Microprocessor & Computer Architecture (µpCA)

UE19CS252

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Microprocessor & Computer Architecture (µpCA)

Unit 3: Cache Replacement Policy

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Microprocessor & Computer Architecture (µpCA)

Syllabus

~~**Unit 1: Basic Processor Architecture and Design**~~

~~**Unit 2: Pipelined Processor and Design**~~

Unit 3: Memory

- ~~Memory Hierarchy~~
- ~~Principles of Locality~~
- ~~Cache Design Principles~~

Mapping Functions

- ~~Direct Mapping~~
- ~~Full Associative Mapping~~
- ~~Set Associative Mapping~~
- Cache Replacement Policy

Unit 4: Input/Output Device Design

Unit 5: Advanced Architecture

REPLACEMENT ALGORITHMS

- When a miss occurs, cache controller must select a cache line to be replaced with the desired data.

➢ First In First Out(FIFO):
  - Evict the page that has been in the cache the longest

➢ Least Recently Used(LRU):
  - Replace the block which is never used or used long ago

➢ Random:
  - Choose a page at random to evict from the cache.

Replacement Algorithms : Direct mapping

- No choice
- Each Block only maps to one Line
- Replace that line

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Exercise 1: Direct Mapping

Consider a Direct Mapping cache with 8 cache blocks (numbered 0-7) and the following sequence of memory block requests:
4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7
Which of the memory blocks will be present in the cache at the end of the sequence? Also, calculate the hit ratio and miss ratio.

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16	25	6,22	3,19,35	4	45	7

j mod 8

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	
Line 1	
Line 2	
Line 3	
Line 4	4
Line 5	
Line 6	
Line 7	

4	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on
j mod 8

Line 0	
Line 1	
Line 2	
Line 3	3
Line 4	4
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	
Line 1	25
Line 2	
Line 3	3
Line 4	4
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	**8**
Line 1	25
Line 2	
Line 3	3
Line 4	4
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	**8**
Line 1	25
Line 2	
Line 3	~~3,~~19
Line 4	4
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	**8**
Line 1	25
Line 2	
Line 3	~~3,~~19
Line 4	4
Line 5	
Line 6	6
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16**~~
Line 1	25
Line 2	
Line 3	~~3,~~19
Line 4	4
Line 5	
Line 6	6
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on
j mod 8

Line 0	~~**8,16**~~
Line 1	25
Line 2	
Line 3	~~3,19,~~35
Line 4	4
Line 5	
Line 6	6
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16**~~
Line 1	25
Line 2	
Line 3	~~3,19,~~35
Line 4	4
Line 5	45
Line 6	6
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16**~~
Line 1	25
Line 2	
Line 3	~~3,19,~~35
Line 4	4
Line 5	45
Line 6	~~6,~~22
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16,8**~~
Line 1	25
Line 2	
Line 3	~~3,19,~~35
Line 4	4
Line 5	45
Line 6	~~6,~~22
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16,8**~~
Line 1	25
Line 2	
Line 3	~~3,19, 35,~~3
Line 4	4
Line 5	45
Line 6	~~6,~~22
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	MISS
3	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on **j mod 8**

Line 0	~~**8,16,8,16**~~
Line 1	25
Line 2	
Line 3	~~3,19, 35,3~~
Line 4	4
Line 5	45
Line 6	~~6,~~22
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	MISS
3	MISS
16	MISS

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Exercise 1: Direct Mapping

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

8,16 | 25 | 6,22 | 3,19,35 | 4 | 45 | 22 | 7

Color is based on
j mod 8

Line 0	~~8,16,8,16~~
Line 1	25
Line 2	
Line 3	~~3, 19,35,~~ 3
Line 4	4
Line 5	45
Line 6	~~6,~~22
Line 7	7

Miss= 14 out of 17 access

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	MISS
3	MISS
16	MISS
25	HIT
7	MISS

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Exercise 2: FIFO-2 Way Set Associative

Consider a 2-way set associative cache with 8 cache blocks (numbered 0-7) and the following sequence of memory block requests:
4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7
Which of the memory blocks will be present in the cache at the end of the sequence if ***FIFO cache replacement policy is used***? Also, calculate the hit ratio and miss ratio.

