

Barriers in OpenMP

Paolo Burgio
paolo.burgio@unimore.it



Outline

- › Expressing parallelism
 - Understanding parallel threads
- › ~~Memory~~ Data management
 - Data clauses
- › Synchronization
 - Barriers, locks, critical sections
- › Work partitioning
 - Loops, sections, single work, tasks...
- › Execution devices
 - Target



OpenMP synchronization

- › OpenMP provides the following synchronization constructs:
 - `barrier`
 - `flush`
 - `master`
 - `critical`
 - `atomic`
 - `taskwait`
 - `taskgroup`
 - `ordered`
 - ..and OpenMP locks

Creating a parreg

› Master-slave, fork-join execution model

- Master thread spawns a team of Slave threads
- They all perform computation in parallel
- At the end of the parallel region, implicit barrier

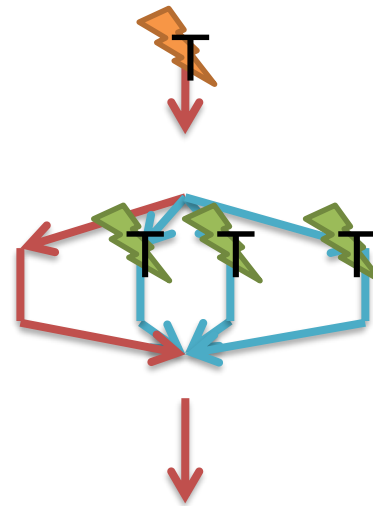
```
int main()
{
    /* Sequential code */

    #pragma omp parallel num_threads(4)
    {

        /* Parallel code */

    } // Parreg end: (implicit) barrier

    /* (More) sequential code */
}
```





OpenMP explicit barriers

```
#pragma omp barrier new-line
```

(a standalone directive)

- › All threads in a team must wait for all the other threads before going on
 - "Each barrier region must be encountered by all threads in a team or by none at all"
 - "The sequence of barrier regions encountered must be the same for every thread in a team"
 - Why?
- › Binding set is the team of threads from the innermost enclosing parreg
 - "It applies to"
- › Also, it enforces a consistent view of the shared memory
 - We'll see this..



Exercise

Let's
code!

- › Spawn a team of (many) parallel Threads
 - Printing "Hello World"
 - Put a `#pragma omp barrier`
 - Reprint "Hello World" after

- › What do you see?
 - Now, remove the `barrier` construct

- › Now, put the barrier inside an `if`
 - E.g., `if(omp_get_thread_num() == 0) { ... }`
 - What do you see?
 - Error!!!!

