Improving Speculative `taskloop` in Hardware Transactional Memory

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Agenda

- Motivating example
- Background
- Speculative Taskloop (STL)
- Lost-Thread Effect and Solution
- Experimental Evaluation
- Conclusions

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Motivating Example

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- susan_corners's loop (`loopV`)

```
for(i=5 ; i < y_size-5; i++){
    …
    x=r[i][j];
    if (x>0 && /*compare x*/){
        corner_list[n].info=0;
        corner_list[n].x=j;
        …
        n++;
    }
    …
}
```

Motivating example

- How can we parallelize this loop?

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- Can we use OpenMP `parallel for` or `taskloop`?

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No!
The loop is non-DOALL

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`ordered` serializes the execution

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Depends on the LLVM OpenMP Runtime

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Using `libomp12`: (`nonmonotonic`) Deadlock!

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Using `libomp12` and `monotonic` scheduling: some speed-ups.

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From deadlocks to 1.16× of speed-up

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- **Background**
  - **Tasks in OpenMP**
  - **`taskloop` construct**
  - **TLS on HTM**
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- Lost-Thread Effect and Solution
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Background

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- It is oblivious of the physical layout and focuses on exposing more parallelism.
- Added to OpenMP version 3.0.
- OpenMP 4.5 added a new construct called `taskloop`.

`taskloop` construct

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- Similar to `parallel for` (lack of `schedule` clause).
- `taskloop` is restricted to loops DOALL or with reduction patterns.
- This restriction precludes the parallelization of many *may* DOACROSS loops.

An example (toy1)

```
for(i=0 ; i < N; i++){
    glob=…;
    A[i]=glob*i;
}
```

An example (toy1)

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#pragma omp single
#pragma omp taskloop ...
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#pragma omp single
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for(i=0 ; i < N; i++){
   glob=…;
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}
```

DOALL parallelization

Another example (toy2)

```
for(i=0 ; i < N; i++){
   if (/*cond*/)
      glob++;
   else
      glob=i;
   ...
}
```

Another example (toy2)

```
#pragma omp parallel
#pragma omp single
#pragma omp taskloop shared(glob)...
for(i=0 ; i < N; i++){
   if (/*cond*/)
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taskloop construct

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#pragma omp single
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Is it correct?

