Cache Coherency in Multiprocessor Systems

The ***Modified Exclusive Shared Invalid*** (MESI) algorithm for cache coherency.

MESI State	Definition
Modified (M)	The line is valid in the cache and in only this cache. The line is modified with respect to system memory—that is, the modified data in the line has not been written back to memory.
Exclusive (E)	The addressed line is in this cache only. The data in this line is consistent with system memory.
Shared (S)	The addressed line is valid in the cache and in at least one other cache. A shared line is always consistent with system memory. That is, the shared state is shared-unmodified; there is no shared-modified state.
Invalid (I)	This state indicates that the addressed line is not resident in the cache and/or any data contained is considered not useful.

Note that:

- Exclusive may also be called CleanExclusive
- Modified may also be called DirtyExclusive

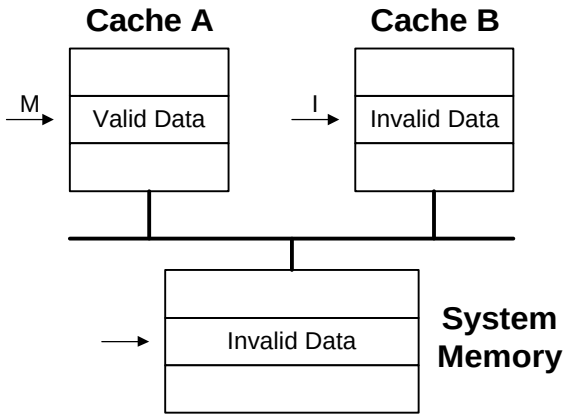
Some processors add a fifth state for ***Shared Modified*** and call it the ***MOESI*** protocol. The caches with the shared modified state update each other's lines with current data, but do not write it back to main memory.

The five MOESI states are defined as:

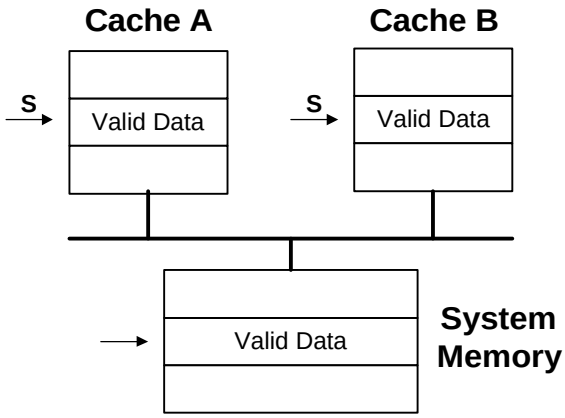
- Exclusively Modified (M)
- Shared Modified (O)
- Exclusive Clean (E)
- Shared Clean (S)
- Invalid (I)

Picture the MESI cache states:

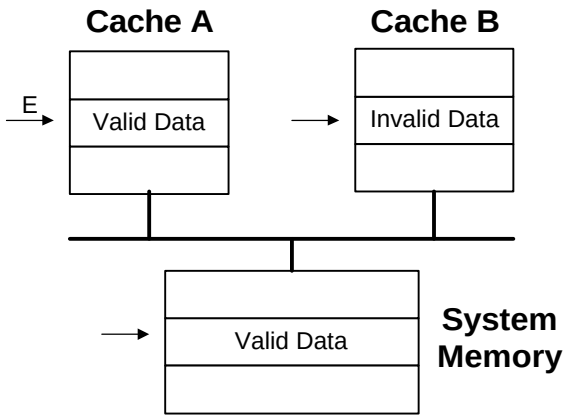
Modified in Cache A



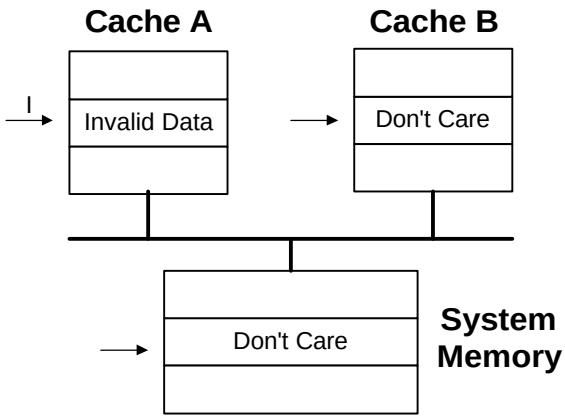
Shared in Cache A



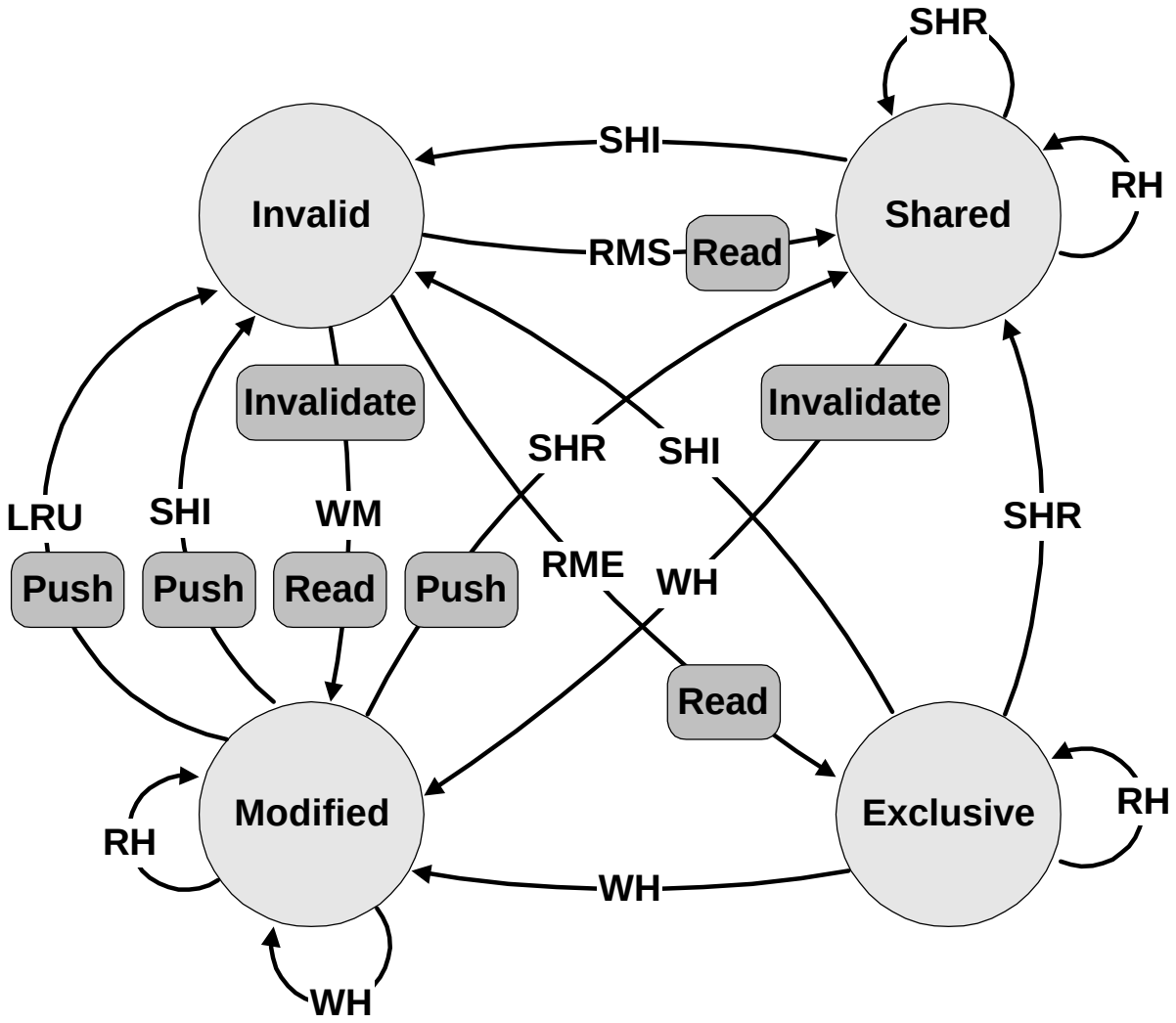
Exclusive in Cache A



Invalid in Cache A



MESI State Diagram



Events:

RH = Read Hit
RMS = Read miss, shared
RME = Read miss, exclusive
WH = Write hit
WM = Write miss
SHR = Snoop hit on read
SHI = Snoop hit on invalidate
LRU = LRU replacement

Bus Transactions:

Push = Write cache line back to memory
Invalidate = Broadcast invalidate
Read = Read cache line from memory

MESI State Table

State	Event	Action	Next State
Invalid	Read miss, shared (cache copies exist)	Read cache line	Shared
	Read miss, exclusive (no cache copies exist)	Read cache line	Exclusive
	Write miss	• Broadcast invalidate • Read cache line • Modify cache line	Modified
Shared	Read hit		Shared
	Write hit	Broadcast invalidate	Modified
	Snoop hit on read		Shared
	Snoop hit on invalidate	Invalidate cache line	Invalid
Exclusive	Read hit		Exclusive
	Write hit		Modified
	Snoop hit on read		Shared
	Snoop hit on invalidate	Invalidate cache line	Invalid
Modified	Read hit		Modified
	Write hit		Modified
	Snoop hit on read	Write cache line back to memory	Shared
	Snoop hit on invalidate	Write cache line back to memory	Invalid
	LRU Replacement	Write cache line back to memory	Invalid

