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1-
Access order – L1→ L2→ L3→ main memory.
Since data access happens only after the tag hit occurs in case of serial tags, we need to consider the data penalty only for hits. But for a miss, the data penalty can be ignored.
For a single load instruction, the memory access time for the given structure is -
.5*1 + .5*(.55*(1+3+18) + .45*(.75*(1+3+25+85) + .25*(1+3+25+440))) = 52.16875
For 2000 load instructions the total number of cycles = 2000*52.16875 = 104337.5 cycles

2- Considering a single cache module, we know that a hit results in access time of 5. If the cache is a miss, main memory is accessed and 150 cycle penalty is required for every 20% accesses. Thus AMAT is given as -
AMAT = $t_h + r_m * t_p$
AMAT = 5 + 0.2*150 = 35

3-
address bits (memory) = 8gb = $2^{33}$ B = 33

For L1 cache:
byte offset = 16B = $2^4$ B = 4
index bits = $32*2^{10}/2^4 = 2^{11}$ B = 11
tag bits = 33-4-11 = 18
tag array = $(18*2^{11})/2^{13}$ = 18/4 KB = 4.5 KB
data array = 32 KB

For L2 Cache:
byte offset = 64B = $2^6$ B = 6
index bits = $2^{20}/4*2^6 = 2^{12}$ B = 12
tag bits = 33-6-12 = 15
tag array = $(15*4*2^{12})/2^{13}$ = 30 KB
data array = 1MB = 1024KB

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4-

a- first pattern

| sequence | IDEAL | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| C | 1 | C | | | |
| A | 1 | C | A | | |
| B | 1 | C | B | | |
| D | 1 | C | B | D | |
| B | 0 | C | B | D | |
| F | 1 | C | B | D | F |
| C | 0 | C | B | D | F |
| E | 1 | C | B | D | E |
| A | 1 | A | B | D | E |
| D | 0 | A | B | D | E |
| B | 0 | A | B | D | E |
| F | 1 | A | B | F | E |
| A | 0 | A | B | F | E |
| B | 0 | A | B | F | E |
| C | 1 | C | B | F | E |
| E | 0 | C | B | F | E |
| B | 0 | C | B | F | E |
| A | 1 | A | B | F | E |
| F | 0 | A | B | F | E |
| D | 1 | A | B | D | E |
| | 11/20 = .55 | | | | |
| | 55.00% | | | | |

| sequence | LRU | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| C | 1 | C | | | |
| A | 1 | C | A | | |
| B | 1 | B | A | | |
| D | 1 | B | A | D | |
| B | 0 | B | A | D | |
| F | 1 | B | A | D | F |
| C | 1 | B | C | D | F |
| E | 1 | B | C | E | F |
| A | 1 | A | C | E | F |
| D | 1 | A | C | E | D |
| B | 1 | A | B | E | D |

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| | | | | | |
|---|---|---|---|---|---|
| F | 1 | A | B | F | D |
| A | 0 | A | B | F | D |
| B | 0 | A | B | F | D |
| C | 1 | C | B | F | D |
| E | 1 | C | B | F | E |
| B | 0 | C | B | F | E |
| A | 1 | A | B | F | E |
| F | 0 | A | B | F | E |
| D | 1 | A | B | F | D |
| | 15/20=7.5 | | | | |
| | 75.00% | | | | |

| sequence | MRU | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| C | 1 | C | | | |
| A | 1 | C | A | | |
| B | 1 | C | B | | |
| D | 1 | C | B | D | |
| B | 0 | C | B | D | |
| F | 1 | C | B | D | F |
| C | 0 | C | B | D | F |
| E | 1 | C | B | D | E |
| A | 1 | A | B | D | E |
| D | 0 | A | B | D | E |
| B | 0 | A | B | D | E |
| F | 1 | A | B | F | E |
| A | 0 | A | B | F | E |
| B | 0 | A | B | F | E |
| C | 1 | A | C | F | E |
| E | 0 | A | C | F | E |
| B | 1 | A | B | F | E |
| A | 0 | A | B | F | E |
| F | 0 | A | B | F | E |
| D | 1 | A | B | D | E |
| | 11/20 = .55 | | | | |
| | 55.00% | | | | |

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# b- second pattern

| sequence | IDEAL | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| D | 1 | | | D | |
| F | 1 | | | D | F |
| C | 1 | C | | D | F |
| B | 1 | C | B | D | F |
| A | 1 | C | A | D | F |
| A | 0 | C | A | D | F |
| F | 0 | C | A | D | F |
| C | 0 | C | A | D | F |
| D | 0 | C | A | D | F |
| D | 0 | C | A | D | F |
| A | 0 | C | A | D | F |
| B | 1 | B | A | D | F |
| A | 0 | B | A | D | F |
| B | 0 | B | A | D | F |
| C | 1 | B | C | D | F |
| E | 1 | B | C | D | E |
| B | 0 | B | C | D | E |
| A | 1 | B | A | D | E |
| B | 0 | B | A | D | E |
| D | 0 | B | A | D | E |
| | 9/20=.45 | | | | |
| | 45.00% | | | | |

| sequence | LRU | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| D | 1 | | | D | |
| F | 1 | | | D | F |
| C | 1 | C | | D | F |
| B | 1 | C | B | D | F |
| A | 1 | A | B | D | F |
| A | 0 | A | B | D | F |
| F | 0 | A | B | D | F |
| C | 1 | A | C | D | F |
| D | 0 | A | C | D | F |
| D | 0 | A | C | D | F |
| A | 0 | A | C | D | F |

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| | | | | | |
|---|---|---|---|---|---|
| B | 1 | A | B | D | F |
| A | 0 | A | B | D | F |
| B | 0 | A | B | D | F |
| C | 1 | C | B | D | F |
| E | 1 | C | B | D | E |
| B | 0 | C | B | D | E |
| A | 1 | A | B | D | E |
| B | 0 | A | B | D | E |
| D | 0 | A | B | D | E |
| | 10/20=0.5 | | | | |
| | 50.00% | | | | |

| sequence | MRU | | | | |
|---|---|---|---|---|---|
| | hit(0)/miss(1) | set1 | | set2 | |
| D | 1 | | | D | |
| F | 1 | | | D | F |
| C | 1 | C | | D | F |
| B | 1 | C | B | D | F |
| A | 1 | C | A | D | F |
| A | 0 | C | A | D | F |
| F | 0 | C | A | D | F |
| C | 0 | C | A | D | F |
| D | 0 | C | A | D | F |
| D | 0 | C | A | D | F |
| A | 0 | C | A | D | F |
| B | 1 | C | B | D | F |
| A | 1 | C | A | D | F |
| B | 1 | C | B | D | F |
| C | 0 | C | B | D | F |
| E | 1 | C | B | E | F |
| B | 0 | C | B | E | F |
| A | 1 | C | A | E | F |
| B | 1 | C | B | E | F |
| D | 1 | C | B | D | F |
| | 12/20=0.6 | | | | |
| | 60.00% | | | | |