ANALYSIS ON TOURNAMENT PREDICTOR

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I. ABSTRACT:
Tournament prediction is a branch prediction technique that has revolutionized the field of computer architecture by significantly improving prediction accuracy. This technique employs a combination of local and global predictors, selecting the most accurate predictor for each branch based on historical performance. This paper provides an overview of tournament prediction, discussing its architecture, operation, advantages, and applications. Additionally, it highlights the implementation of tournament prediction in the Alpha 21264 processor and presents a detailed analysis of its effectiveness. Overall, tournament prediction emerges as a crucial tool for enhancing performance in modern processors, offering a balance between prediction accuracy and adaptability.

II. INTRODUCTION:
Branch prediction plays a pivotal role in modern computer architecture, influencing the performance and efficiency of processors. Conditional branches, which determine the flow of program execution based on certain conditions, are common in most programs. Predicting the outcome of these branches accurately can significantly improve the processor's performance by reducing the number of pipeline stalls and improving instruction throughput.

Traditional branch predictors, such as bimodal and gshare predictors, use a single prediction mechanism to guess the outcome of a branch. However, these predictors may not always be accurate, leading to mispredictions and potentially impacting performance. Tournament prediction addresses this issue by utilizing multiple predictors and selecting the best predictor for each branch based on their past performance.

Tournament prediction is a branch prediction technique that is widely used in modern processors that aims to improve prediction accuracy by using multiple predictors and selecting the best predictor for each branch based on their past performance. This technique has been widely adopted in modern processors to enhance performance by reducing the number of mispredictions.

III. OVERVIEW:
Tournament predictors use the concept of "Predicting the predictor" to select the right predictor for each branch, based on their behavior. Tournament predictors typically consist of two main components: local predictors and global predictors. Local predictors use information about the branch history of a specific instruction, while global predictors use information about the overall branch behavior of the program.
Since 2006, tournament predictors using around 30K bits have been used in processors like the Power5 and Pentium 4, achieving better accuracy at medium sizes (8K – 32K bits) and effectively utilizing a large number of prediction bits. They are the most popular form of

multilevel branch predictors, using several levels of branch-prediction tables together with an algorithm for choosing among the multiple predictors.

IV. ARCHITECTURE OF TOURNAMENT PREDICTOR:

The architecture of a tournament predictor includes the following components:

1. Local History Table: Stores the history of recent branch outcomes for each address.
2. Local Prediction Table: Uses local history as an index to make predictions.
3. Global History Register: Stores the recent global branch outcomes.
4. Global Prediction Table: Uses global history as an index to make predictions.
5. Selector Table: Decides which predictor to trust for each branch.

V. WORKING OF TOURNAMENT PREDICTOR:

The operation of tournament predictors revolves around the concept of dynamically selecting the best predictor for each branch based on their past performance. Tournament predictors typically consist of two main predictors: a local predictor and a global predictor. These predictors are combined with a selector, which determines which predictor to use for each branch. The adaptive approach allows tournament predictors to achieve higher prediction accuracy and improve overall processor performance.

1. Prediction Phase:

- Both the local and global predictors make predictions for a given branch.
- The selector then decides which predictor to use based on their past performance.
- If the selected predictor's prediction matches the actual outcome, the predictor is rewarded.
- If the prediction is incorrect, the other predictor is given a chance in the next iteration.

2. Update Phase:

- After the branch outcome is known, the predictor that made the correct prediction is rewarded.
- The selector's decision is also updated based on the outcome, favoring predictors that have made accurate predictions in the past.

3. Adaptation:

- The selector's decision-making process is dynamic, allowing it to adapt to changing branch behavior.
- If one predictor consistently outperforms the other, the selector will favor that predictor for future branches.
- This adaptive approach helps improve prediction accuracy over time.

4. Performance Evaluation:

- The performance of each predictor is continuously evaluated based on their predictions and the actual branch outcomes.
- Predictors that consistently make accurate predictions are given more weight in the selection process.
- This continuous evaluation and adaptation process allows tournament predictors to achieve higher prediction accuracy compared to traditional predictors.

