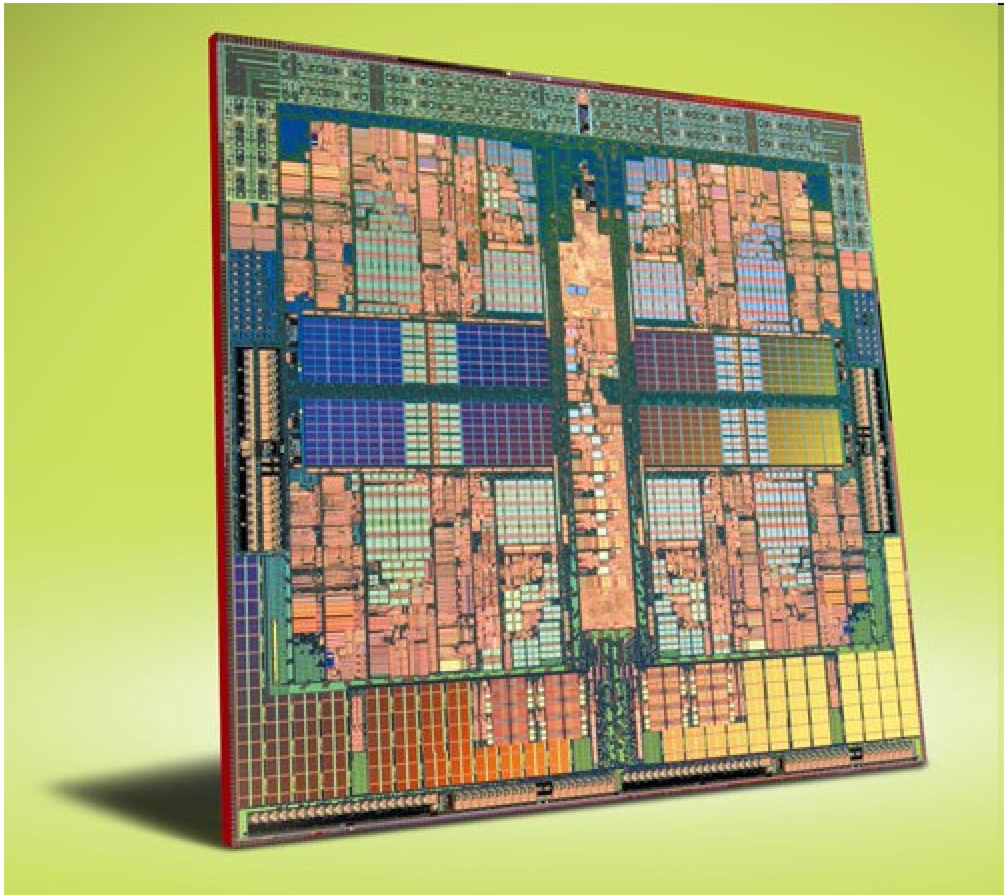
Multi-core processors



History

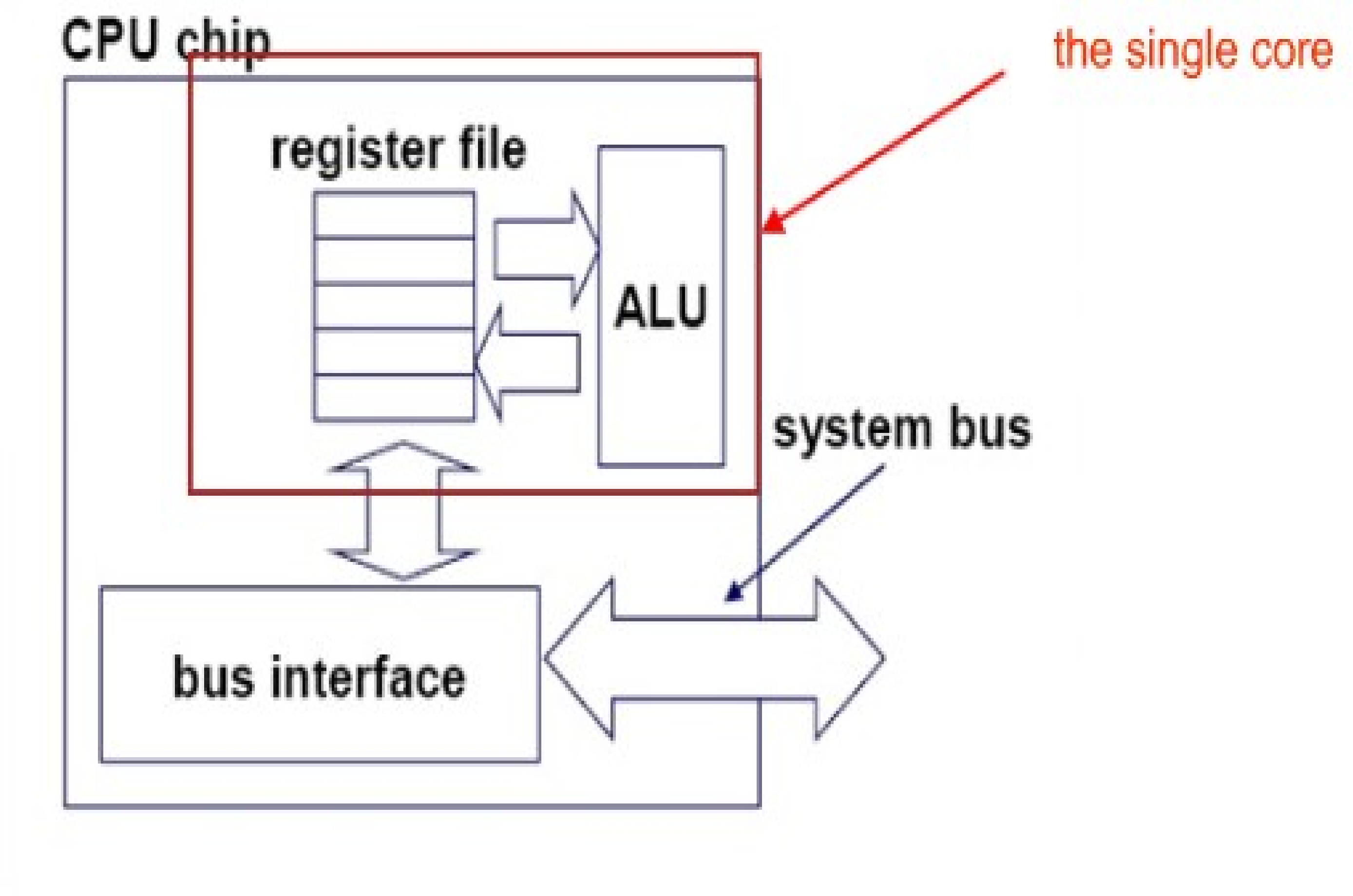
- In the early 1970’s the first Microprocessor was developed by Intel.
- It was a 4 bit machine that was named the 4004
- The 4004 was followed by Intel’s 8008 and 8080, as well as motorola’s 6800 and 68000

Growth

With each new generation of processors there were several developments such as:

- Smaller size
- Faster
- Increased heat dissipation
- Greater Consumption of power

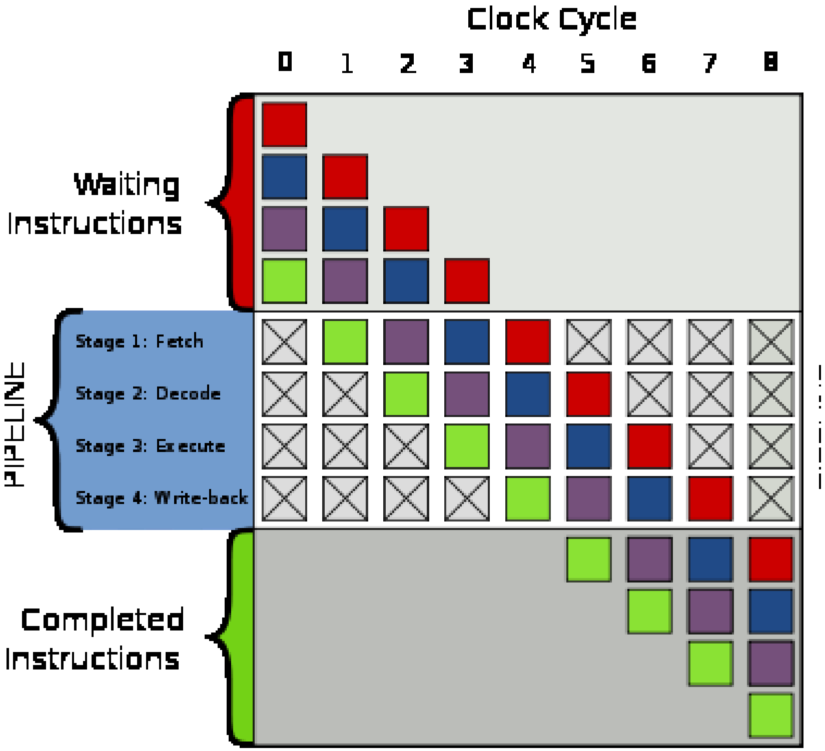
Design
Single core architecture



Single Core Performance

On technique used to increase single core performance was:

