CMPE 110 Computer Architecture

Fall 2016, Homework #4

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Submission Guidelines

➔ The homework must be submitted to eCommons by 11:59pm on Wednesday, November 30th ➔ Anything later is a late submission. Format

➔ The homework must be typed and submitted as a single file in PDF

Format.

➔ Homework file should be saved as cmpe110-hw1-yourcruzid.pdf.

➔ Please write your name and your UCSC email address.

➔ The homework should be "readable" without too much effort.

➔ To increase readability, use heading styles and a monospaced font (e.g. courier) for code.

Content

➔ Keep your responses coherent and organized or you may lose points.

➔ Clearly state all assumptions and provide details on how to reach a solution. An answer without explanation gets no credit.

Points

64 = 20 + 24 + 20

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1. Address Translation (20 points)

Below, you are provided with a snapshot of a 4 entry, fully associative TLB (translation lookaside buffer) and a page table.

➔ If needed, you may assume that the value of the page table register is 0

PARAMETER	VALUE
Page size	4 KB
associativity	Fully associative
Replacement policy	LRU - the entry that has not been used for the longest time will be evicted if a new entry is to be added.

Initial TLB State

TLB INTERPRETATION

COLUMN	VALUE	MEANING
VALID	0	Entry is not valid (TLB miss)
	1	Entry is valid (TLB hit)
DIRTY	0	Data has not been modified
	1	Data has been modified
LRU	1	Most recently used
	4	Least recently used

TLB TABLE

VALID	DIRTY	LRU	TAG	PHYSICAL PAGE #
1	0	2	0101	0111
1	0	3	1100	1011
1	0	1	0001	1001
1	0	4	0010	0101

INITIAL PAGE TABLE STATE

ADDRESS	VALID	PHYSICAL PAGE #
0000	0	Disk

0001	1	1001
0010	1	0101
0011	1	0010
0100	1	0101
0101	0	Disk
0110	1	0111
0111	1	0110
1000	1	1001
1001	1	1000
1010	0	Disk
1011	1	1010
1100	1	1011
1101	1	1100
...	...	...

Problems:

Show the final state of the TLB after processing the 2 virtual address sequence given below. If a page fault happens, the physical page number to be entered into the page table would be 0000; if another page fault happens, use physical page number 0001.

VIRTUAL ADDRESSES SUPPLIED
1. (MSB) 1010 1111 1110 1010 (LSB) (load instruction)
2. (MSB) 0011 1100 1001 0001 (LSB) (store instruction)

Answer:

The final TLB state is as shown below:

- The entry with tag 1100 has been evicted.
- Other LRU bits have been updated accordingly
- The fact that the last entry involves a write will cause the dirty bit to be set to 1.

VALID	DIRTY	LRU	TAG	PHYSICAL PAGE #
1	0	4	0101	0000
1	1	1	0011	0010

1	0	3	0001	0000
1	0	2	1010	0000

2. Cache Coherence (24 points)

Consider a processor with 4 cores. In each of the following parts you will fill out a table for a different cache coherence protocol. For the following memory references, show the state of the cache line containing the variable x in each core's cache. Consider the cache line only in L1.

2.A VI Protocol (8 points)

Assume for this part that we use the VI protocol for cache coherence. Fill out the table as specified at the beginning of the question.

	CORE	REQUEST TYPE	C0 $ LINE STATE	C1 $ LINE STATE	C2 $ LINE STATE	C3 $ LINE STATE
1	0	read x	V	-	-	-
2	1	read x	I	V	-	-
3	2	read x	I	I	V	-
4	3	write x	I	I	I	V
5	1	read x	I	V	I	I

2.B MSI Protocol (8 points)

Assume for this part that we use the MSI protocol for cache coherence. Fill out the table as specified at the beginning of the question.

