EXTENDED EVALUATION REPORT

This report presents an extension of the experiments conducted in Sec. VI, based on the system settings described in Sec. VI-A. The extension includes four main aspects: (i) an increased number of tasks in TacleBench (from 12 to 36); (ii) comparison of the total WCET with inter-core cache interference; (iii) a detailed comparison of each evaluated task; and (iv) additional experiments using Papabench.

Extended Evaluation. First, Tab. IX presents an extended version of the inter-core cache interference estimations comparison for tasks in TacleBench. The number of tasks being examined is extended from 12 tasks to 36 tasks, where each task is analysed under 12 interfering tasks. Compared to the state-of-the-art (*i.e.*, the analysis labelled with "Zhang2022" [4]), the proposed analysis reduces the inter-core cache interference estimations by 52.31% on average for all 36 tasks. In the table, the tasks are organised into three groups based on their L2 cache behaviours:

- Tasks that can incur evictions on the L2 cache due to the interfering task. For such tasks (26 out of 36 tasks), the proposed analysis outperforms Zhang2022 [4] by reducing the inter-core cache interference estimations by 72.43% on average.
- Tasks that always hit the L1 cache except the first miss, *i.e.*, all data required by the task can be fitted in the L1 cache. For such tasks (3 out of the 36 tasks), they would not incur additional delay on the L2 cache due to the interfering task. In this case, both competing methods return an inter-task interference of zero.
- Tasks that always miss the L2 cache, based on the intra-core cache analysis without considering any inter-core interference. Hence, for these tasks (7 out of 36 tasks), both methods yield the same inter-core cache interference of zero.

Comparison of WCET Estimations. Second, Tab. X shows the comparison of the total WCET of 36 tasks under Zhang2022 [4] and the proposed analysis. The tasks are organised by the same approach as described above. From the results, we observed that for certain tasks (e.g., huff_dec), the inter-core cache interference is indeed negligible to the total WCET, i.e., the reduction in the inter-core cache interference estimations barely affects the total WCET estimations. However, the results also show there are 17 tasks in which the inter-core cache interference is non-trivial to the WCET, where our analysis can lead to reduced WCET estimations. Compared to [4], our analysis reduces the total WCET estimations by 12.38% on average for tasks in the first group (26 tasks) and 8.94% on average for all evaluated tasks, respectively. This observation illustrates the reviewer's point on the inter-core cache interference of some tasks, but it also justifies the effectiveness of the proposed analysis in a general case.

Detailed Comparison of Each Evaluated Task. Third, Fig. 8 to 43 present the absolute value of the inter-core cache interference and the total WCET estimations of the 36 tasks under different interfering tasks. The results highlight the portion of the inter-core cache interference in the total WCET of each task, which validates the results presented above and the effectiveness of the proposed analysis.

TABLE VIII: FLY-BY-WIRE and AUTOPILOT Tasks with F	i Freduencies
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Tasks in AUTOPILOT	Tasks in FLY-BY-WIRE
altitude_control_task	check_failsafe_task
climb_control_task	check_mega128_values_task
link_fbw_send	send_data_to_autopilot_task
stabilisation_task	servo_transmit
radio_control_task	test_ppm_task

Evaluation of Papabench. Finally, the tasks in Papabench are analysed using the proposed analysis and Zhang2022. The Papabench produces two executable files (Fly-By-Wire and Autopilot), representing two applications running on two processors. Each application invokes a set of different tasks, as shown in Tab. VIII. However, we observe that most tasks (8 out of 10) in Papabench can always hit the L1 cache (except the first miss). For these tasks, both competing methods return an inter-core cache interference of zero with an identical WCET, and hence, their results are omitted.

