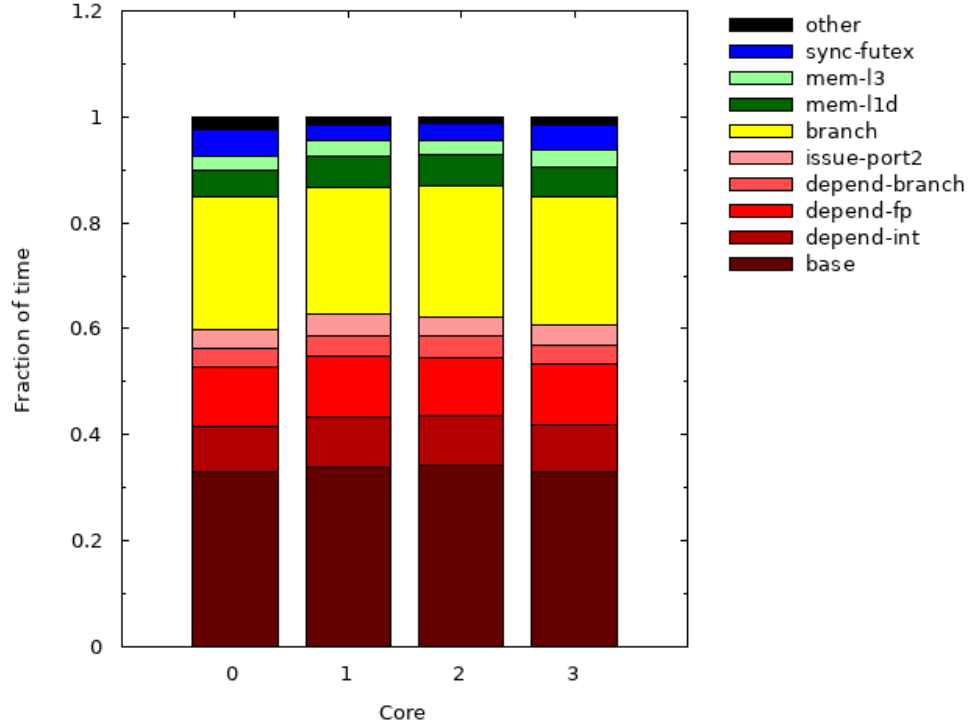
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 18: 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 19: Specific values for each components' CPI stack.