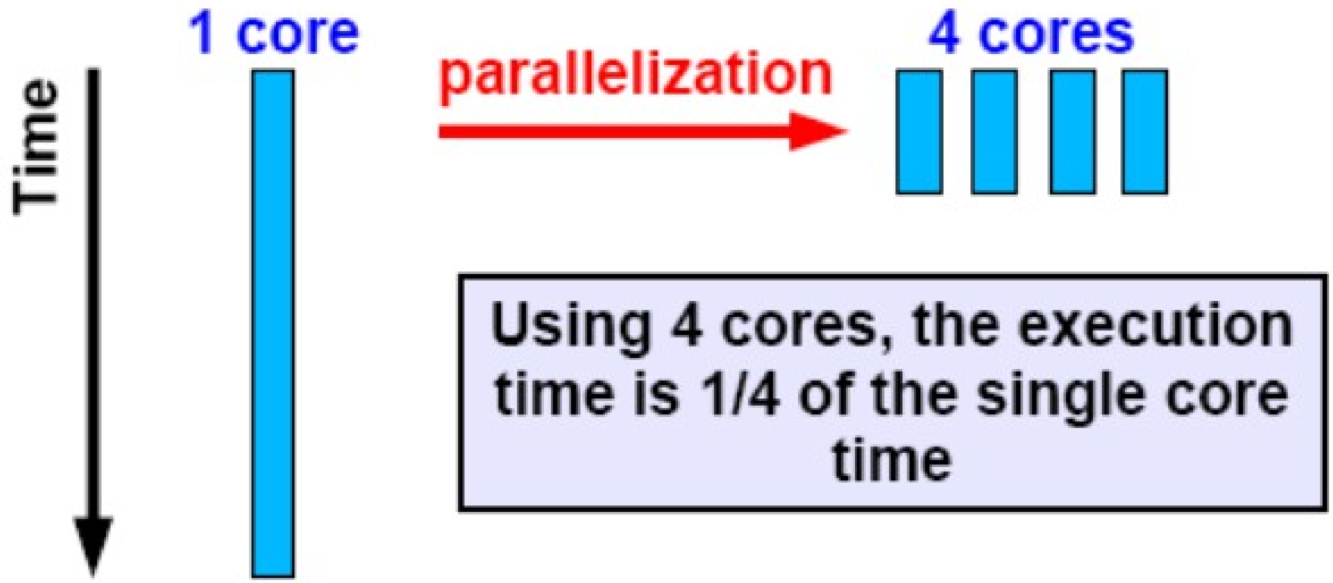
- Pipelining: beginning other waiting instructions before the first finishes



Why parallelization ?

Parallelization is another optimization technique.
The goal is to reduce the execution time.

To this end, multiple processors or cores are used.

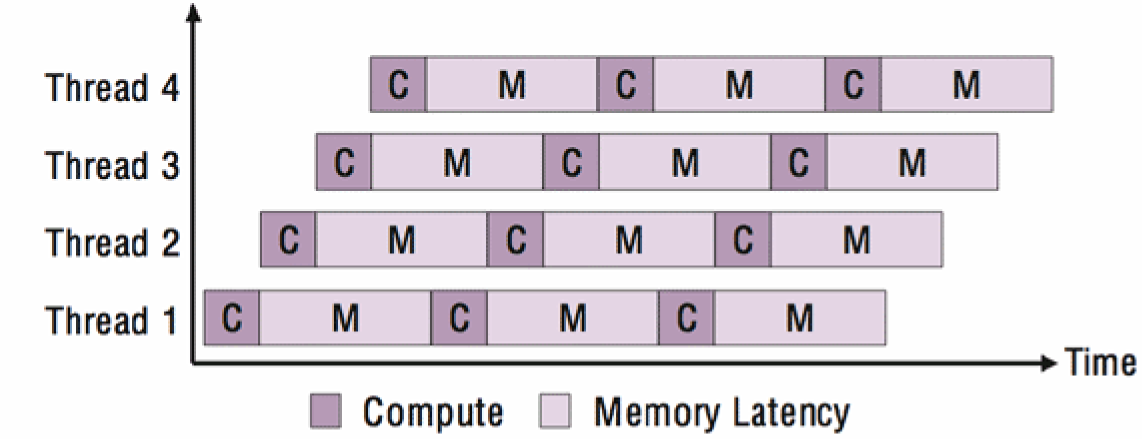


Using 4 cores, the execution time is 1/4 of the single core time

Single Core continued

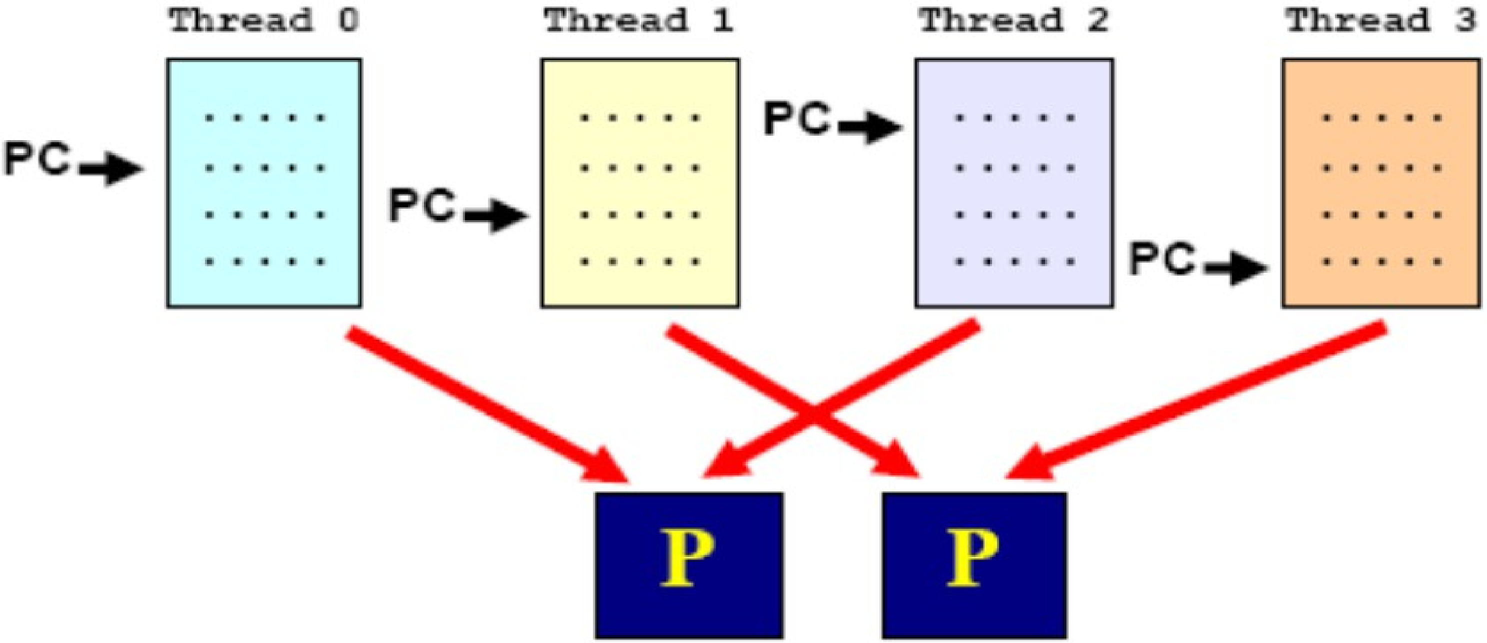
Another technique was multithreading

- Multithreading involves execution of two separate threads.
- Time is divided and interlaced between the two threads in order to simulate simultaneous execution



What is a thread ?

- Loosely said, a thread consists of a series of instructions with its own program counter(”PC”) and state.
- A parallel program executes threads in parallel.
- These threads are then scheduled onto processors.



Problems with Single Core

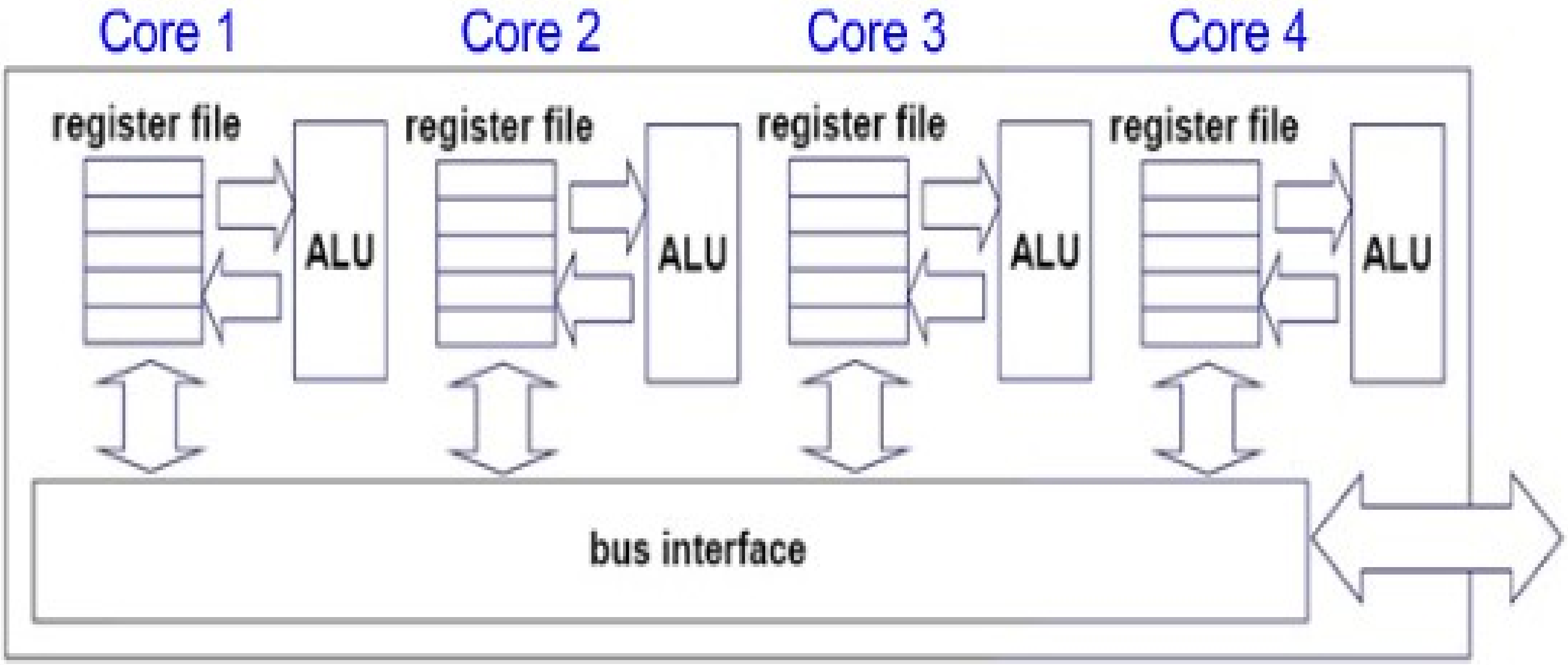
To execute the tasks faster you must increase the clock time.