The task radio_control_task (in AUTOPILOT) and task send_data_to_autopilot_task (in FLY-BY-WIRE) would incur L2 cache evictions due to interfering tasks. Fig. 44 presents the inter-core cache interference and the total WCET for radio_control_task when being executed under the interference from each of the five tasks in FLY-BY-WIRE. Fig. 45 shows the results of send_data_to_autopilot_task under the interference of each task in Autopilot. As observed, for task radio_control_task, the proposed analysis outperforms Zhang2022 by reducing the inter-core cache interference and total WCET estimations by 87.1% and 7.56%, respectively. For task send_data_to_autopilot_task, the proposed analysis outperforms Zhang2022 by reducing the inter-core cache interference and total WCET estimations by 62.42% and 2.78%, respectively.

TABLE IX: Ratio of the inter-core cache interference of proposed analysis to Zhang2022 (binaryS: binarysearch; insertS: insertSort).

Classification	Benchmark	adpcm_dec	binaryS	cover	fir2dim	fmref	huff_dec	iir	insertS	jfdctint	ndes	st	statemate	Avg.
	adpcm_dec	0.48	0.31	0.28	0.07	0.06	0.10	0.19	0.21	0.38	0.11	0.04	0.70	0.24
	binarysearch	1.0	0.01	0.33	0.03	0.07	0.07	1.0	1.0	0.17	0.06	0.05	0.25	0.34
	fir2dim	0.24	0.06	0.53	0.05	0.07	0.09	0.04	0.06	0.10	0.12	0.02	0.70	0.17
	fmref	0.15	0.01	0.23	0.02	0.10	0.10	0.01	0.01	0.02	0.02	0.02	0.20	0.07
	huff_dec	0.12	1.0	1.0	0.01	0.09	0.11	0.01	0.01	0.01	0.08	0.01	0.25	0.22
	iir	1.0	1.0	0.20	0.14	0.08	0.14	0.08	0.06	0.24	0.11	0.03	0.33	0.29
	insertsort	0.23	0.01	0.25	0.14	0.01	0.07	0.01	0.33	0.06	0.14	0.05	0.40	0.14
	jfdctint	0.81	0.19	0.39	0.11	0.11	0.16	0.22	0.25	0.13	0.16	0.06	0.64	0.27
	ndes	0.30	0.21	0.43	0.11	0.10	0.23	0.01	0.01	0.22	0.15	0.03	0.60	0.20
	st	0.92	0.04	0.51	0.15	0.20	0.34	0.01	0.34	0.27	0.27	0.01	0.82	0.32
	statemate	0.12	0.03	0.18	0.03	0.07	0.07	0.01	0.01	0.05	0.09	0.05	0.70	0.12
Tasks that	audiobeam	0.61	0.13	0.40	0.18	0.07	0.14	1.0	1.0	0.50	0.11	0.08	1.0	0.43
incur evictions on	cjpeg_transupp	0.46	0.12	0.75	0.42	0.16	0.47	0.18	0.02	0.42	0.48	0.23	1.0	0.39
the L2 cache due to	dijkstra	1.0	1.0	0.03	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.92
the interfering task	g723_enc	0.20	0.01	0.18	0.05	0.05	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.62
	gsm_dec	0.62	0.01	0.25	0.01	0.08	0.07	0.02	0.01	0.02	0.09	0.01	1.0	0.18
	gsm_enc	0.57	0.10	0.24	0.09	0.05	0.10	0.01	0.01	0.17	0.12	0.08	0.50	0.17
	h264_dec	0.12	0.01	0.08	0.01	0.03	0.06	0.01	0.01	0.04	0.04	0.01	0.39	0.07
	lift	0.01	0.01	0.07	0.01	0.08	0.08	0.01	0.02	0.05	0.04	0.01	0.25	0.05
	md5	1.0	1.0	0.07	0.01	0.11	0.12	0.01	0.01	0.01	0.01	0.04	0.09	0.20
	minver	0.52	0.16	0.23	0.06	0.02	0.05	0.15	0.10	0.15	0.16	0.05	0.41	0.17
	petrinet	1.0	0.01	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.92
	pm	0.05	0.01	0.02	0.01	0.11	0.05	0.01	0.01	0.01	0.02	0.01	0.11	0.03
	powerwindow	0.01	0.01	0.05	0.01	0.06	0.09	0.01	0.01	0.01	0.02	0.01	0.29	0.04
	prime	0.92	0.13	0.41	0.14	0.14	0.19	0.28	0.26	0.34	0.22	0.06	0.76	0.32
	sha	0.67	0.01	0.14	0.10	0.06	0.14	0.01	0.01	1.0	0.15	0.12	1.0	0.28
Tasks that always hit the L1 cache except the first miss	bsort	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	cover	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	complex_updates	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tasks that cannot hit the L2 cache according to	cjpeg_wrbmp	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	countnegative	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	fft	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	filterbank	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
the intra-core	lms	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
cache analysis	ludcmp	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	matrix1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE X: Ratio of total WCET of proposed analysis to Zhang2022 (binaryS: binarysearch; insertS: insertsort). $1.0^* \approx 1$ means the situation where the proposed analysis tightens the inter-core cache interference compared to [4], however, such interference is negligible to the total WCET.