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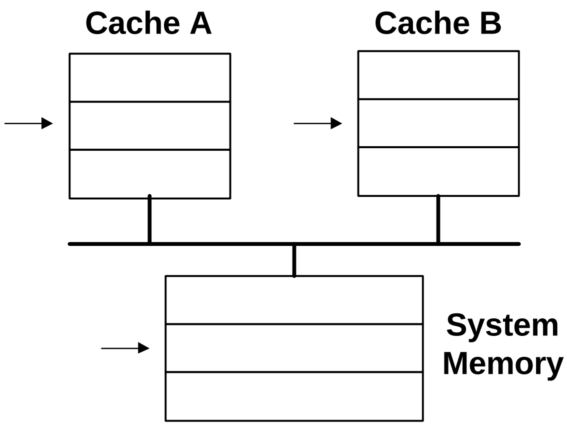
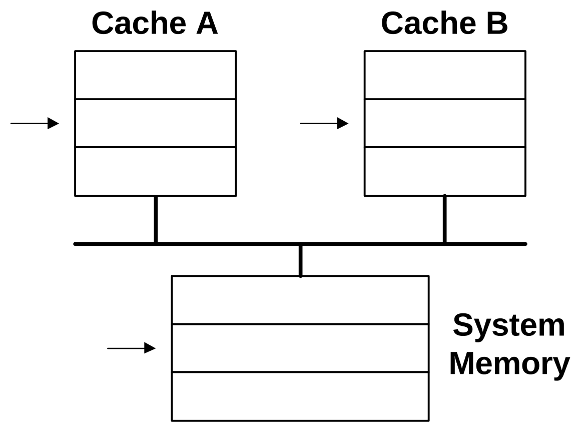

Cache A
Cache B
System Memory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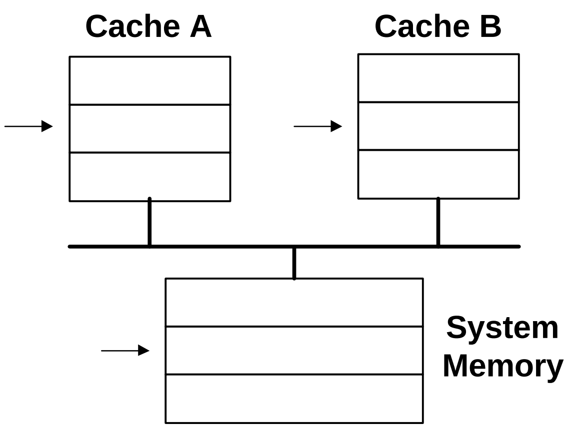
System Memory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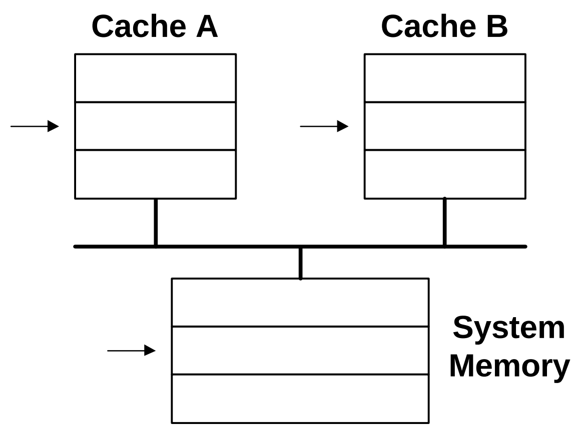
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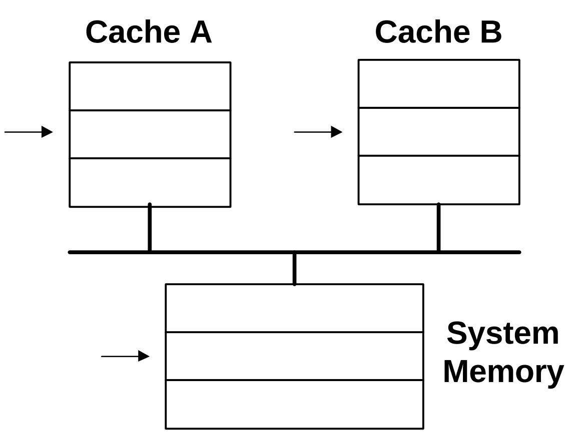
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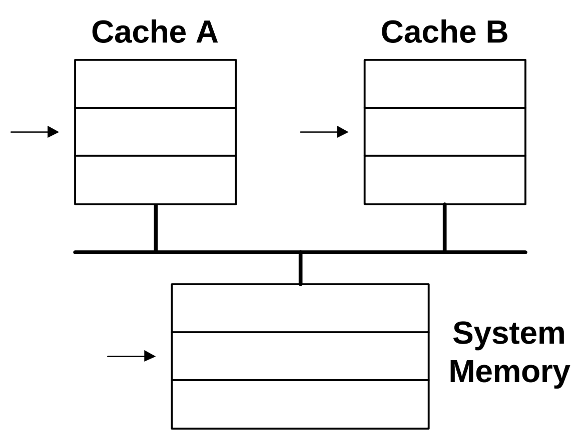
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