Increasing clock times too high drastically increases power consumption and heat dissipation to extremely high levels, making the processor inefficient.

Drawbacks of unicore processor

- Difficult to make single-core Clock frequencies even higher
- Deeply pipelined circuits
  - Heat problems
  - Speed of light problems
  - Difficult design and verification
  - Large design
  - Server farms need expensive air-conditioning
- Many new applications are multithreaded
- General trend in computer architecture (shift towards more parallelism

Multi-core architecture



Multi-core CPU chip

Multi Core solution

Creating two cores or more on the same Die increases processing power while keeping clock speeds at an efficient level.

A processor with 2 cores running at efficient clock speeds can process instructions with similar speed to a single core processor running at twice the clock speed, yet the dual core processor would still consume less energy.

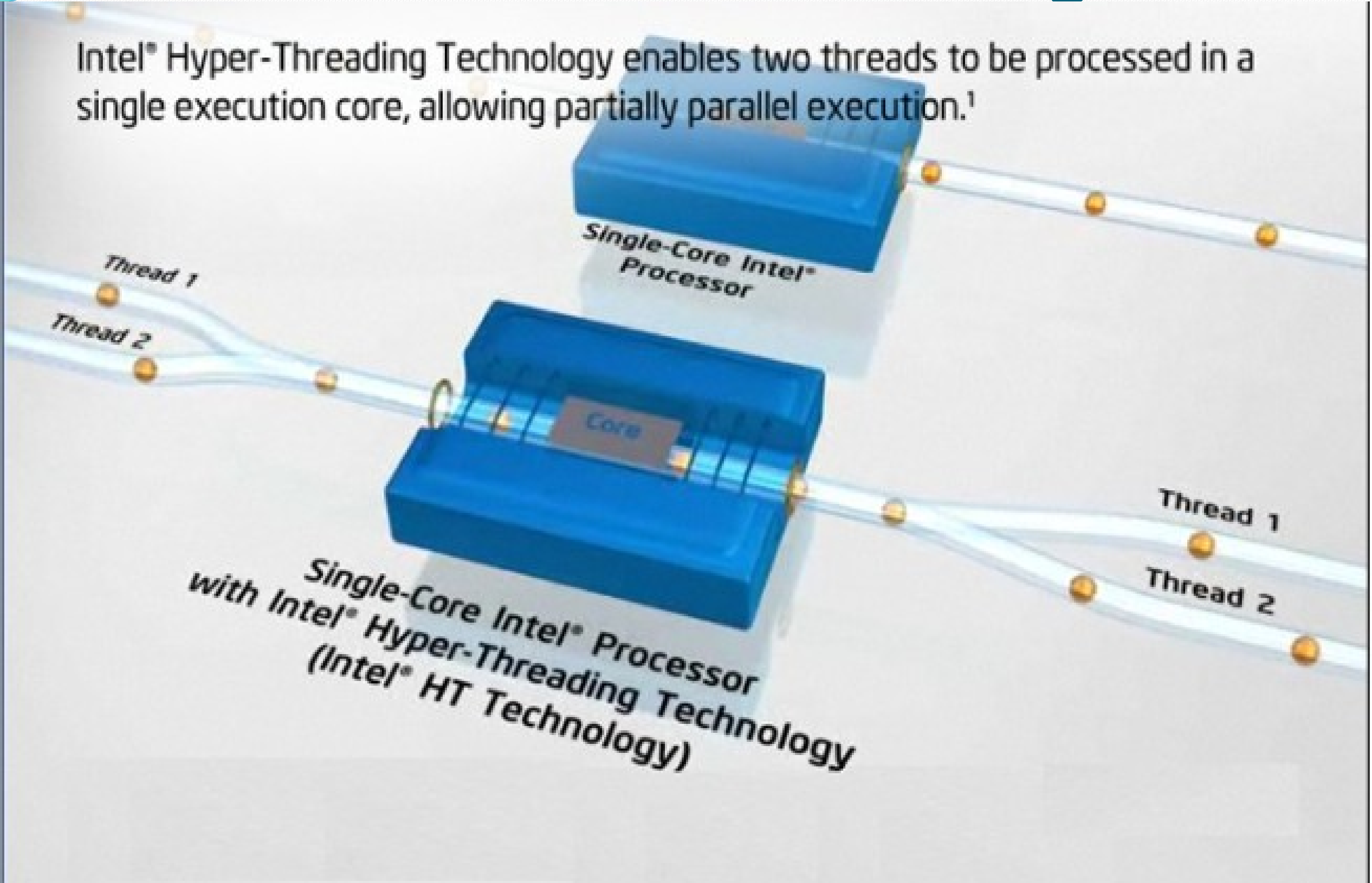
What is Multi Core Architecture?

- When a processor has more than one core to execute all the necessary functions of a computer, it’s processor is known to be a multi core architecture.
- In other words, a chip with more than one

CPU’s(Central Processing Unit).

How multi-core processor Work?

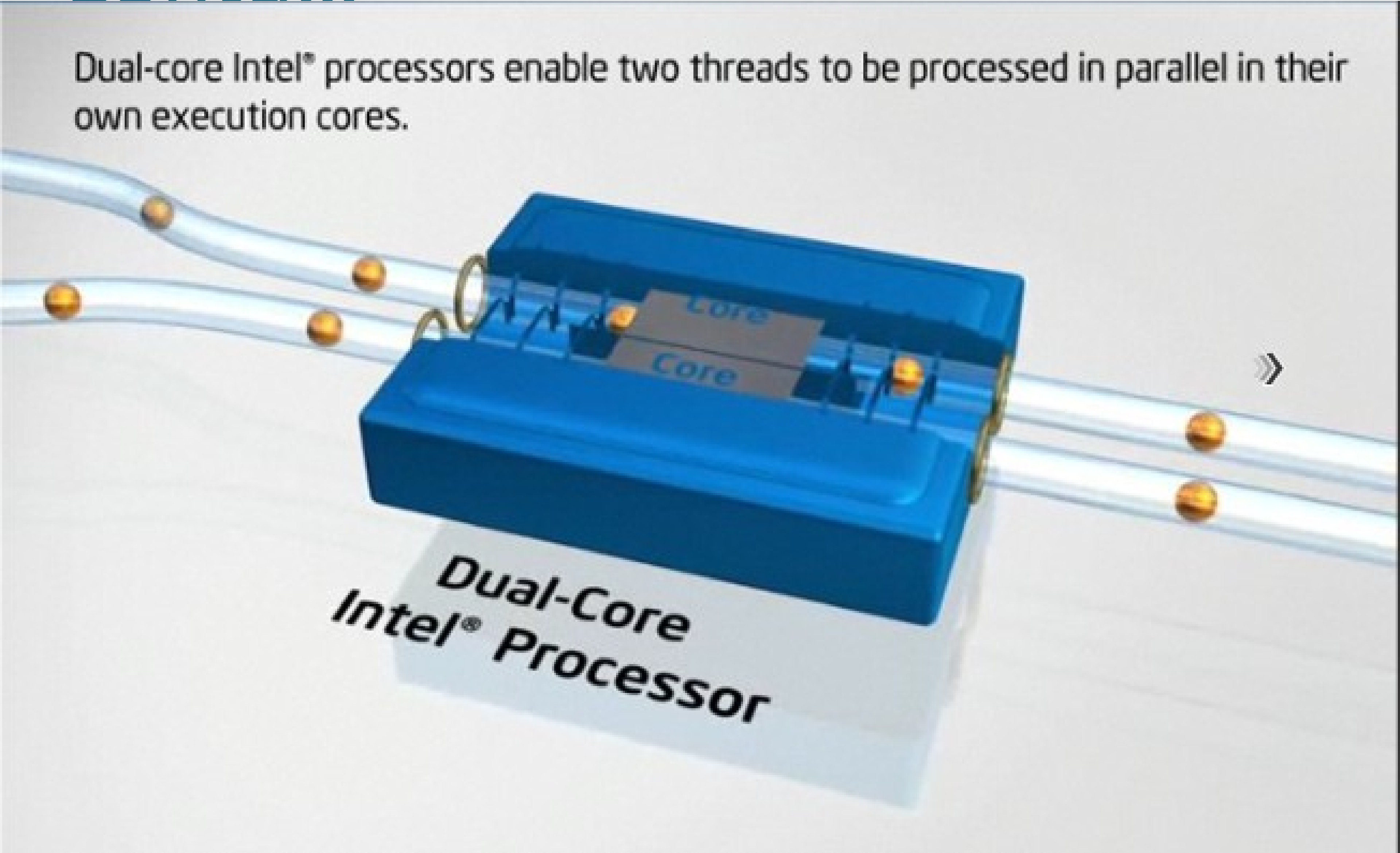
Multi-core & Multi-threading



Intel® Hyper-Threading Technology enables two threads to be processed in a single execution core, allowing partially parallel execution.[1]

