Parallelism on CPU What's hidden from the eyes?

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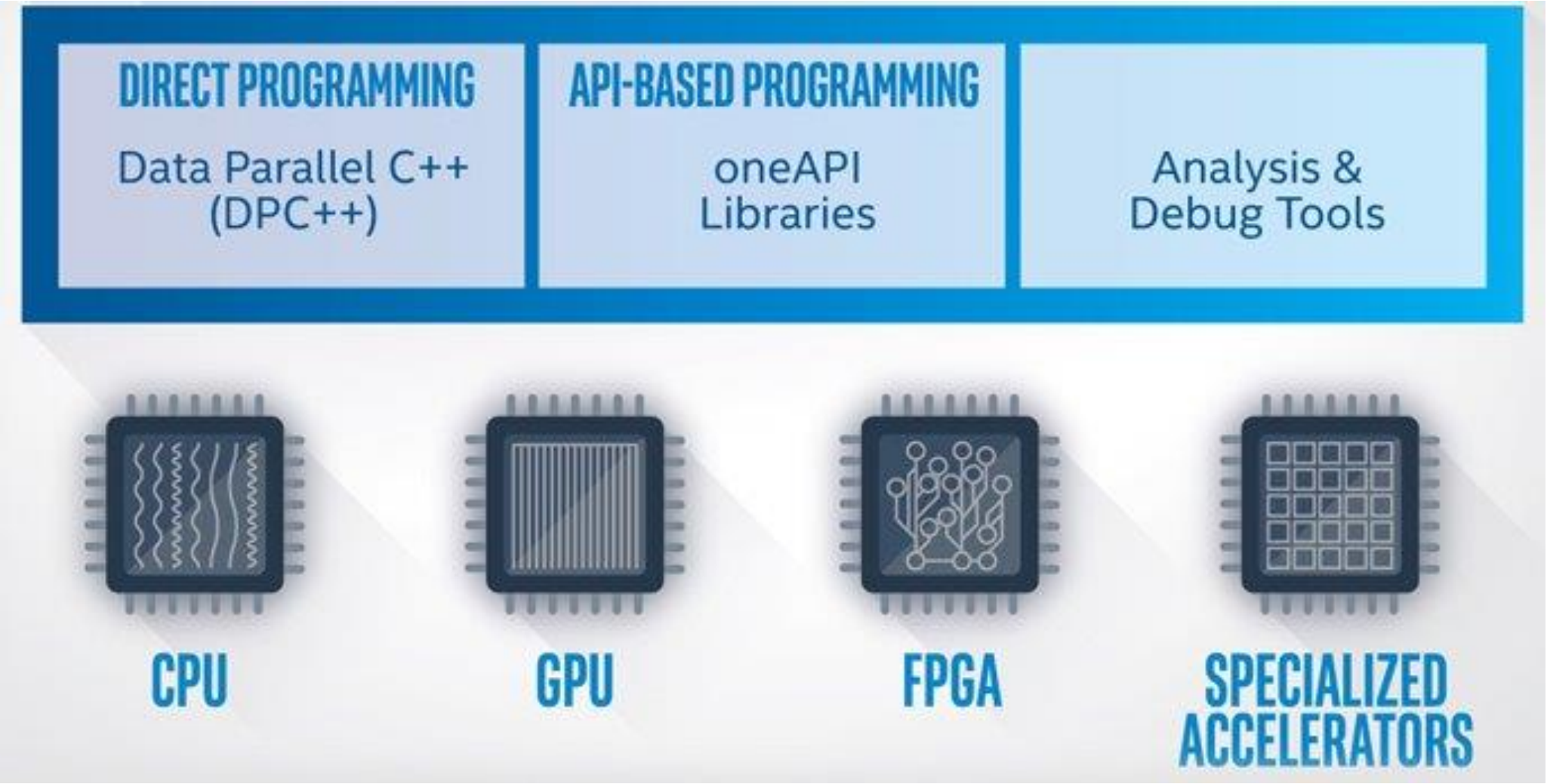
intel®

Agenda

- Intel® oneAPI overview
- Intel® oneAPI Threading Building Blocks (oneTBB) overview
- Problem statement
- Parallel solution with oneTBB
- Self-made task group
- Synchronization mechanisms
- Possible improvements

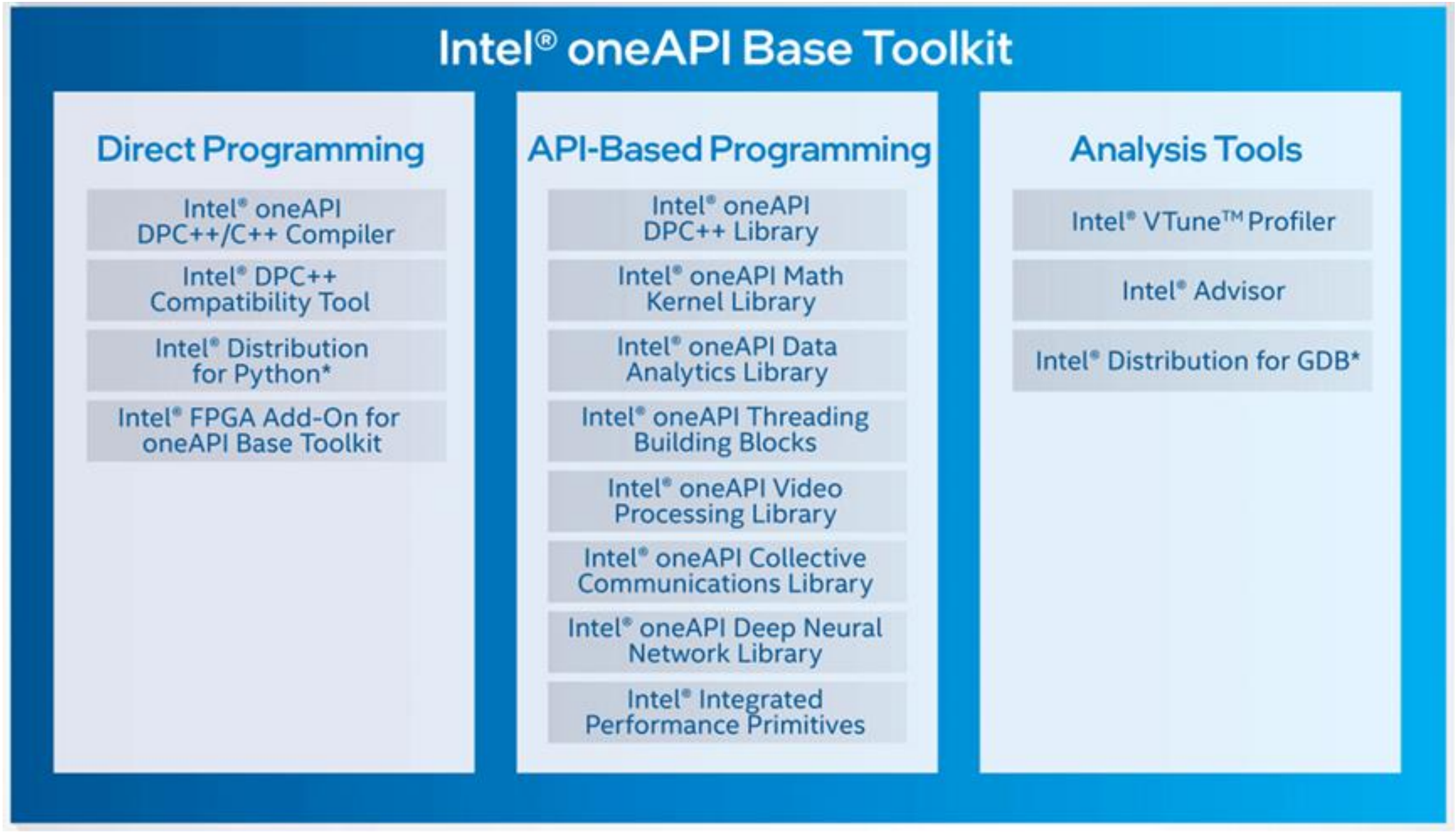
Intel® oneAPI overview

oneAPI: Unified cross-architecture programming



Why oneAPI?