VI. APPLICATIONS OF TOURNAMENT PREDICTOR:

Tournament prediction is commonly used in modern processors, including CPUs in desktops, laptops, and servers. It is also used in embedded systems and mobile devices to improve branch prediction accuracy and overall performance.

VII. TOURNAMENT PREDICTOR USED IN ALPHA 21264 :

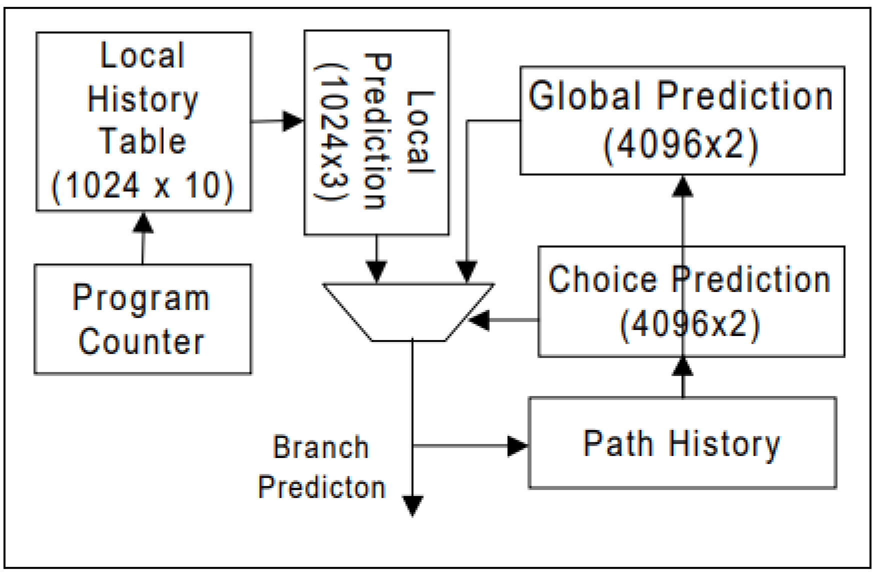

Fig 1: Tournament predictor used in Alpha 21264

VIII. RESULTS:

Warmup Instructions: 1 million
Simulation Instruction: 10 million

1) 401.bzip2 SPEC CPU2006 Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	1.50262	1.56853	1.58849	Tournament shows the highest IPC

2	Branch Prediction Accuracy	97.1115%	98.1587%	98.4082%	Tournament shows the highest accuracy
3	MPKI	4.6825	2.985	2.5804	Bimodal shows the highest MPKI
4	Average ROB Occupancy at Mispredict	35.3659	58.1229	64.3713	Tournament shows the highest ROB occupancy

2) 410.bwaves SPEC CPU2006 Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	0.713265	0.718625	0.718558	Tournament and gshare shows the highest IPC
2	Branch Prediction Accuracy	83.7541%	97.2546%	99.9559%	Tournament shows the highest accuracy
3	MPKI	4.5291	0.7654	0.0123	Tournament shows the lowest MPKI
4	Average ROB Occupancy at Mispredict	136.146	335.19	322.211	Gshare shows the highest ROB occupancy

3) 433.milc-274B Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	0.671009	0.699148	0.699148	Tournament and GShare has the highest cumulative IPC, followed by Bimodal.
2	Branch Prediction Accuracy	72.0929%	100%	100%	Tournament and GShare has the highest Branch Prediction accuracy, followed by Bimodal.
3	MPKI	11.439	0	0	Tournament predictor and Gshare has the

					lowest MPKI, followed by Bimodal.
4	Average ROB Occupancy at Mispredict	121.001	Nil	Nil	Bimodal has the highest average ROB occupancy at mispredict

4) 657.xz_s-3167B Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	0.973311	0.983738	0.989372	Tournament has the highest cumulative IPC, followed by gshare then Bimodal.
2	Branch Prediction Accuracy	92.2142%	92.2233%	92.7874%	Tournament predictor has the highest branch prediction accuracy, followed by GShare, then Bimodal.
3	MPKI	11.7607	11.7469	10.8948	Tournament predictor has the lowest MPKI, followed by GShare, then Bimodal.
4	Average ROB Occupancy at Mispredict	22.046	20.344	22.7581	Tournament has the highest average ROB occupancy at mispredict, followed by Bimodal, then gshare.