5.5 raytrace

5.5.1 Power Results

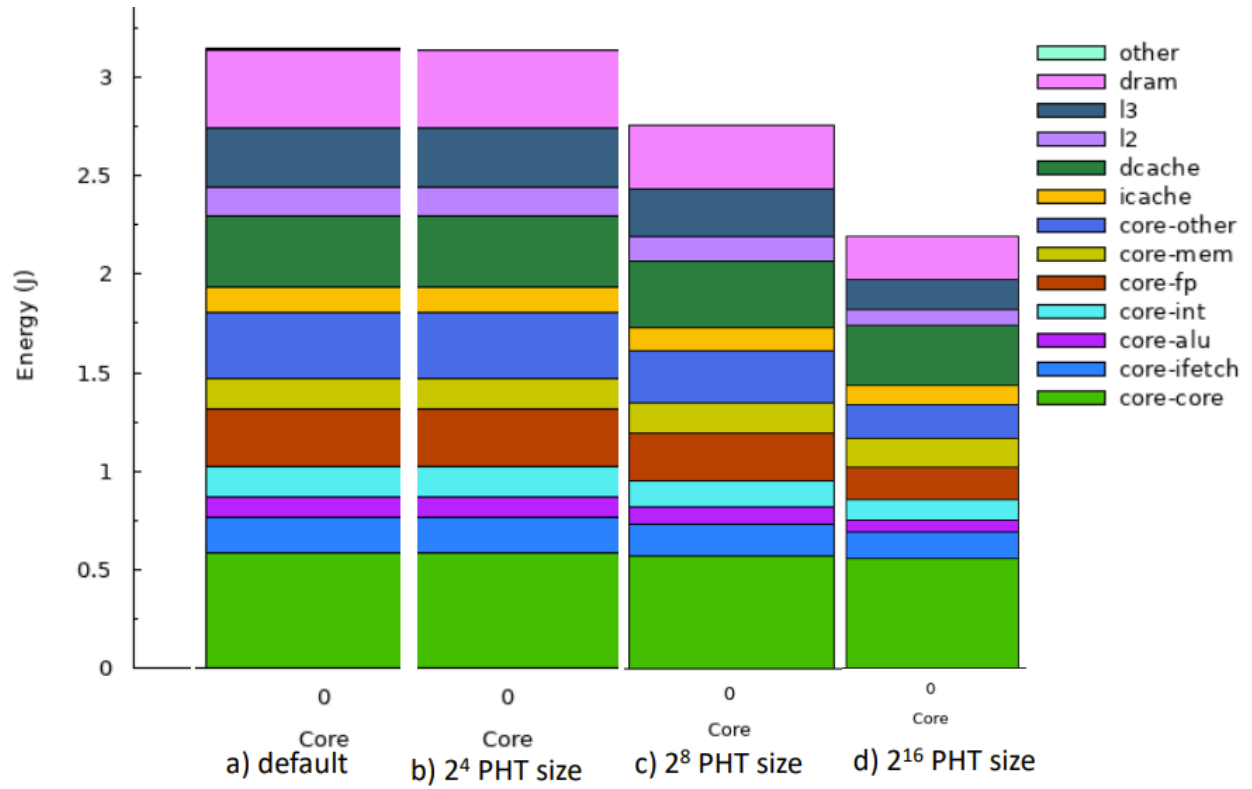


Figure 20: Processor power for various PHT sizes.

