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CS 219 – Assignment #10

Purpose: Become familiar with MIPS virtual memory implementation

Points: 90

Reading/References: Chapter 5

Assignment:

Virtual memory systems use a page table to track the mapping of virtual addresses to physical

addresses. The following table shows the results of a stream of virtual addresses generated on a given system. Assume 4 KB pages, a four-entry fully associative TLB and a true LRU replacement (top to bottom otherwise). If a page must be brought in from the disk, choose the lowest available page. [a, b, c → 30 pts each]

Initial Contents

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11 | 12 |
| 1 | 7 | 1 |
| 1 | 3 | 6 |
| 0 | 4 | 9 |

Page Table:

|  |  |
| --- | --- |
| valid | physical page or “disk” |
| 1 | 5 |
| 0 | disk |
| 0 | disk |
| 1 | 6 |
| 1 | 9 |
| 1 | 11 |
| 0 | disk |
| 1 | 1 |
| 0 | disk |
| 0 | disk |
| 1 | 2 |
| 1 | 12 |

1) Given the provided address stream and the initial TLB and page table entries provided, show

the final state of the system (TLB and page table) for address stream 1 and address stream 2. For each reference show if it is a hit in the TLB, page table, or a page fault.

Address Stream 1: 36863, 31272, 15789, 15000, 7193, 4096, 8912

Address Stream 2: 5356, 30964, 12300, 19136, 46502, 38110, 16653, 48480

2) Repeat exercise a) with 8 KB pages (instead of the 4KB pages).

3)Repeat exercise a) with 16KB pages (instead of the 4KB pages).

**Question #1**

1. Address Stream 1 (4 KB): 36863, 31272, 15789, 15000, 7193, 4096, 8912

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 36863 | 0x8FFF | 8 | fault, page 0 |
| 31272 | 0x7A28 | 7 | hit TLB |
| 15789 | 0x3DAD | 3 | hit TLB |
| 15000 | 0x3A98 | 3 | hit TLB |
| 7193 | 0x1C19 | 1 | fault, page 3 |
| 4096 | 0x1000 | 1 | hit TLB |
| 8912 | 0x22D0 | 2 | fault, page 4 |

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->1 | 12->3 |
| 1 | 7 | 1 |
| 1 | 3 | 6 |
| 0->1 | 4->8->2 | 9->0->4 |

Page Table:

|  |  |  |
| --- | --- | --- |
|  | valid | physical page or “disk” |
| 0 | 1 | 5 |
| 1 | 0->1 | disk->3 |
| 2 | 0->1 | disk->4 |
| 3 | 1 | 6 |
| 4 | 1 | 9 |
| 5 | 1 | 11 |
| 6 | 0 | disk |
| 7 | 1 | 1 |
| 8 | 0->1 | disk->0 |
| 9 | 0 | disk |
| 10 | 1 | 2 |
| 11 | 1 | 12 |

free: ~~0, 3, 4~~ 7, 8, 10

b) Address Stream 2 (4 KB): 5356, 30964, 12300, 19136, 46502, 38110, 16653, 48480

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 5356 | 0x14EC | 1 | fault, page 0 |
| 30964 | 0x78F4 | 7 | hit TLB |
| 12300 | 0x300C | 3 | hit TLB |
| 19136 | 0x4AC0 | 4 | hit PT |
| 46502 | 0xB5A6 | 11 | hit PT |
| 38110 | 0x94DE | 9 | faut, page 3 |
| 16653 | 0x410D | 4 | hit TLB |
| 48480 | 0xBD60 | 11 | hit TLB |

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->4 | 12->9 |
| 1 | 7->9 | 1->3 |
| 1 | 3 | 6 |
| 0->1 | 4->1->11 | 9->0->12 |

Page Table:

|  |  |  |
| --- | --- | --- |
|  | valid | physical page or “disk” |
| 0 | 1 | 5 |
| 1 | 0->1 | disk->0 |
| 2 | 0 | disk |
| 3 | 1 | 6 |
| 4 | 1 | 9 |
| 5 | 1 | 11 |
| 6 | 0 | disk |
| 7 | 1 | 1 |
| 8 | 0 | disk |
| 9 | 0->1 | disk->3 |
| 10 | 1 | 2 |
| 11 | 1 | 12 |

free: ~~0, 3,~~ 4 7, 8, 10

**Question #2**

a) Address Stream 1 (8 KB): 36863, 31272, 15789, 15000, 7193, 4096, 8912

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 36863 | 0x8FFF | 4 | hit PT |
| 31272 | 0x7A28 | 3 | hit TLB |
| 15789 | 0x3DAD | 1 | fault, page 0 |
| 15000 | 0x3A98 | 1 | TLB |
| 7193 | 0x1C19 | 0 | hit pT |
| 4096 | 0x1000 | 0 | hit TLB |
| 8912 | 0x22D0 | 1 | hit TLB |

