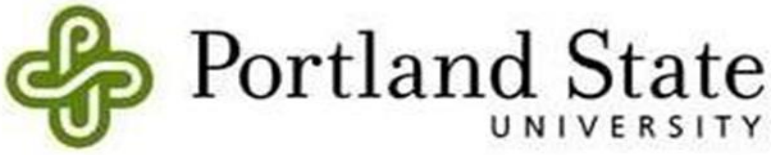


ECE 585: MICROPROCESSOR SYSTEM DESIGN – FINAL PROJECT REPORT

DESIGN AND SIMULATION OF LAST LEVEL CACHE

Project Authors:

Dhrumil Kansagra

Manak Bhavsar

Sanket Patil

Aadityasingh Chouhan

Table of Contents

1. Introduction

- As day by day the technology is advancing the hunger of performance in computer's is increasing. In modern applications there is massive requirements of information and that to demand instant response but accessing this data from primary storage can introduce latency. Caching is a key component in computing at large, to improve performance and efficiency. Caches would bridge this gap by temporarily storing frequently accessed data and instructions. Caches keep this data close to the processor so that less latency is incurred by fetching the information in comparison from the slow main memory.
- Caches are used extensively across all types of systems, from processors to web applications to databases. In hardware, CPU caches store redundant copies of frequently used main memory sections for quicker task execution. Modern processors often have several levels of caches (e.g., L1, L2 and sometimes L3), of varying sizes and speeds, acting as a compromise between cost and performance.
- Our Project involves designing and simulating the Last Level Cache(L2) for a new 32 bit processor that can be used with up to three other processors in shared memory configuration. Below is the detailed description of the specifications for the design.

2. Design Specification

Configurations for the Last Level Cache(L2):

- Total capacity: 16MB
- Cache line size: 64 bytes
- Associativity: 16 way set associative
- Replacement Policy: Pseudo- LRU
- Coherence Protocol: MESI (Modified, Exclusive, Shared, Invalid)
- Write Decision policy: Write back
- Write Miss Decision policy: Write allocate

Integrations with Higher-Level Cache(L1):

- Cache Byte Line: 64 – byte
- Write decision policy: Write Once Policy

  (First Write: Write through, Subsequent Writes: Write back)
- Associativity: 4 – way
- The cache hierarchy employs Inclusivity.
- The simulations model the LLC communications with the next level cache, bus operations performed by LLC and the snoop results reported on bus in response to operations by other

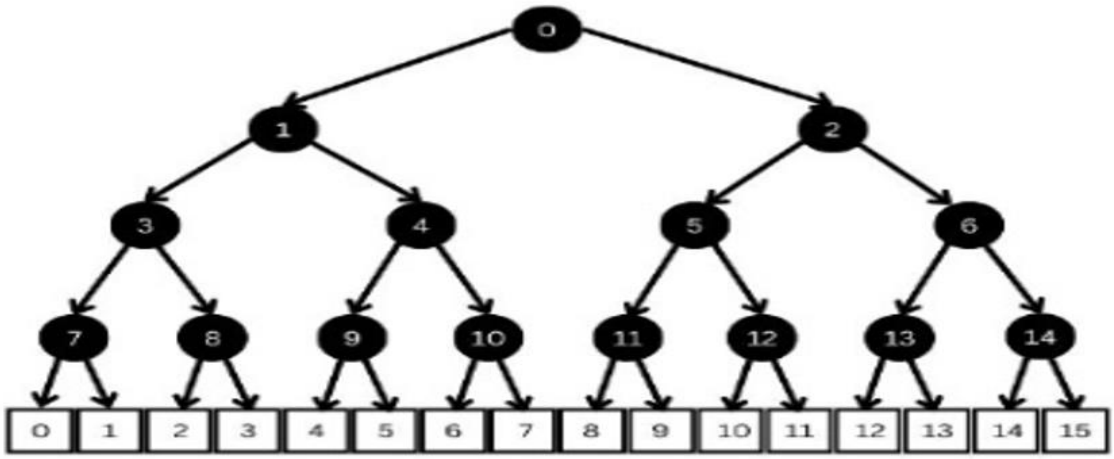
processors and their caches.

- Our design is Implemented in System Verilog and reports the following statistics for each trace file after it has finished execution.
- By tracking these statistics, we can evaluate our cache design and make any necessary improvements to optimize cache performance.
    - Number of cache reads
    - Number of cache writes
    - Number of cache hits
    - Number of cache misses
    - Cache Hit Ratio
- Out Simulation supports two modes:
    - **Mode 0:** Displays only the summary of usage statistics and responses to 9s in trace file.
    - **Mode 1:** Displays all the portions of Mode0 as well as displays bus operations, snoop results and communication message to higher level cache.

2.1 PLRU Policy

- The Pseudo-Least Recently Used (PLRU) policy is a cache-replacement policy that approximates the behavior of the Least Recently Used (LRU) algorithm while consuming less resources for tracking usage history. In this type of PLRU the tree is made up of binary trees as well as the bits that are used to store the cache line usage, this significantly reduces the overhead in maintaining a full usage history. However, when a replacement is selected, the PLRU policy chooses a cache line that is most probably least recently used using this approximation. Although not as accurate as an LRU replacement strategy, PLRU is an attractive performance/hardware complexity trade-off compared to other strategies and especially appropriate for highly associative caches.

- Below is an image of binary tree that represents the PLRU policy for 16-way associative cache and its working. The black circles are the nodes that guide the replacement process. Each leaf node corresponds to way (0 to 15). The arrow indicates the direction of traversal, determined by state of decision bits. Each decision bit stores a direction (0 or 1) to indicate which branch was last accessed. If a node is set to 0 then left child would be accessed and similarly if a node is set to 1 then right child is accessed.