Classification	Benchmark	adpcm_dec	binaryS	cover	fir2dim	fmref	huff_dec	iir	insertS	jfdctint	ndes	st	statemate	Avg.
	adpcm_dec	0.93	0.93	0.85	0.50	0.46	0.61	0.93	0.93	0.90	0.63	0.50	0.97	0.76
	binarysearch	1.0	0.98	0.96	0.60	0.76	0.76	1.0	1.0	0.96	0.75	0.71	0.94	0.87
	fir2dim	0.97	0.99	0.99	0.80	0.85	0.88	0.99	0.96	0.98	0.90	0.90	0.99	0.93
	fmref	0.99	0.96	0.97	0.92	0.76	0.79	0.96	0.91	0.89	0.39	0.56	0.95	0.84
	huff_dec	1.0*	1.0	1.0	0.99	0.99	0.97	0.99	1.0*	0.98	0.97	0.90	0.99	0.98
	iir	1.0	1.0	0.81	0.91	0.85	0.91	0.94	0.85	0.89	0.73	0.49	0.92	0.86
	insertsort	0.86	0.80	0.96	0.96	0.41	0.90	0.70	0.98	0.96	0.91	0.80	0.98	0.85
	jfdctint	0.97	0.74	0.75	0.45	0.48	0.46	0.86	0.87	0.72	0.49	0.32	0.90	0.67
	ndes	0.92	0.96	0.93	0.78	0.61	0.84	0.91	0.72	0.93	0.74	0.56	0.96	0.82
	st	1.0*	0.99	0.99	0.96	0.96	0.98	0.99	0.99	0.98	0.97	0.93	1.0*	0.98
	statemate	0.28	0.97	0.73	0.07	0.63	0.10	0.92	0.82	0.88	0.67	0.67	0.98	0.64
Tasks that	audiobeam	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0	1.0	1.0*	1.0*	1.0*	1.0	0.83
incur evictions on	cjpeg_transupp	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0	1.0*
the L2 cache due to	dijkstra	1.0	1.0	1.0*	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0*
the interfering task	g723_enc	1.0*	1.0*	1.0*	0.99	0.99	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0*
	gsm_dec	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0	1.0*
	gsm_enc	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*
	h264_dec	0.74	0.52	0.93	0.11	0.81	0.21	0.96	0.96	0.96	0.29	0.80	0.98	0.69
	lift	0.88	0.95	0.82	0.63	0.92	0.86	0.91	0.96	0.98	0.68	0.44	0.94	0.83
	md5	1.0	1.0	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*
	minver	0.97	0.94	0.78	0.65	0.33	0.40	0.97	0.93	0.85	0.70	0.50	0.90	0.74
	petrinet	1.0	1.0*	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0*
	pm	1.0*	1.0*	1.0*	0.99	1.0*	0.99	1.0*	1.0*	1.0*	0.99	0.99	1.0*	1.0*
	powerwindow	0.89	0.89	0.74	0.44	0.50	0.53	0.83	0.95	0.80	0.50	0.32	0.91	0.69
	prime	0.99	0.73	0.90	0.77	0.31	0.74	0.94	0.94	0.92	0.77	0.62	0.97	0.80
	sha	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0	1.0*	1.0*	1.0	1.0*
Tasks that always	bsort	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
hit the L1 cache	cover	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
except the first miss	complex_updates	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	cjpeg_wrbmp	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tasks that cannot hit the L2 cache according to the intra-core cache analysis	countnegative	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	fft	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	filterbank	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	lms	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	ludemp	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	matrix1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