taskloop construct

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No, the loop is non-DOALL

ordered construct

```
for(i=0 ; i < N; i++){
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may DOACROSS loop

ordered construct

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for(i=0 ; i < N; i++){
   #pragma omp ordered depend (sink:i-1)
   if (/*cond*/)
      glob++;
   else
      glob=i;
   #pragma omp ordered depend (source)
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```

Using `ordered`, the parallelization is correct

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- HTM implements three out of the four key features required by TLS: conflict detection, speculative storage, and transaction roll-back.
- Thus these architectures have the potential to be used to implement it.
- STL is based on this approach.

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Speculative Taskloop

Speculative Taskloop

- Previous work proposed Speculative Taskloop (STL) to have the best of two worlds: (a) the advantages of task-based parallelism over worksharing constructs; and (b) the effectiveness of TLS to parallelize may DOACROSS loops where OpenMP DOALL or DOACROSS techniques fail.

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- Another previous work added clauses (`spec_private` and `spec_reduction`) and directives (`tls if_read`, `tls if_write`, etc.) from Speculative Privatization in OpenMP to Speculative Taskloop, and evaluated the results of this parallelization technique.

Speculative Taskloop

- STL speculates data dependences between tasks generated by a `taskloop` construct in non-DOALL loops and executes multiple tasks of loop iterations to exploit task parallelism and to accelerate code execution.

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- Parallelization of *may* DOACROSS loops using the TLS algorithm on HTM but reusing the `taskloop` mechanism to create OpenMP explicit tasks and to divide iterations among them.