- Unified cross-architecture programming
- Standards-based (C++, DPC++)
- Stable and open API
- Backward compatibility


Intel® oneAPI Base Toolkit
Direct Programming
Intel® oneAPI DPC++/C++ Compiler
Intel® DPC++ Compatibility Tool
Intel® Distribution for Python*
Intel® FPGA Add-On for oneAPI Base Toolkit
API-Based Programming
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Intel® oneAPI Math Kernel Library
Intel® oneAPI Data Analytics Library
Intel® oneAPI Threading Building Blocks
Intel® oneAPI Video Processing Library
Intel® oneAPI Collective Communications Library
Intel® oneAPI Deep Neural Network Library
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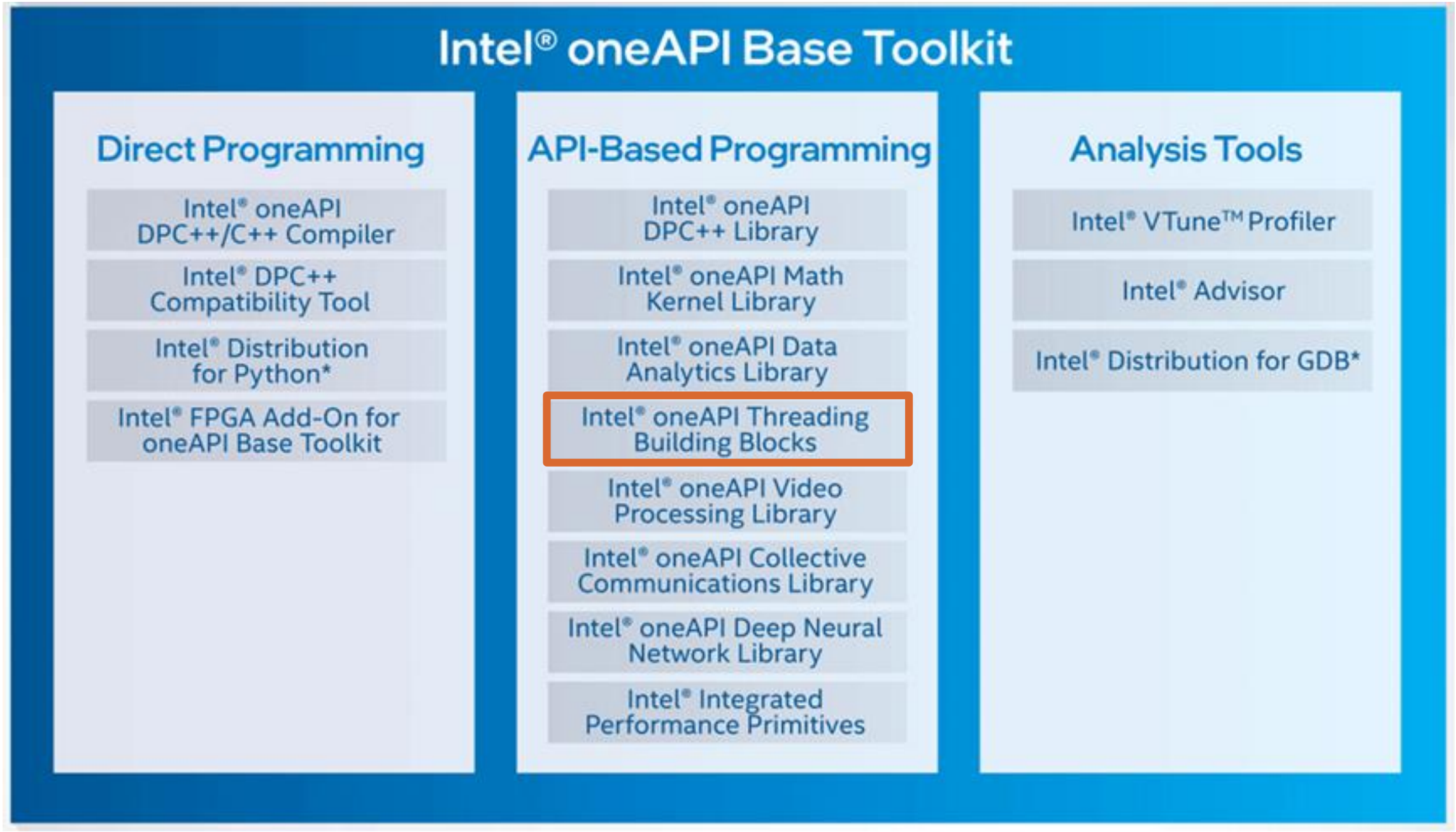
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oneTBB overview

oneTBB overview

Parallel algorithms and data structures

Threads and synchronization

Memory allocation and task scheduling

Generic Parallel Algorithms

Efficient scalable way to exploit the power of multi-core without having start to scratch

Flow Graph

A set of classes to express parallelism as a graph of compute dependencies and/or data flow

Concurrent Containers

Concurrent access and a scalable alternative to serial containers with external locking

Synchronization Primitives

A variety of mutexes with different properties

Task Scheduler

Sophisticated work scheduling engine that empowers parallel algorithms and flow graph

Thread Local Storage

Unlimited number of thread local variables

Miscellaneous

Thread-safe timers, system topology traversing

Memory allocation

Scalable memory management, Thread-safe allocator

oneTBB role in oneAPI

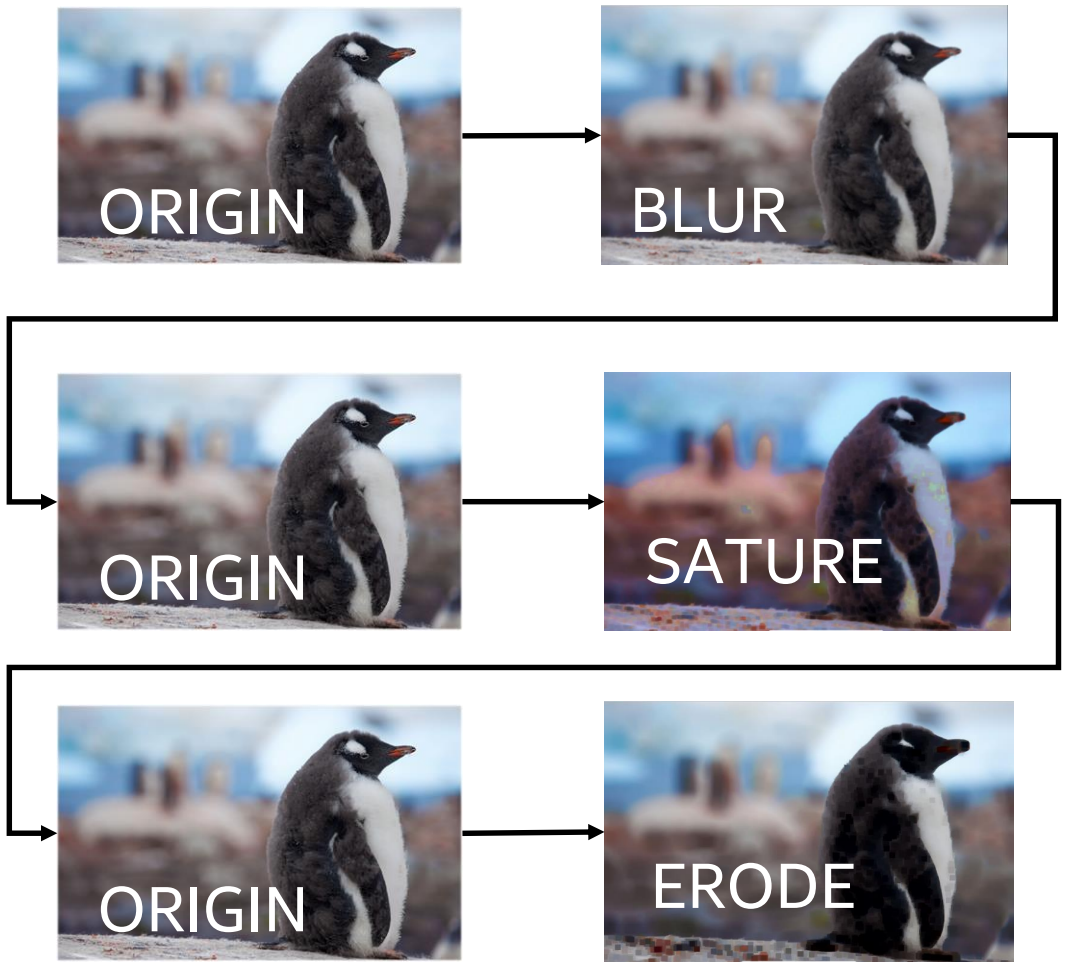
- Public API for CPU parallelism
- Internal layer for parallelism on CPU used by:
  - DPC++/C++ Compiler
  - DPC++ Library
  - Various oneAPI libraries