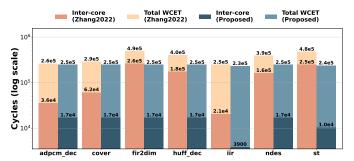


Fig. 8: Inter-core cache interference and total WCET of adpcm_dec with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

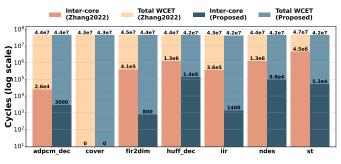


Fig. 12: Inter-core cache interference and total WCET of huff_dec with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

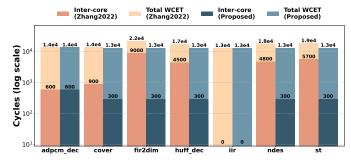


Fig. 9: Inter-core cache interference and total WCET of binarysearch with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

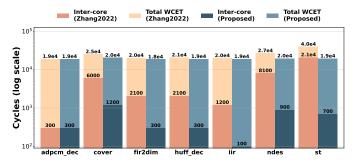


Fig. 13: Inter-core cache interference and total WCET of iir with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

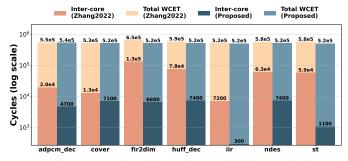


Fig. 10: Inter-core cache interference and total WCET of fir2dim with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

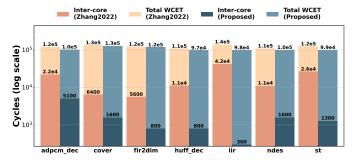


Fig. 14: Inter-core cache interference and total WCET of insertsort with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

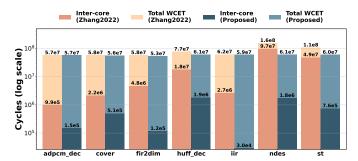


Fig. 11: Inter-core cache interference and total WCET of fmref with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

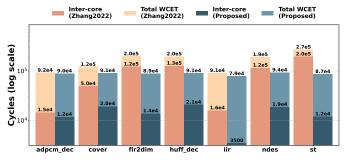


Fig. 15: Inter-core cache interference and total WCET of jfdctint with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

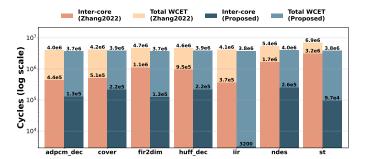


Fig. 16: Inter-core cache interference and total WCET of ndes with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

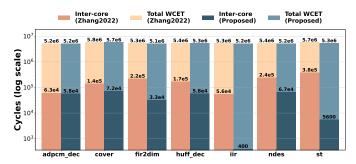


Fig. 17: Inter-core cache interference and total WCET of st with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

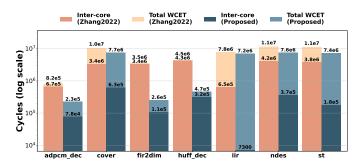


Fig. 18: Inter-core cache interference and total WCET of statemate with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