5) 429.mcf-184B Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	0.0713423	0.0745029	0.0751841	Tournament prediction achieves the highest IPC, indicating superior overall performance

2	Branch Prediction Accuracy	89.1231%	91.5752%	91.7565%	Tournament prediction exhibits the highest accuracy, reducing mispredictions effectively.
3	MPKI	26.0874	20.2063	19.7715	Tournament prediction results in the lowest MPKI, signifying better prediction efficiency
4	Average ROB Occupancy at Mispredict	21.2036	27.3748	28.9805	Although slightly higher, tournament prediction still offers competitive performance in ROB occupancy at mispredictions

6)Parsec_2.1.blackscholes Parsec Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	1.34733	1.21146	1.4196	Tournament shows the highest cumulative IPC followed by bimodal and then gshare. Indicating the best performance
2	Branch Prediction Accuracy	97.2761%	95.2751%	99.1526%	Tournament shows the highest accuracy.Indicating the reducing rate of misprediction.
3	MPKI	2.6723	4.6354	0.8314	Tournament shows the lowest MPKI. indicating the better performance among all the three.
4	Average ROB Occupancy at Mispredict	122.64	96.5669	195.661	Tournament has the highest occupancy.

7) Parsec_2.1.bodytrack Parsec Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	1.51324	1.51921	1.56636	Tournament shows the highest IPC
2	Branch Prediction Accuracy	97.3509%	97.8361%	98.43%	Tournament shows the highest accuracy
3	MPKI	2.392	1.9539	1.4176	Tournament shows the lowest MPKI
4	Average ROB Occupancy at Mispredict	73.5697	82.9359	88.2424	Tournament has the highest occupancy, indicating a more aggressive prediction.

8) Parsec_2.1.canneal Parsec Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	0.770321	0.770321	0.770321	All predictors have the same IPC
2	Branch Prediction Accuracy	100%	100%	100%	All predictors have 100% accuracy
3	MPKI	0	0	0	All predictors have 0 MPKI value.
4	Average ROB Occupancy at Mispredict	Nil	Nil	Nil	Data for ROB Occupancy is missing

9) parsec_2.1.raytrace Benchmark:

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	1.85966	1.84536	1.85085	Bimodal predictor has the highest cumulative IPC.
2	Branch Prediction Accuracy	87.2153%	89.5899%	90.7478%	Tournament predictor has the highest

					accuracy. Reducing the misprediction.
3	MPKI	2.6807	2.1828	1.94	Tournament predictor has the lowest MPKI value.
4	Average ROB Occupancy at Mispredict	74.9442	80.3257	89.0195	Tournament has the highest occupancy, indicating a more aggressive prediction.

10) parsec_2.1.swaptions Benchmark :

S.No.	Parameters	Bimodal	gshare	Tournament	Analysis
1	Cumulative IPC	1.36299	1.35871	1.38073	Tournament performs the best
2	Branch Prediction Accuracy	97.3383%	97.2298%	98.0118%	Tournament has the highest accuracy
3	MPKI	3.4535	3.5942	2.5796	Tournament has the lowest MPKI, indicating better performance.
4	Average ROB Occupancy at Mispredict	86.2757	81.1502	97.4497	Tournament has the highest occupancy, indicating a more aggressive prediction.

