ECE552 lab2 report
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Microbenchmark:

N = 100000	A. Loop number = N Modulo divisor = 7	B. Loop number = N Modulo divisor = 10	C. Loop number = 10N Modulo divisor = 10
# mispredictions	2486	12512	102489
MPKI	1.195	5.748	5.057

The microbenchmark is designed to run a for loop (index i) with loop number N, and inside the for loop there is an if-statement comparing i%divisor to 0. The branch decision of the if statement is the main analysis target in the microbenchmark. Since the width of branch history is 6, it can track the correct pattern of at most the cycle of 7. Therefore, if modulo divisor <= 7 (mb.A), there are only 2486 mispredictions. If modulo divisor > 7 (mb.B and mb.7), for each cycle of 10 (modulo divisor = 10), there is 1 misprediction (a total of N/10 additional mispredictions). More details can be found in comments in mb.c.

Benchmarks	Two-bit saturation		Two-level PAp		O-GEHL	
	# mispre.	MPKI	# mispre.	MPKI	# mispre.	MPKI
astar	3695830	24.639	1785464	11.903	424952	2.833
bwaves	1182969	7.886	1071909	7.146	207473	1.383
bzip2	1224967	8.166	1297677	8.651	1072184	7.148
gcc	3161868	21.079	2223671	14.824	300919	2.006
gromacs	1363248	9.088	1122586	7.484	760423	5.069
hmmer	2035080	13.567	2230774	14.872	1712958	11.420
mcf	3657986	24.387	2024172	13.494	1286319	8.575
soplex	1065988	7.107	1022869	6.819	647165	4.314
average		14.490		10.649		5.344

Open-ended branch predictor implementation:

A. Storage requirements
   [Global branch history register (192bits)] + [Threshold counter & threshold 7 bits + 8 bits] + [Prector tables: 5 bit counter * 2048 entries * 11 tables]
   = Total: 112847 bits = 110.202Kbits
B. Details
   The design is inspired by O-GEHL (Optimized Geometric History Length Branch Predictor) [1]. There are 11 hash tables used as the prediction lookups. Each predictor table provides a prediction as a signed 5-bit counter for each entry. The indexing function of each hash table is re-designed by combining the value of PC and global branch history

(of different lengths) to output a 11-bit wide index of each table. (The hash functions are adjusted upon multiple experiments.) The prediction result of the signed counters of each predictor table is summed up and checked for the sign. If the sum >= 0, the prediction is TAKEN, else the prediction is NOT_TAKEN.

The counters in predictor tables are updated when there is a misprediction or the sum of the last prediction does not exceed the threshold value θ. The counter value is updated as how a normal saturation counter works.

There are two additional registers implemented in the O-GEHL design: Threshold value θ and Threshold counter. The 7-bit threshold counter is used to keep track of the θ change. Once triggering a change of θ, the counter will be reset to 0. The 5-bit saturation counters in the predictor tables are updated when the sum is less than the threshold or there is a misprediction.

C. Report area access latency, and leakage power for the two-level and your open-ended branch predictors, using CACTI.

2-level:

	Area	Access Latency	Leakage Power
2-level BHT	$1.0528 \times 10^{-3}\ mm^2$	$0.163585\ ns$	$0.195006\ mw$
2-level PHT	$1.0528 \times 10^{-3}\ mm^2$	$0.163585\ ns$	$0.195006\ mw$
2-level overall	$2.1056 \times 10^{-3}\ mm^2$	$0.163585\ ns$	0.390012 mw

Private history table:

Size = 512 Because the width is 6 bits which rounds to 1 byte; there's 512 entries therefore 512*1 = 512 bytes.

Private predictor tables:

Size = 512 Because the width is 2 bits which rounds to 1 byte; there's 64 entries per private table, there's 8 tables in total therefore 1*64*8 = 512 bytes.

Open-ended:

Area	Access Latency	Leakage Power
$0.032466\ mm^2$	$0.377209\ ns$	$7.15174\ mw$

Size = 22528 because the width is 5 bits which rounds to 1 byte; here's 2048 entries and 11 tables therefore 11 * 2048 * 1 = 22528 bytes.

D. Distribution: 50% and 50% amongst the 2 members

References:

[1] Andre´ Sezne "Analysis of the O-GEometric History Length branch predictor" Available: https://www.irisa.fr/caps/people/seznec/ISCA05.pdf [Accessed: 18-Oct-2022].