Problem statement

Problem statement

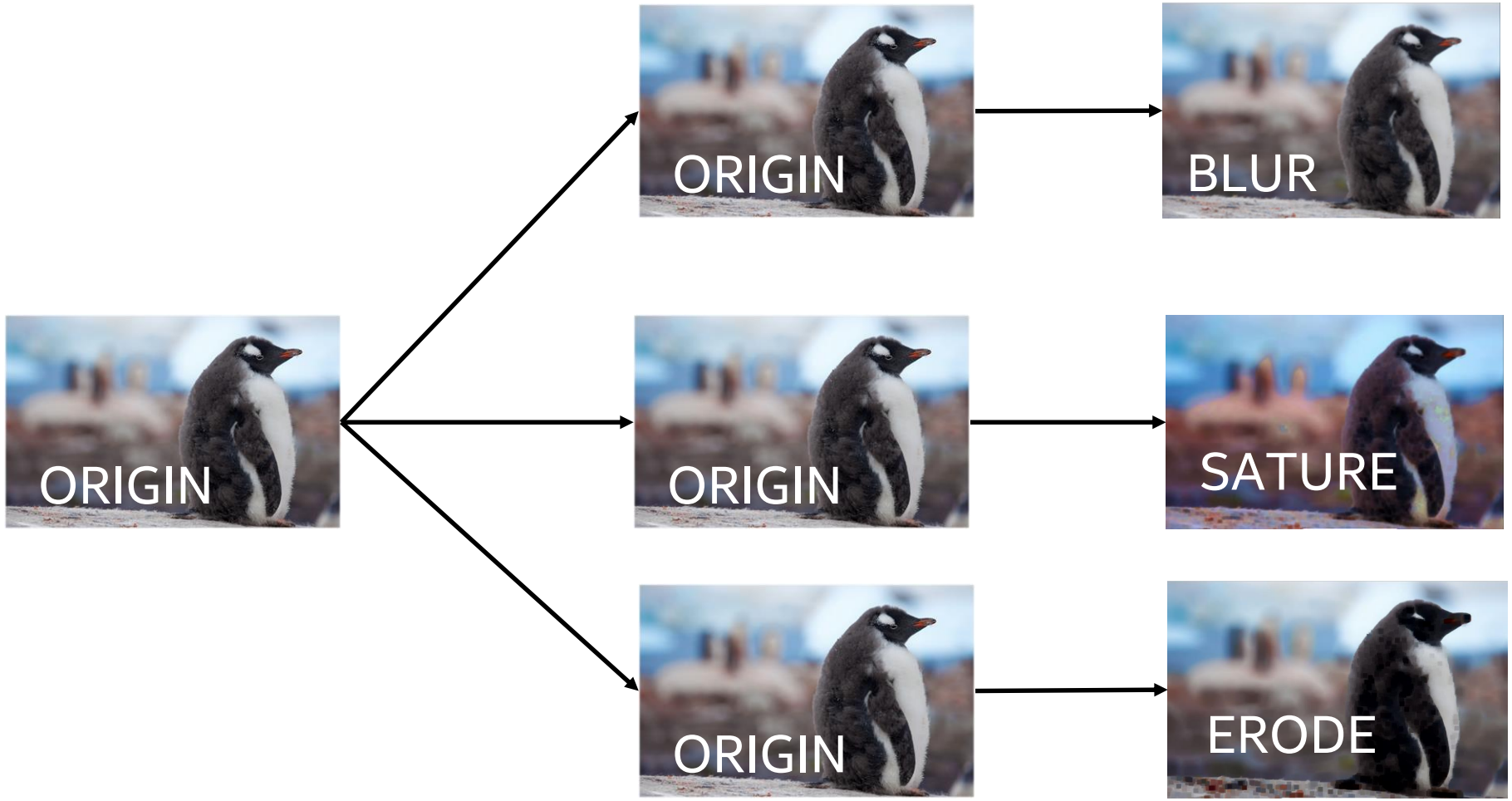
Problem statement (cont.)

Possible solution



Parallel solution with oneTBB

Parallel solution



Self-made task group

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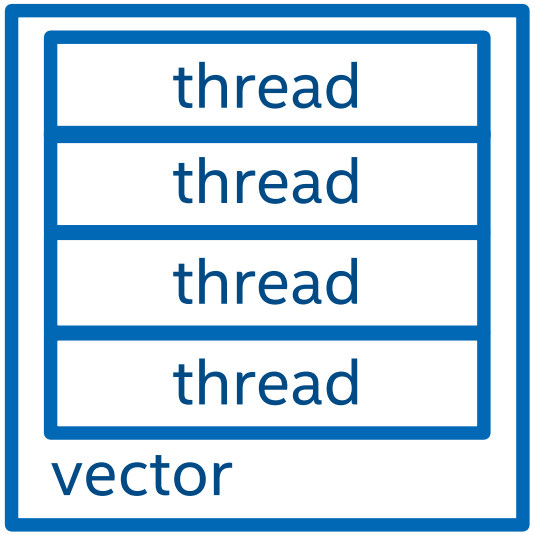
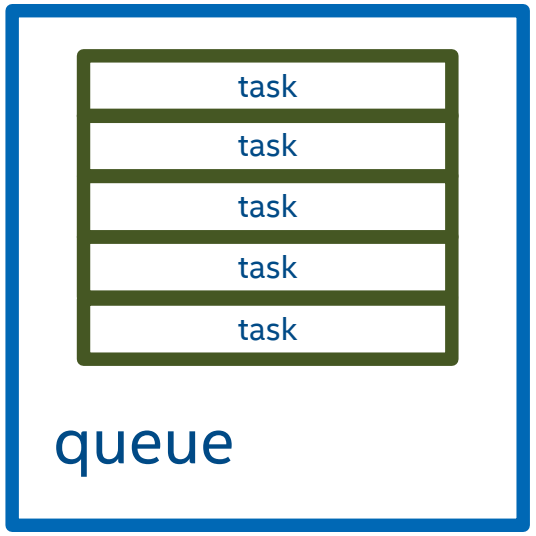
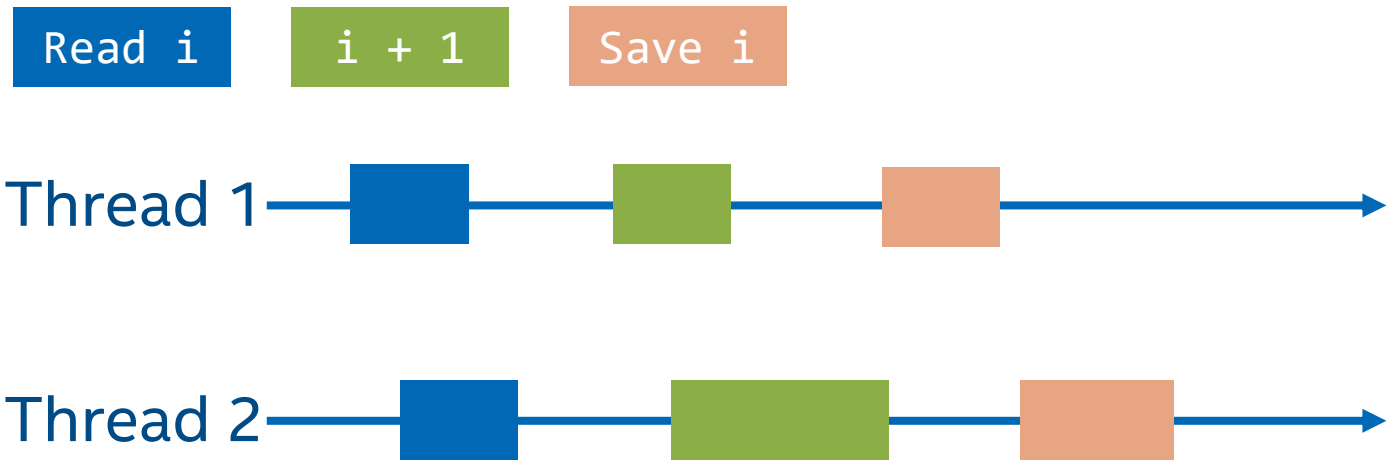




Synchronization mechanisms

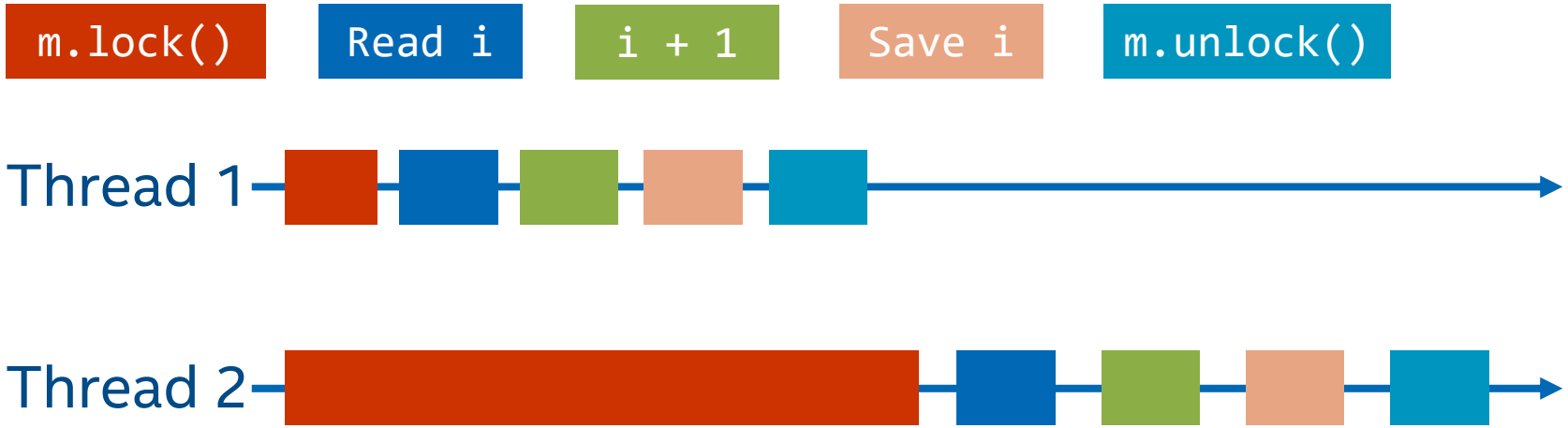
Data race example

```
int i = 0;
++i;
```