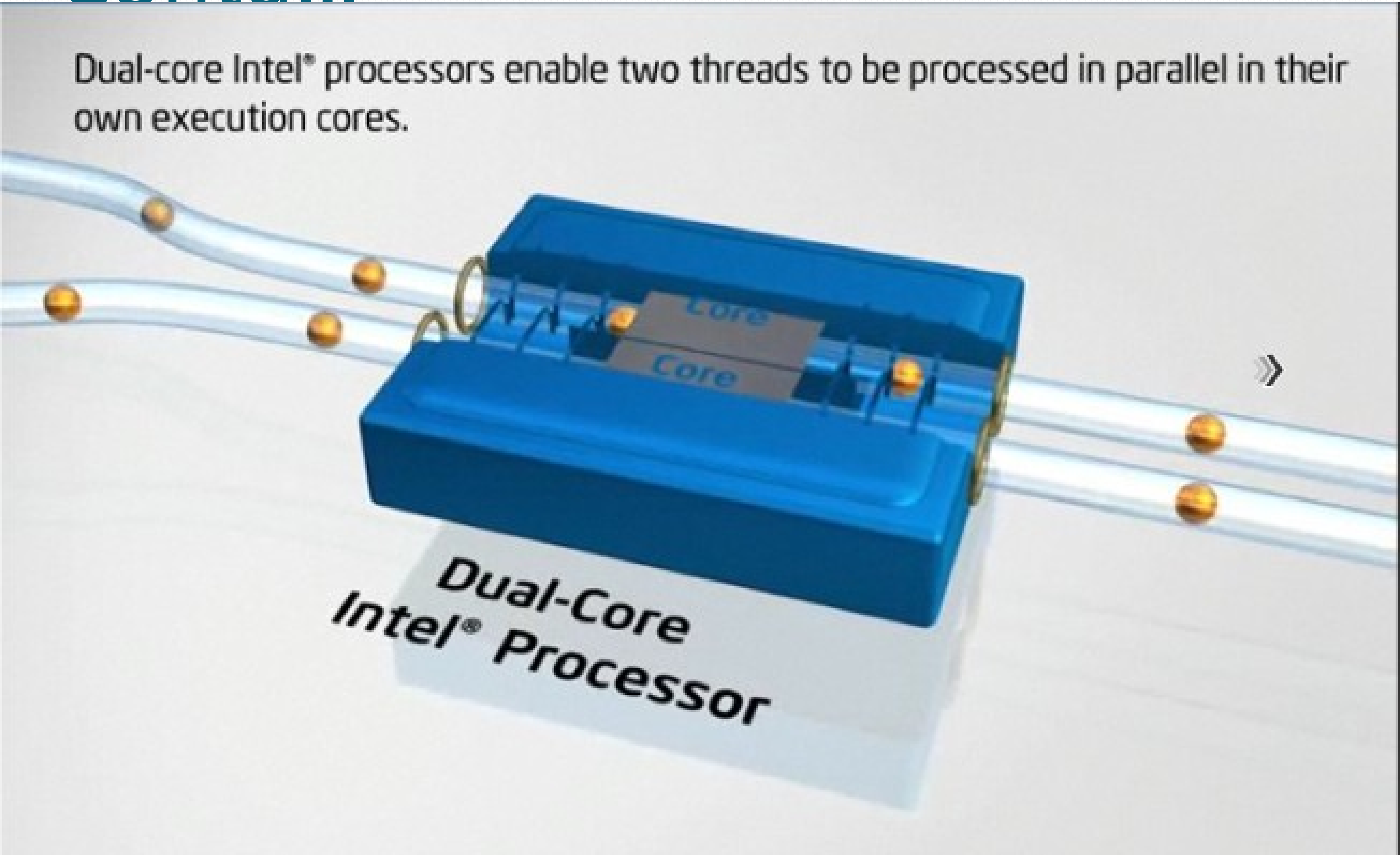
Single-Core Intel® Processor
Thread 1
Thread 2
Core
Thread 1
Thread 2
Single-Core Intel® Processor with Intel® Hyper-Threading Technology (Intel® HT Technology)

Contd…



Dual-core Intel® processors enable two threads to be processed in parallel in their own execution cores.

Contd…



Dual-core Intel® processors enable two threads to be processed in parallel in their own execution cores.

Advantages

- Thread level parallelism
- Great energy efficient
- Performance
- Lower cost
- Faster
- Better heat dissipation
- Ease of use

Thread-level parallelism (TLP)

- This is parallelism on a more coarser scale
- Server can serve each client in a separate thread (Web server, database server)
- A computer game can do AI, graphics, and sound in three separate threads
- Single-core superscalar processors cannot fully exploit TLP
- Multi-core architectures are the next step in processor evolution: explicitly exploiting TLP

Disadvantages

- Adjustment to existing software required
- Memory bandwidth limit the real performance advantage

What is Multi Core Architecture?

- It may look like a single processor but actually it contains two(dual core). three(tri-core), four(quad-core), six(hexa-core), eight(octa-core) or ten(deca-core) cores.
- Some processor even have 22 or 32 cores
- Due to power & temperature constraint, the multicore processors are only practical solution for increasing the speed of future components.

Multi-Core Advantages

- While working with many threads, a Multi Core processor with n cores can execute n threads simultaneously by assigning a core to each thread. If it must process more than n threads , say x, it can apply multithreading procedures with each core working with an average of x/n threads.

- A Single core processor must multithread with every single thread.

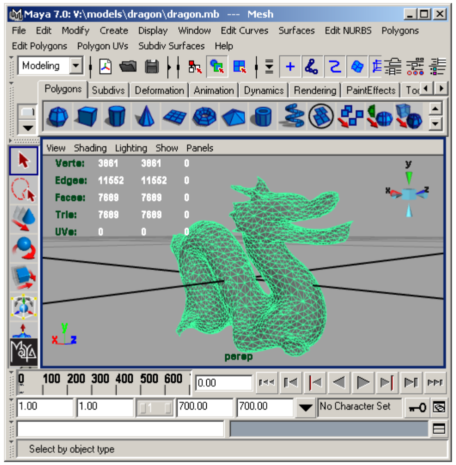
Multi-Core Advantages

✓ the largest boost in performance will likely be noticed in improved response-time while running CPU intensive processes, like anti-virus scans, ripping/burning media.

✓ assuming that the die can fit into the package, physically, the multi-core CPU designs require much less printed Circuit Board(PCB) space than multi-chip SMP designs. Also, a dual core processor uses slightly less power than two coupled single core processors, principally because of the decreased power required to drive signals external to the chip

What applications benefit from multi-core?

- Database servers
- Web servers (Web commerce)
- Multimedia applications
- Scientific applications, CAD/CAM
- In general, applications with *Thread-level parallelism* (as opposed to instruction-level parallelism)


Maya 7.0: V:\models\dragon\dragon.mb --- Mesh
File Edit Modify Create Display Window Edit Curves Surfaces Edit NURBS Polygons
Edit Polygons Polygon UVs Subdiv Surfaces Help
Modeling
Polygons Subdivs Deformation Animation Dynamics Rendering PaintEffects
View Shading Lighting Show Panels
Verts: 3861 3861 0
Edges: 11552 11552 0
Faces: 7689 7689 0
Tris: 7689 7689 0
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persp
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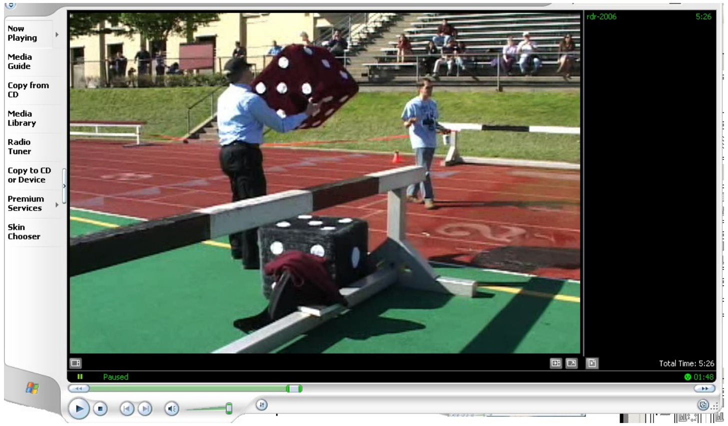
Each can run on its own core



More examples

- Editing a photo while recording a TV show through a digital video recorder
- Downloading software while running an anti-virus program
- “Anything that can be threaded today will map efficiently to multi-core”
- BUT: some applications difficult to parallelize

Problems with Multicore

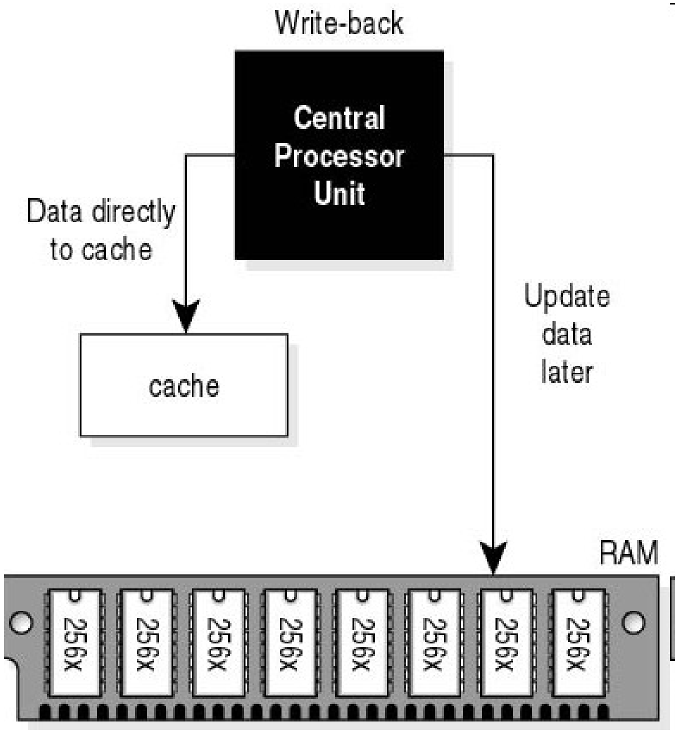
- According to Amdahl's law, the performance of parallel computing is limited by its serial components.
- So, increasing the number of cores may not be the best solution.
- There is need to increase the clock speed of individual cores.