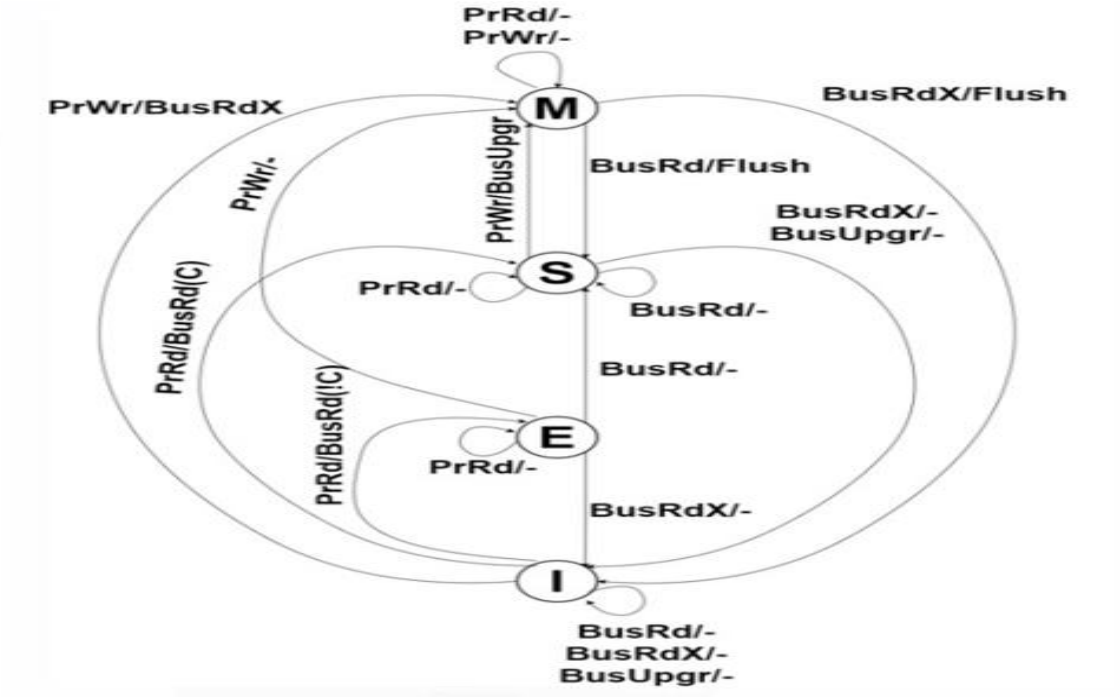
- **Updating the Tree:** When cache line is accessed decision bits along the path to that line are updated to reflect that line is now the most recently used. For instance, if way 0 is accessed then the nodes 0, 1, 3, and 7 are set to 0 to indicate way 0 is most recently used.
- **Replacement Algorithm:** when replacement is needed it starts from node 0. It flips the current value and based upon that it accesses the left or right child. The next node in the path would again flip the bit and move to the next node based on the flipped bit. This process would repeat until it reaches to a leaf node identifying the cache line to evicted.

2.2 MESI protocol

- MESI stands for Modified, Exclusive, Shared and Invalid. It is used as cache coherency protocol that ensures consistency among multiple caches in shared memory system. It defines four states for each line as per below:

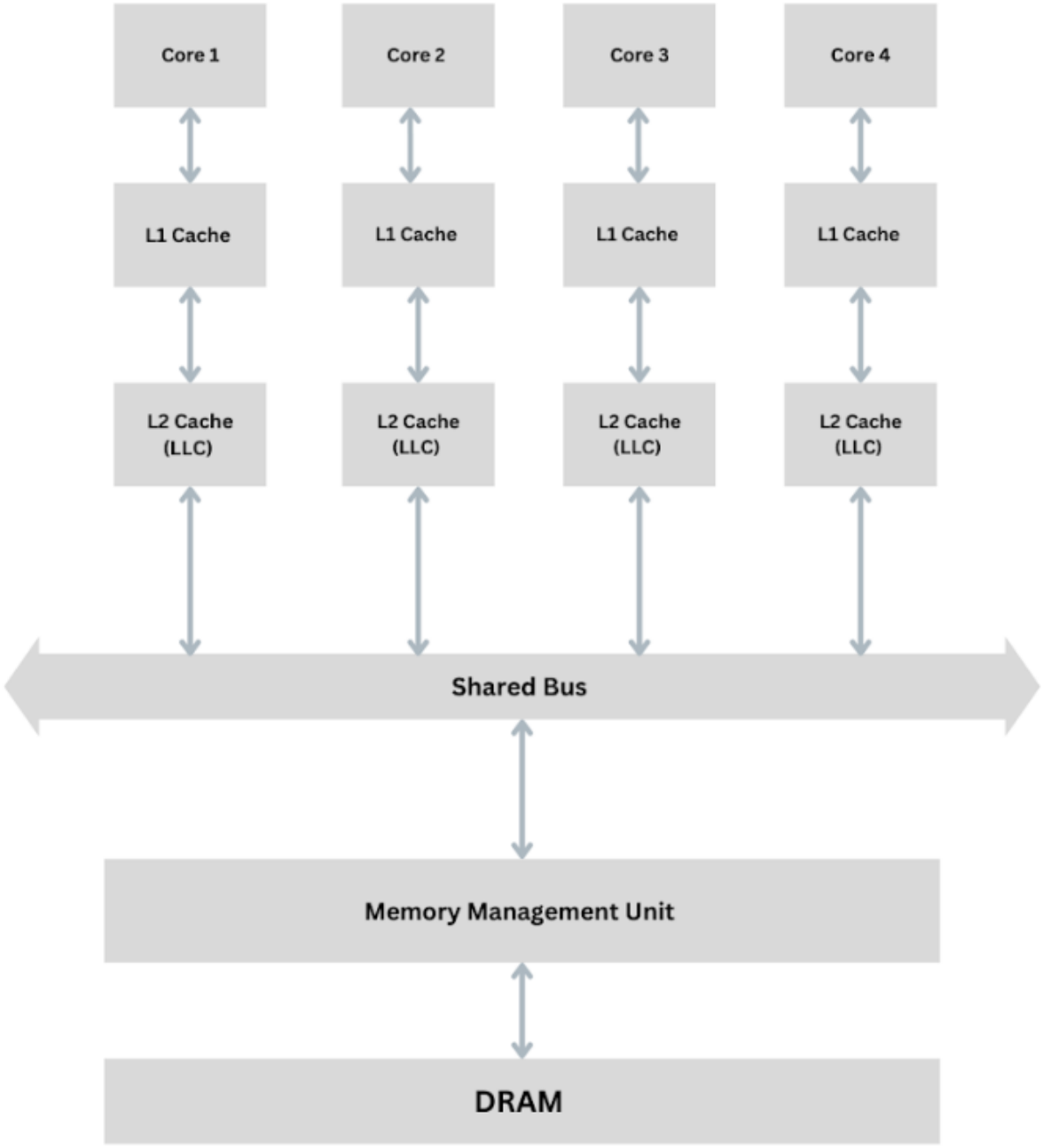
3. MESI States

- Modified (M): The cache line is updated and it only has valid copy of line. No other processor caches contain the line. The line is dirty meaning it must be written back to memory if evicted.
- Exclusive (E): The cache line contains the same value as in memory but it exists only in this cache. The cache has exclusive ownership and can modify the data without notifying others.
- Shared (S): The cache line is modified and at least one other one other processor has a copy of this line. It is consistent with the main memory, and the line is read only for all caches.
- Invalid (I): The cache line is invalid meaning it does not contain valid data and any accesses to this line would result in cache miss.
- Below is the diagram depicting the MESI protocol Processor Initiated Transactions and snooping of it.