Mutex solution

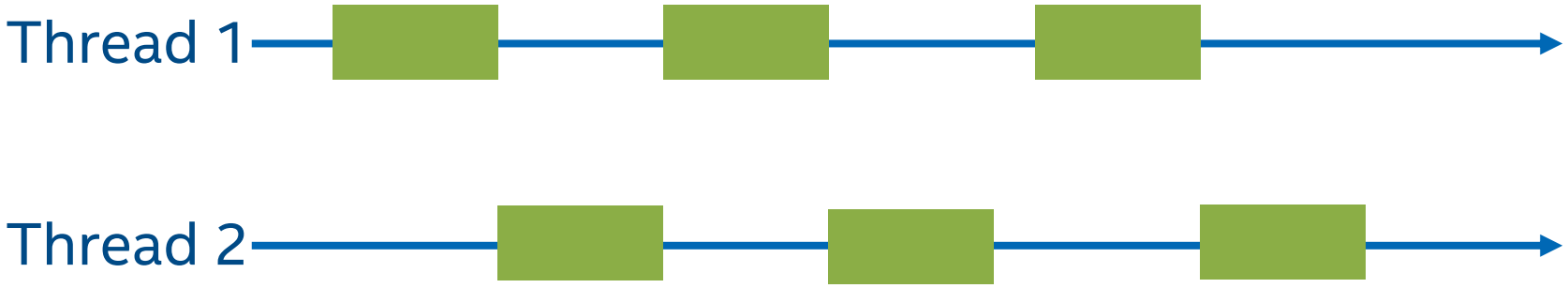
```
int i = 0;
std::mutex m;
++i;
```



Atomic operations

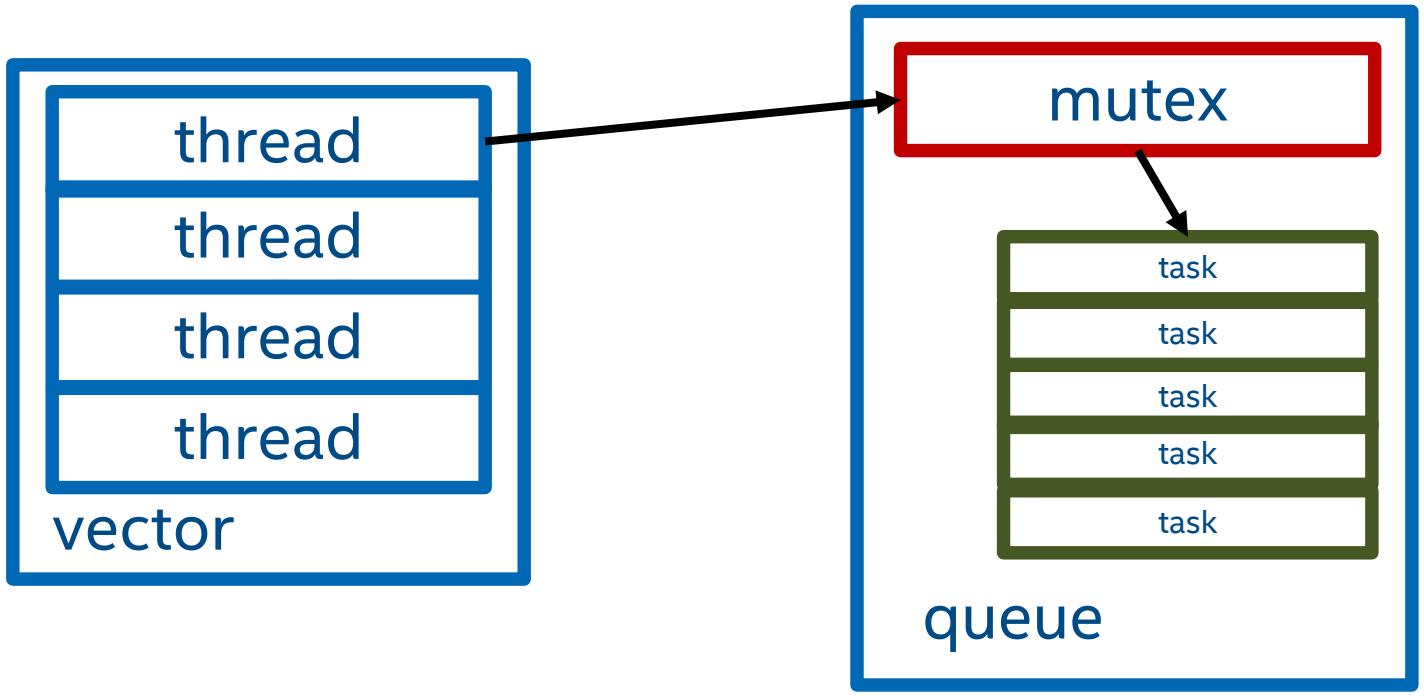
```
std::atomic<int> i(0);
```

```
++i
```