	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%

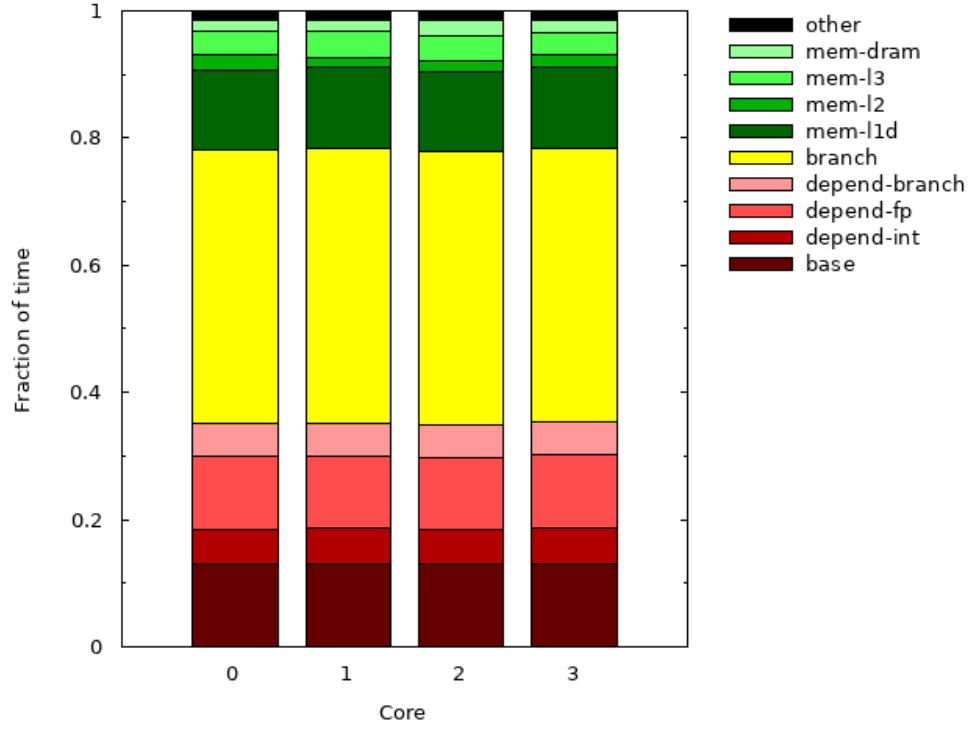
(c) 2^8 PHT size

	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%

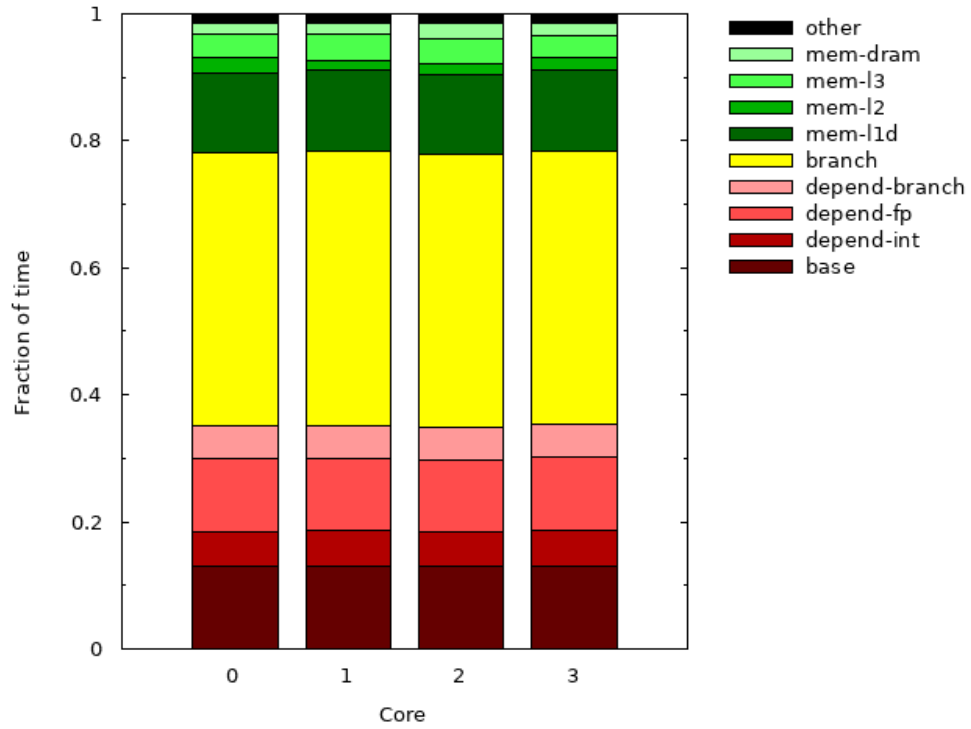
(d) 2^{16} PHT size

Figure 21: Specific values for each components' power consumption.