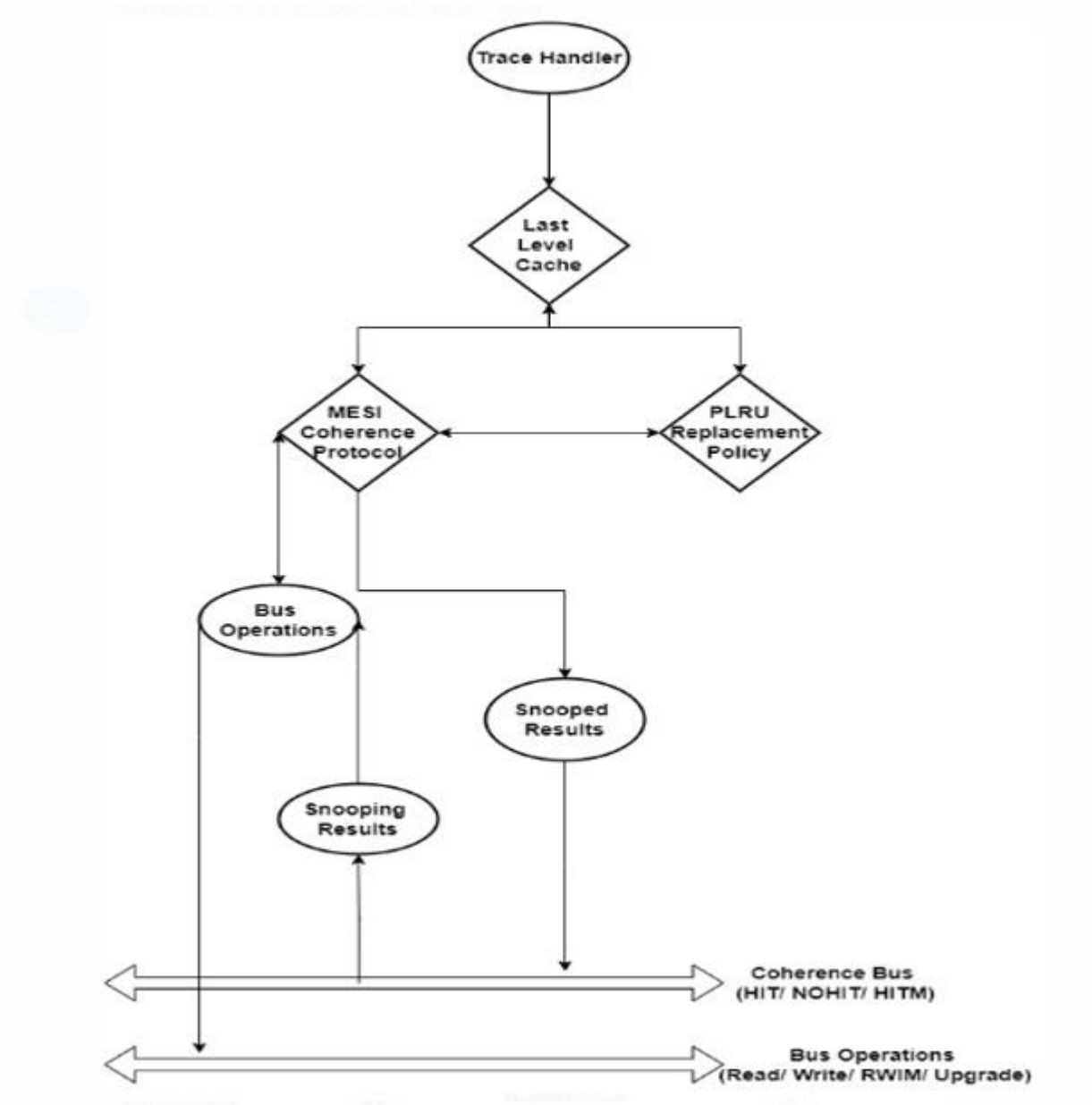


4. **Design Assumptions**
    - When the system is started all cache lines are in Invalid state.
    - Since we don't have a message from L1 to L2 whenever there is eviction/flush and Invalidate from L2, we get the line from L1 and issue a Bus operation(Specifically when a cache line in L1 is in a modified state).

5. **Multiprocessor Environment**



6. Design Architecture



7. Source Code Modules

Below are the files which are used in our project:

- **defines.sv:** The package file where all the variables are parameterized and have global scope.
- **trace_pkg.sv**: This file parses the trace file and slices the physical address.
- **cache_struct_pkg.sv**: This file contains global methods and generic logic for PLRU along with user defined data types declaration.
- **cache.sv:** This file contains MESI state Implementation, read write, snooping logic along with bus operation and communication with higher level cache(L1).

8. Test Plan:

8.1 Compulsory CPU write miss

```
1 00008000
1 006EC000
1 006FFFFF
9
```

Output:

```
# NORMAL MODE is Enabled
# ================================================================================
#                          TRACE LINE : 1
# ================================================================================
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00008000 at CACHE_MEM [SET=512][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 00008000, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 00008000
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ================================================================================
#                          TRACE LINE : 2
# ================================================================================
# * CPU Write Request
# COMPULSORY WRITE-MISS for 006ec000 at CACHE_MEM [SET=15104][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 006ec000, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 006ec000
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ================================================================================
#                          TRACE LINE : 3
# ================================================================================
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 006fffff at CACHE_MEM [SET=16383][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 006fffff, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 006fffff
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ================================================================================
#                          TRACE LINE : 4
# ================================================================================
# * Print Contents and State of Each Valid Cache Line *
# ================================================================================
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ================================================================================
# CACHE_MEM [512][0]       [000000000000000] = [0]       [MODIFIED]
# CACHE_MEM [15104][0]     [000000000000000] = [6]       [MODIFIED]
# CACHE_MEM [16383][0]     [000000000000000] = [6]       [MODIFIED]
```

```
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS                = 0
# NUMBER OF CACHE WRITES       = 3
# NUMBER OF CACHE HITS                 = 0
# NUMBER OF CACHE MISSES       = 3
# CACHE HIT RATIO            = 0.000000
# CACHE HIT RATIO PERCENTAGE           = 0.00 %
# ------------------------------------------------------------------------------
```