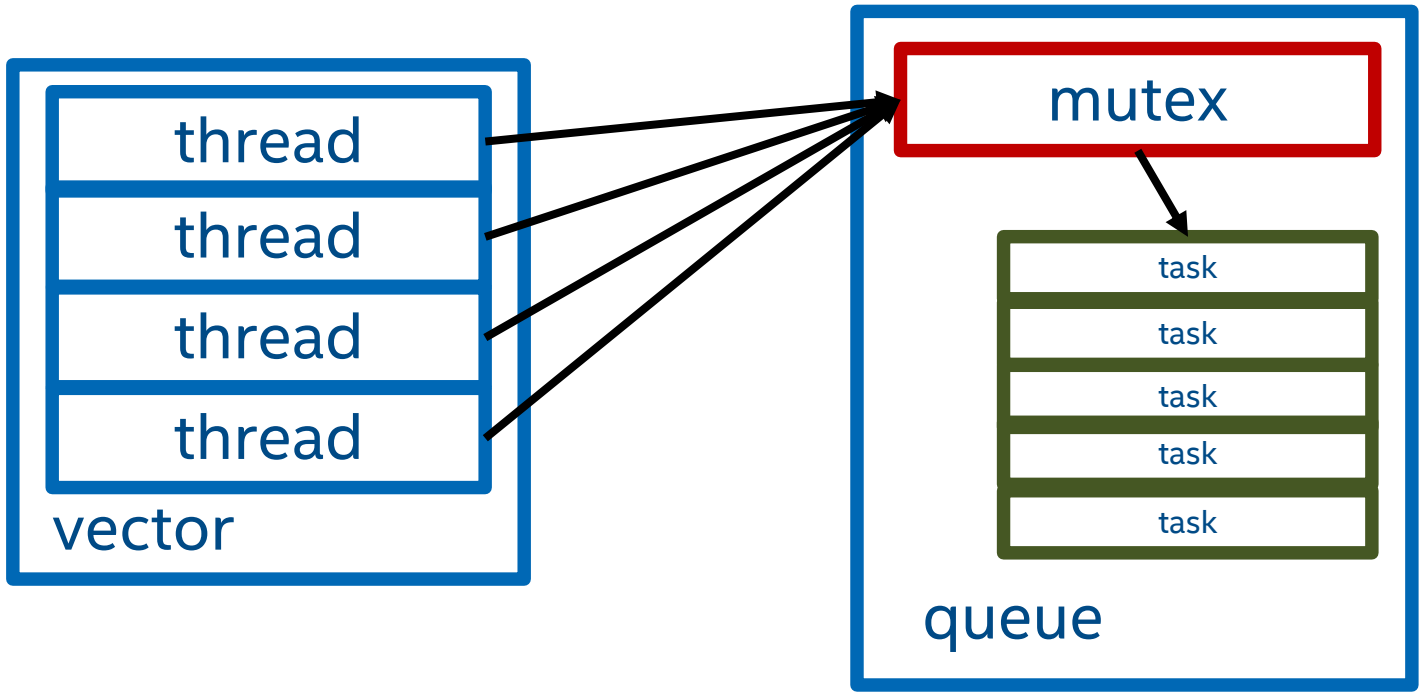


Contention

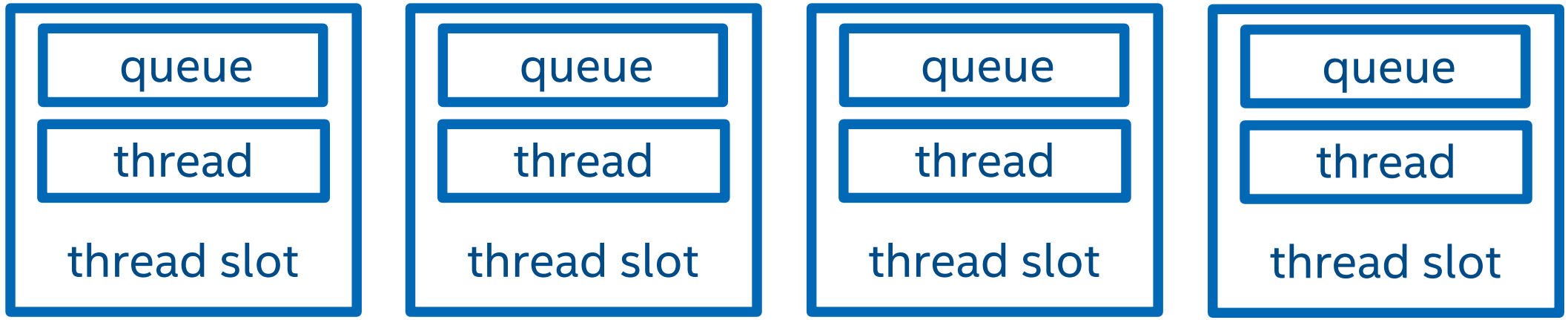
Contention on mutex



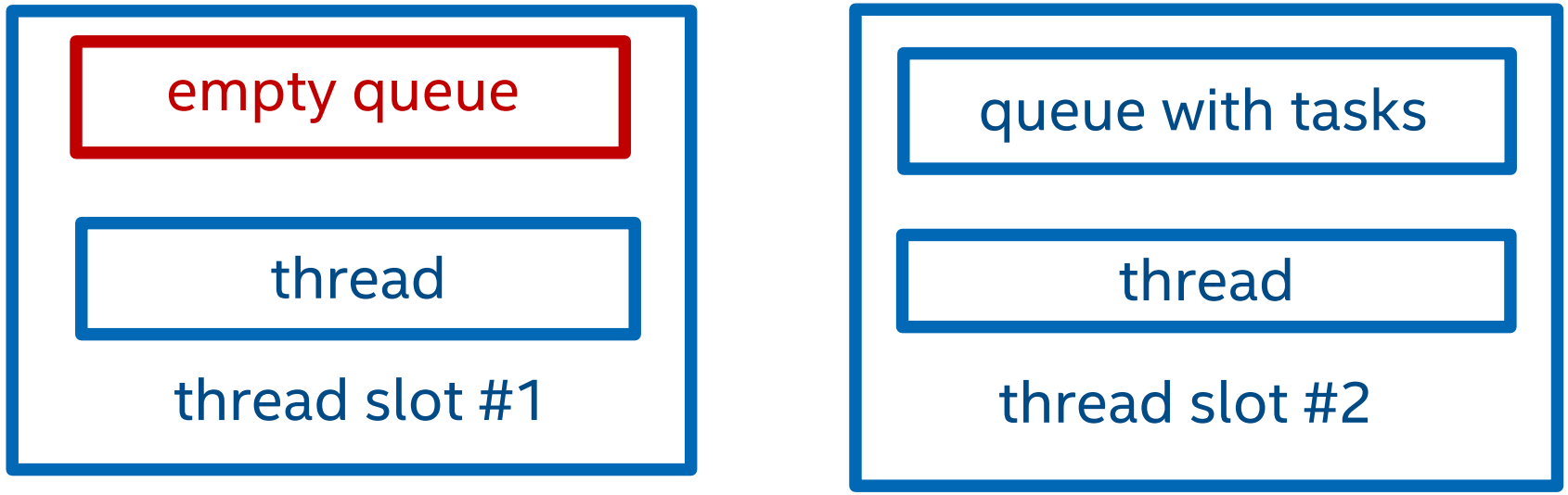
Contention on mutex (cont.)



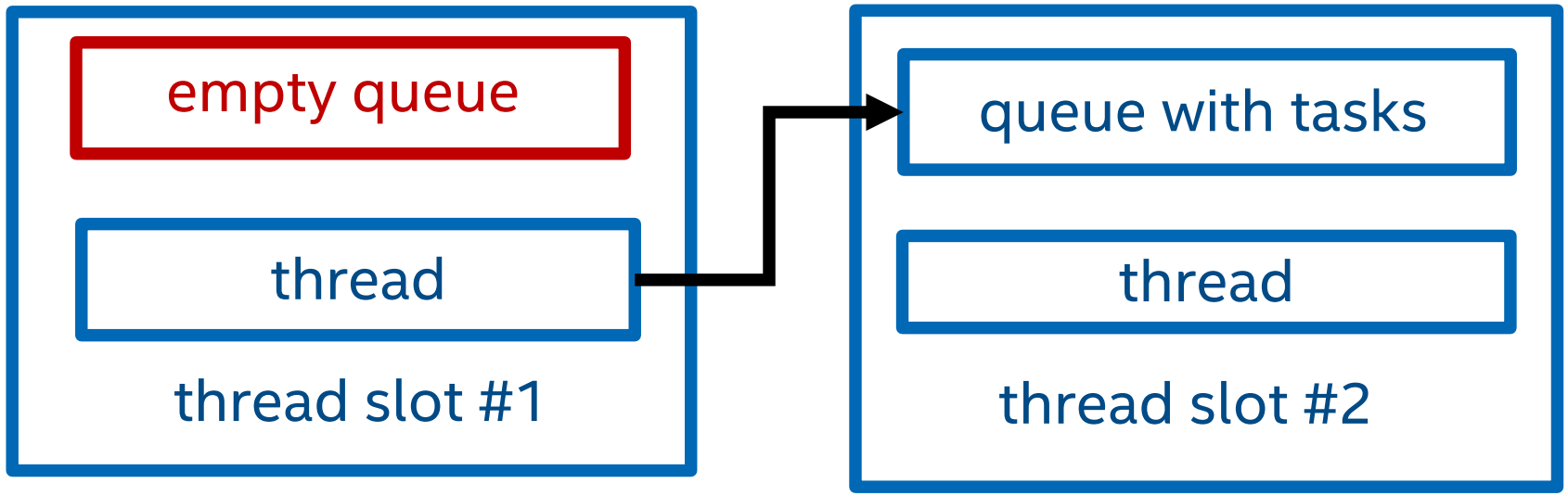
Solution: local task queue for each thread



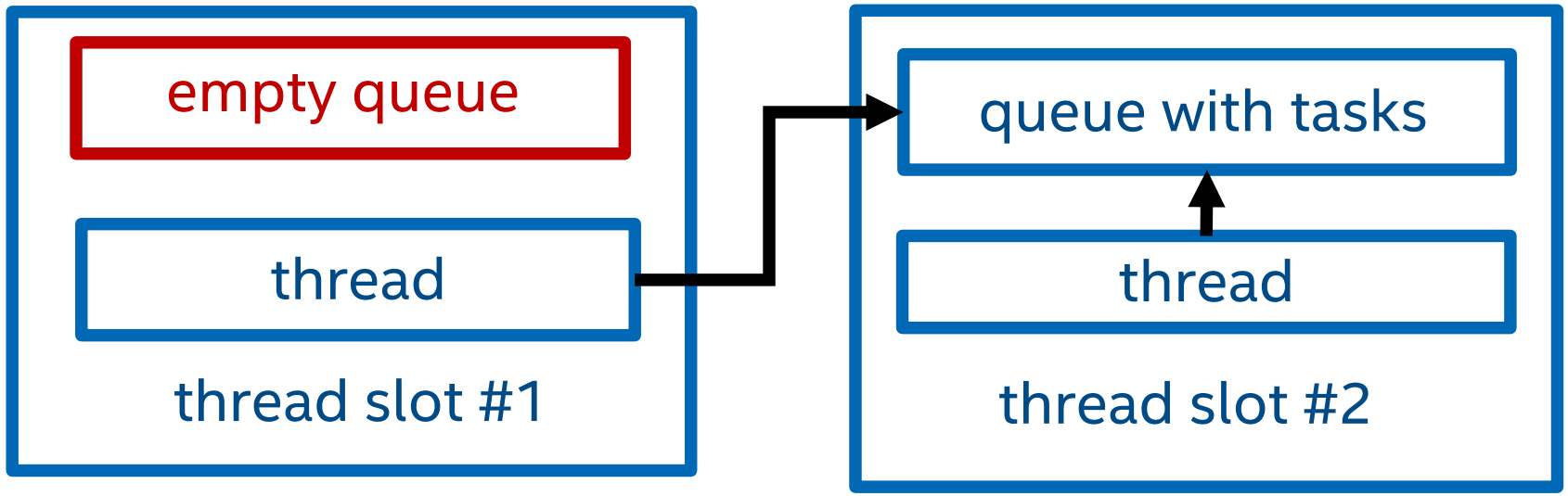
Task stealing



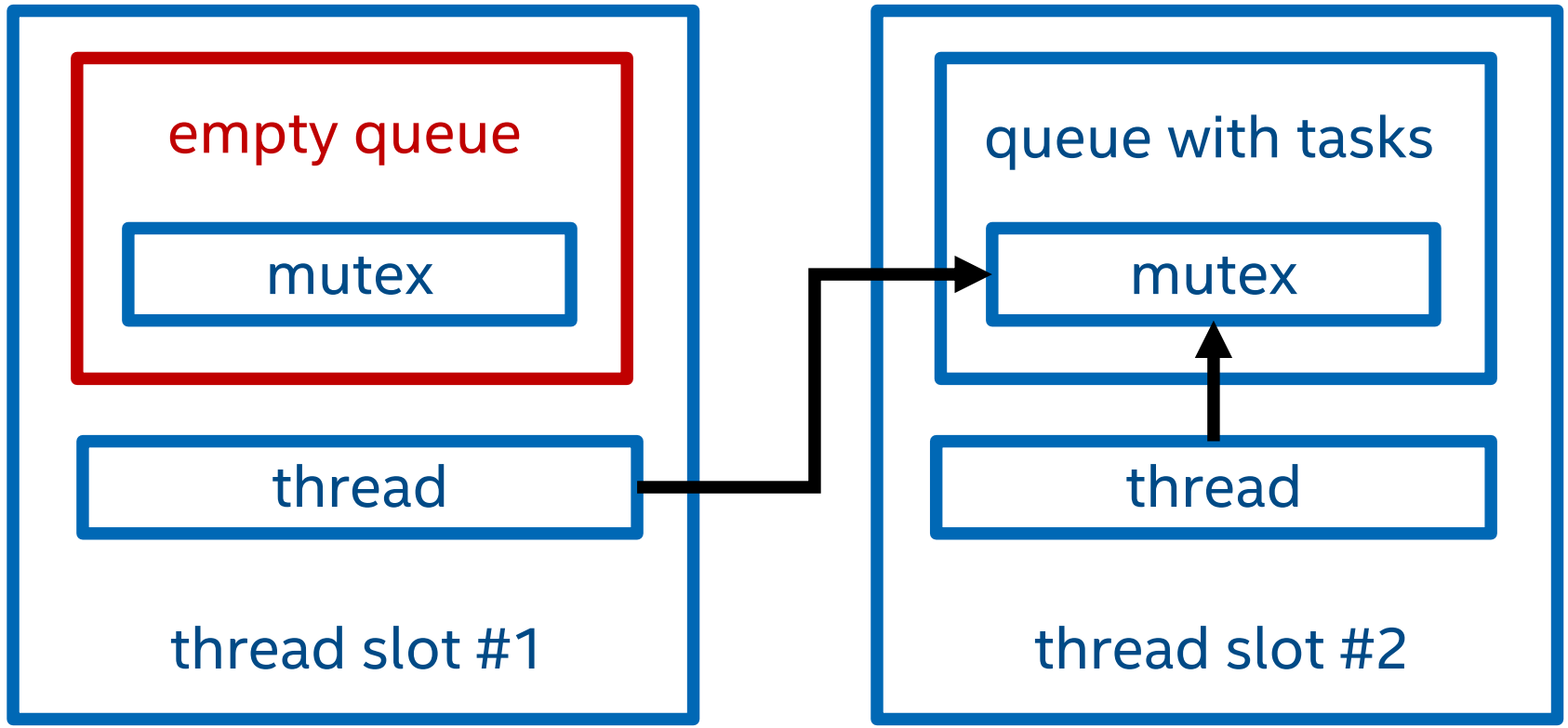
Task stealing (cont.)