Effects on memory

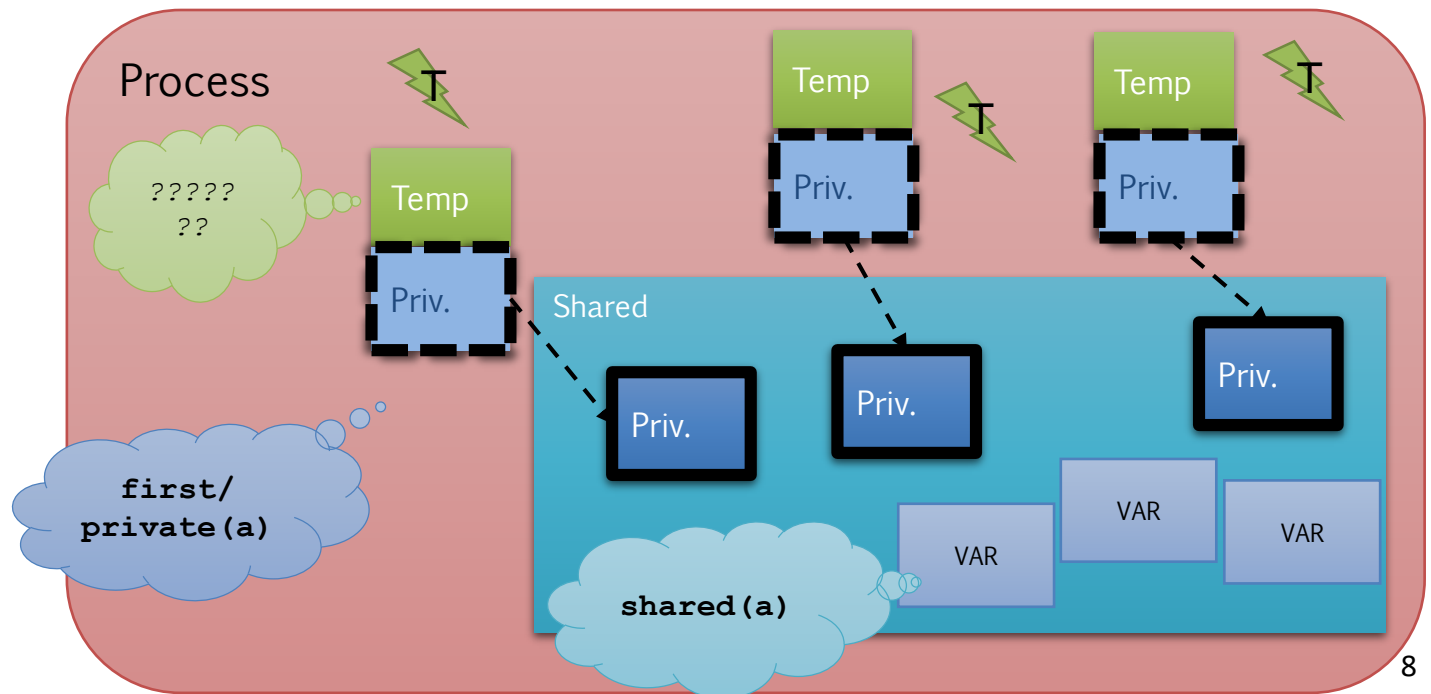
- › Besides synchronization, a barrier has the effect of making threads' temporary view of the shared memory consistent
 - You cannot trust any (potentially modified) `shared` vars before a barrier
 - Of course, there are no problems with `private` vars
- › ..what???



The OpenMP memory model

› Shared memory with relaxed consistency

- Threads have access to "a place to store and to retrieve variables, called the memory"
- Threads can have a temporary view of the memory
 - › Caches, registers, scratchpads...
 - › Can still be accessed by other threads





A bit of architecture...



Caches in a nutshell

- › A quick memory connected to the core processor
 - ..and to the main memory
 - Few KB of data

- › (If any,) caches are a pure hardware mechanism
 - Used to store **a copy** mostly accessed data
 - To speedup execution even by 10-20 times
 - Instruction caches/Data caches