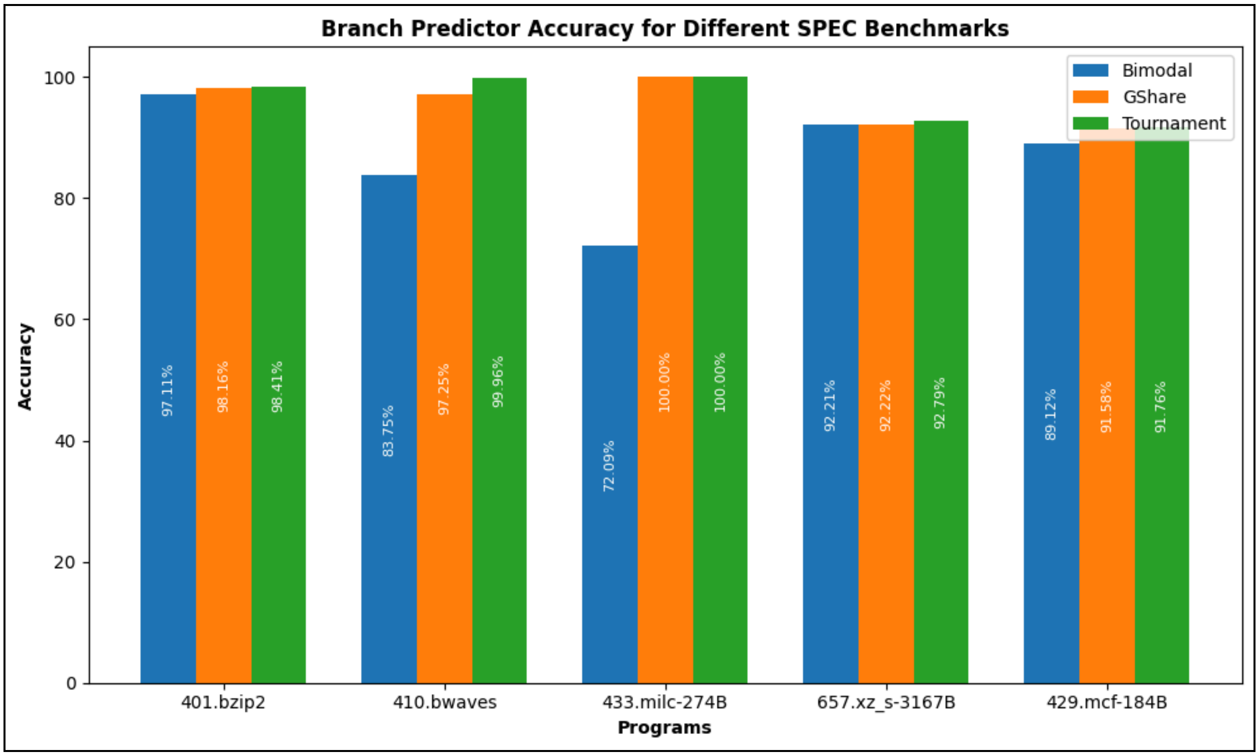

Fig 2: Bar Plot for Branch Predictor Accuracy for Different SPEC Benchmarks

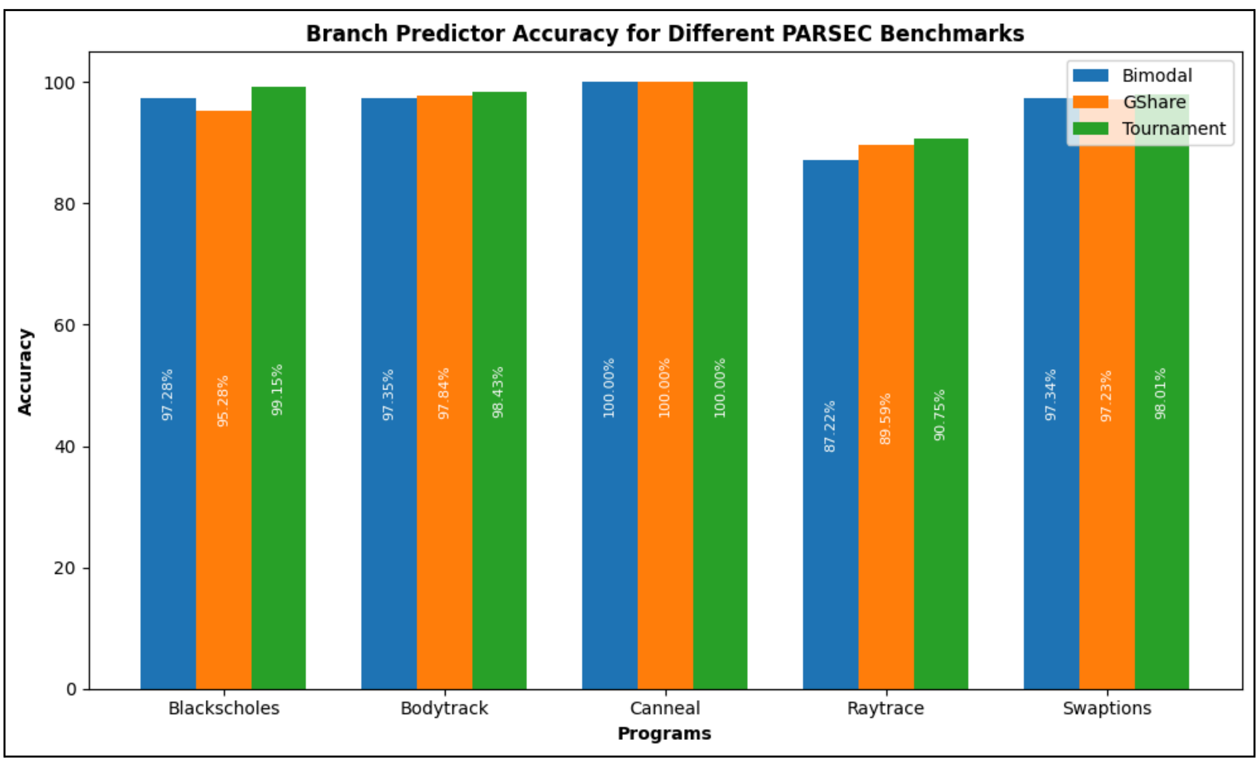

Fig 3: Bar Plot for Branch Predictor Accuracy for Different PARSPEC Benchmarks

IX. ANALYSIS:

Based on the results, the Tournament Predictor appears to outperform both the GShare and Bimodal predictors in terms of various parameters such as IPC (Instructions Per Cycle), Branch Prediction Accuracy, MPKI (Mispredictions Per Thousand Instructions), and Average ROB Occupancy at Mispredict. The Tournament Predictor is better:

1. Improved Prediction Accuracy: The Tournament Predictor achieves higher Branch Prediction Accuracy compared to both GShare and Bimodal predictors across most benchmarks. This higher accuracy indicates that the Tournament Predictor can better predict the outcome of branches, leading to fewer mispredictions and potentially higher performance.

2. Balanced Performance: The Tournament Predictor offers a balance between local and global prediction strategies. It combines the strengths of both predictors and dynamically selects the most accurate predictor for each branch. This balance allows the Tournament Predictor to perform well across a wide range of branch patterns and program types, as evidenced by its competitive performance in various benchmarks.

3. Efficient Resource Utilization: The Tournament Predictor achieves comparable or better performance with a more modest number of prediction bits compared to GShare, which requires a larger number of prediction bits for high accuracy in global branches. This efficient resource utilization makes the Tournament Predictor a more practical choice for implementation in processors.

4. Adaptability: The Tournament Predictor's adaptive nature allows it to dynamically select the best predictor for each branch based on their behavior. This adaptability helps improve prediction accuracy over time as the predictor learns from past outcomes, making it more effective in handling diverse branch patterns.