Task stealing (cont.)

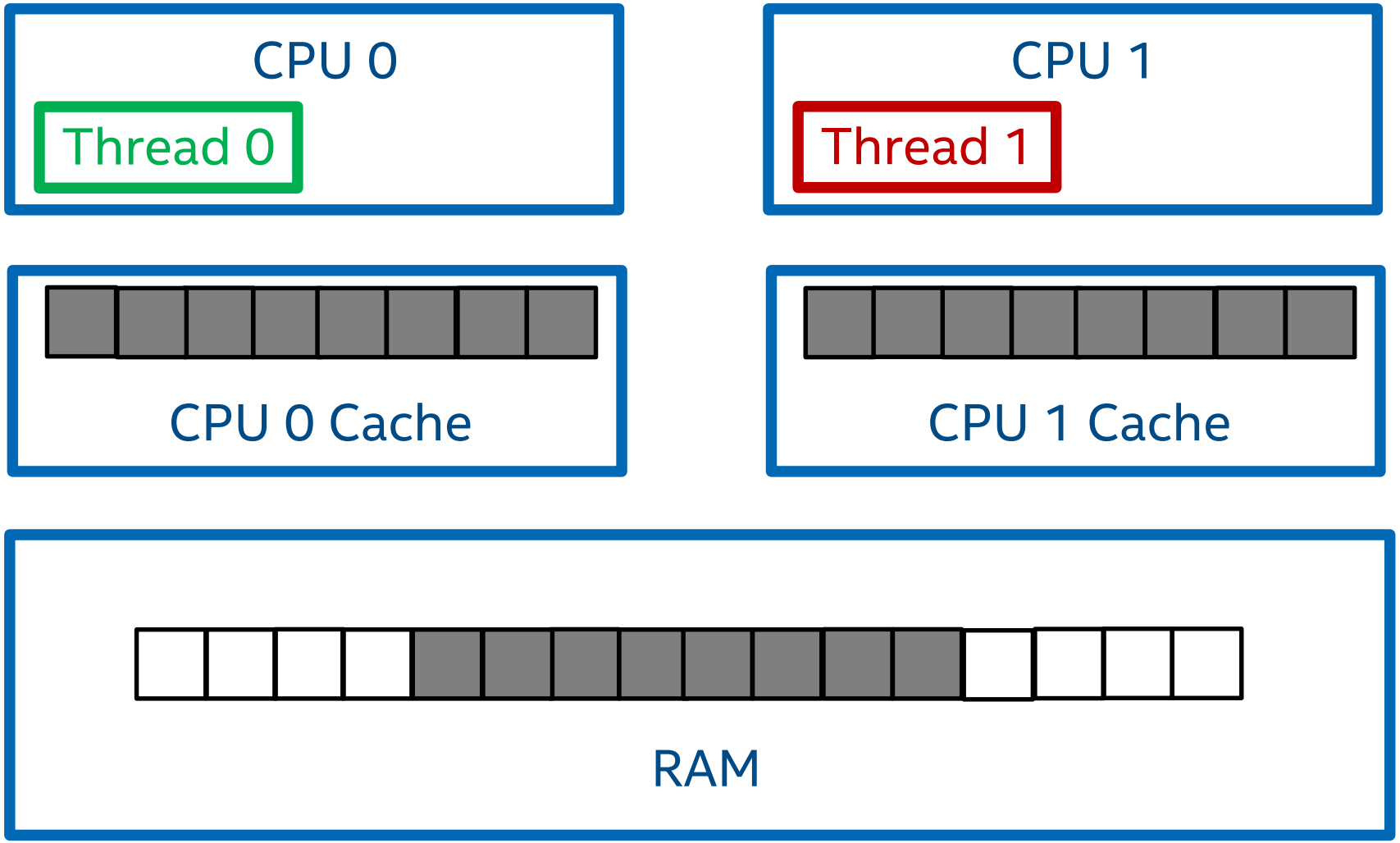


Task stealing (cont.)



False sharing

Thread slot alignment (false sharing)



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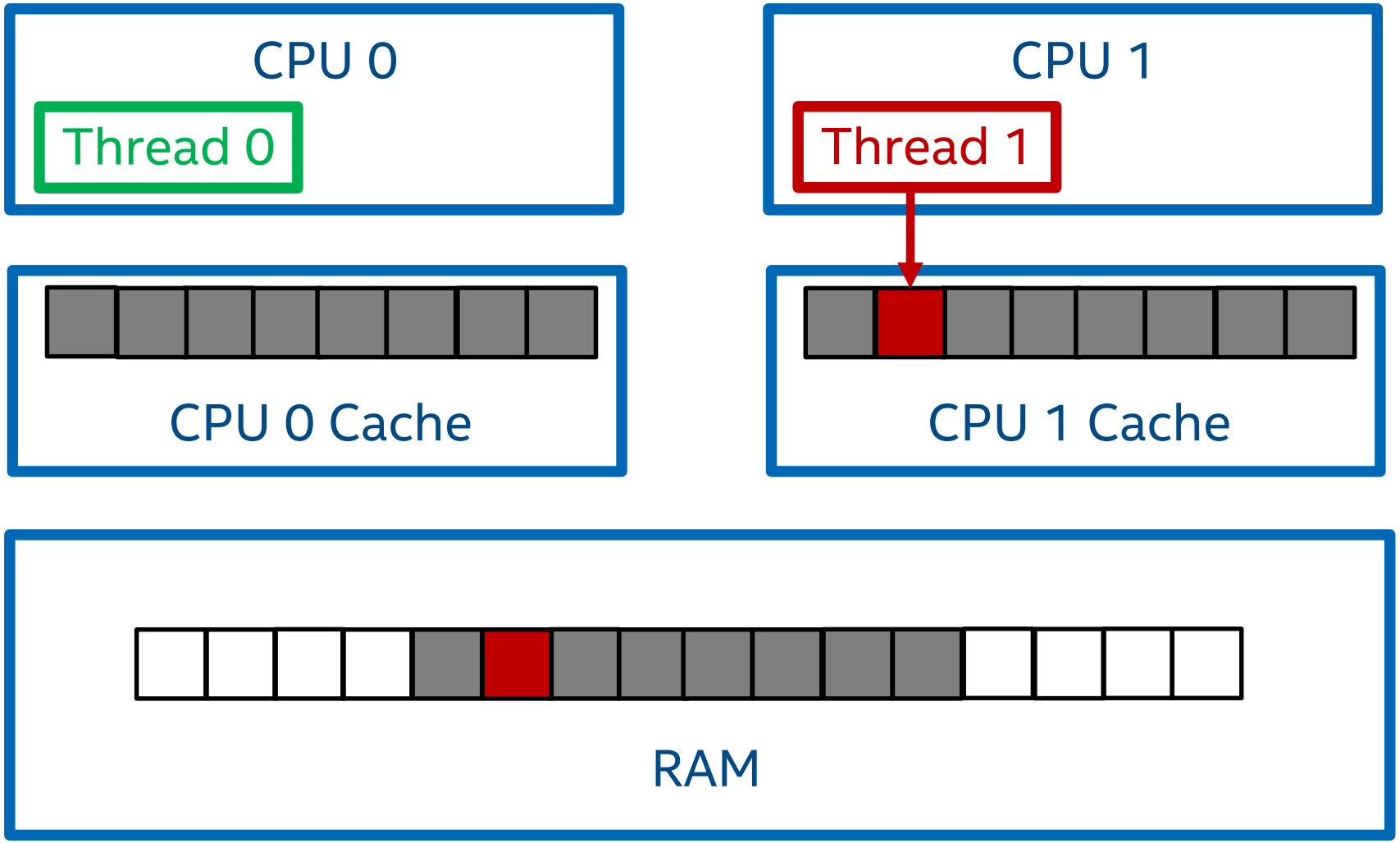