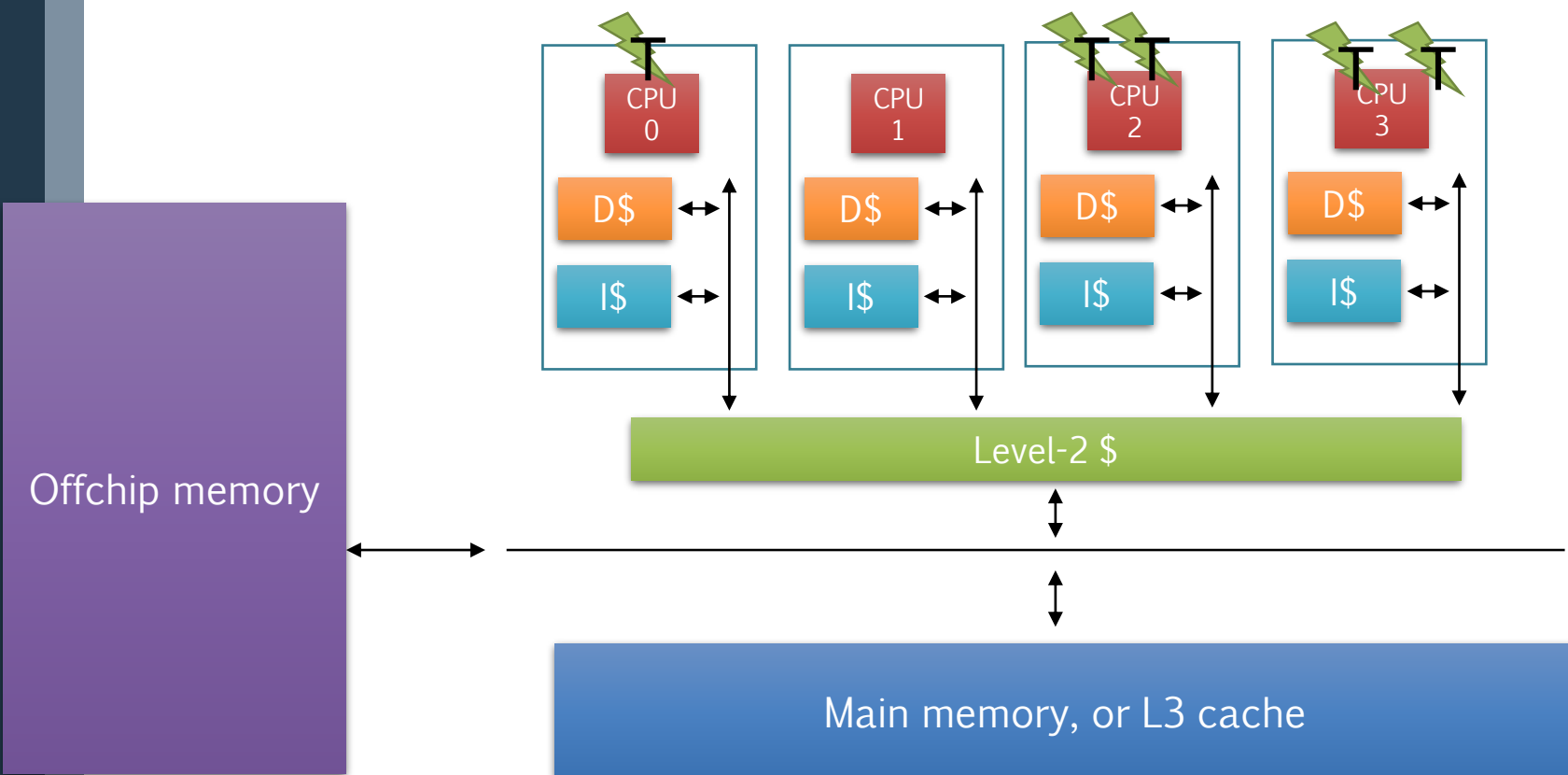
- › They perform their work **automatically**
 - And transparently
 - Poor or no control at all at application level
 - Extremely dangerous in multi- and many-cores



Caches

eng.wikipedia.org

A cache is a hardware or software component that stores data so future requests for that data can be served faster; the data stored in a cache might be the result of an earlier computation, or the *duplicate of data stored elsewhere*.