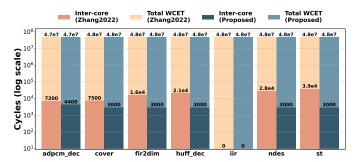


Fig. 19: Inter-core cache interference and total WCET of audiobeam with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

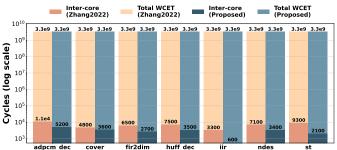


Fig. 20: Inter-core cache interference and total WCET of cjpeg_transupp with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

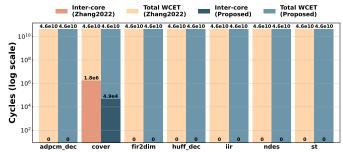


Fig. 21: Inter-core cache interference and total WCET of dijkstra with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

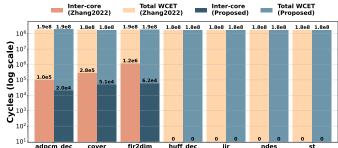


Fig. 22: Inter-core cache interference and total WCET of g723_enc with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

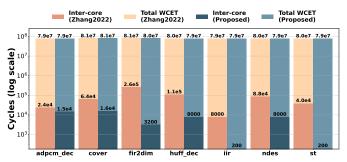


Fig. 23: Inter-core cache interference and total WCET of gsm_dec with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

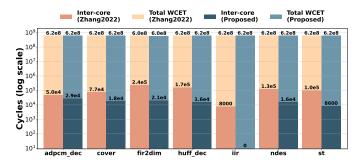


Fig. 24: Inter-core cache interference and total WCET of gsm_enc with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

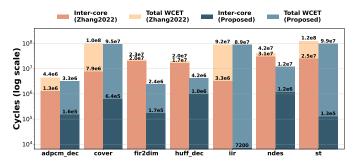


Fig. 25: Inter-core cache interference and total WCET of h264_dec with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

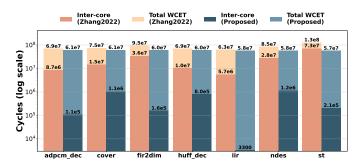


Fig. 26: Inter-core cache interference and total WCET of lift with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

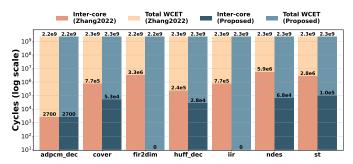


Fig. 27: Inter-core cache interference and total WCET of md5 with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

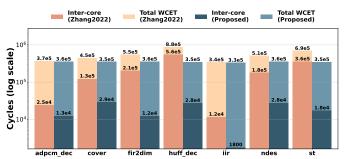


Fig. 28: Inter-core cache interference and total WCET of minver with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

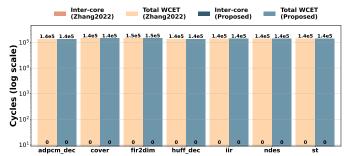


Fig. 29: Inter-core cache interference and total WCET of petrinet with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

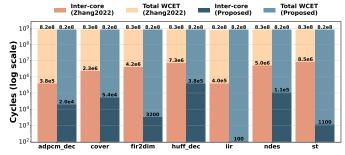


Fig. 30: Inter-core cache interference and total WCET of pm with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

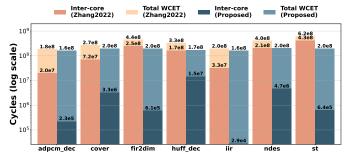


Fig. 31: Inter-core cache interference and total WCET of powerwindow with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

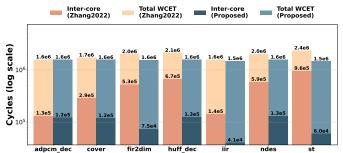
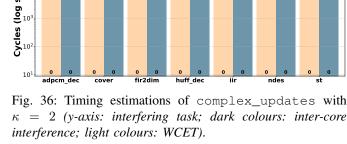


Fig. 32: Inter-core cache interference and total WCET of prime with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).