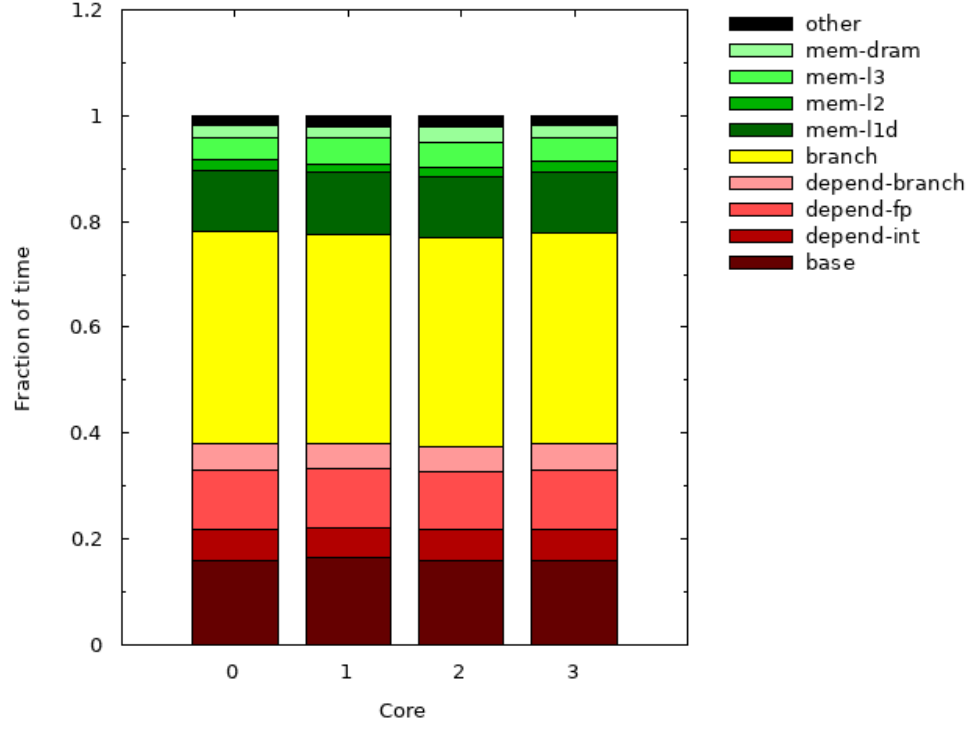
5.5.2 CPI Stacks



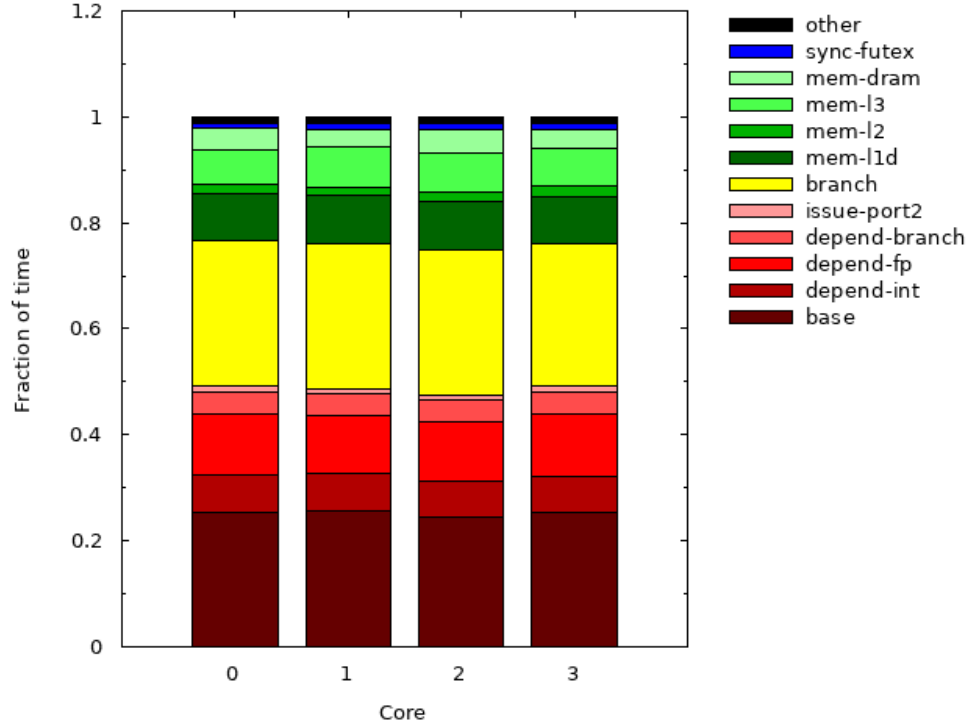
(a) default



(b) 2^4 PHT size



(c) 2^8 PHT size



(d) 2^{16} PHT size

Figure 22: 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 23: Specific values for each components' CPI stack.