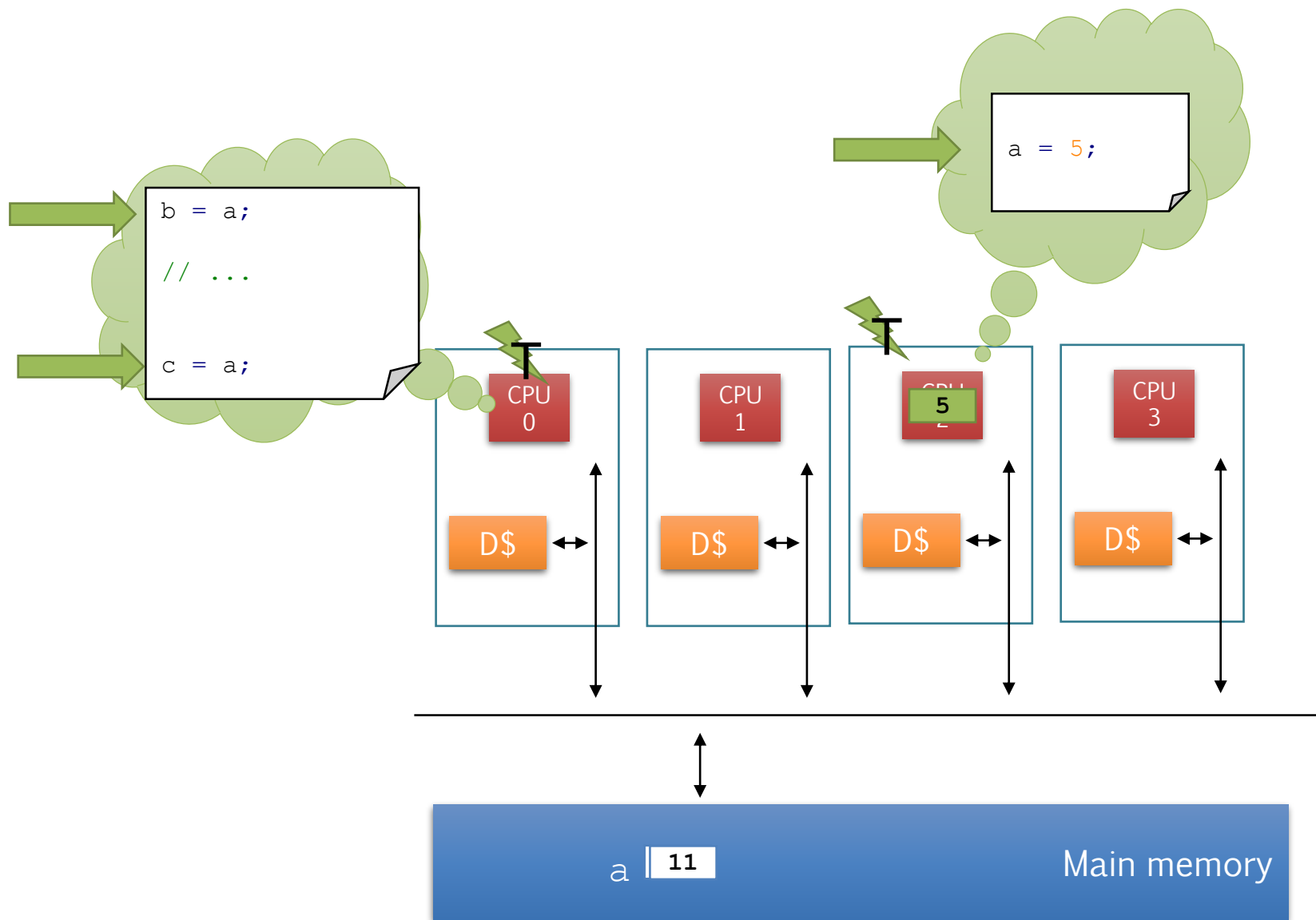


The catch(es)

- › Caches are power hungry
 - Some embedded architectures do not have D\$
- › They are not suitable for critical systems
 - E.g., BOSCH removed D\$s
- › Hardware mechanism, poor control on them
 - Flush command (typically, all cache)
 - Color cache (assign to threads)
 - Prefetch (move data before it's actually needed)