8.2 Conflict CPU Write Miss:

```
1 001044C8
1 002044E5
1 003044C9
1 004044DC
1 005044FA
1 006044C5
1 007044FB
1 008044EB
1 009044F0
1 00A044CE
1 00B044E3
1 00C044C6
1 00D044D9
1 00E044D9
1 00F044EA
1 0AA044CF
1 0BB044D6
1 0CC044D6
1 0DD044D6
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                              TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 001044c8 at CACHE_MEM [SET=275][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 001044c8, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 001044c8
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
```

```
#                       TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 002044e5 at CACHE_MEM [SET=275][WAY=1]
# PLRU = 000000010000000
# Bus Operation: RWIM, Address = 002044e5, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 002044e5
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 3
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 003044c9 at CACHE_MEM [SET=275][WAY=2]
# PLRU = 000000010001000
# Bus Operation: RWIM, Address = 003044c9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 003044c9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 4
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 004044dc at CACHE_MEM [SET=275][WAY=3]
# PLRU = 000000110001000
# Bus Operation: RWIM, Address = 004044dc, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 004044dc
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 5
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 005044fa at CACHE_MEM [SET=275][WAY=4]
# PLRU = 000000110001010
# Bus Operation: RWIM, Address = 005044fa, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 005044fa
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 6
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 006044c5 at CACHE_MEM [SET=275][WAY=5]
# PLRU = 000001110001010
# Bus Operation: RWIM, Address = 006044c5, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 006044c5
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 7
```

```
# ----------------------------------------------------------------------------
# * CPU Write Request *
 COMPULSORY WRITE-MISS for 007044fb at CACHE_MEM [SET=275][WAY=6]
# PLRU = 000001110011010
# Bus Operation: RWIM, Address = 007044fb, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 007044fb
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                           TRACE LINE : 8
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 008044eb at CACHE_MEM [SET=275][WAY=7]
# PLRU = 000011110011010
# Bus Operation: RWIM, Address = 008044eb, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 008044eb
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                           TRACE LINE : 9
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 009044f0 at CACHE_MEM [SET=275][WAY=8]
# PLRU = 000011110011011
# Bus Operation: RWIM, Address = 009044f0, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 009044f0
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                           TRACE LINE : 10
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00a044ce at CACHE_MEM [SET=275][WAY=9]
# PLRU = 000111110011011
# Bus Operation: RWIM, Address = 00a044ce, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00a044ce
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                           TRACE LINE : 11
# ----------------------------------------------------------------------------
#
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00b044e3 at CACHE_MEM [SET=275][WAY=10]
# PLRU = 000111110111011
# Bus Operation: RWIM, Address = 00b044e3, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00b044e3
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                           TRACE LINE : 12
```

```
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00c044c6 at CACHE_MEM [SET=275][WAY=11]
# PLRU = 001111110111011
#
# Bus Operation: RWIM, Address = 00c044c6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00c044c6
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 13
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00d044d9 at CACHE_MEM [SET=275][WAY=12]
# PLRU = 001111110111111
# Bus Operation: RWIM, Address = 00d044d9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 00d044d9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 14
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00e044d9 at CACHE_MEM [SET=275][WAY=13]
# PLRU = 011111110111111
# Bus Operation: RWIM, Address = 00e044d9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 00e044d9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 15
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00f044ea at CACHE_MEM [SET=275][WAY=14]
# PLRU = 011111111111111
# Bus Operation: RWIM, Address = 00f044ea, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00f044ea
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 16
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 0aa044cf at CACHE_MEM [SET=275][WAY=15]
# PLRU = 111111111111111
#
# Bus Operation: RWIM, Address = 0aa044cf, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0aa044cf
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
```

```
#                           TRACE LINE : 17
# ------------------------------------------------------------------------------
# * CPU Write Request *
# CONFLICT WRITE-MISS for 0bb044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 0
# PLRU = 111111101110100
# Message: L2 to L1 -> EVICTLINE, Address = 001044Xx
# Bus Operation: WRITE, Address = 001044Xx, Snoop Result = HIT
# Bus Operation: RWIM, Address = 0bb044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0bb044d6
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 18
# ------------------------------------------------------------------------------
# * CPU Write Request *
# CONFLICT WRITE-MISS for 0cc044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 8
# PLRU = 111011101010001
# Message: L2 to L1 -> EVICTLINE, Address = 009044Xx
# Bus Operation: WRITE, Address = 009044Xx, Snoop Result = HIT
# Bus Operation: RWIM, Address = 0cc044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0cc044d6
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 19
# ------------------------------------------------------------------------------
# * CPU Write Request *
# CONFLICT WRITE-MISS for 0dd044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 4
# PLRU = 111010101000010
# Message: L2 to L1 -> EVICTLINE, Address = 005044Xx
# Bus Operation: WRITE, Address = 005044Xx, Snoop Result = HIT
# Bus Operation: RWIM, Address = 0dd044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0dd044d6
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 20
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [275][0]      [111010101000010] = [bb]    [MODIFIED]
# CACHE_MEM [275][1]      [111010101000010] = [2]     [MODIFIED]
# CACHE_MEM [275][2]      [111010101000010] = [3]     [MODIFIED]
# CACHE_MEM [275][3]      [111010101000010] = [4]     [MODIFIED]
# CACHE_MEM [275][4]      [111010101000010] = [dd]    [MODIFIED]
# CACHE_MEM [275][5]      [111010101000010] = [6]     [MODIFIED]
```

```
# CACHE_MEM [275][6]    [111010101000010] = [7]    [MODIFIED]
# CACHE_MEM [275][7]    [111010101000010] = [8]    [MODIFIED]
# CACHE_MEM [275][8]    [111010101000010] = [cc]   [MODIFIED]
# CACHE_MEM [275][9]    [111010101000010] = [a]    [MODIFIED]
# CACHE_MEM [275][10]   [111010101000010] = [b]    [MODIFIED]
# CACHE_MEM [275][11]   [111010101000010] = [c]    [MODIFIED]
# CACHE_MEM [275][12]   [111010101000010] = [d]    [MODIFIED]
# CACHE_MEM [275][13]   [111010101000010] = [e]    [MODIFIED]
# CACHE_MEM [275][14]   [111010101000010] = [f]    [MODIFIED]
# CACHE_MEM [275][15]   [111010101000010] = [aa]   [MODIFIED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS              = 0
# NUMBER OF CACHE WRITES     = 19
# NUMBER OF CACHE HITS               = 0
# NUMBER OF CACHE MISSES     = 19
# CACHE HIT RATIO                    = 0.000000
# CACHE HIT RATIO PERCENTAGE         = 0.00 %
# ------------------------------------------------------------------------------
```

8.3 **CPU Write Hit Test**

```
1 00008000
1 00008000
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00008000 at CACHE_MEM [SET=512][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 00008000, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 00008000
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 0 = 0
# 1 - WRITE-HIT for 00008000 at CACHE_MEM [SET=512][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 00008000
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
```

```
  # ------------------------------------------------------------------------------
  #                            TRACE LINE : 3
  # ------------------------------------------------------------------------------
  # * Print Contents and State of Each Valid Cache Line *
  # ------------------------------------------------------------------------------
  #               CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
  # ------------------------------------------------------------------------------
  # CACHE_MEM [512][0]      [000000000000000] = [0]      [MODIFIED]
  # ------------------------------------------------------------------------------
  #                               SUMMARY
  # ------------------------------------------------------------------------------
  # NUMBER OF CACHE READS                = 0
  # NUMBER OF CACHE WRITES     = 2
  # NUMBER OF CACHE HITS                 = 1
  # NUMBER OF CACHE MISSES     = 1
  # CACHE HIT RATIO                      = 0.500000
  # CACHE HIT RATIO PERCENTAGE           = 50.00 %
# ------------------------------------------------------------------------------
```

