CS422 Assignment-2 Report

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This report consists analysis of the **SPEC 2006** benchmark applications using PIN tool. Different types of control flow predictor ideas are experimented by making them predict on benchmark applications. For each application, control flow instructions in 1 billion instructions are analysed after fast-forwarding them by a specified amount. Following benchmark applications are analysed:

- Perlbench
- GCC
- Soplex
- Omnetpp
- BZip2
- MCF
- Hmmer
- Xalancbmk

For each benchmark application, there is a table showing different conditional branch predictors and their accuracy. There is another table showing different BTB caches types and their accuracy in predicting indirect control flow target.

Perl benchmark

Fast-forward count = 207000000000
Condition branches predicted = 129940264

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	41.256	53608218
Bimodal	9.58381	12453225
SAg	3.66192	4758307
GAg	11.7987	15331224
gshare	10.2202	13280103
Hybrid SAg GAg	3.07352	3993734
Hybrid SAg GAg gshare majority	5.02546	6530097
Hybrid SAg GAg gshare tournament	2.77721	3608710

Indirect Control flows predicted = 28074167

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	35.6083	9996732	0.02533	7111
BTB(Hash of PC and GHR indexed)	11.1472	3129489	2.23484	627413

Observations:

1. SAg in this case performs better than GAg and gshare which implies that local correlation is stronger than global correlation. As SAg predictions are better than Bimodal, this means branches in some local domains are not very independent of each other. FNBT is the worst because of its default assumption. The majority predictors's predictions are worse than SAg because the gshare and GAg are both promoting global correlation (suppressing SAg) which leads to wrong results. The tourament predictor is best as it outputs the prediction of the most most accurate predictor.
2. PC indexed BTB's prediction are very poor than **HASH(PC,GHR)** indexed BTB which means that the control flow is an important factor in deciding the outcome of indirect control flow branch.

BZip2 benchmark

Fast-forward count = 301000000000
Condition branches predicted = 129923090

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	46.8919	60923401
Bimodal	9.99839	12990214
SAg	10.1409	13175327
GAg	12.5105	16254008
gshare	11.3094	14693535
Hybrid SAg GAg	9.58241	12449764
Hybrid SAg GAg gshare majority	9.30161	12084941
Hybrid SAg GAg gshare tournament	9.12147	11850893

Indirect Control flows predicted = 791921

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	48.2937	382448	0.00745	59
BTB(Hash of PC and GHR indexed)	47.5236	376349	0.02702	214

Observations:

1. Again FNBT is worst. SAg, GAg and gshare - all 3 have almost same rate of misprediction rate which means global and local correlation are almost comparable. This same fact can be used to explain the comparable prediction outcomes of hybrid predictors.
2. Both the predictor's outcomes are almost comparable which means that there is not much of control flow correlation in deciding target.

GCC benchmark

Fast-forward count = 107000000000
Condition branches predicted = 133386122

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	10.5371	14055026
Bimodal	4.32138	5764116
SAg	2.70371	3606372
GAg	4.09929	5467888
gshare	3.94156	5257493
Hybrid SAg GAg	2.07025	2761428
Hybrid SAg GAg gshare majority	2.52814	3372183
Hybrid SAg GAg gshare tournament	1.87085	2495458

Indirect Control flows predicted = 7037469

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	35.5645	2502843	0.00682	480
BTB(Hash of PC and GHR indexed)	12.7023	893917	1.51383	106535

Observations:

1. FNBT is worst predictor but its prediction are much better than previous cases which means its deafult assumption is very much true. This may imply that there are many loops in this application. Again tournament predictor is best because of its design.
2. The same case as perl benchmark application i.e. control flow is a deciding factor in determining target.

MCF benchmark

Fast-forward count = 377000000000
Condition branches predicted = 178242990

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	31.9495	56947795
Bimodal	18.02	32119434
SAg	13.0502	23261046
GAg	9.28587	16551408
gshare	10.2195	18215516
Hybrid SAg GAg	8.77529	15641342
Hybrid SAg GAg gshare majority	8.68154	15474228
Hybrid SAg GAg gshare tournament	8.40325	14978202

Indirect Control flows predicted = 12556322

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	0.613492	77032	0.00007	9
BTB(Hash of PC and GHR indexed)	0.409913	51470	0.00084	105

Observations:

1. GAg predictions are better than bimodal and SAg which means global correlation is dominant. FNBT is worst and tournament predictor is best.