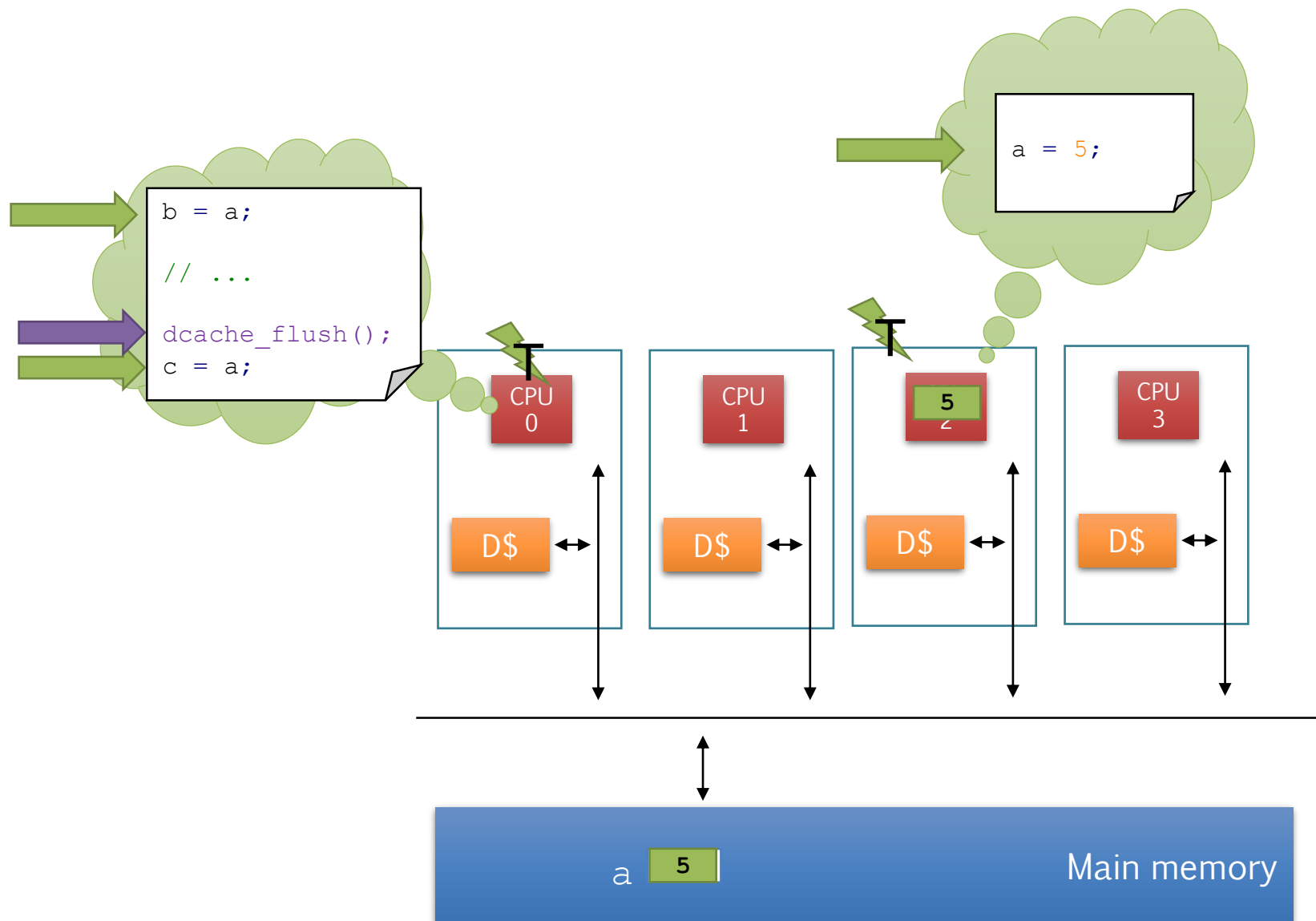
Coherency problem in multi/many-cores!!