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

			j mod 4
4,8,16	25,45	6,22	3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4	
Set 1		
Set 2		
Set 3		

4,8,16 25,45 6,22 3,7,19,35

4	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4	
Set 1		
Set 2		
Set 3	3	

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4	
Set 1	25	
Set 2		
Set 3	3	

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4
	8
Set 1	25
Set 2	
Set 3	3

4	MISS
3	MISS
25	MISS
8	MISS

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4
	8
Set 1	25
Set 2	
Set 3	3
	19

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4
	8
Set 1	25
Set 2	6
Set 3	3
	19

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	4
	8
Set 1	25
Set 2	6
Set 3	3
	19

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4~~ ~~16~~
	8
Set 1	25
Set 2	6
Set 3	3
	19

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4, 16~~
	8
Set 1	25
Set 2	6
Set 3	~~3,~~35
	19

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4,~~ ~~16~~
	8
Set 1	25
	45
Set 2	6
Set 3	~~3,~~35
	19

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4,~~ ~~16~~
	8
Set 1	25
	45
Set 2	6
	22
Set 3	~~3,~~35
	19

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4, 16~~
	8
Set 1	25
	45
Set 2	6
	22
Set 3	~~3,~~35
	19

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Set 0	~~4,~~ ~~16~~
	8
Set 1	25
	45
Set 2	6
	22
Set 3	~~3,~~35
	~~19,~~3

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS

4,8,16 25,45 6,22 3,7,19,35

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Exercise 2: FIFO-2 Way Set Associative

Set 0	~~4~~,~~16~~
	8
Set 1	25
	45
Set 2	6
	22
Set 3	~~3~~,~~35~~,7
	~~19~~,3

Miss= 12 out of 17 access

4,8,16 25,45 6,22 3,7,19,35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS
16	HIT
25	HIT
7	MISS

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Exercise 3: FIFO- Fully Associative

Consider a Fully Associative Mapping cache with 8 cache blocks (numbered 0-7) and the following sequence of memory block requests:
4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7
Which of the memory blocks will be present in the cache at the end of the sequence? Also, calculate the hit ratio and miss ratio.

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	
Line 1	
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	3
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	3
Line 2	25
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~4~~, 45
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,**~~ **45**
Line 1	~~**3,**~~22
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,** **45**~~
Line 1	~~**3,**~~22
Line 2	~~25,~~3
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,** **45**~~
Line 1	~~**3,**~~22
Line 2	~~25,~~3
Line 3	~~8,~~25
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS
16	HIT
25	MISS

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Exercise 3: FIFO- Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,** **45**~~
Line 1	~~**3,**~~22
Line 2	~~25~~,3
Line 3	~~8,~~25
Line 4	~~19,~~7
Line 5	6
Line 6	16
Line 7	35

Miss= 13 out of 17 access

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS
16	HIT
25	MISS
7	MISS

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Exercise 4: LRU-Fully Associative

Consider a Fully Associative Mapping cache with 8 cache blocks (numbered 0-7) and the following sequence of memory block requests:
4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7
Which of the memory blocks will be present in the cache at the end of the sequence? Also, calculate the hit ratio and miss ratio.

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	
Line 1	
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS

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Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	3
Line 2	
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS

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Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	4
Line 1	3
Line 2	25
Line 3	
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS

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Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS

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Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	**4**
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~4,~~ 45
Line 1	3
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,**~~ **45**
Line 1	~~**3,**~~22
Line 2	25
Line 3	8
Line 4	19
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,**~~ **45**
Line 1	~~**3,**~~22
Line 2	25
Line 3	8
Line 4	~~**19,**~~3
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,**~~ **45**
Line 1	~~**3,**~~22
Line 2	25
Line 3	8
Line 4	~~**19,**~~3
Line 5	6
Line 6	16
Line 7	35

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS
16	HIT
25	HIT

Microprocessor & Computer Architecture (µpCA)

Exercise 4: LRU-Fully Associative

Given 4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7

Line 0	~~**4,** **45**~~
Line 1	~~**3,**~~22
Line 2	25
Line 3	8
Line 4	~~**19,**~~3
Line 5	~~6,~~7
Line 6	16
Line 7	35

Miss= 13 out of 17 access

4	MISS
3	MISS
25	MISS
8	MISS
19	MISS
6	MISS
25	HIT
8	HIT
16	MISS
35	MISS
45	MISS
22	MISS
8	HIT
3	MISS
16	HIT
25	MISS
7	MISS

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Exercise 5: LRU-4 Way Set Associative

Consider a 4-way set associative mapping with 16 cache blocks. The memory block requests are in the order-
0, 255, 1, 4, 3, 8, 133, 159, 216, 129, 63, 8, 48, 32, 73, 92, 155
If LRU replacement policy is used, which cache block will not be present in the cache? Also, calculate the hit ratio and miss ratio.