- Explicit tasks instead of threads as units of speculative parallelization.
- Believe on the task scheduler to distribute tasks onto cores.

`tls` clause for `taskloop`

- `#pragma omp taskloop` **`tls`**`(size)`

  `for-loop`

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- In `taskloop` consctructs.
- Enables programmers to parallelize *may* DOACROSS using STL.
- `size` is the number of iterations assigned to each speculative task.

How STL works

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- A thread encounters `taskloop` which partitions the iterations of the loop into tasks.
- These tasks are scheduled at runtime to be executed speculatively by the team.
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- STL works well with `monotonic` schedule.

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Lost-Thread Effect and Solution

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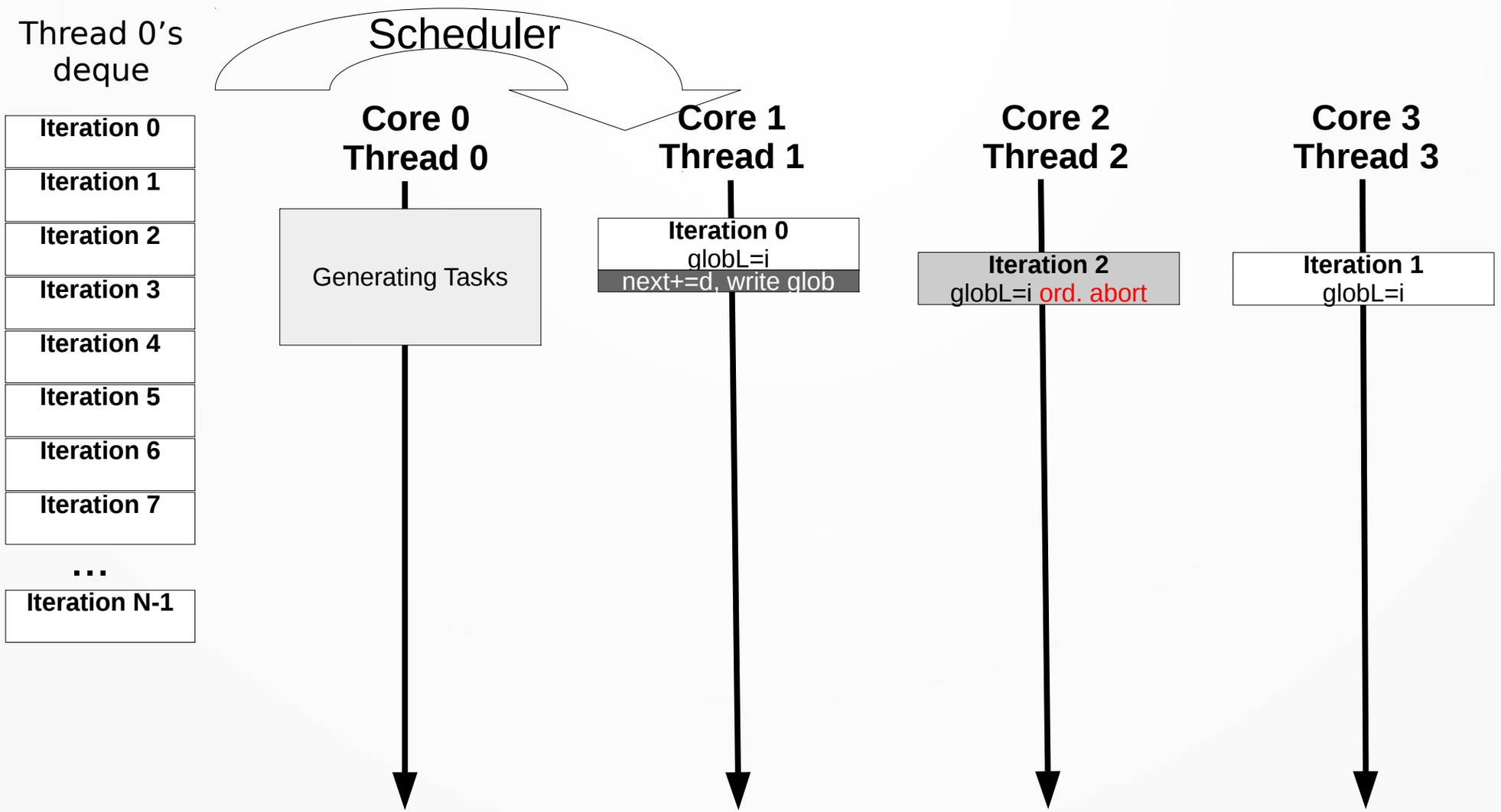