An example: read stale data





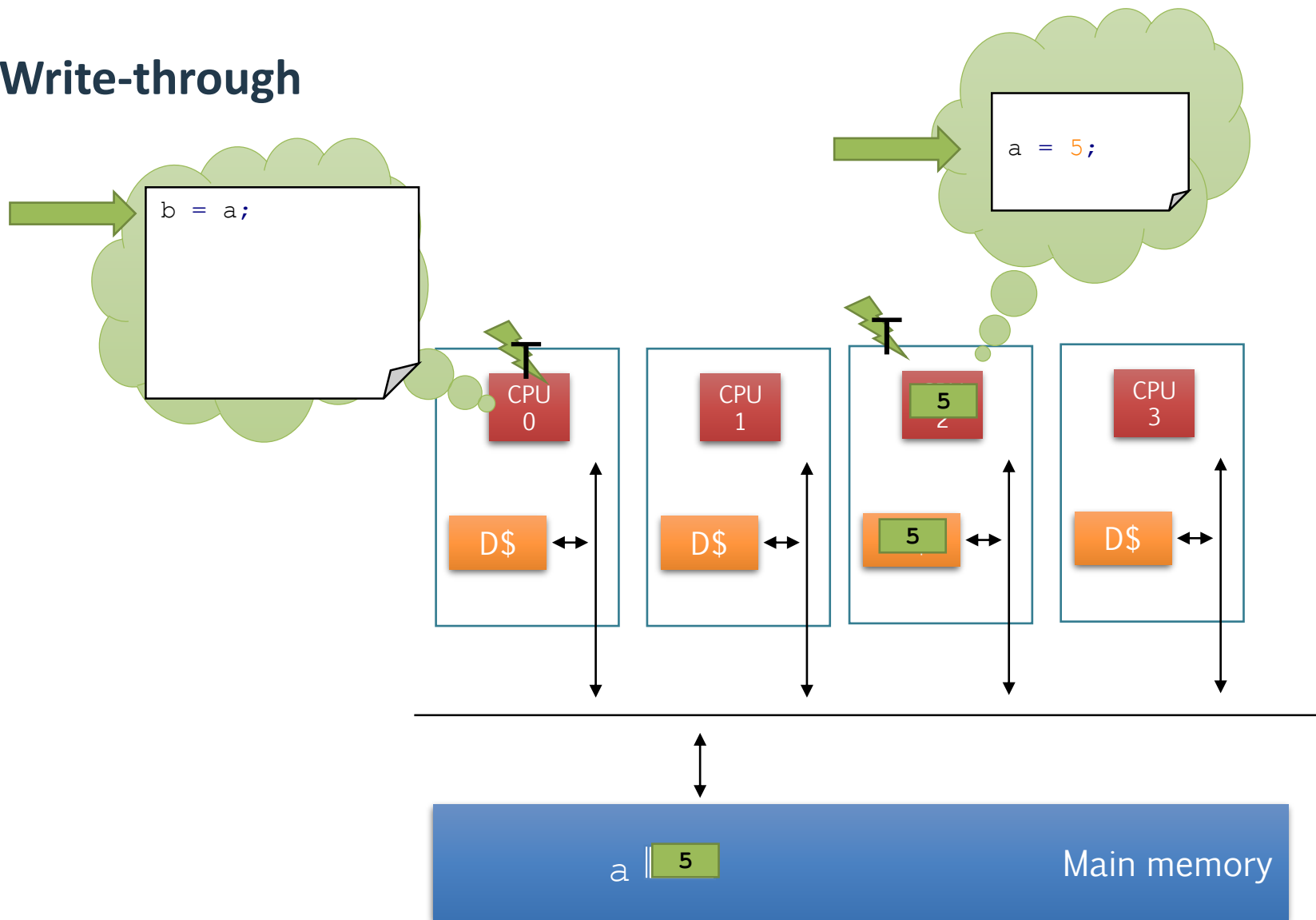
An example: read stale data





An(other) example: \$ writing policies

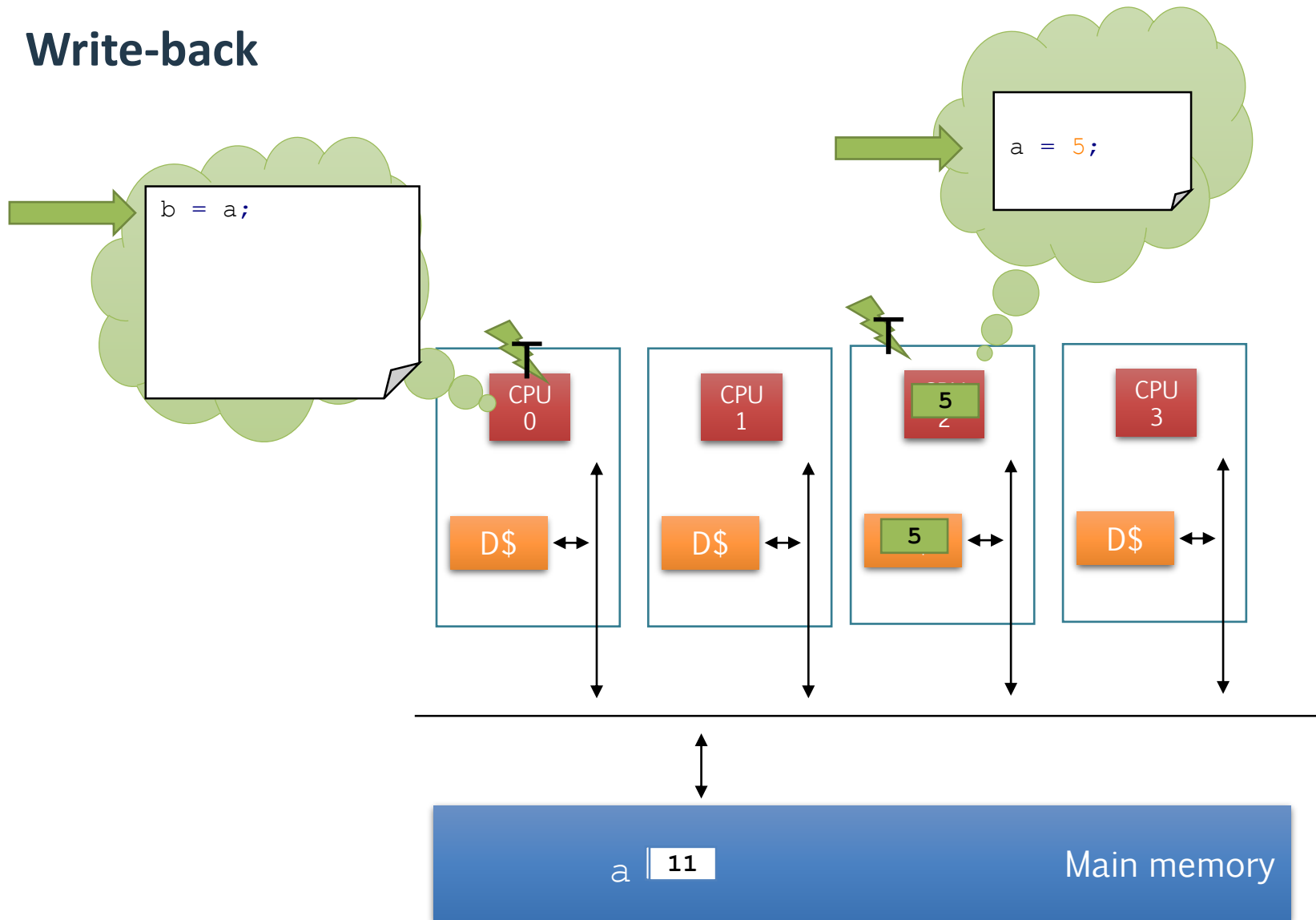
Write-through





An(other) example: \$ writing policies

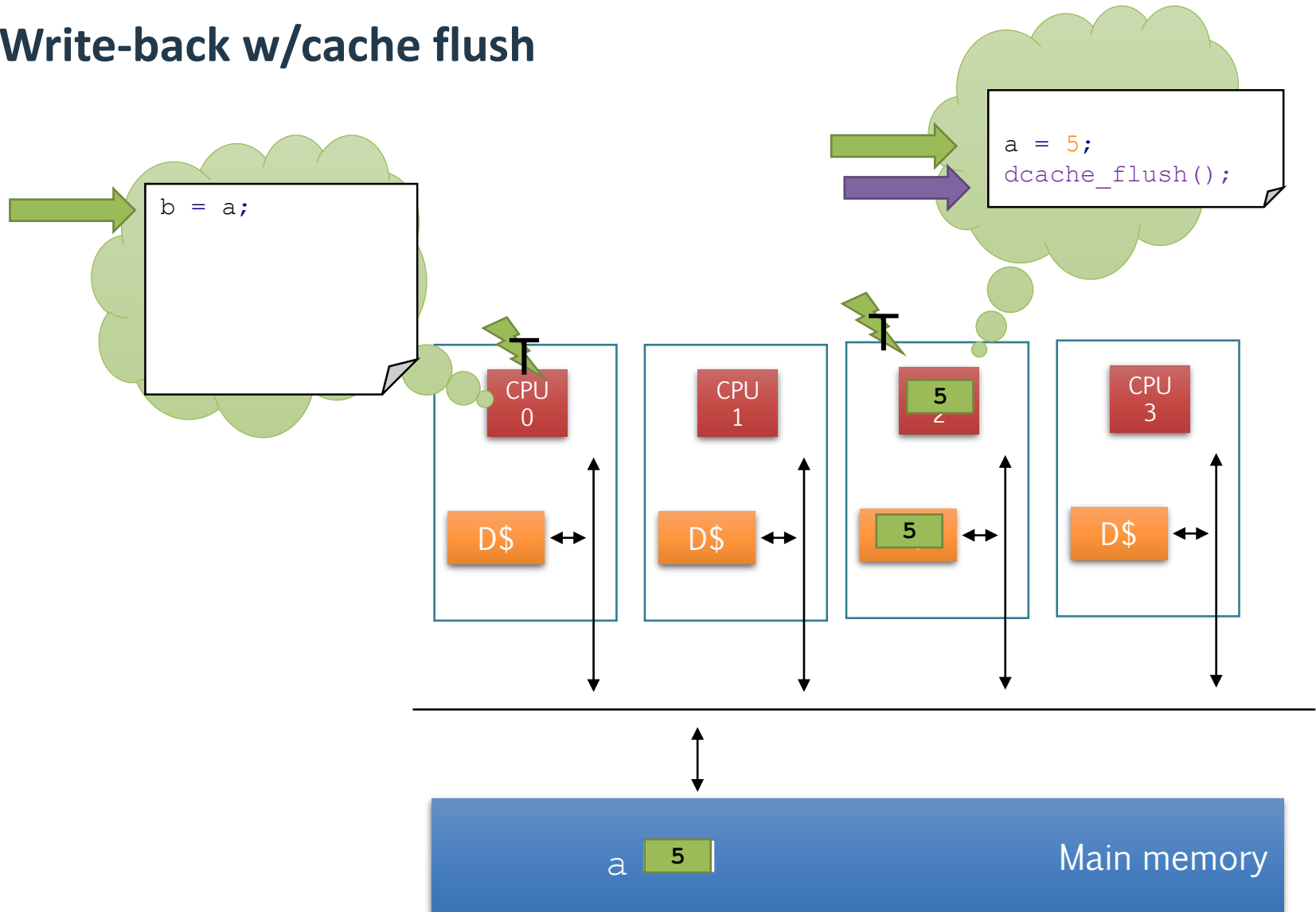
Write-back





An(other) example: \$ writing policies

Write-back w/cache flush





The `flush` directive

```
#pragma omp flush [(list)] new-line
```

- › Binding thread set is **the encountering thread**
 - More "relaxed"
- › "It executes the OpenMP flush operation"
 - Makes its temporary view of the shared memory consistent with other threads