Implementations

- Two main ways to have multiple cores interact are the shared memory model, and the distributed memory model.

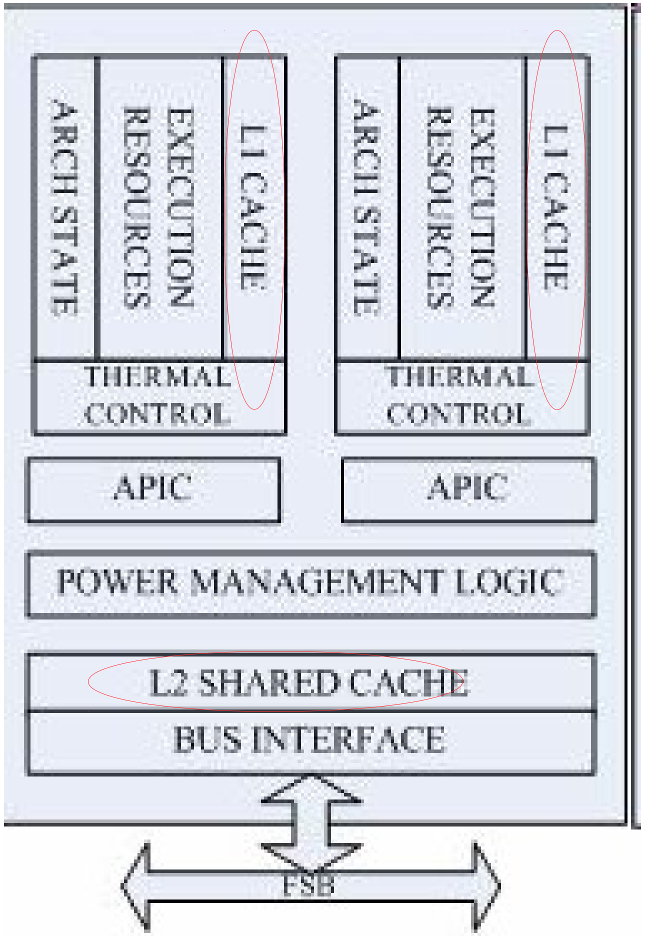
- In the **shared memory model**, all cores share the same cache memory.

- In the **distributed memory model**, each core has its own cache memory.



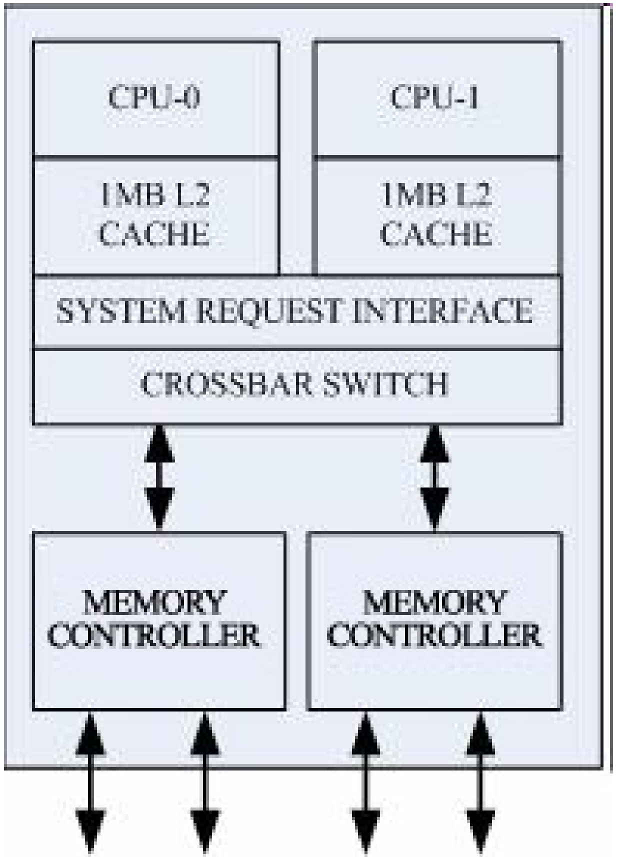
Implementations continued

- The Intel core duo design has a separate L1 cache memory for each core, but both cores share an L2 cache.



Implementations continued

- The AMD Athlon 64 X2 implementation has separate L1 and L2 cache memory for each core.

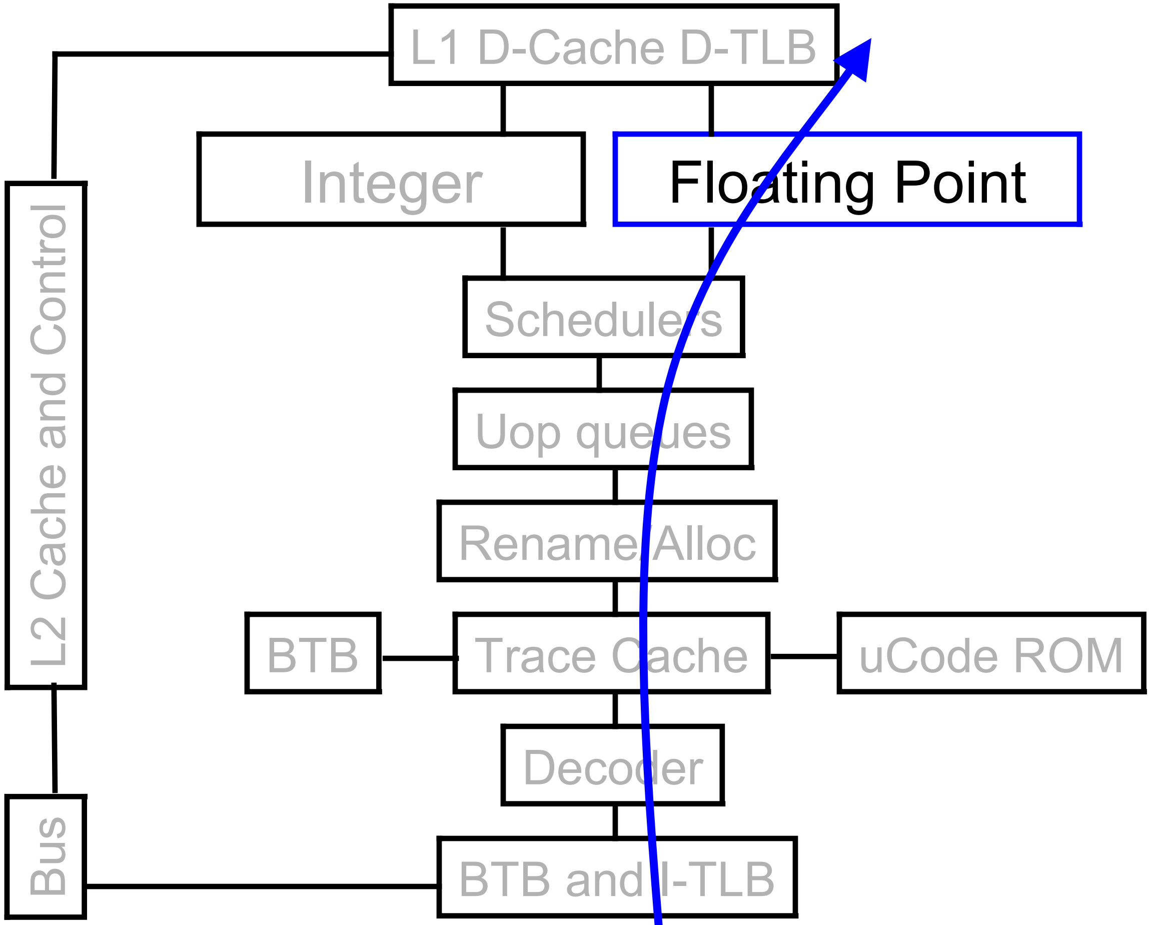


Conclusion

- Multicore chips an important new trend in computer architecture
- Several new multi-core chips in design phases
- Parallel programming techniques likely to gain importance