5. Overall Performance: Across the benchmarks analyzed, the Tournament Predictor often achieves the highest IPC and lowest MPKI, indicating superior overall performance compared to both GShare and Bimodal predictors. Additionally, its competitive performance in Average ROB Occupancy at Mispredict suggests that it can efficiently recover from mispredictions, further enhancing its performance.

The Tournament Predictor's combination of improved prediction accuracy, balanced performance, efficient resource utilization, adaptability, and overall performance makes it a superior choice over both GShare and Bimodal predictors for branch prediction in modern processors.

X. CONCLUSION:

Tournament prediction emerges as a crucial technique for improving branch prediction accuracy in modern processors. By employing a combination of local and global predictors and dynamically selecting the most accurate predictor for each branch, Tournament predictors can effectively reduce the number of mispredictions. This leads to improved performance across various computing applications, making them a valuable asset in enhancing the overall efficiency and speed of modern processors.

Overall, Tournament prediction stands out as a powerful and versatile technique for enhancing processor performance. The tournament predictor is a powerful and effective technique for improving branch prediction accuracy in modern processors. This balance results in improved prediction accuracy and efficient use of hardware resources, leading to enhanced overall processor performance.

References:

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[2] A. Akram and L. Sawalha, "A Survey of Computer Architecture Simulation Techniques and Tools," in IEEE Access, vol. 7, pp. 78120-78145, 2019, doi: 10.1109/ACCESS.2019.2917698.
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