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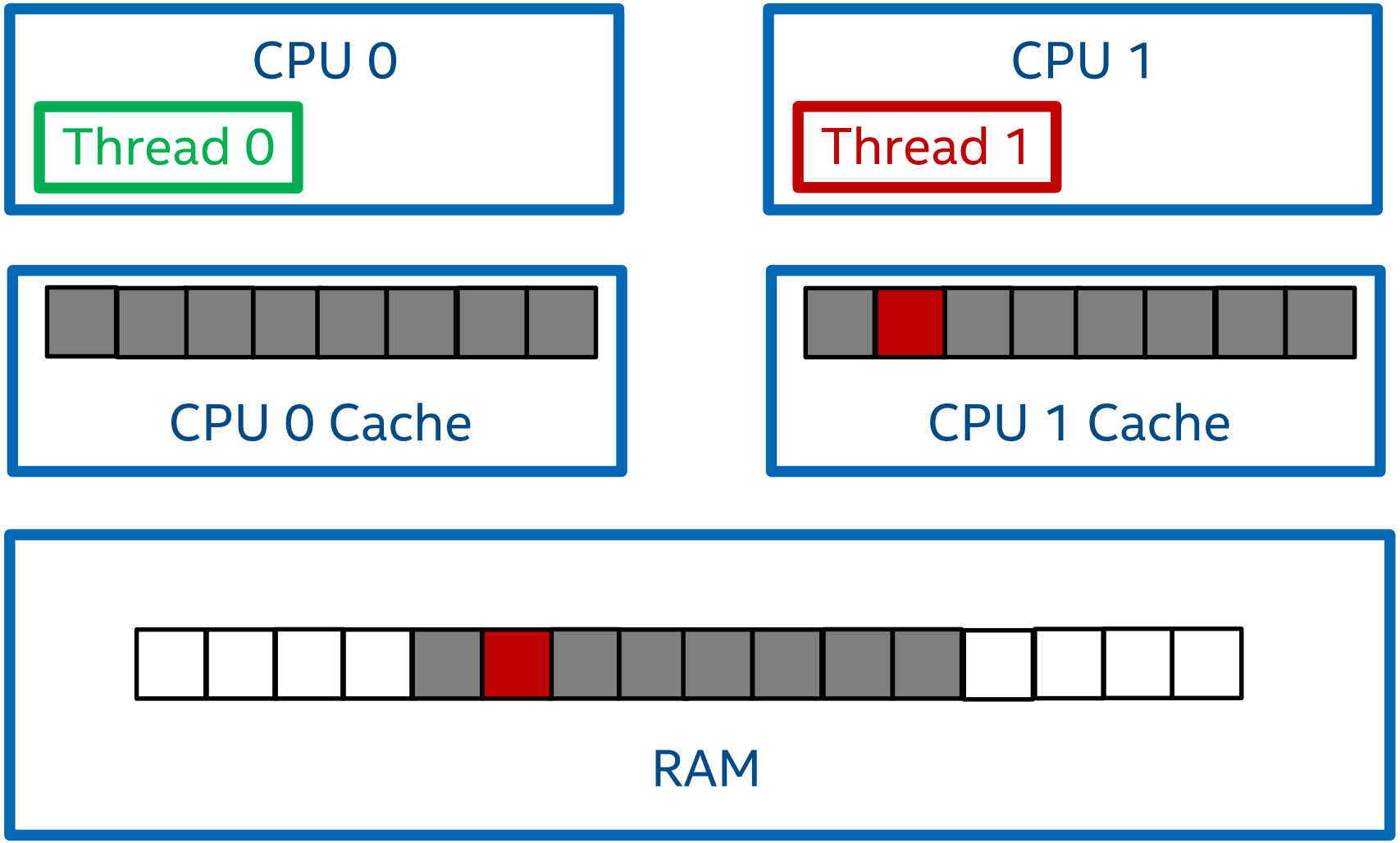

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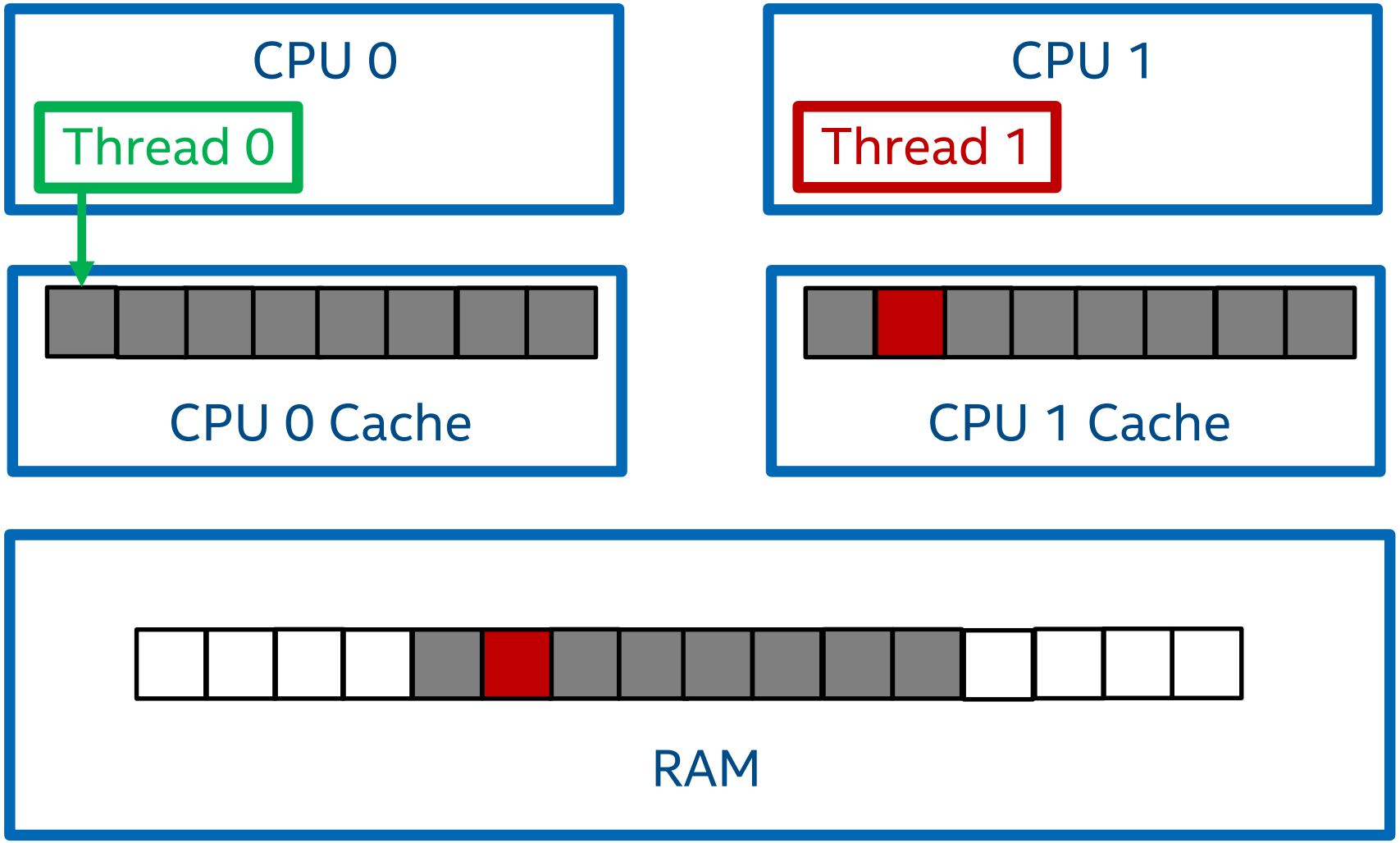

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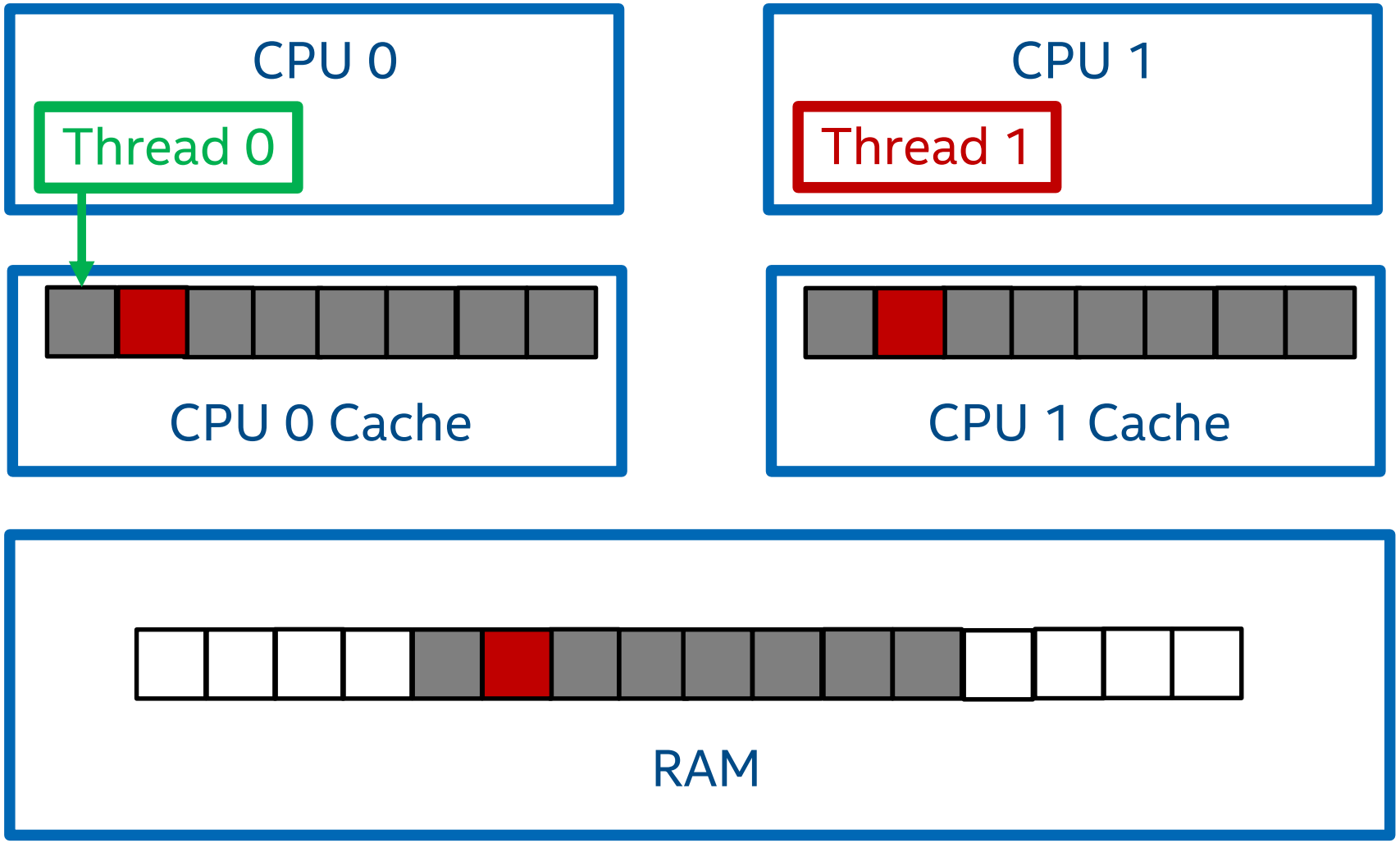