	CORE	REQUEST TYPE	C0 $ LINE STATE	C1 $ LINE STATE	C2 $ LINE STATE	C3 $ LINE STATE
1	0	read x	S	-	-	-
2	1	read x	S	S	-	-
3	2	read x	S	S	S	-
4	3	write x	I	I	I	M
5	1	read x	I	S	I	S

2.C MESI Protocol (8 points)

Assume for this part that we use the MESI protocol for cache coherence. Fill out the table as specified at the beginning of the question.

	CORE	REQUEST TYPE	C0 $ LINE STATE	C1 $ LINE STATE	C2 $ LINE STATE	C3 $ LINE STATE
1	0	read x	E	-	-	-
2	1	read x	S	S	-	-
3	2	read x	S	S	S	-
4	3	write x	I	I	I	M
5	1	read x	I	S	I	S

3. Virtual Memory (20 points)

An ISA supports an 8-bit, byte-addressable virtual address space. The corresponding physical memory has only 256 bytes. Each page contains 32 bytes. A simple, one-level translation scheme is used and the page table resides in physical memory. The initial contents of the frames of physical memory are shown below.

Note: LRU policy is used to select pages for replacement in physical memory. Assume initial conditions where physical page number (PPN) 0 was used less recently than PPN 4, which was used less recently than PPN 6:

PARAMETER	VALUE
Address size	8 bit
Addressing type	Byte addressable - each byte of memory has its own address
Page size	32 B
Physical memory size	256 B

Physical Page Contents

Frame (Physical Page) Number	VALUE

0	8 bit
1	Page 7
2	Page 1
3	Page 4
4	Empty
5	Page 3
6	Empty
7	Page Table

Questions

A three-entry TLB that uses Least Recently-Used (LRU) replacement is added to this system. Initially, this TLB contains the entries for pages 3, 4, and 7.

Initial TLB

LRU	TAG (VPN)	PHYSICAL PAGE #
?	3	5
?	4	3
?	7	1

3.A TLB MISSES / PAGE FAULTS

For the following sequence of references, put a circle around those that generate a TLB hit and put a rectangle around those that generate a page fault. What is the hit rate of the TLB for this sequence of references? (Note: LRU policy is used to select pages for replacement in physical memory.)

Page References

3, 7, 1, 4, 10, 10, 7, 11, 11, 7, 8, 10, 8, 7, 12, 9

3.B TLB ENTRIES

At the end of this sequence, what three entries are contained in the TLB?

3.C FRAME CONTENTS

What are the contents of the 8 physical frames?

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ANSWERS:

3.A TLB MISSES / PAGE FAULTS

A)

- Initially the TLB contains the entries for the pages 3 , 4 and 7
- For the sequence of given pages, the status mark as give in the problem can be depicted as below.
- The page that is old in the list will be replaced by the algorithm.
- Since the table initially contains the map of three pages 3, 4 and 7 the page reference to them will be a page hit and any new reference will replaces the old entry of the list.
- The hit and page fault will be as given below.
  Note: ( ) means a circle and [ ] means a square
  (3),(7), [1], [4], [10], (10), [7], [11], (11), (7), [8], [10], (8), [7], [12], [9]
- Hit rate is given by $\frac{number\ of\ hit}{Total\ reference} = \frac{6}{16}$
- Page Faults: 1, 4, 10, 11, 8, 12, 9

LRU	TLB (VPN)	PHYSICAL PAGE #
?	3	5
?	4	3
?	7	1
3	3	5
7	7	1
1	1	3
4	4	5
10	10	1
10	10	1
7	7	3
11	11	5
11	11	5
7	7	3

8	8	1
10	10	5
8	8	1
7	7	3
12	12	5
9	9	1

Problem B

After the given sequence of page references, the last three pages references will be in the table, that is 7, 12, and 9.

LRU	TLB(VPN)	PHYSICAL PAGE #
7	7	3
12	12	5
9	9	1

Problem C

The last 8 page references will be there in the list.
1, 4, 11, 10, 8, 7, 12, and 9

FRAME (PHYSICAL PAGE) NUMBERS	FRAME CONTENTS
0	EMPTY
1	9
2	1
3	7
4	EMPTY
5	12
6	EMPTY

7	PAGE TABLE