8.4 CPU Read Compulsory Miss

```
0 00008000
0 00254002
9
```

Output

```
  # NORMAL MODE is Enabled
  #
  # ------------------------------------------------------------------------------
  #                            TRACE LINE : 1
  # ------------------------------------------------------------------------------
  # * CPU Read Request *
  # COMPULSORY READ-MISS for 00008000 at CACHE_MEM [SET=512][WAY=0]
  # PLRU = 000000000000000
  # Bus Operation: READ, Address = 00008000, Snoop Result = HIT
  # Message: L2 to L1 -> SENDLINE, Address = 00008000
  # PREVIOUS MESI STATE = INVALID
  # CURRENT MESI STATE = SHARED
  # ------------------------------------------------------------------------------
  #                            TRACE LINE : 2
  # ------------------------------------------------------------------------------
  # * CPU Read Request *
  # COMPULSORY READ-MISS for 00254002 at CACHE_MEM [SET=5376][WAY=0]
  # PLRU = 000000000000000
  # Bus Operation: READ, Address = 00254002, Snoop Result = NOHIT
  # Message: L2 to L1 -> SENDLINE, Address = 00254002
  # PREVIOUS MESI STATE = INVALID
  # CURRENT MESI STATE = EXCLUSIVE
  # ------------------------------------------------------------------------------
```

```
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [512][0]      [000000000000000] = [0]      [SHARED]
# CACHE_MEM [5376][0]     [000000000000000] = [2]      [EXCLUSIVE]
# ------------------------------------------------------------------------------
#                             SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS               = 2
# NUMBER OF CACHE WRITES     = 0
# NUMBER OF CACHE HITS                = 0
# NUMBER OF CACHE MISSES     = 2
# CACHE HIT RATIO                     = 0.000000
# CACHE HIT RATIO PERCENTAGE          = 0.00 %
# ------------------------------------------------------------------------------
```

8.5 CPU Read Conflict MISS

```
0 001044C8
0 002044E5
0 003044C9
0 004044DC
0 005044FA
0 006044C5
0 007044FB
0 008044EB
0 009044F0
0 00A044CE
0 00B044E3
0 00C044C6
0 00D044D9
0 00E044D9
0 00F044EA
0 0AA044CF
0 0BB044D6
0 0CC044D6
0 0DD044D6
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
```

```
# * CPU Read Request *
# COMPULSORY READ-MISS for 001044c8 at CACHE_MEM [SET=275][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 001044c8, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 001044c8
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 002044e5 at CACHE_MEM [SET=275][WAY=1]
# PLRU = 000000010000000
# Bus Operation: READ, Address = 002044e5, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 002044e5
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 3
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 003044c9 at CACHE_MEM [SET=275][WAY=2]
# PLRU = 000000010001000
# Bus Operation: READ, Address = 003044c9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 003044c9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 4
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 004044dc at CACHE_MEM [SET=275][WAY=3]
# PLRU = 000000110001000
# Bus Operation: READ, Address = 004044dc, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 004044dc
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                           TRACE LINE : 5
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 005044fa at CACHE_MEM [SET=275][WAY=4]
# PLRU = 000000110001010
# Bus Operation: READ, Address = 005044fa, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 005044fa
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                           TRACE LINE : 6
# ------------------------------------------------------------------------------
# * CPU Read Request *
```

```
# COMPULSORY READ-MISS for 006044c5 at CACHE_MEM [SET=275][WAY=5]
# PLRU = 000001110001010
# Bus Operation: READ, Address = 006044c5, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 006044c5
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 7
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 007044fb at CACHE_MEM [SET=275][WAY=6]
# PLRU = 000001110011010
# Bus Operation: READ, Address = 007044fb, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 007044fb
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 8
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 008044eb at CACHE_MEM [SET=275][WAY=7]
# PLRU = 000011110011010
# Bus Operation: READ, Address = 008044eb, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 008044eb
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 9
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 009044f0 at CACHE_MEM [SET=275][WAY=8]
# PLRU = 000011110011011
# Bus Operation: READ, Address = 009044f0, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 009044f0
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 10
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00a044ce at CACHE_MEM [SET=275][WAY=9]
# PLRU = 000111110011011
# Bus Operation: READ, Address = 00a044ce, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00a044ce
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 11
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00b044e3 at CACHE_MEM [SET=275][WAY=10]
```

```
# PLRU = 000111110111011
# Bus Operation: READ, Address = 00b044e3, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00b044e3
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 12
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00c044c6 at CACHE_MEM [SET=275][WAY=11]
# PLRU = 001111110111011
# Bus Operation: READ, Address = 00c044c6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00c044c6
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 13
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00d044d9 at CACHE_MEM [SET=275][WAY=12]
# PLRU = 001111110111111
# Bus Operation: READ, Address = 00d044d9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 00d044d9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 14
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00e044d9 at CACHE_MEM [SET=275][WAY=13]
# PLRU = 011111110111111
# Bus Operation: READ, Address = 00e044d9, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 00e044d9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 15
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00f044ea at CACHE_MEM [SET=275][WAY=14]
# PLRU = 011111111111111
# Bus Operation: READ, Address = 00f044ea, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00f044ea
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 16
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 0aa044cf at CACHE_MEM [SET=275][WAY=15]
# PLRU = 111111111111111
```

```
# Bus Operation: READ, Address = 0aa044cf, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0aa044cf
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                              TRACE LINE : 17
# ------------------------------------------------------------------------------
# * CPU Read Request *
# CONFLICT READ-MISS for 0bb044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 0
# PLRU = 111111101110100
# Message: L2 to L1 -> EVICTLINE, Address = 001044Xx
# Bus Operation: WRITE, Address = 001044Xx, Snoop Result = HIT
# Bus Operation: READ, Address = 0bb044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0bb044d6
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                              TRACE LINE : 18
# ------------------------------------------------------------------------------
# * CPU Read Request *
# CONFLICT READ-MISS for 0cc044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 8
# PLRU = 111011101010001
# Message: L2 to L1 -> EVICTLINE, Address = 009044Xx
# Bus Operation: WRITE, Address = 009044Xx, Snoop Result = HIT
# Bus Operation: READ, Address = 0cc044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0cc044d6
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                              TRACE LINE : 19
# ------------------------------------------------------------------------------
# * CPU Read Request *
# CONFLICT READ-MISS for 0dd044d6 at CACHE_MEM [SET=275][WAY=0]
# Targeted Eviction at WAY = 4
# PLRU = 111010101000010
# Message: L2 to L1 -> EVICTLINE, Address = 005044Xx
# Bus Operation: WRITE, Address = 005044Xx, Snoop Result = HIT
# Bus Operation: READ, Address = 0dd044d6, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 0dd044d6
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                              TRACE LINE : 20
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#               CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [275][0]      [111010101000010] = [bb]     [SHARED]
```

```
# CACHE_MEM [275][1]      [111010101000010] = [2]      [SHARED]
# CACHE_MEM [275][2]      [111010101000010] = [3]      [SHARED]
# CACHE_MEM [275][3]      [111010101000010] = [4]      [SHARED]
# CACHE_MEM [275][4]      [111010101000010] = [dd]     [EXCLUSIVE]
# CACHE_MEM [275][5]      [111010101000010] = [6]      [SHARED]
# CACHE_MEM [275][6]      [111010101000010] = [7]      [EXCLUSIVE]
# CACHE_MEM [275][7]      [111010101000010] = [8]      [EXCLUSIVE]
# CACHE_MEM [275][8]      [111010101000010] = [cc]     [SHARED]
# CACHE_MEM [275][9]      [111010101000010] = [a]      [EXCLUSIVE]
# CACHE_MEM [275][10]     [111010101000010] = [b]      [EXCLUSIVE]
# CACHE_MEM [275][11]     [111010101000010] = [c]      [EXCLUSIVE]
# CACHE_MEM [275][12]     [111010101000010] = [d]      [SHARED]
# CACHE_MEM [275][13]     [111010101000010] = [e]      [SHARED]
# CACHE_MEM [275][14]     [111010101000010] = [f]      [EXCLUSIVE]
# CACHE_MEM [275][15]     [111010101000010] = [aa]     [EXCLUSIVE]

# ------------------------------------------------------------------------------
#                                SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS                = 19
# NUMBER OF CACHE WRITES     = 0
# NUMBER OF CACHE HITS                 = 0
# NUMBER OF CACHE MISSES     = 19
# CACHE HIT RATIO                      = 0.000000
# CACHE HIT RATIO PERCENTAGE           = 0.00 %
# ------------------------------------------------------------------------------
```

