HY425

Homework Problem Set 5

Assignment: 8/6/2008

Due Date: 23/6/2008

Instructions: Solve all problems in a **.pdf** file and send them via e-mail to Stamatis Kavadias (kavadias@ics.forth.gr), with a copy to the instructor (dsn@ics.forth.gr). Use the following subject in your e-mail: **HY425: Homework 5 Submission**. Please the aforementioned subject only, so that your homework is read and graded.

Problem 1 (68 points)

Consider the distributed-shared memory multiprocessor illustrated in the following figure:

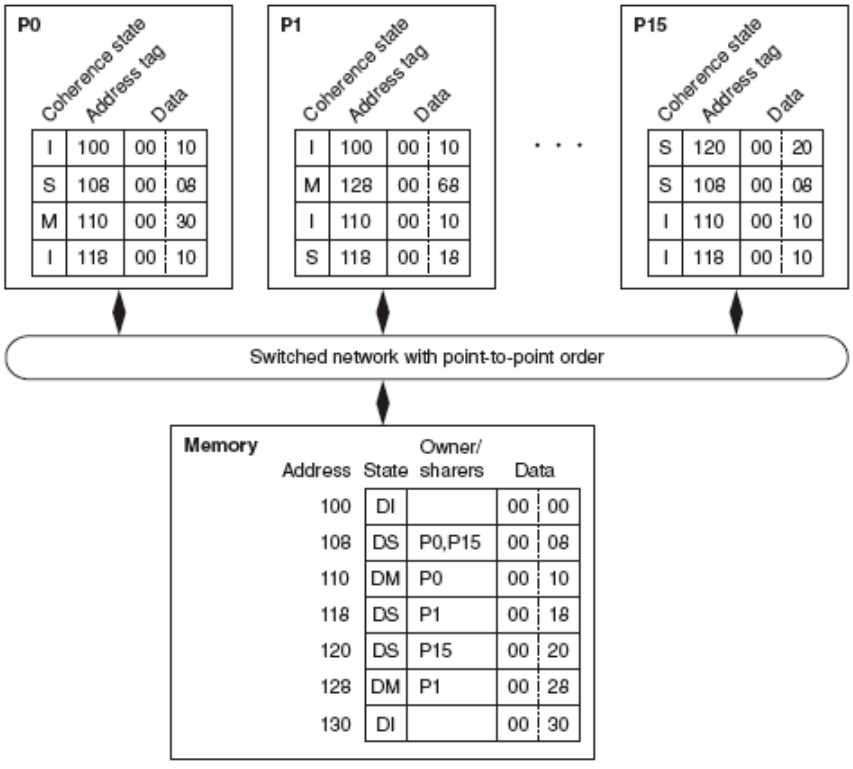

Figure 1: Initial cache and memory state

Each processor has one direct-mapped cache that holds four blocks, each holding two words. To simplify the illustration, the cache tag contains the entire address and each word shows only two hex characters. The cache states are denoted with M, S, and I, for Modified, Shared, and Invalid. The directory states are

denoted with DM, DS, and DI, for directory-modified, directory-shared and directory-invalid. The directory protocol is described in the following figures:

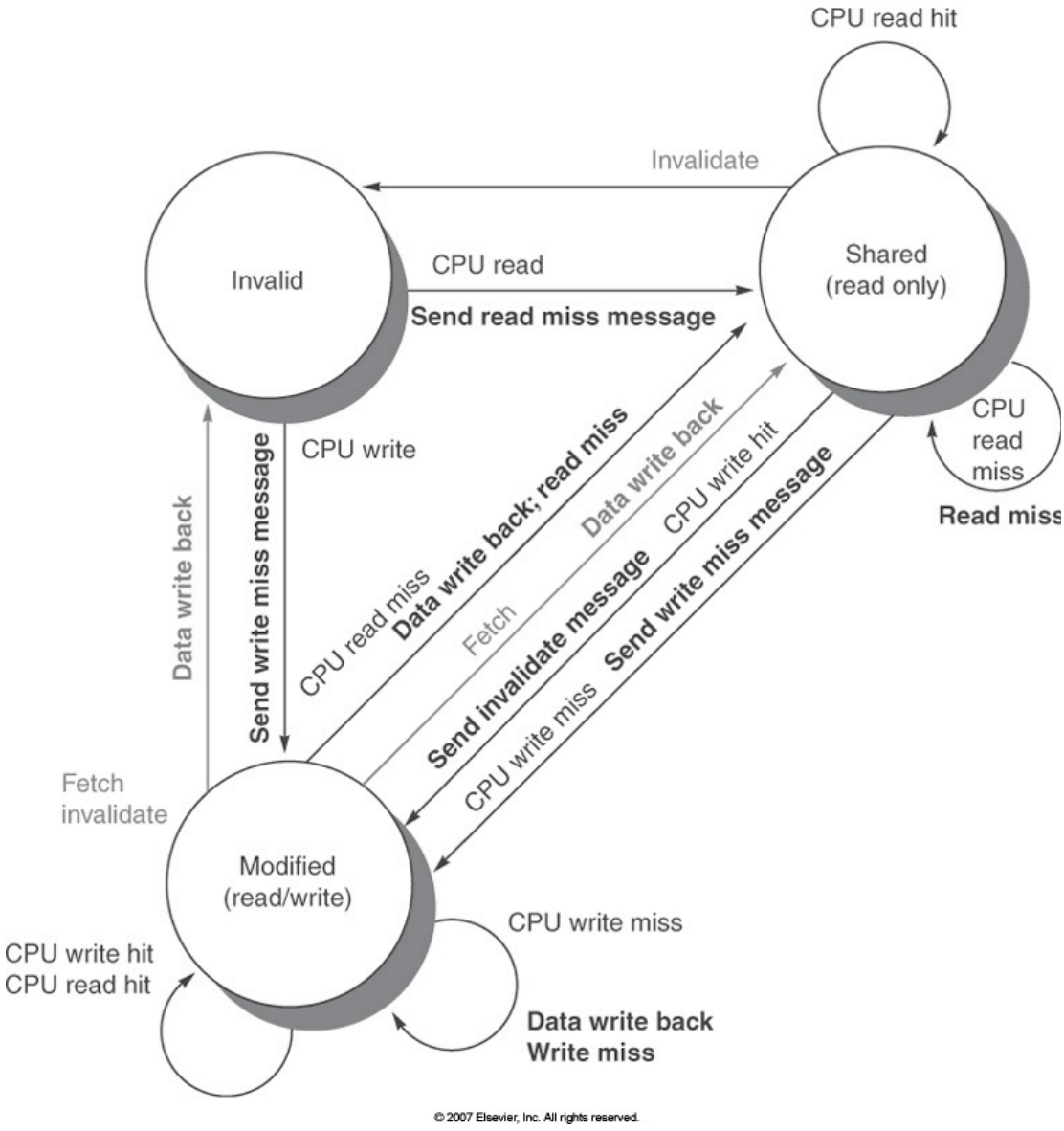

Figure 2: Directory coherence protocol, CPU side

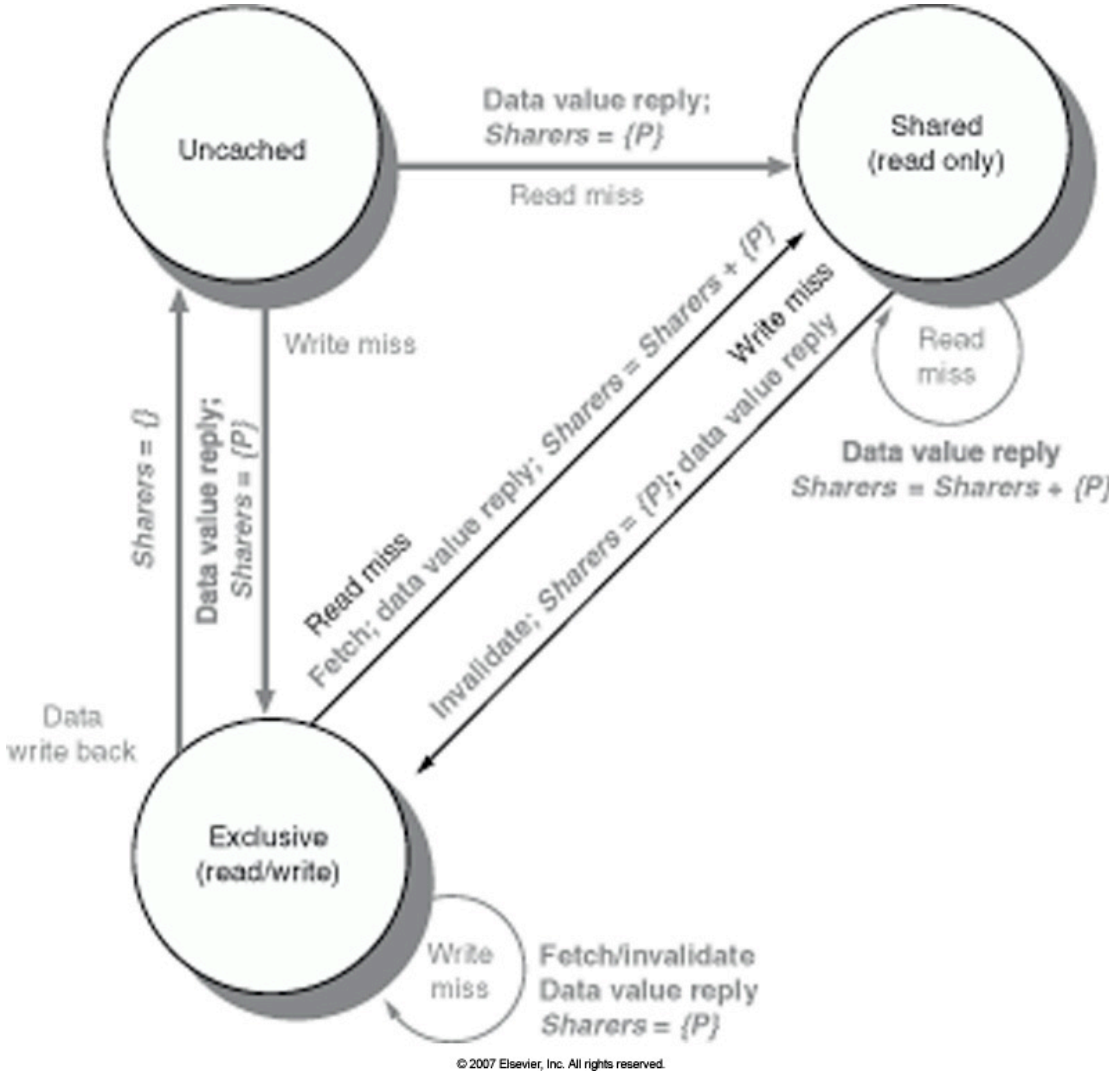

Figure 3: Directory coherence protocol, directory side

For each part of the exercise, assume the initial cache and memory state depicted in Figure 1. Each part of the exercise specifies a sequence of one or more CPU operations of the form:

P#: <op> address [← <value>]

where P# designates the CPU (e.g. P0), <op> is the CPU operation (e.g. read or write), <address> denotes the memory address, and <value> indicates the new word to be assigned on a write operation. What is the final state (i.e. coherence state, tags, and data) of the caches and memory after the given sequence of CPU operations has completed? Also, what value is returned by each read operation?

a. P0: read 110 (8 points)
b. P15: read 128 (8 points)
c. P0: write 120 ← 80 (8 points)
d. P15: write 120 ← 80 (8 points)
e. P0: read 130
   P1: read 110 (12 points)

f. P1: write 110 ← 80
   P0: read 110 (12 points)
g. P1: write 110 ← 90
   P0: read 130 (12 points)

Problem 2 (32 points)

Directory protocols are more scalable than snooping protocols because they send explicit request and invalidate messages to those nodes that have copies of a block, while snooping protocols broadcast all requests and invalidates to all nodes. Consider a 16-processor system with the organization illustrated in Figure 1 and assume all caches not shown have only invalid blocks. For each of the sequences below, identify which nodes receive each request and invalidation.

a. P1: Write 120 ← 80 (8 points)
b. P1: Write 110 ← 88 (8 points)
c. P15: Write 118 ← 90 (8 points)
d. P15: Write 108 ← 98 (8 points)