 - "Calls to `dcache_flush()`"
- › Enforces an order on the memory operations on the variables specified in `list`



Semantics: barrier vs flush

`#pragma omp barrier`

- › Joins the threads of a team
- › Applies to all threads of a team
- › Forces consistency of threads' temporary view of the shared memory

`#pragma omp flush`

- › Applies to one thread
- › Forces consistency of its temporary view of the shared memory
- › Much lighter!



OpenMP software stack



› Multi-layer stack

- Engineered for portability

User code



```
a = 5;  
  
#pragma omp flush
```

OpenMP runtime

```
void GOMP_flush() {  
    dcache_flush();  
}
```

Operating System

```
void dcache_flush()  
{  
    asm("mov r15, #1");  
}
```

Hardware

D\$



How to run the examples

Let's
code!

› Download the Code/ folder from the course website

› Compile

› `$ gcc -fopenmp code.c -o code`

› Run (Unix/Linux)

`$./code`

› Run (Win/Cygwin)

`$./code.exe`

References



- › "Calcolo parallelo" website
 - http://hipert.unimore.it/people/paolob/pub/Calcolo_Parallelo/

- › My contacts
 - paolo.burgio@unimore.it
 - <http://hipert.mat.unimore.it/people/paolob/>

- › Useful links
 - <http://www.google.com>
 - <http://www.openmp.org>
 - <https://gcc.gnu.org/>

- › A "small blog"
 - <http://www.google.com>