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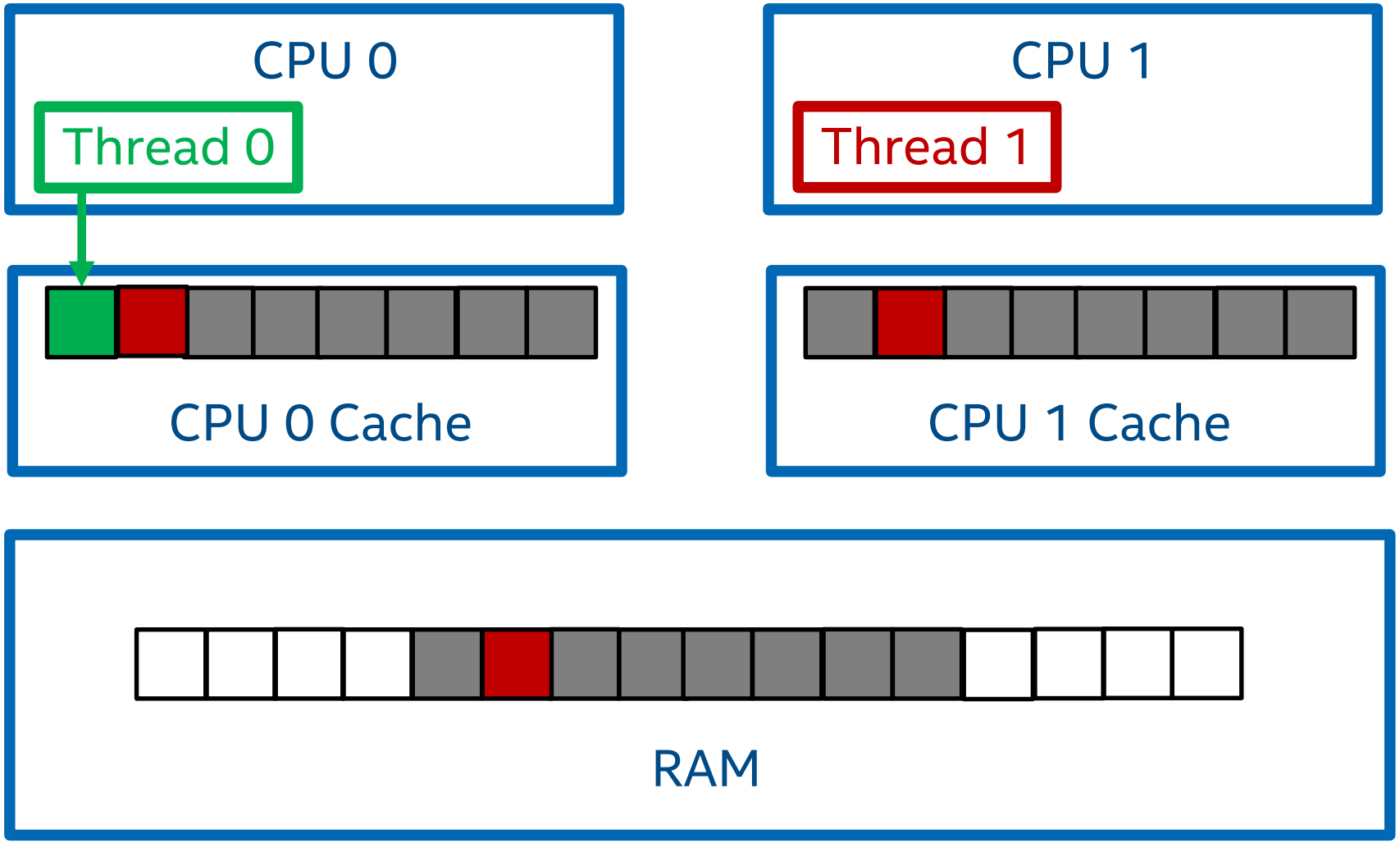

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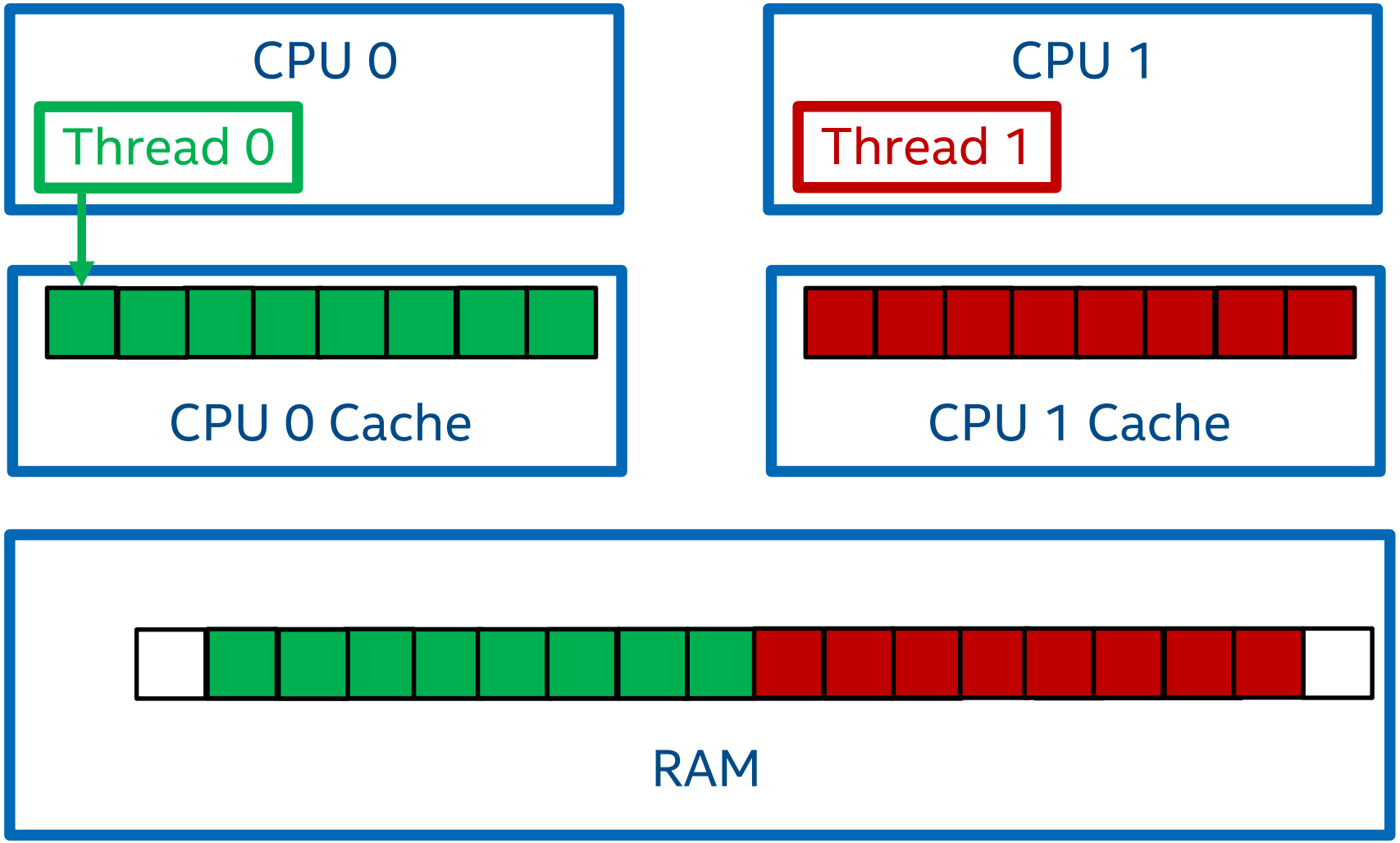

Possible improvements

- Cache-line aligned tasks
- Condition variable synchronization