8.6 CPU Read HIT

```
0 006EC001
0 006EC001
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                        TRACE LINE : 1
# ------------------------------------------------------------------------------

# * CPU Read Request *
# COMPULSORY READ-MISS for 006ec001 at CACHE_MEM [SET=15104][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 006ec001, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 006ec001
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                        TRACE LINE : 2
```

```
# ------------------------------------------------------------------------------
# * CPU Read Request *
# TAG MATCHED! 6 = 6
# READ-HIT for 006ec001 at CACHE_MEM [SET=15104][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 006ec001
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [15104][0]  [000000000000000] = [6]        [SHARED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS        =  2
# NUMBER OF CACHE WRITES       = 0
# NUMBER OF CACHE HITS              =        1
# NUMBER OF CACHE MISSES       =             1
# CACHE HIT RATIO              =        0.500000
# CACHE HIT RATIO PERCENTAGE   =     50.00 %
```

Test Cases for PLRU : We have tested PLRU with hits in between to understand that the eviction is working as expected and also not as true LRU.

8.7 Eviction With Cache HIT In between:

```
0 00185D42
0 00285D42
1 00385D42
0 00485D40
0 00585D42
0 00685D40
1 00785D42
0 01785D42
0 00985D42
1 00A85D42
0 00B85D42
0 10985D42
1 00385D42
0 00E85D42
0 00F85D42
1 00485D40
```

0 A0A85D42
1 B0B85D42
0 C0C85D42
9

Output

```
# NORMAL MODE is Enabled

# ------------------------------------------------------------------------------
#                        TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00185d42 at CACHE_MEM [SET=8565][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 00185d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00185d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                        TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00285d42 at CACHE_MEM [SET=8565][WAY=1]
# PLRU = 000000010000000
# Bus Operation: READ, Address = 00285d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00285d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                        TRACE LINE : 3
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00385d42 at CACHE_MEM [SET=8565][WAY=2]
# PLRU = 000000010001000
# Bus Operation: RWIM, Address = 00385d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00385d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                        TRACE LINE : 4
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00485d40 at CACHE_MEM [SET=8565][WAY=3]
# PLRU = 000000110001000
# Bus Operation: READ, Address = 00485d40, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 00485d40
# PREVIOUS MESI STATE = INVALID
```

```
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 5
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00585d42 at CACHE_MEM [SET=8565][WAY=4]
# PLRU = 000000110001010
# Bus Operation: READ, Address = 00585d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00585d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 6
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00685d40 at CACHE_MEM [SET=8565][WAY=5]
# PLRU = 000001110001010
# Bus Operation: READ, Address = 00685d40, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 00685d40
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 7
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00785d42 at CACHE_MEM [SET=8565][WAY=6]
# PLRU = 000001110011010
# Bus Operation: RWIM, Address = 00785d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00785d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 8
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 01785d42 at CACHE_MEM [SET=8565][WAY=7]
# PLRU = 000011110011010
# Bus Operation: READ, Address = 01785d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 01785d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 9
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00985d42 at CACHE_MEM [SET=8565][WAY=8]
# PLRU = 000011110011011
# Bus Operation: READ, Address = 00985d42, Snoop Result = NOHIT
```

```
# Message: L2 to L1 -> SENDLINE, Address = 00985d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 10
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 00a85d42 at CACHE_MEM [SET=8565][WAY=9]
# PLRU = 000111110011011
# Bus Operation: RWIM, Address = 00a85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00a85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 11
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00b85d42 at CACHE_MEM [SET=8565][WAY=10]
# PLRU = 000111110111011
# Bus Operation: READ, Address = 00b85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00b85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 12
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 10985d42 at CACHE_MEM [SET=8565][WAY=11]
# PLRU = 001111110111011
# Bus Operation: READ, Address = 10985d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 10985d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 13
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 3 = 3
# 1 - WRITE-HIT for 00385d42 at CACHE_MEM [SET=8565][WAY=2]
# PLRU = 001111010111000
# Message: L2 to L1 -> SENDLINE, Address = 00385d42
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 14
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00e85d42 at CACHE_MEM [SET=8565][WAY=12]
```

```
# PLRU = 001111010111101
# Bus Operation: READ, Address = 00e85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00e85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 15
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 00f85d42 at CACHE_MEM [SET=8565][WAY=13]
# PLRU = 011111010111101
# Bus Operation: READ, Address = 00f85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 00f85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 16
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 4 = 4
# 1 - WRITE-HIT for 00485d40 at CACHE_MEM [SET=8565][WAY=3]
# PLRU = 011111110111100
# Message: L2 to L1 -> SENDLINE, Address = 00485d40
# Bus Operation: INVALIDATE, Address = 00485d40, Snoop Result = HIT
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 17
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for a0a85d42 at CACHE_MEM [SET=8565][WAY=14]
# PLRU = 011111111111101
# Bus Operation: READ, Address = a0a85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = a0a85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                       TRACE LINE : 18
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for b0b85d42 at CACHE_MEM [SET=8565][WAY=15]
# PLRU = 111111111111101
# Bus Operation: RWIM, Address = b0b85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = b0b85d42
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 19
```

```
# ----------------------------------------------------------------------------
# * CPU Read Request *
# CONFLICT READ-MISS for c0c85d42 at CACHE_MEM [SET=8565][WAY=0]
# Targeted Eviction at WAY = 4
# PLRU = 111110111101110
# Message: L2 to L1 -> EVICTLINE, Address = 00585dXx
# Bus Operation: WRITE, Address = 00585dXx, Snoop Result = HIT
# Bus Operation: READ, Address = c0c85d42, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = c0c85d42
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = EXCLUSIVE
# ----------------------------------------------------------------------------
#                          TRACE LINE : 20
# ----------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ----------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ----------------------------------------------------------------------------
# CACHE_MEM [8565][0]    [111110111101110] = [1]          [EXCLUSIVE]
# CACHE_MEM [8565][1]    [111110111101110] = [2]          [EXCLUSIVE]
# CACHE_MEM [8565][2]    [111110111101110] = [3]          [MODIFIED]
# CACHE_MEM [8565][3]    [111110111101110] = [4]          [MODIFIED]
# CACHE_MEM [8565][4]    [111110111101110] = [c0c]        [EXCLUSIVE]
# CACHE_MEM [8565][5]    [111110111101110] = [6]          [SHARED]
# CACHE_MEM [8565][6]    [111110111101110] = [7]          [MODIFIED]
# CACHE_MEM [8565][7]    [111110111101110] = [17]         [EXCLUSIVE]
# CACHE_MEM [8565][8]    [111110111101110] = [9]          [EXCLUSIVE]
# CACHE_MEM [8565][9]    [111110111101110] = [a]          [MODIFIED]
# CACHE_MEM [8565][10]   [111110111101110] = [b]          [EXCLUSIVE]
# CACHE_MEM [8565][11]   [111110111101110] = [109]        [EXCLUSIVE]
# CACHE_MEM [8565][12]   [111110111101110] = [e]          [EXCLUSIVE]
# CACHE_MEM [8565][13]   [111110111101110] = [f]          [EXCLUSIVE]
# CACHE_MEM [8565][14]   [111110111101110] = [a0a]        [EXCLUSIVE]
# CACHE_MEM [8565][15]   [111110111101110] = [b0b]        [MODIFIED]
# ----------------------------------------------------------------------------
#                             SUMMARY
# ----------------------------------------------------------------------------
# NUMBER OF CACHE READS                    = 13
# NUMBER OF CACHE WRITES          = 6
# NUMBER OF CACHE HITS            = 2
# NUMBER OF CACHE MISSES          = 17
# CACHE HIT RATIO             = 0.105263
# CACHE HIT RATIO PERCENTAGE      = 10.53 %
# ----------------------------------------------------------------------------
```