2. Both the predictor's outputs are comparable and very accurate. Cache misses are also negligible. This means most of the indirect control flows rarely change their target and control flow.

Soplex benchmark

Fast-forward count = 364000000000
Condition branches predicted = 103254447

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	16.9547	17506507
Bimodal	4.82514	4982167
SAg	4.01567	4146353
GAg	3.80075	3924448
gshare	3.97118	4100422
Hybrid SAg GAg	3.57653	3692923
Hybrid SAg GAg gshare majority	3.78274	3905847
Hybrid SAg GAg gshare tournament	3.57613	3692508

Indirect Control flows predicted = 6315969

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	0.00535151	338	0.00149	94
BTB(Hash of PC and GHR indexed)	0.0101964	644	0.00519	328

Observations:

1. Almost all predictors (except FNBT) have comparable performances. Tournament predictor is the best.

2. Same explanation as MCF BTB outputs.

Hmmer benchmark

Fast-forward count = 264000000000
Condition branches predicted = 144361425

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	63.9146	92268043
Bimodal	8.55505	12350185
SAg	9.12542	13173585
GAg	11.7688	16989666
gshare	10.2741	14831829
Hybrid SAg GAg	8.64264	12476639
Hybrid SAg GAg gshare majority	8.68883	12543320
Hybrid SAg GAg gshare tournament	8.35233	12057541

Indirect Control flows predicted = 201570

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	6.38041	12861	0.04911	99
BTB(Hash of PC and GHR indexed)	2.63928	5320	0.42367	854

Observations:

1. Very poor performance of FNBT which means its assumption is very inaccurate. This means forward branches are mostly taken as opposed to assumption of FNBT
2. Same explanation as MCF BTB outputs.

Omnetpp benchmark

Fast-forward count = 43000000000
Condition branches predicted = 117335262

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	34.1219	40037036
Bimodal	10.3997	12202550
SAg	5.003	5870281
GAg	12.2328	14353351
gshare	10.8435	12723228
Hybrid SAg GAg	4.11895	4832975
Hybrid SAg GAg gshare majority	5.48415	6434839
Hybrid SAg GAg gshare tournament	3.90018	4576289

Indirect Control flows predicted = 30294698

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	29.4196	8912576	0.09038	27379
BTB(Hash of PC and GHR indexed)	15.7237	4763456	5.29928	1605400

Observations:

1. SAg prediction is much better than GAg and gshare which implies the dominance of local correlation. Tournament is again best because of its best of 3 principle.
2. PC indexed BTB less accurate than hash indexed BTB which implies control flow is important in deciding targets.

Xalancbmk benchmark

Fast-forward count = 1331000000000
Condition branches predicted = 174995523

Predictor	Percentage mispredicted	No of Mispredictions
FNBT	8.16086	14281145
Bimodal	3.79514	6641318
SAg	1.98183	3468118
GAg	4.90326	8580486
gshare	4.25928	7453552
Hybrid SAg GAg	1.48806	2604039
Hybrid SAg GAg gshare majority	2.26756	3968120
Hybrid SAg GAg gshare tournament	1.35788	2376235

Indirect Control flows predicted = 33531625

BTB Predictor	% Mispredicted	Mispredictions	% Cache miss	Cache miss
BTB(PC indexed)	31.2751	10487062	6.30970	2115746
BTB(Hash of PC and GHR indexed)	34.2326	11478734	23.07599	7737754

Observations:

1. All predictors have comparable accuracy. But still SAg is slightly better than GAg which means in some regions, local correlation is dominant. FNBT's assumption is also very precise which means there are lot of backward branches. Tournament predictor is best.
2. Both predictors have comparable outcomes but hash based BTB is worse in this case. This means control flow is not very important in deciding target. Cache misses for hash indexed BTB are also very high in this case.

General Results:

1. In all cases tournament predictor is the best as it uses the best of 3 predictors to predict.
2. In most of the cases hash indexed BTB cache is better as it takes into account the control flow.