10

Scale)

Total WCET (Proposed)

Inter-core (Zhang2022) Total WCET (Proposed) Total WCET (Proposed)

2.768 2.768 2.86

Fig. 33: Inter-core cache interference and total WCET of sha with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

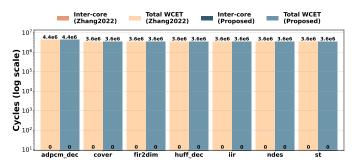


Fig. 37: Inter-core cache interference and total WCET of cjpeg_wrbmp with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

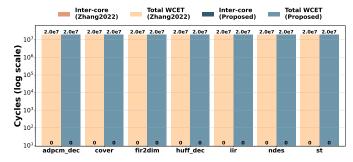


Fig. 34: Inter-core cache interference and total WCET of bsort with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

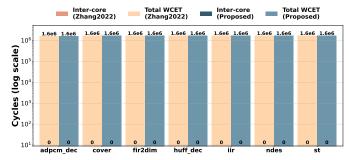


Fig. 38: Inter-core cache interference and total WCET of countnegative with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

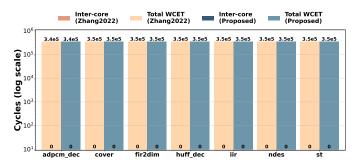


Fig. 35: Inter-core cache interference and total WCET of cover with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

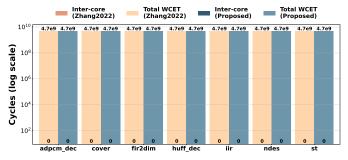


Fig. 39: Inter-core cache interference and total WCET of fft with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

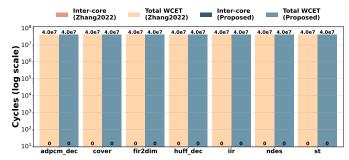


Fig. 40: Inter-core cache interference and total WCET of filterbank with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

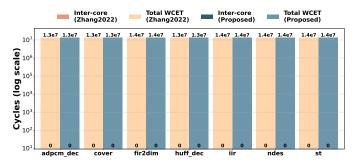


Fig. 41: Inter-core cache interference and total WCET of 1ms with $\kappa = 2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

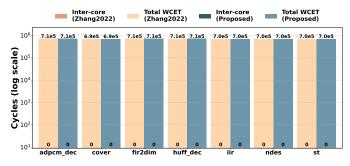


Fig. 42: Inter-core cache interference and total WCET of ludcmp with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

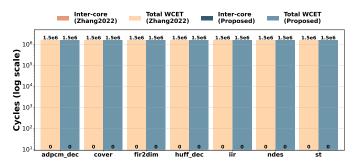


Fig. 43: Inter-core cache interference and total WCET of matrix1 with $\kappa=2$ (y-axis: interfering task; dark colours: inter-core cache interference; light colours: WCET).

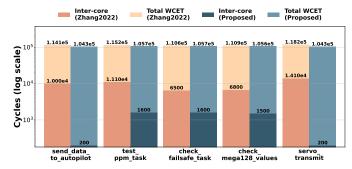


Fig. 44: Inter-core cache interference and WCET of the PapaBench task radio_control_task (AUTOPILOT) with $\kappa = 2$ (y-axis: interfering task in FLY-BY-WIRE program; dark colours: inter-core cache interference; light colours: WCET).

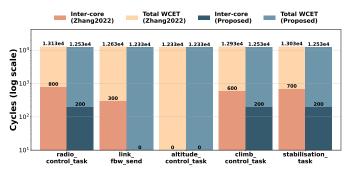


Fig. 45: Inter-core cache interference and total WCET of the PapaBench task send_data_to_autopilot_task (FLY-BY-WIRE) with $\kappa=2$ (y-axis: interfering task in AUTOPILOT program; dark colours: inter-core cache interference; light colours: WCET).