- Order inversion is an issue due to the lack of ordered transactions but it is exacerbated in OpenMP tasks due to the Lost-Thread Effect.
- Solutions: (a) Force order of tasks with `priority`?; (b) Implement `monotonic` schedule.

toy2's STL Parallelization



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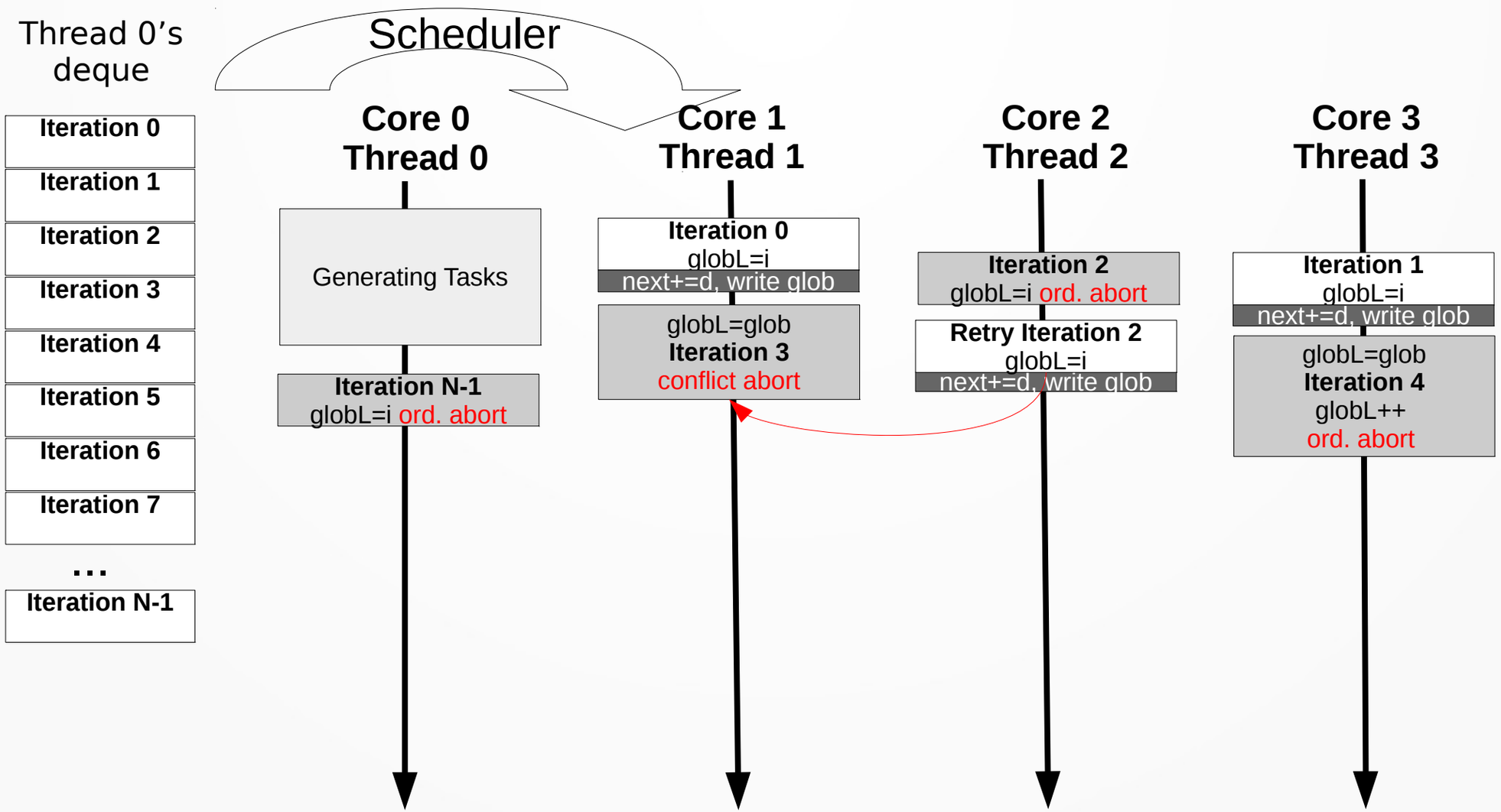

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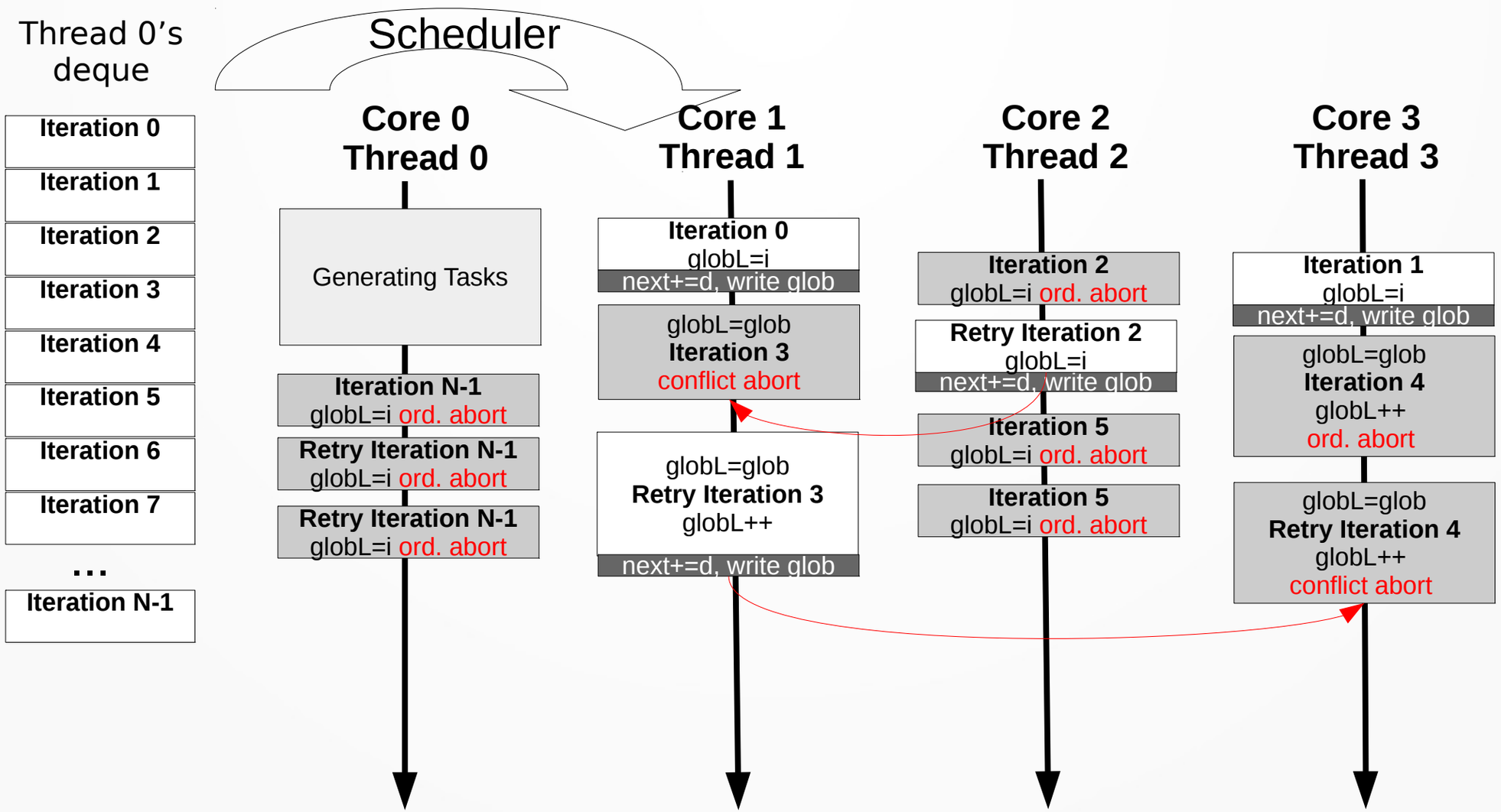

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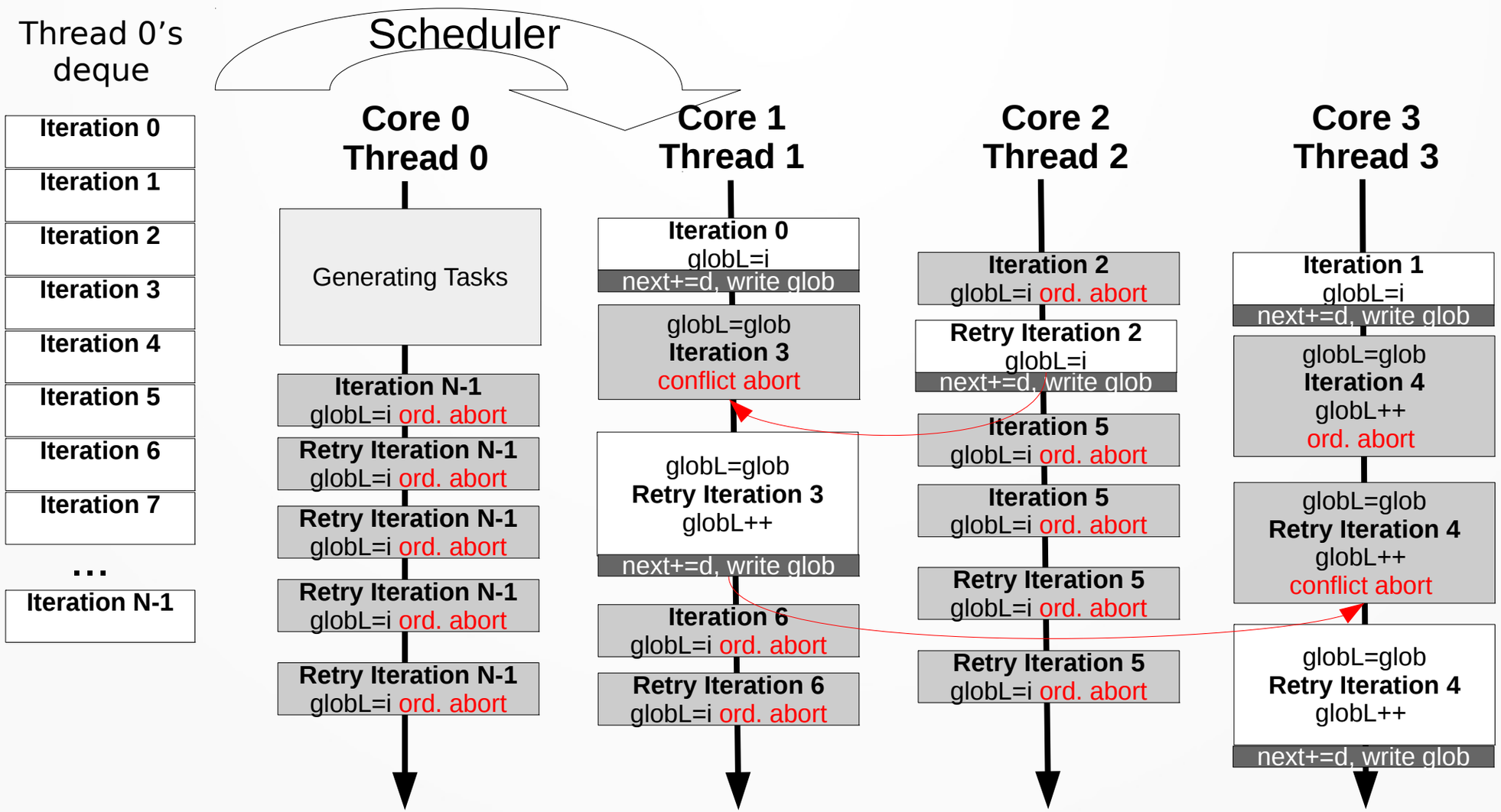

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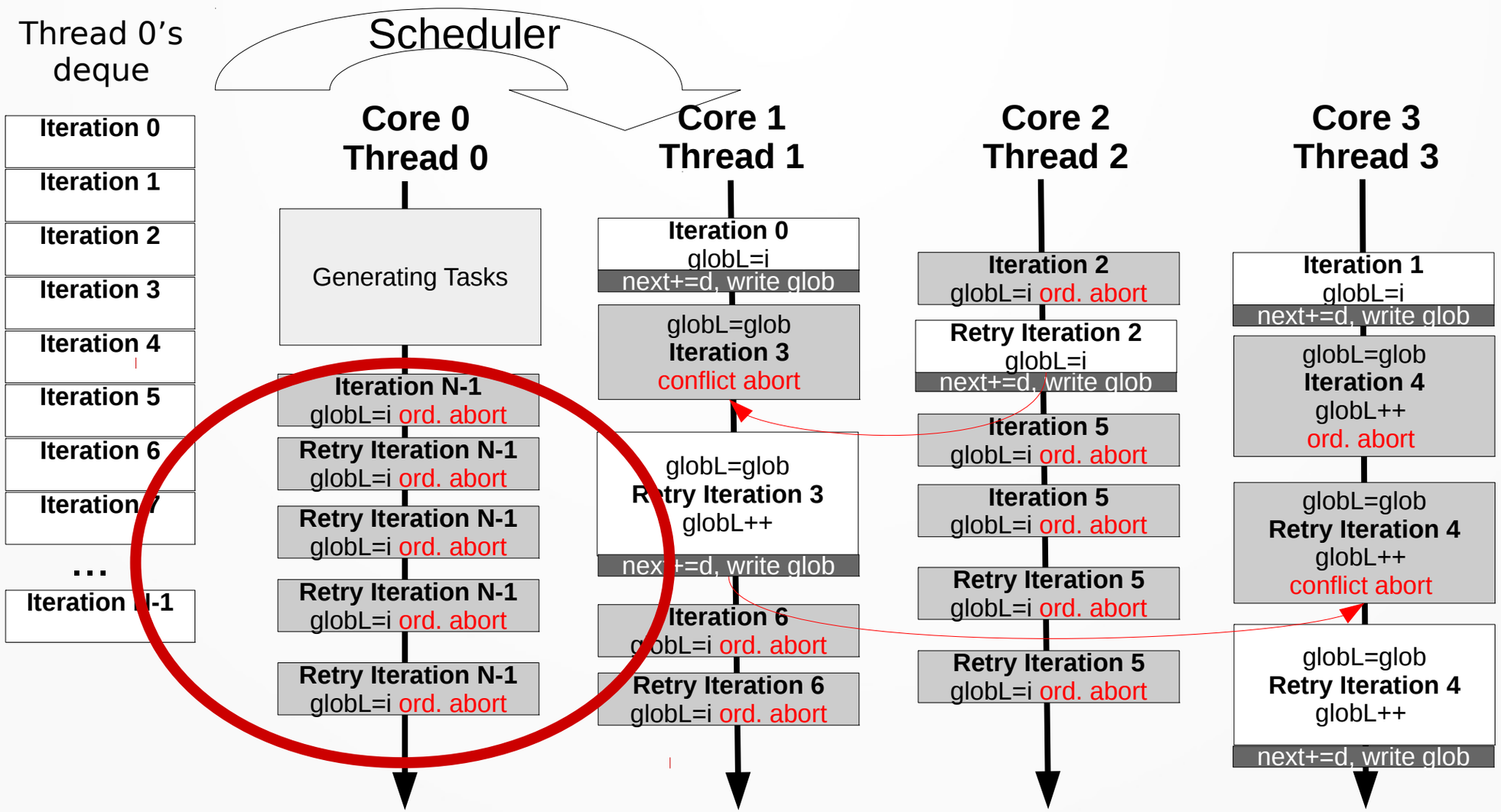

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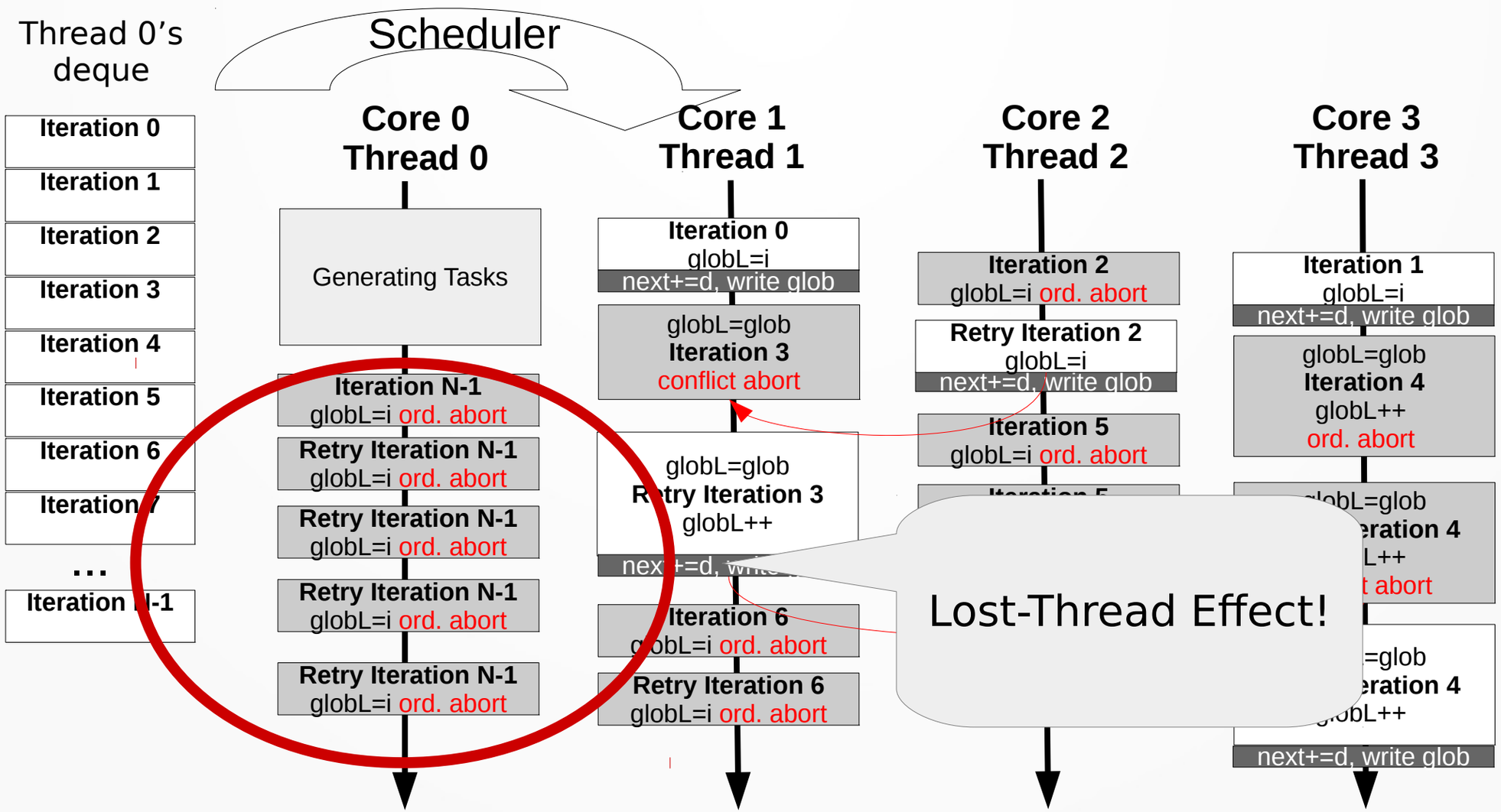

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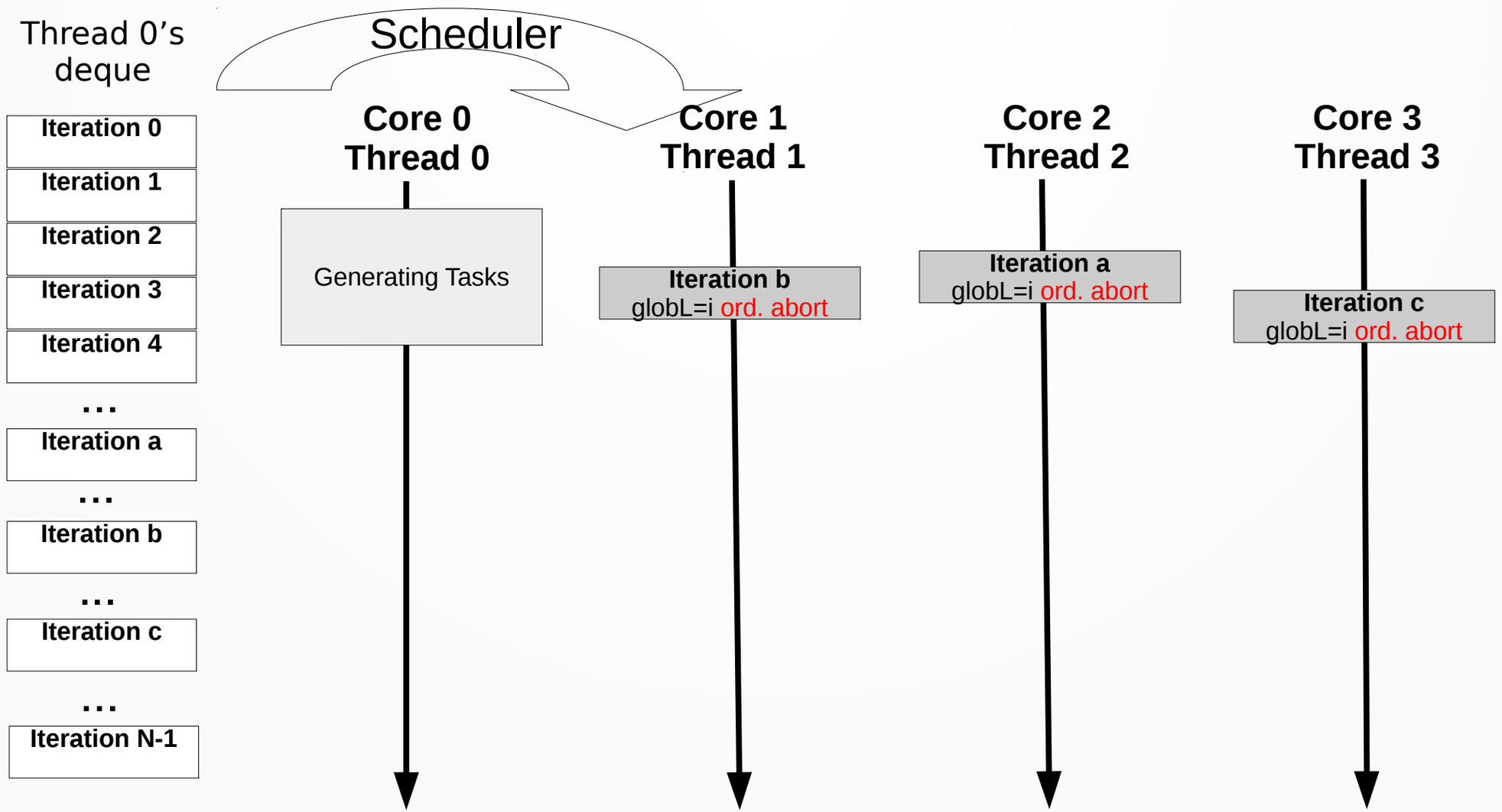
  - The immediate execution of tasks by the generating thread when its deque is full.
  - The recursive partition of iterations to generate tasks in a `nonmonotonic` fashion (`libomp12`).

Recursive Partition (nonmonotonic)