Set 0	~~0,~~48
	~~4,~~ 32
	8
	~~216,~~92
Set 1	1
	133
	129
	73
Set 2	
Set 3	~~255,~~ 155
	3
	159
	63

0 % 4 = 0
255 % 4 = 3
1 % 4 = 1
4 % 4 = 0
3 % 4 = 3
8 % 4 = 0
133 % 4 = 1
159 % 4 = 3
216 % 4 = 0
129 % 4 = 1
63 % 4 = 3
8 % 4 = 0
48 % 4 = 0
32 % 4 = 0
73 % 4 = 1
92 % 4 = 0
155 % 4 = 3

0	MISS
255	MISS
1	MISS
4	MISS
3	MISS
8	MISS
133	MISS
159	MISS
216	MISS
129	MISS
63	MISS
8	HIT
48	MISS
32	MISS
73	MISS
92	MISS
155	MISS

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Exercise For Practice

Consider the cache has 4 blocks. For the memory references-
5, 12, 13, 17, 4, 12, 13, 17, 2, 13, 19, 13, 43, 61, 19
What is the hit ratio for the following cache replacement algorithms-

i. Fully Associative FIFO
ii. Fully Associative LRU
iii. Direct mapping
iv. 2-way set associative mapping using LRU

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Fully Associative FIFO

5, 12, 13, 17, 4, 12, 13, 17, 2, 13, 19, 13, 43, 61, 19

~~5,~~ ~~4,~~ **43**
~~12, 2,~~ 61
~~13,~~ 19,
~~17,~~ 13

HIT RATIO = 5/15

5	**MISS**
12	MISS
13	MISS
17	MISS
4	MISS
12	HIT
13	HIT
17	HIT
2	MISS
13	HIT
19	MISS
13	MISS
43	MISS
61	MISS
19	HIT

Microprocessor & Computer Architecture (µpCA)

Fully Associative LRU

5, 12, 13, 17, 4, 12, 13, 17, 2, 13, 19, 13, 43, 61, 19

~~5, 4, 2,~~
~~12,~~ 19
13,
~~17,~~ 43

HIT RATIO = 6/15

5	MISS
12	MISS
13	MISS
17	MISS
4	MISS
12	HIT
13	HIT
17	HIT
2	MISS
13	HIT
19	MISS
13	HIT
43	MISS
61	MISS
19	HIT

Direct Mapping

5, 12, 13, 17, 4, 12, 13, 17, 2, 13, 19, 13, 43, 61, 19

~~12,4,~~12
~~5,13,17, 13,17, 13,~~61
2
~~19,43,~~ 19

5%4	1
12%4	0
13%4	1
17%4	1
4%4	0
2%4	2
19%4	3
43%4	3
61%4	1

HIT RATIO = 1/15

5	Miss
12	Miss
13	Miss
17	Miss
4	Miss
12	Miss
13	Miss
17	Miss
2	Miss
13	Miss
19	Miss
13	Hit
43	Miss
61	Miss
19	Miss

Set Associative Mapping with LRU

5, 12, 13, 17, 4, 12, 13, 17, 2, 13, 19, 13, 43, 61, 19

Set 0	**12**
	~~4,~~2
Set 1	~~5,17,19,43,~~ 19
	~~13,~~ 61

5%2	1
12%2	0
13%2	1
17%2	1
4%2	0
2%2	0
19%2	1
43%2	1
61%2	1

HIT RATIO = 5/15

5	Miss
12	Miss
13	Miss
17	Miss
4	Miss
12	Hit
13	Hit
17	Hit
2	Miss
13	Hit
19	Miss
13	Hit
43	Miss
61	Miss
19	Miss

Next Session

Write Policies

THANK YOU

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