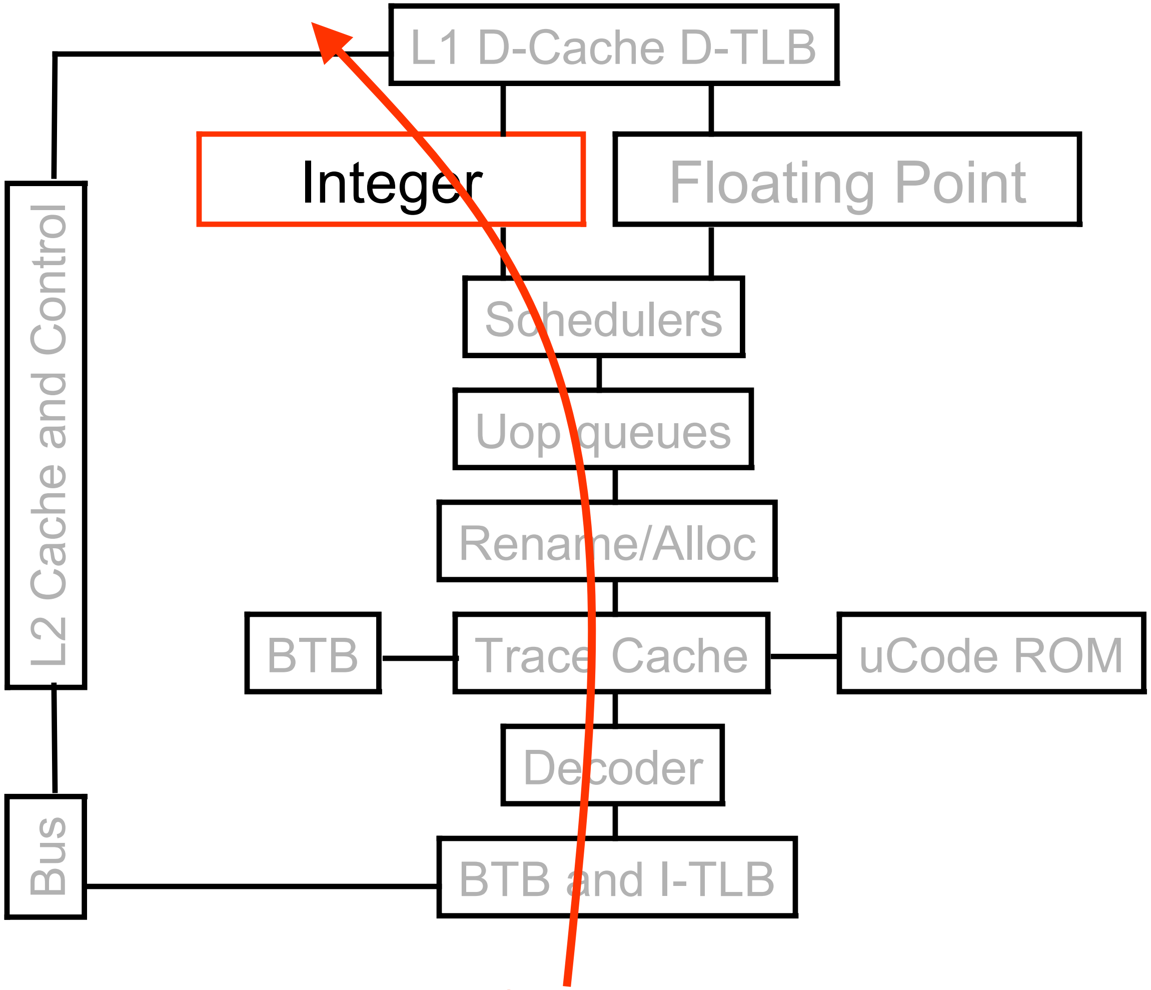
Additional Explanations ….

Without SMT, only a single thread can run at any given time



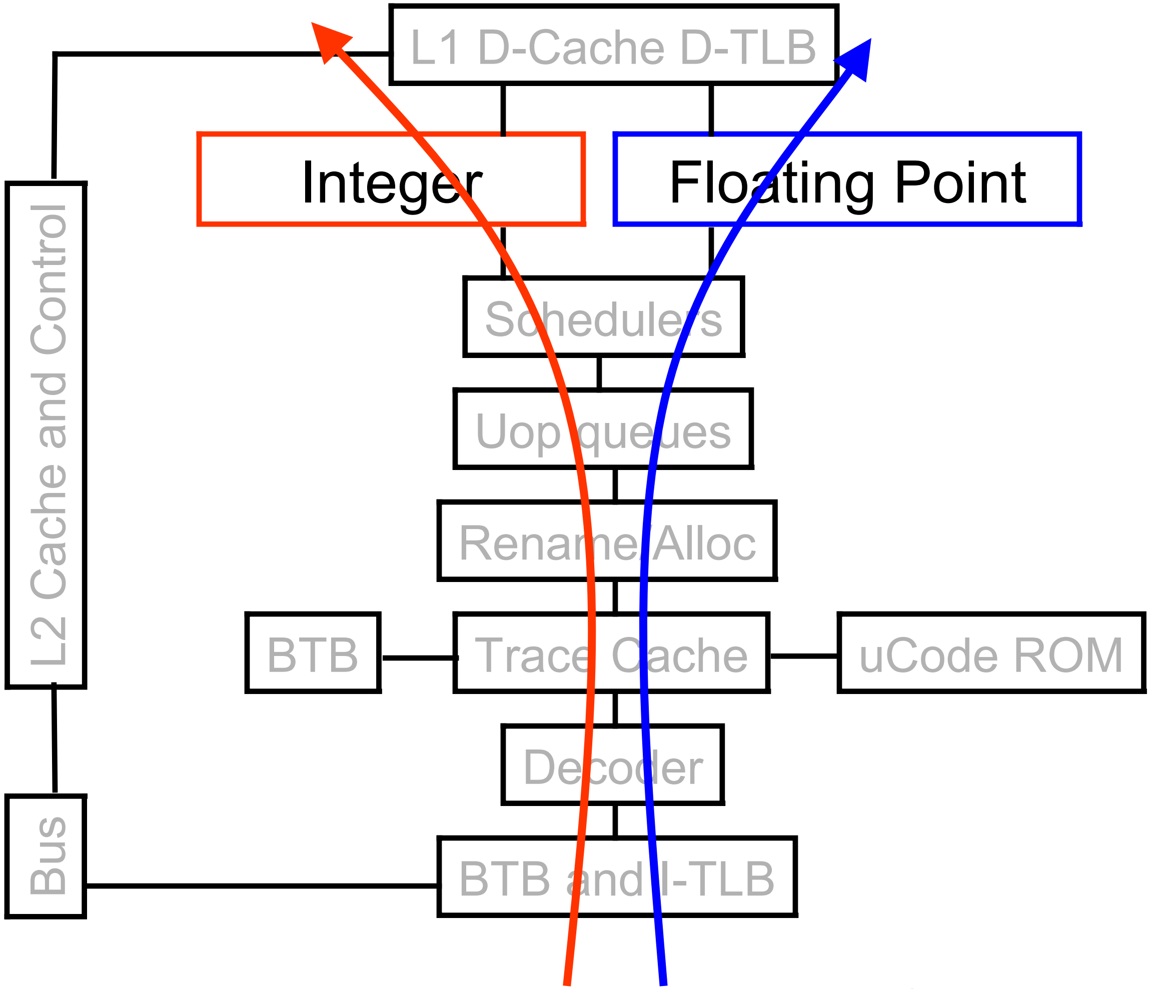
Thread 1: floating point

Without SMT, only a single thread can run at any given time



Thread 2:
integer operation

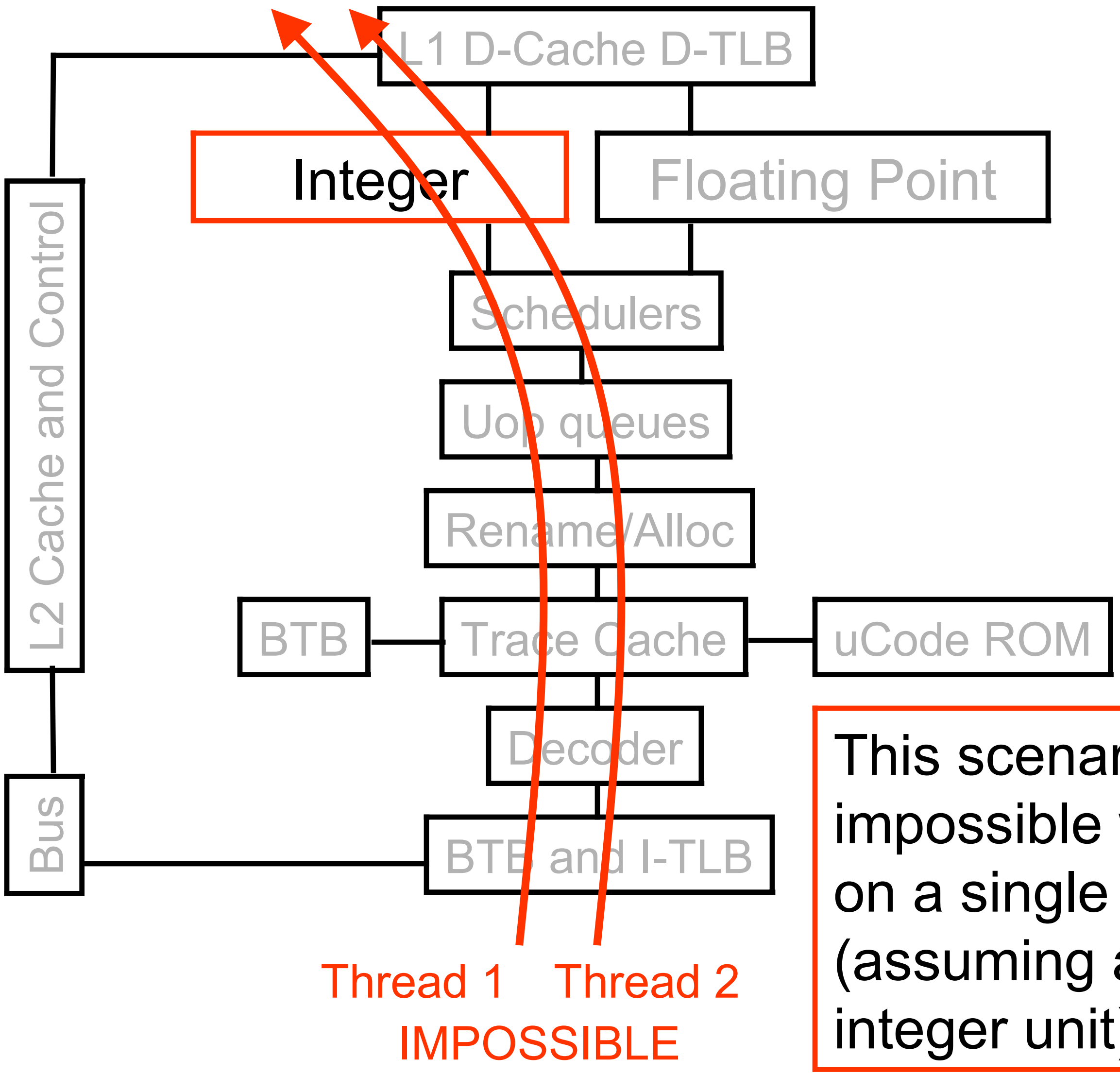
SMT processor: both threads can run concurrently