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->1 | 12->0 |
| 1 | 7->0 | 1->5 |
| 1 | 3 | 6 |
| 0->1 | 4 | 9 |

Page Table:

|  |  |
| --- | --- |
| valid | physical page or “disk” |
| 1 | 5 |
| 0->1 | disk->0 |
| 0 | disk |
| 1 | 6 |
| 1 | 9 |
| 1 | 11 |
| 0 | disk |
| 1 | 1 |
| 0 | disk |
| 0 | diak |
| 1 | 2 |
| 1 | 12 |

**Question #2**

b) Address Stream 2 (8 KB): 5356, 30964, 12300, 19136, 46502, 38110, 16653, 48480

13 bits

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 5356 | 0x14EC | 0 | hit PT |
| 30964 | 0x78F4 | 3 | hit TLB |
| 12300 | 0x300C | 1 | fault, page 0 |
| 19136 | 0x4AC0 | 2 | fault, page 3 |
| 46502 | 0xB5A6 | 5 | hit PT |
| 38110 | 0x94DE | 4 | hit PT |
| 16653 | 0x410D | 2 | hit TLB |
| 48480 | 0xBD60 | 5 | hit TLB |

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->1 | 12->0 |
| 1 | 7->2 | 1->3 |
| 1 | 3->5 | 6->11 |
| 0->1 | 4->0->4 | 9->5->9 |

Page Table:

|  |  |  |
| --- | --- | --- |
|  | valid | physical page or “disk” |
| 0 | 1 | 5 |
| 1 | 0->1 | disk->0 |
| 2 | 0->1 | disk->3 |
| 3 | 1 | 6 |
| 4 | 1 | 9 |
| 5 | 1 | 11 |
| 6 | 0 | disk |
| 7 | 1 | 1 |
| 8 | 0 | disk |
| 9 | 0 | disk |
| 10 | 1 | 2 |
| 11 | 1 | 12 |

free: ~~0, 3,~~ 4 7, 8, 10

**Question #3**

a) Address Stream 1 (16 KB): 36863, 31272, 15789, 15000, 7193, 4096, 8912

14 bits

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 36863 | 0x8FFF | 2 | fault, page 0 |
| 31272 | 0x7A28 | 1 | fault, page 3 |
| 15789 | 0x3DAD | 0 | hit PT |
| 15000 | 0x3A98 | 0 | TLB |
| 7193 | 0x1C19 | 0 | TLB |
| 4096 | 0x1000 | 0 | TLB |
| 8912 | 0x22D0 | 0 | TLB |

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->1 | 12->3 |
| 1 | 7->0 | 1->5 |
| 1 | 3 | 6 |
| 0->1 | 4->2 | 9->0 |

Page Table:

|  |  |  |
| --- | --- | --- |
|  | valid | physical page or “disk” |
| 0 | 1 | 5 |
| 1 | 0->1 | disk->3 |
| 2 | 0->1 | disk->0 |
| 3 | 1 | 6 |
| 4 | 1 | 9 |
| 5 | 1 | 11 |
| 6 | 0 | disk |
| 7 | 1 | 1 |
| 8 | 0 | disk |
| 9 | 0 | disk |
| 10 | 1 | 2 |
| 11 | 1 | 12 |

free: ~~0, 3,~~ 4 7, 8, 10

Question #3

b) Address Stream 1 (16 KB): 36863, 31272, 15789, 15000, 7193, 4096, 8912

|  |  |  |  |
| --- | --- | --- | --- |
| Reference | Reference (hex) | tag | hit? |
| 5356 | 0x14EC | 0 | hit PT |
| 30964 | 0x78F4 | 1 | fault, page 0 |
| 12300 | 0x300C | 0 | hit TLB |
| 19136 | 0x4AC0 | 1 | hit TLB |
| 46502 | 0xB5A6 | 2 | fault, page 3 |
| 38110 | 0x94DE | 2 | TLB |
| 16653 | 0x410D | 1 | TLB |
| 48480 | 0xBD60 | 2 | TLB |

TLB:

|  |  |  |
| --- | --- | --- |
| valid | tag | physical page number |
| 1 | 11->1 | 12->0 |
| 1 | 7->2 | 1->3 |
| 1 | 3 | 6 |
| 0->1 | 4->0 | 9->5 |

Page Table:

|  |  |  |
| --- | --- | --- |
|  | valid | physical page or “disk” |
| 0 | 1 | 5 |
| 1 | 0->1 | disk->0 |
| 2 | 0->1 | disk->3 |
| 3 | 1 | 6 |
| 4 | 1 | 9 |
| 5 | 1 | 11 |
| 6 | 0 | disk |
| 7 | 1 | 1 |
| 8 | 0 | disk |
| 9 | 0 | disk |
| 10 | 1 | 2 |
| 11 | 1 | 12 |

free: ~~0, 3,~~ 4 7, 8, 10