MESI Protocol Test Cases

Processor Initiated Transactions

8.8 Invalid to Exclusive to Exclusive

0 56F00C92
0 56F00C92
9

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 56f00c92 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 56f00c92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 56f00c92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Read Request *
# TAG MATCHED! 56f = 56f
# READ-HIT for 56f00c92 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 56f00c92
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [50][0]        [000000000000000] = [56f]       [EXCLUSIVE]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS                    = 2
# NUMBER OF CACHE WRITES          = 0
# NUMBER OF CACHE HITS            = 1
# NUMBER OF CACHE MISSES          = 1
# CACHE HIT RATIO             = 0.500000
# CACHE HIT RATIO PERCENTAGE      = 50.00 %
# ------------------------------------------------------------------------------
```

8.9 Invalid to Exclusive to Modified State

0 56F00C92
1 56F00C92
9

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 56f00c92 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 56f00c92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 56f00c92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 56f = 56f
# 1 - WRITE-HIT for 56f00c92 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 56f00c92
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [50][0]     [000000000000000] = [56f]      [MODIFIED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 1
# NUMBER OF CACHE WRITES        = 1
# NUMBER OF CACHE HITS          = 1
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.500000
# CACHE HIT RATIO PERCENTAGE    = 50.00 %
# ------------------------------------------------------------------------------
```

8.10 Invalid to Modified to Modified

1 56F00A92
1 56F00A92
9
Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 56f00a92 at CACHE_MEM [SET=42][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 56f00a92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 56f00a92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 56f = 56f
# 1 - WRITE-HIT for 56f00a92 at CACHE_MEM [SET=42][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 56f00a92
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [42][0]        [000000000000000] = [56f]       [MODIFIED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS                    = 0
# NUMBER OF CACHE WRITES          = 2
# NUMBER OF CACHE HITS            = 1
# NUMBER OF CACHE MISSES          = 1
# CACHE HIT RATIO             = 0.500000
# CACHE HIT RATIO PERCENTAGE      = 50.00 %
# ------------------------------------------------------------------------------
```

8.11 Invalid to Shared to Modified

0 3A8F5EEC
1 3A8F5EEC
9

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 3a8f5eec at CACHE_MEM [SET=15739][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 3a8f5eec, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 3a8f5eec
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 3a8 = 3a8
# 1 - WRITE-HIT for 3a8f5eec at CACHE_MEM [SET=15739][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 3a8f5eec
# Bus Operation: INVALIDATE, Address = 3a8f5eec, Snoop Result = HIT
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [15739][0]  [000000000000000] = [3a8]      [MODIFIED]
# ------------------------------------------------------------------------------
#                             SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS        = 1
# NUMBER OF CACHE WRITES       = 1
# NUMBER OF CACHE HITS         = 1
# NUMBER OF CACHE MISSES       = 1
# CACHE HIT RATIO              = 0.500000
# CACHE HIT RATIO PERCENTAGE   = 50.00 %
```

```
# ------------------------------------------------------------------------------
```

8.12 Invalid to Shared to Shared

```
0 56F00C90
0 56F00C91
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 56f00c90 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 56f00c90, Snoop Result = HIT
# Message: L2 to L1 -> SENDLINE, Address = 56f00c90
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Read Request *
# TAG MATCHED! 56f = 56f
# READ-HIT for 56f00c91 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 56f00c91
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [50][0]    [000000000000000] = [56f]      [SHARED]
# ------------------------------------------------------------------------------
#                             SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 2
# NUMBER OF CACHE WRITES        = 0
# NUMBER OF CACHE HITS          = 1
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.500000
```

```
# CACHE HIT RATIO PERCENTAGE     = 50.00 %
# ------------------------------------------------------------------------------
```

Snooping Operations

8.13 Snoop Read Intent to Modify

```
0 AAA00C92
5 AAA00C92
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
# TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for aaa00c92 at CACHE_MEM [SET=50][WAY=0]
# PLRU = 000000000000000
#
# Bus Operation: READ, Address = aaa00c92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = aaa00c92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * Snoop Read with Intent to Modify Request *
# Snoop Result: Address = aaa00c92, Snoop Result = HIT
# Message: L2 to L1 -> GETLINE, Address = aaa00c92
# Bus Operation: WRITE, Address = aaa00c92, Snoop Result = NOHIT
# Message: L2 to L1 -> INVALIDATELINE, Address = aaa00c92
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = INVALID
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 1
# NUMBER OF CACHE WRITES        = 0
```

```
# NUMBER OF CACHE HITS          = 0
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.000000
# CACHE HIT RATIO PERCENTAGE    = 0.00 %
# ------------------------------------------------------------------------------
```