Thread 2:
integer operation

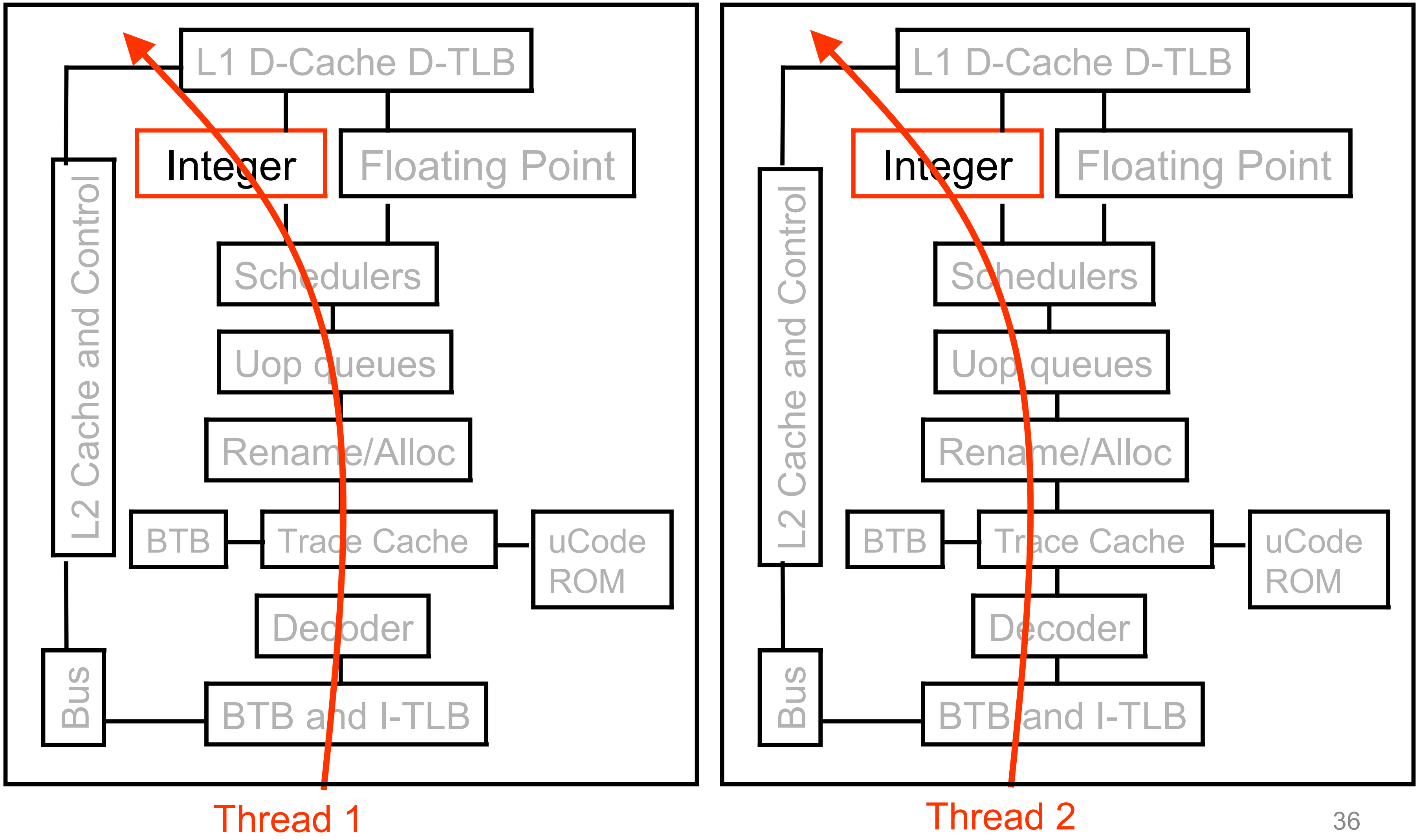
Thread 1: floating point

But: Can’t simultaneously use the same functional unit

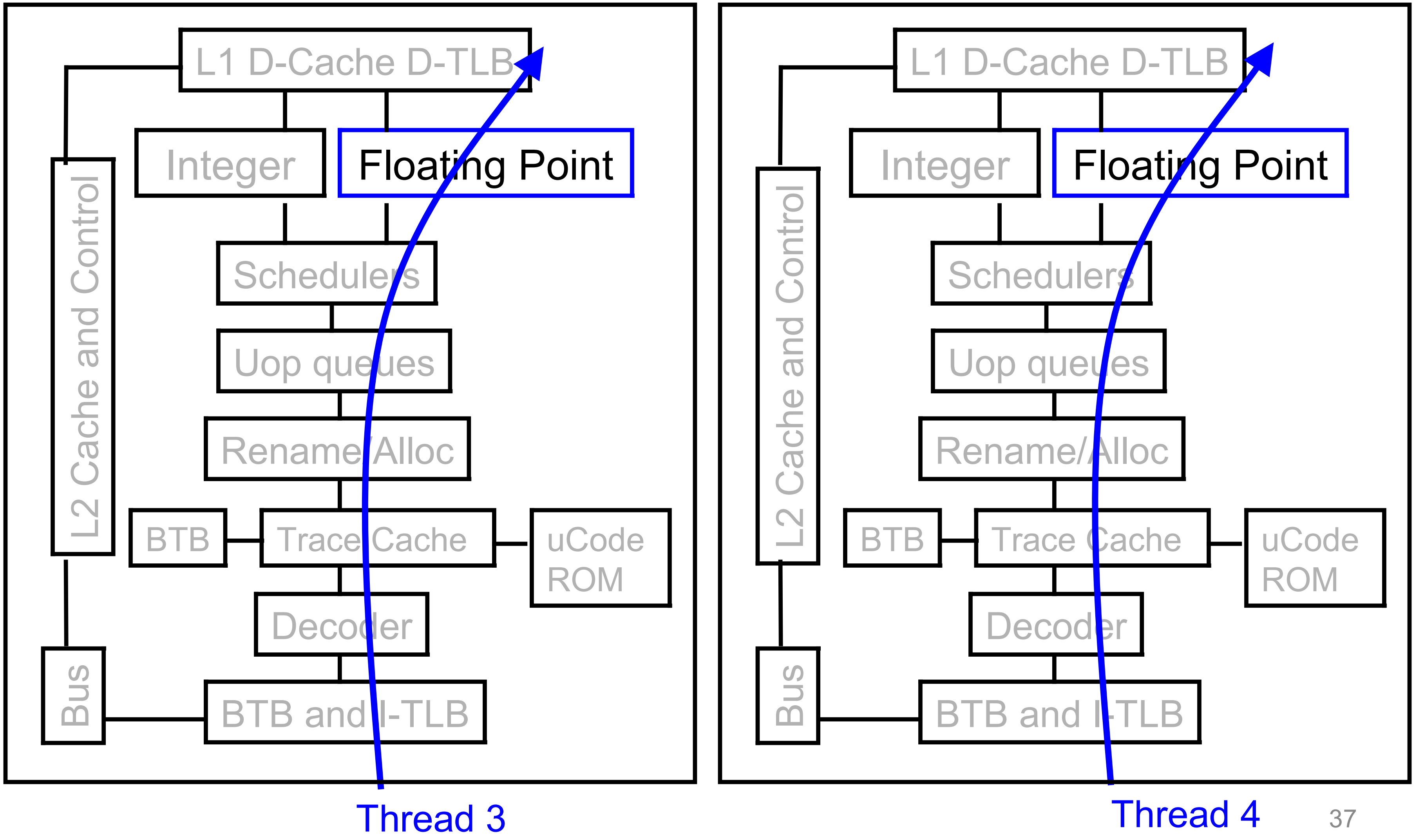


This scenario is impossible with SMT on a single core (assuming a single integer unit)

