Coding Assignment 3 - Cache Replacement Policy

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***Abstract*—We developed a custom DRRIP cache replacement policy combining two SRRIP policies. This policy achieved an average miss rate of 50.28%, which is below the baseline of 51.2% average miss rate. The overall storage overhead is 12.38 kB.**

I. Introduction

Dynamic Re-Reference Interval Prediction (DRRIP) [1] is an advanced cache replacement policy designed to improve cache performance by dynamically adapting to varying workload behaviors. DRRIP combines two RRIP policies and utilizes a dynamic selection mechanism to choose the better-performing policy at runtime. This report explored our design approach on DRRIP, tradeoffs, design storage overhead, and evaluation performance.

II. Design

Unlike the traditional DRRIP policy that uses 2-bit RRPV, we used 3-bit RRPV to provide more gradations about how likely a block will be re-referenced. Additionally, our custom DRRIP policy combines two SRRIP policies (instead of the usual SRRIP + BRRIP). One sets RRPV to 5 on cache miss ($SRRIP_5$), and the other sets RRPV to 6 on cache miss ($SRRIP_6$). We will explain our design choice in the rest of the report.

A. Leader Set Selection

In our custom DRRIP policy, we randomly chose 32 unique leader sets for each policy. The selected leader sets always perform the assignment replacement policy. Using these 64 total leader sets, we observe which policy has better performance using a 7-bit saturated counter.

B. Selection Mechanism

The performance is further improved by dynamically switching between the two RRIP policies for the remaining "follower" cache sets. On leader set hits, we reward the respective policy by incrementing the counter towards the policy's select region. Likewise, when a leader set has a miss we penalize by incrementing/decrementing towards the opposite policy region. When the saturated counter is 0-63, we select $SRRIP_5$, and when the saturated counter is 64-127, we select $SRRIP_6$.

III. Results & Discussion

A. Performance & Discussion

We conducted several experiments to optimize the hyperparameters such as RRPV size, install locations, ratio of install location frequency for brrip, as well as the size of the saturated counter for selection. Because the combinations of possible hyperparameters is a very large space, we treated variables independently and only tested a subset of different install locations. We found that performance increased with RRPV's range, so we stopped at the full range of 3 bits (0-7) to avoid increasing overhead too much. We then tested DRRIP with varied install RRPV values as shown in table I.

SRRIP RRPV	BRRIP RRPV's (90% / 10%)	Average Missrate
6	7 / 6	55.739%
5	6 / 5	50.355%
4	5 / 4	50.839%

TABLE I

Average missrate for SRRIP + BRRIP trials are shown for various initial RRPV values.

When we tested different values for the BRRIP stochastic selection with the optimal settings from the previous trials. We noticed the performance increased when we lowered the percentage. In fact the best performance we found was when it was completely off, simplifying the model to dynamically choosing between two SRRIP policies with different install RRPV settings of 5 or 6 ($SRRIP_5$ and $SRRIP_6$). With this model, we were able to achieve an average missrate of 50.283%. The full results for this run are listed in table II

Trace File Name	Total Access	Total Miss	Miss Rate
bzip2_10M.trace.gz	104771	19854	18.950%
graph_analytics_10M.trace.gz	142548	95094	66.710%
libquantum_10M.trace.gz	770071	425287	55.227%
mcf_10M.trace.gz	1017544	613015	60.245%
Average Miss Rate			50.283%

TABLE II

The custom DRRIP performance across all given trace files

B. Overhead

There are three components in our DRRIP implementation: RRPV array, two leader-set arrays, and a saturated counter for policy selection on follower sets, as shown in the table III. For the RRPV array, each entry has 3 bits as mentioned in the previous section, and there are 2048×16 (total number of sets$\times$number of ways) entries. Therefore, the total storage of RRPV array is 12288 Bytes. The leader-set arrays store the index of the randomly selected sets. Since there are 2048 sets in total, each entry of the leader-set arrays has 11 bits. With 64 leader-set arrays, the storage is 88 Bytes. Lastly, the saturated counter, as we mentioned in the design section, is 7 bits. By adding them together, the overall storage overhead is 12.38 kB.

IV. Conclusion

Our DRRIP cache replacement policy has shown a better miss prediction rate than the baseline. Although the use of

Component	Size
RRPV	12288 Byte
Leader Sets	88 Byte
Saturated Counter	0.875 Byte
Total	12.38 kB

TABLE III
THE STORAGE OVERHEAD OF OUR DRRIP POLICY

3-bit RRPV requires a higher storage overhead, it provides noticeable improvements in cache miss rate.

REFERENCES

[1] Aamer Jaleel, Kevin B. Theobald, Simon C. Steely, and Joel Emer. 2010. High performance cache replacement using re-reference interval prediction (RRIP). In Proceedings of the 37th annual international symposium on Computer architecture (ISCA '10). Association for Computing Machinery, New York, NY, USA, 60–71. https://doi.org/10.1145/1815961.1815971