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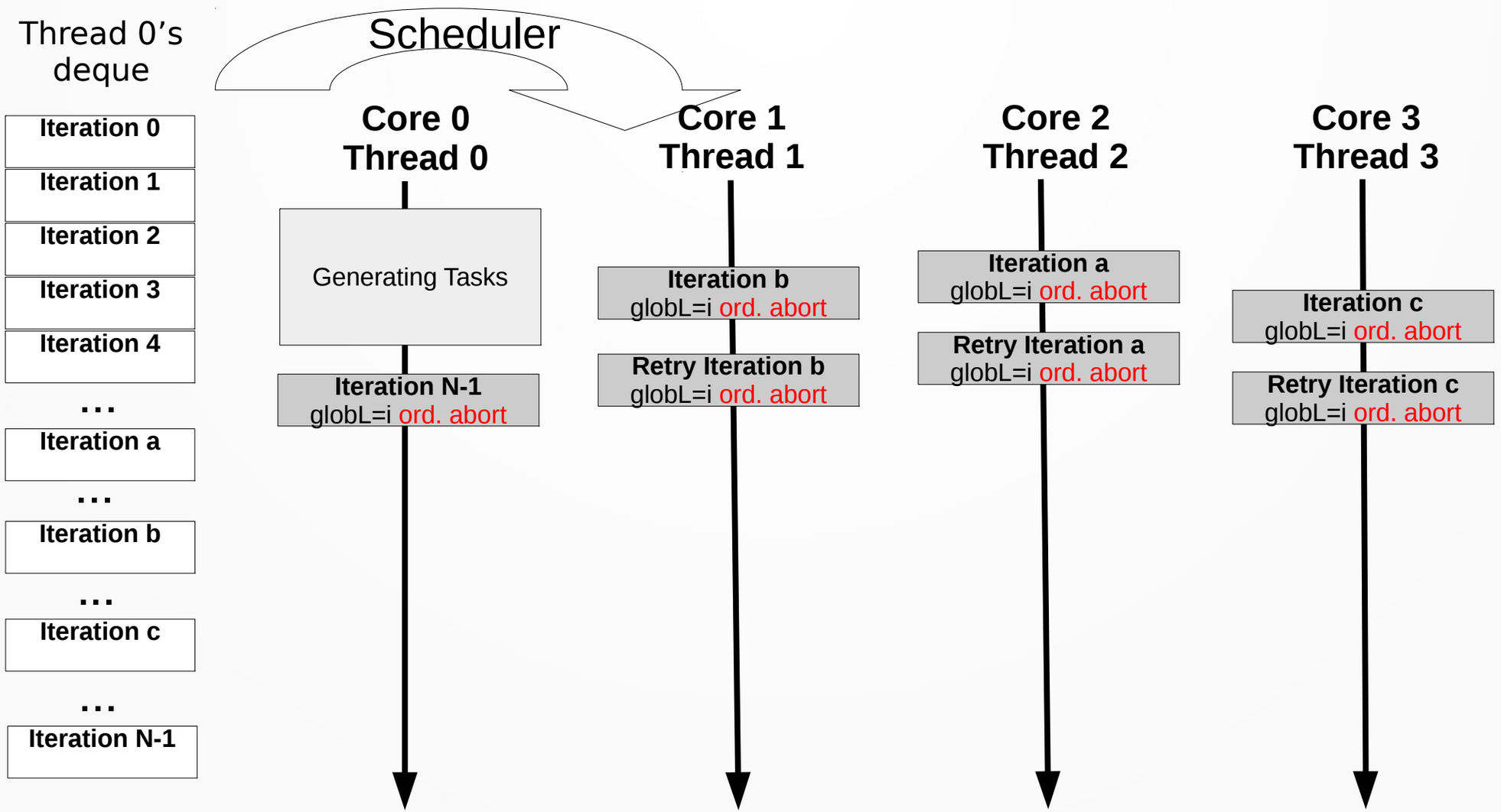

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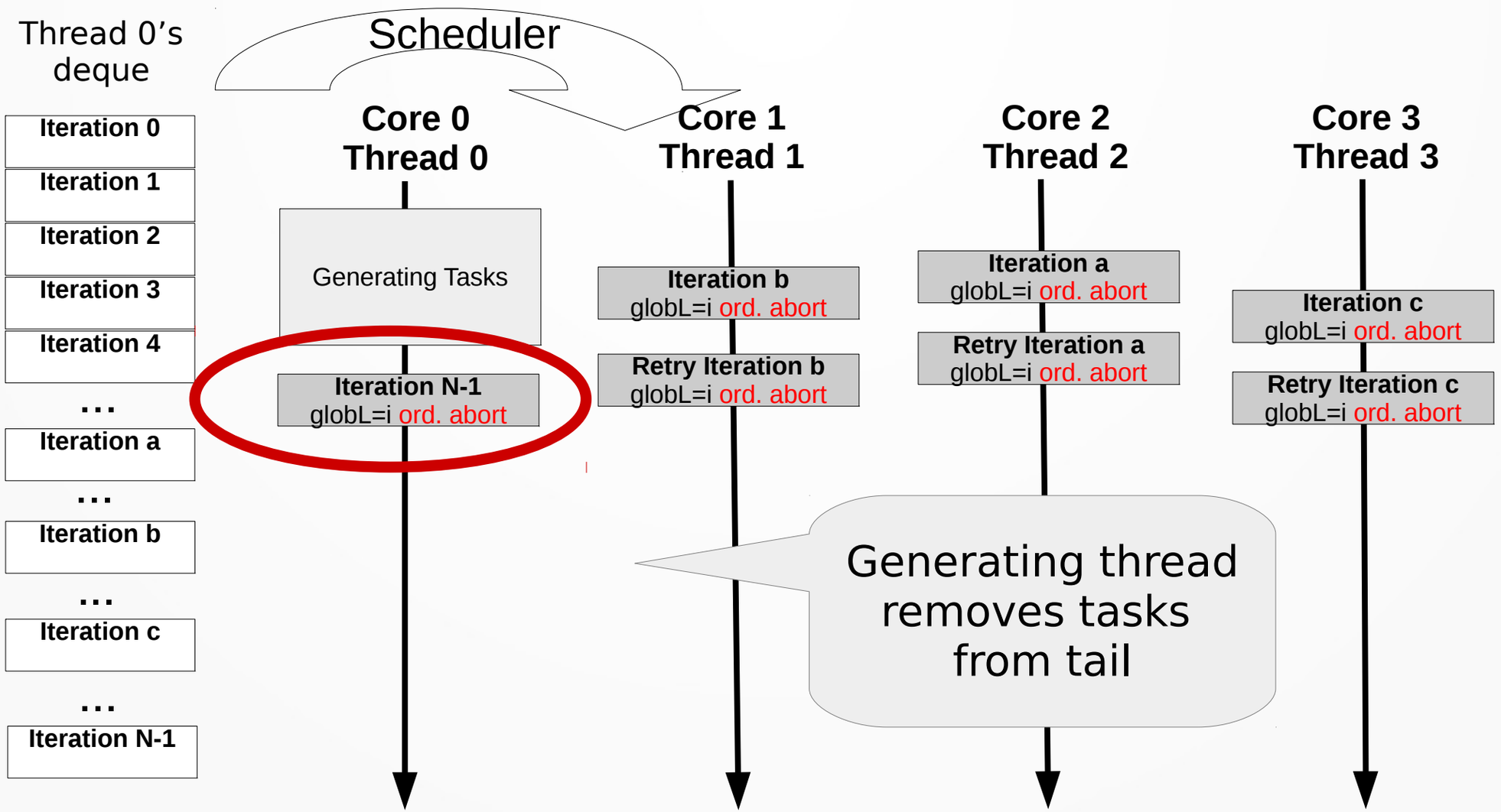

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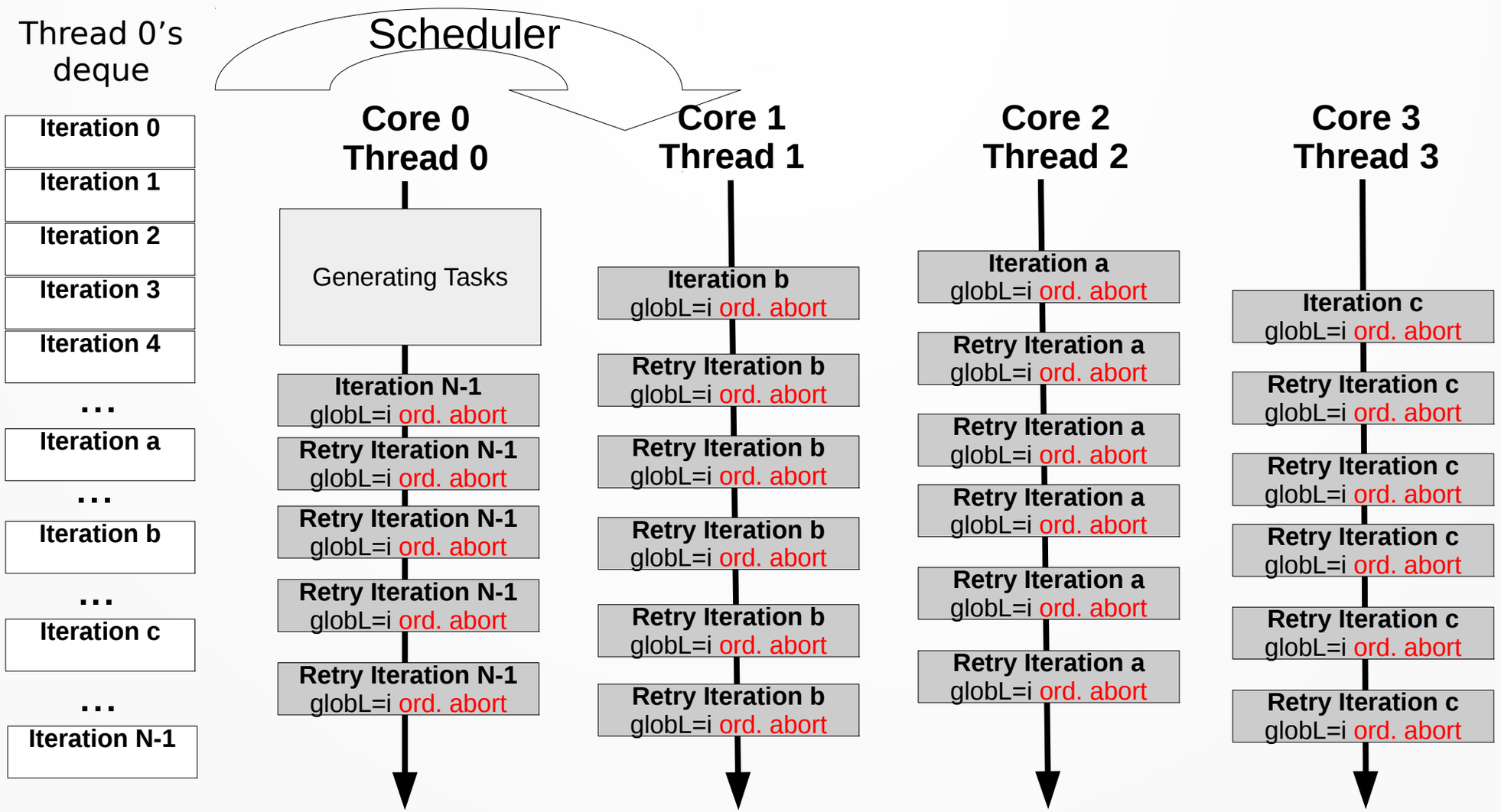

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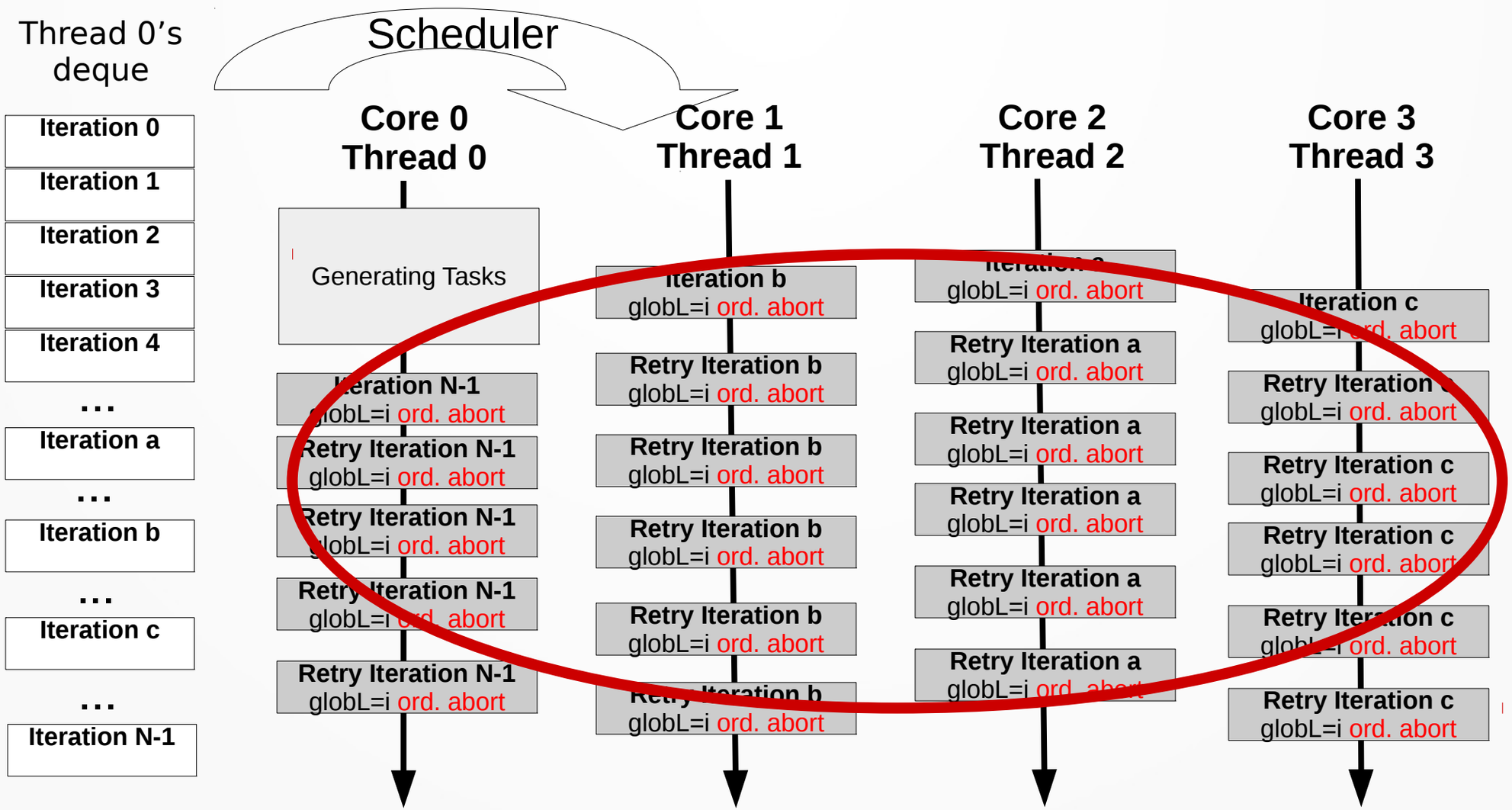

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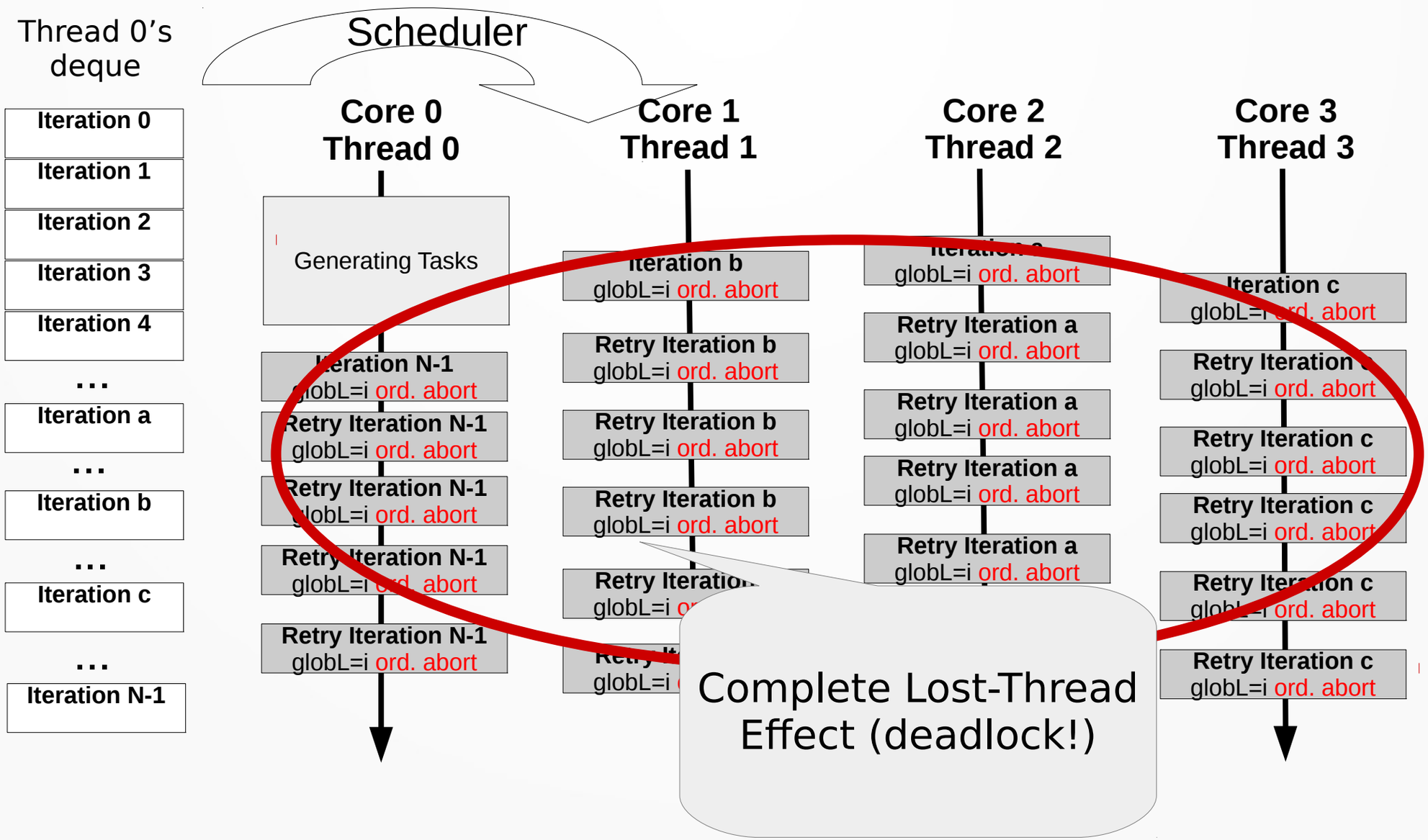

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  - Prevent a task from being executed immediately if the deque is full by reallocating it with an increased size.
  - Increase the initial deque size.
  - Ensure that the generating thread also removes its own tasks from its deque’s head.

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- We used two versions of the LLVM OpenMP Runtime: `libomp2016` and `libomp12`.
- Both versions in two flavors: `monotonic` (`stl-lx-mon`) and `nonmonotonic` (`stl-lx-nm`).