Multi-core: threads can run on separate cores



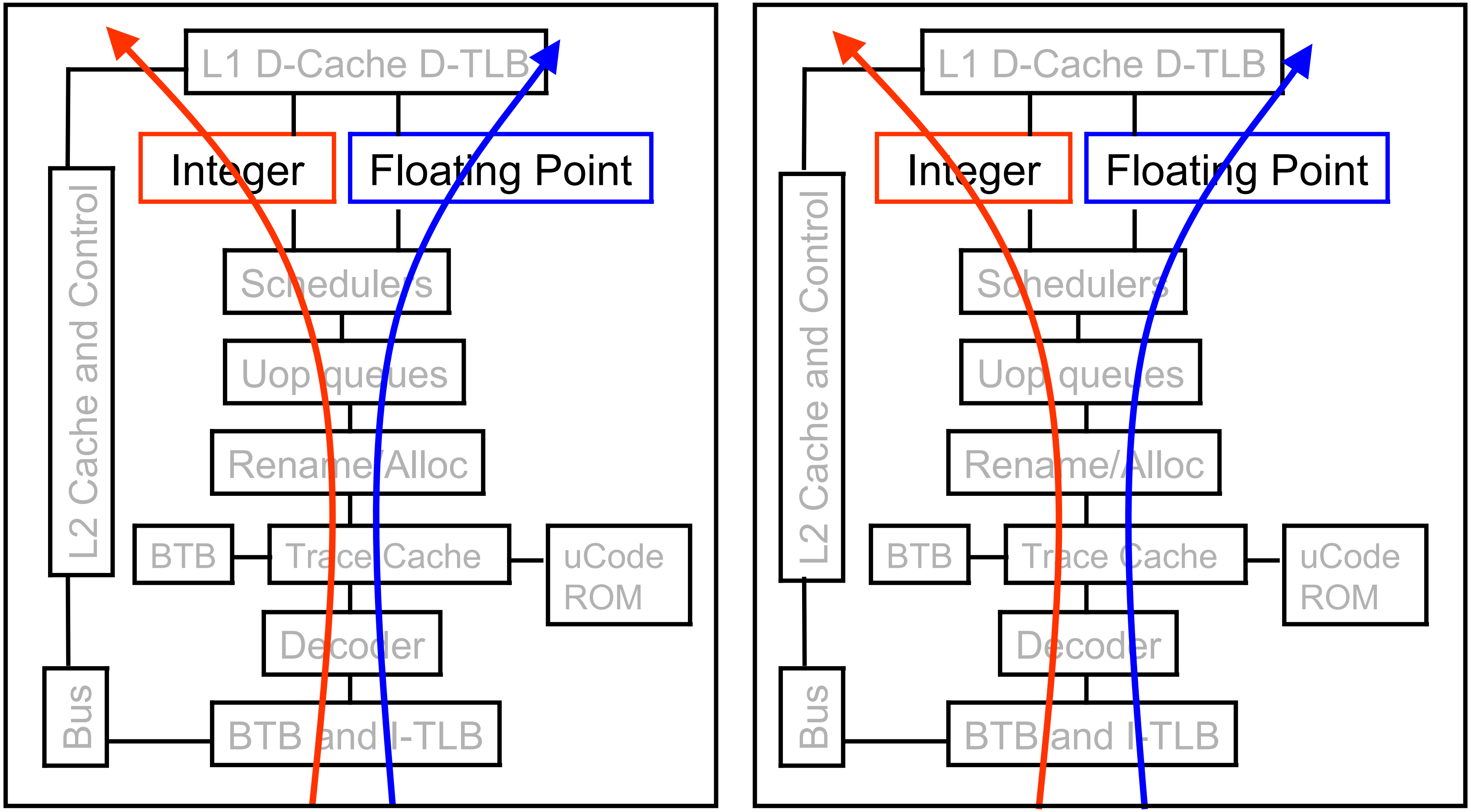
Multi-core: threads can run on separate cores



Combining Multi-core and SMT

- Cores can be SMT-enabled (or not)
- The different combinations:
  - Single-core, non-SMT: standard uniprocessor
  - Single-core, with SMT
  - Multi-core, non-SMT
  - Multi-core, with SMT: our fish machines
- The number of SMT threads:
  2, 4, or sometimes 8 simultaneous threads
- Intel calls them “hyper-threads”

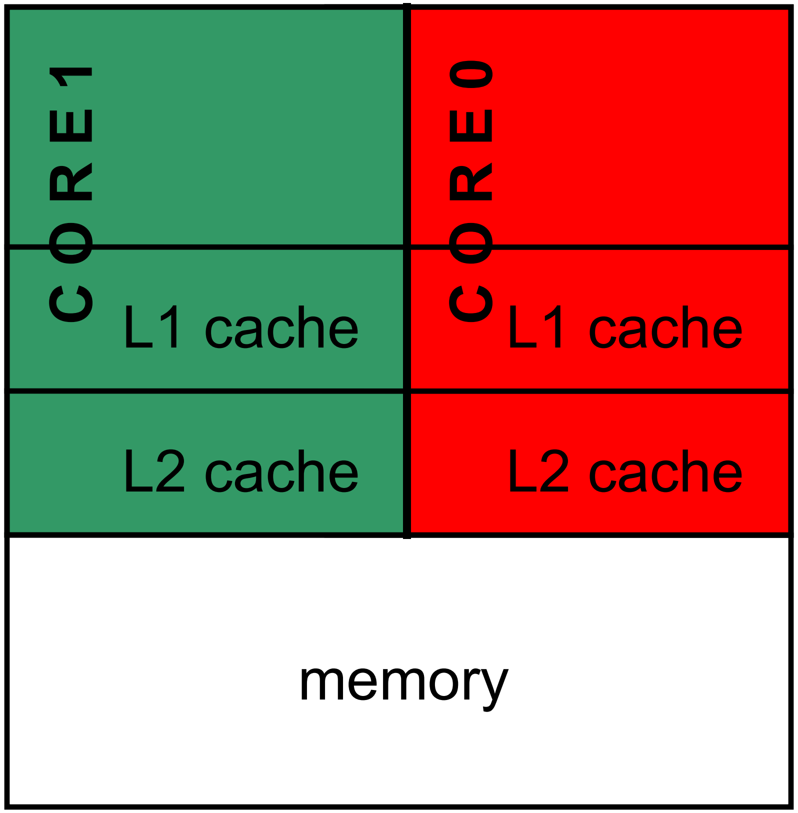
SMT Dual-core: all four threads can run concurrently



Thread 1 Thread 3

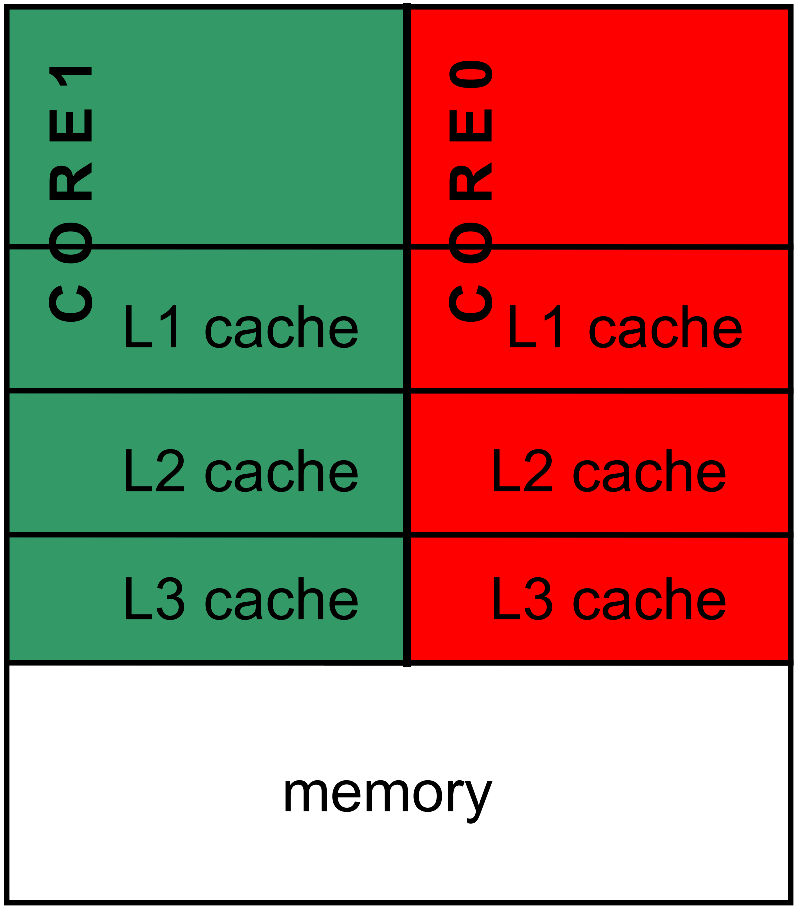
Thread 2 Thread 4

Multi-Core and caches coherence



Both L1 and L2 are private

Examples: AMD Opteron, AMD Athlon, Intel Pentium D



A design with L3 caches

Example: Intel Itanium 2

Problems

Some of the current problems found with multi core processors include:

- Memory/Cache coherence. As mentioned earlier, some implementations have distributed L1 caches but must share an L2 cache. This poses the problem of making sure each core keeps the other updated with changes in the data in its own cache.

Problems continued

- Multi threading is also a problem when the software being run is not designed to take advantage of the multi core processor. This may mean that one core does most of the work which means that the processor is running no more efficiently than a single core.

Future of Multi Core

- Current debates argue over whether future multi core processors should be homogenous or heterogenous.

- That is, should all the cores be the same or should there be a mix of different types?

Future continued

- Having all cores be the same makes production easier and keeps its complexity to a minimum.

- Having different cores that are specialized in specific tasks increases complexity but has the potential to be much more efficient in speed and power consumption.

References

- http://www.intel.com/multi-core/
- http://www.faqs.org/patents/app/20090055826
- http://www.csa.com/discoveryguides/multicore/review2.php?SID=s0s5lp3hcg6fa6pf2ba28u84d0