

## 8 Prefetching [45 points]

An ETH student writes two programs A and B and runs them on 3 different toy machines, M1, M2, and M3, to determine the type of the prefetching mechanism used in each of these 3 machines. She observes programs A and B to have the following access patterns to cache blocks. Note that the addresses are *cache block addresses*, not byte addresses.

**Program A:** 27 accesses

$a, a + 1, a + 2, a + 3, a + 4, a + 8, a + 16, a + 32, a + 64,$   
 $a, a + 1, a + 2, a + 3, a + 4, a + 8, a + 16, a + 32, a + 64,$   
 $a, a + 1, a + 2, a + 3, a + 4, a + 8, a + 16, a + 32, a + 64$

**Program B:** 501 accesses

$b, b + 2, b + 4, \dots, b + 998, b + 1000$

The student is able to measure the accuracy and coverage of the prefetching mechanism in each of the machines. The following table shows her measurement results:

	Machine M1		Machine M2		Machine M3	
	Coverage	Accuracy	Coverage	Accuracy	Coverage	Accuracy
Program A	6/27	6/27	0	0	1/3	9/26
Program B	499/501	499/501	0	0	499/501	499/500

The student knows the following facts about M1, M2, and M3 machines:

- The prefetcher prefetches into a fully-associative cache whose size is 8 cache blocks. The cache employs the FIFO (First-In First-Out) replacement policy.
- The prefetchers have large enough resources to detect and store access patterns.
- Each cache block access is separated long enough in time such that all prefetches issued can complete before the next access happens.
- There are 5 different possible choices for the prefetching mechanism:
  - 1) Markov prefetcher with a correlation table of 4 entries
  - 2) Markov prefetcher with a correlation table of 10 entries
  - 3) 1st-next-block prefetcher (degree = 1) – prefetches block  $N + 1$  after seeing block  $N$
  - 4) 4th-next-block prefetcher (degree = 1) – prefetches block  $N + 4$  after seeing block  $N$
  - 5) stride prefetcher
- None of the above-mentioned prefetchers employ confidence bits.
- The prefetchers start out with an empty table when each program A and B start execution.
- The prefetcher sends only one prefetch request after a program access (i.e., prefetch degree = 1).

Determine what type of prefetching mechanism each of the above-mentioned machines use:

Machine M1:	4th-next-block prefetcher
Machine M2:	Markov prefetcher with a correlation table of 4 entries
Machine M3:	Stride prefetcher

Extra space for explanation:

We calculate the accuracy and coverage for all 5 types of prefetchers, and then we can answer what prefetcher each machine is using:

The 5 prefetechers work in the following ways when running Application A:

**Markov, table size=4:** Coverage: 0, Accuracy: 0

$a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$

**Markov, table size=10:** Coverage: 17/27, Accuracy: 17/18

$a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64$  | **unused:**  $a$

**1st-next-block:** Coverage: 4/9, Accuracy: 4/9

$a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a+5, a+9, a+17, a+33, a+65,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a+5, a+9, a+17, a+33, a+65,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64$  | **unused:**  $a+5, a+9, a+17, a+33, a+65$

**4th-next-block:** Coverage: 6/27, Accuracy: 6/27

$a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a+5, a+6, a+7, a+12, a+20, a+36, a+68,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a+5, a+6, a+7, a+12, a+20, a+36, a+68,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64$  | **unused:**  $a+5, a+6, a+7, a+12, a+20, a+36, a+68$

**Stride:** Coverage: 1/3, Accuracy: 9/26

$a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a+5, a+12, a+24, a+48, a+96,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64,$  | **unused:**  $a-64, a+5, a+12, a+24, a+48, a+96,$   
 $a, a+1, a+2, a+3, a+4, a+8, a+16, a+32, a+64$  | **unused:**  $a-64, a+5, a+12, a+24, a+48, a+96$

The 5 prefetechers work in the following ways when running Application B:

**Markov, table size=4:** Coverage: 0, Accuracy: 0

$b, b+2, b+4, b+6, b+8, b+10, \dots, b+998, b+1000$

**Markov, table size=10:** Coverage: 0, Accuracy: 0

$b, b+2, b+4, b+6, b+8, b+10, \dots, b+998, b+1000$

**1st-next-block:** Coverage: 0, Accuracy: 0

$b, b+2, b+4, b+6, b+8, b+10, \dots, b+998, b+1000$  | **unused:**  $b+1, b+3, \dots, b+999, b+1001$

**4th-next-block:** Coverage: 499/501, Accuracy: 499/501

$b, b+2, b+4, b+6, b+8, b+10, \dots, b+998, b+1000$  | **unused:**  $b+1002, b+1004$

**Stride:** Coverage: 499/501, Accuracy: 499/500

$b, b+2, b+4, b+6, b+8, b+10, \dots, b+998, b+1000$  | **unused:**  $b+1002$