Setup and Environment

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- Baseline: serial execution of the same benchmark program compiled at the same optimization level

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- Quadcore Intel Skylake (TSX-NI)
- 5 loops from cBench and 1 loop from SPEC
- 5 benchmarks: `susan_c`, `susan_e`, `susan_s`, `bitcount`, and `429.mcf`
- Baseline: serial execution of the same benchmark program compiled at the same optimization level
- Default input for each benchmark and reference input for `mcf`

Setup and Environment

Loop ID	Loop Information			
	Benchmark	Location	%*Cov*	Invocations
A	automotive_bitcount	bitcnts.c,65	100%	560
E	automotive_susan_s	susan.c,725	100%	22050
H	automotive_susan_e	susan.c,1117	18%	374
I	automotive_susan_e	susan.c,1056	56%	374
V	automotive_susan_c	susan.c,1614	7%	782
mcf	429.mcf	pbeampp.c,165	40%	21854886

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stl-lx-mm

- The `mcf` hottest loop is a particular case because, with the `S_SIZE` used, only four tasks are generated. The Lost-Thread Effect does not occur because the other three threads will execute the three first tasks and will arrive quickly when the generating thread is executing the fourth task.

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- In the evaluated loops, the performance is poor because either it is not possible to distinguish parallel/serial components or the work of the parallel components is not significant.

Agenda

- ~~Motivating example~~
- ~~Background~~
- ~~Speculative Taskloop (STL)~~
- ~~Lost-Thread Effect and Solution~~
- ~~Experimental Evaluation~~
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- We present an evaluation with two different versions of the OpenMP runtime, both optimized for STL, that reveals that, for certain loops, slowdowns or infinite slowdowns (deadlocks), using the original OpenMP runtime, can be transformed in speed-ups by applying `monotonic` scheduling.

Thanks!