8.14 Snoop Read

```
0 BBBAFF92
3 BBBAFF92
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for bbbaff92 at CACHE_MEM [SET=11262][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = bbbaff92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = bbbaff92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIVE
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * Snoop Read Request *
# Snoop Result: Address = bbbaff92, Snoop Result = HIT
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [11262][0]  [000000000000000] = [bbb]      [SHARED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 1
# NUMBER OF CACHE WRITES        = 0
# NUMBER OF CACHE HITS          = 0
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.000000
```

```
# CACHE HIT RATIO PERCENTAGE     = 0.00 %
# ------------------------------------------------------------------------------------
```

8.15 Snooping with Invalidate State

```
3 AAA00C92
5 99900C92
6 99900C92
9
```

Output

```
# NORMAL MODE is Enable
# ------------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------------
# * Snoop Read Request *
# Snoop Result: Address = aaa00c92, Snoop Result = NOHIT
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = INVALID
# ------------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------------
# * Snoop Read with Intent to Modify Request *
# Snoop Result: Address = 99900c92, Snoop Result = NOHIT
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = INVALID
# ------------------------------------------------------------------------------------
#                          TRACE LINE : 3
# ------------------------------------------------------------------------------------
# * Snoop Invalidate Command *
# Snoop Result: Address = 99900c92, Snoop Result = NOHIT
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = INVALID
# ------------------------------------------------------------------------------------
#                          TRACE LINE : 4
# ------------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------------
# ------------------------------------------------------------------------------------
#                             SUMMARY
# ------------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 0
# NUMBER OF CACHE WRITES        = 0
# NUMBER OF CACHE HITS          = 0
# NUMBER OF CACHE MISSES        = 0
# CACHE HIT RATIO               = 0.000000
```

```
# CACHE HIT RATIO PERCENTAGE     = 0.00 %
# ------------------------------------------------------------------------------
```

8.16 Snoop Modified to Invalidate State

```
0 12F22C92
1 12F22C92
5 12F22C92
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                       TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 12f22c92 at CACHE_MEM [SET=2226][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 12f22c92, Snoop Result = NOHIT
# Message: L2 to L1 -> SENDLINE, Address = 12f22c92
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = EXCLUSIV
# ------------------------------------------------------------------------------
#                       TRACE LINE : 2
# ------------------------------------------------------------------------------
# * CPU Write Request *
# TAG MATCHED! 12f = 12f
# 1 - WRITE-HIT for 12f22c92 at CACHE_MEM [SET=2226][WAY=0]
# PLRU = 000000000000000
# Message: L2 to L1 -> SENDLINE, Address = 12f22c92
# PREVIOUS MESI STATE = EXCLUSIVE
# CURRENT MESI STATE = MODIFIED
# ------------------------------------------------------------------------------
#                       TRACE LINE : 3
# ------------------------------------------------------------------------------
# * Snoop Read with Intent to Modify Request *
# Message: L2 to L1 -> GETLINE, Address = 12f22c92
# Bus Operation: WRITE, Address = 12f22c92, Snoop Result = NOHIT
# Message: L2 to L1 -> INVALIDATE LINE, Address = 12f22c92
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = INVALID
# ------------------------------------------------------------------------------
#                       TRACE LINE : 4
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
```

```
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ----------------------------------------------------------------------------
# ----------------------------------------------------------------------------
#                                SUMMARY
# ----------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 1
# NUMBER OF CACHE WRITES        = 1
# NUMBER OF CACHE HITS          = 1
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.500000
# CACHE HIT RATIO PERCENTAGE    = 50.00 %
# ----------------------------------------------------------------------------
```

8.17 Snoop Modified to Shared

```
1 12F22C91
3 12F22C91
4 00122C91
9
```

Output

```
# NORMAL MODE is Enabled
# ----------------------------------------------------------------------------
#                          TRACE LINE : 1
# ----------------------------------------------------------------------------
# * CPU Write Request *
# COMPULSORY WRITE-MISS for 12f22c91 at CACHE_MEM [SET=2226][WAY=0]
# PLRU = 000000000000000
# Bus Operation: RWIM, Address = 12f22c91, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 12f22c9
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = MODIFIED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 2
# ----------------------------------------------------------------------------
# * Snoop Read Request *
# Snoop Result: Address = 12f22c91, Snoop Result = HITM
# Message: L2 to L1 -> GETLINE, Address = 12f22c91
# Bus Operation: WRITE, Address = 12f22c91, Snoop Result = HIT
# PREVIOUS MESI STATE = MODIFIED
# CURRENT MESI STATE = SHARED
# ----------------------------------------------------------------------------
#                          TRACE LINE : 3
# ----------------------------------------------------------------------------
# * Snoop Write Request *
# PREVIOUS MESI STATE = SHARED
```

```
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 4
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [2226][0]   [000000000000000] = [12f]      [SHARED]
# ------------------------------------------------------------------------------
#                              SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 0
# NUMBER OF CACHE WRITES        = 1
# NUMBER OF CACHE HITS          = 0
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.000000
# CACHE HIT RATIO PERCENTAGE    = 0.00 %
# ------------------------------------------------------------------------------
```

8.18 Snoop Shared to Shared

```
0 2200CE91
3 2200CE91
9
```

Output

```
# NORMAL MODE is Enabled
# ------------------------------------------------------------------------------
#                          TRACE LINE : 1
# ------------------------------------------------------------------------------
# * CPU Read Request *
# COMPULSORY READ-MISS for 2200ce91 at CACHE_MEM [SET=826][WAY=0]
# PLRU = 000000000000000
# Bus Operation: READ, Address = 2200ce91, Snoop Result = HITM
# Message: L2 to L1 -> SENDLINE, Address = 2200ce91
# PREVIOUS MESI STATE = INVALID
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 2
# ------------------------------------------------------------------------------
# * Snoop Read Request *
# Snoop Result: Address = 2200ce91, Snoop Result = HIT
# PREVIOUS MESI STATE = SHARED
# CURRENT MESI STATE = SHARED
# ------------------------------------------------------------------------------
#                          TRACE LINE : 3
```

```
# ------------------------------------------------------------------------------
# * Print Contents and State of Each Valid Cache Line *
# ------------------------------------------------------------------------------
#              CACHE_MEM [SET] [WAY] [PLRU Bits]= [TAG] [MESI STATE]
# ------------------------------------------------------------------------------
# CACHE_MEM [826][0]    [000000000000000] = [220]      [SHARED]
# ------------------------------------------------------------------------------
#                                SUMMARY
# ------------------------------------------------------------------------------
# NUMBER OF CACHE READS         = 1
# NUMBER OF CACHE WRITES        = 0
# NUMBER OF CACHE HITS          = 0
# NUMBER OF CACHE MISSES        = 1
# CACHE HIT RATIO               = 0.000000
# CACHE HIT RATIO PERCENTAGE    = 0.00 %
# ------------------------------------------------------------------------------
```