CSC 256/456: Operating Systems

Multiprocessor Support

John Criswell
University of Rochester

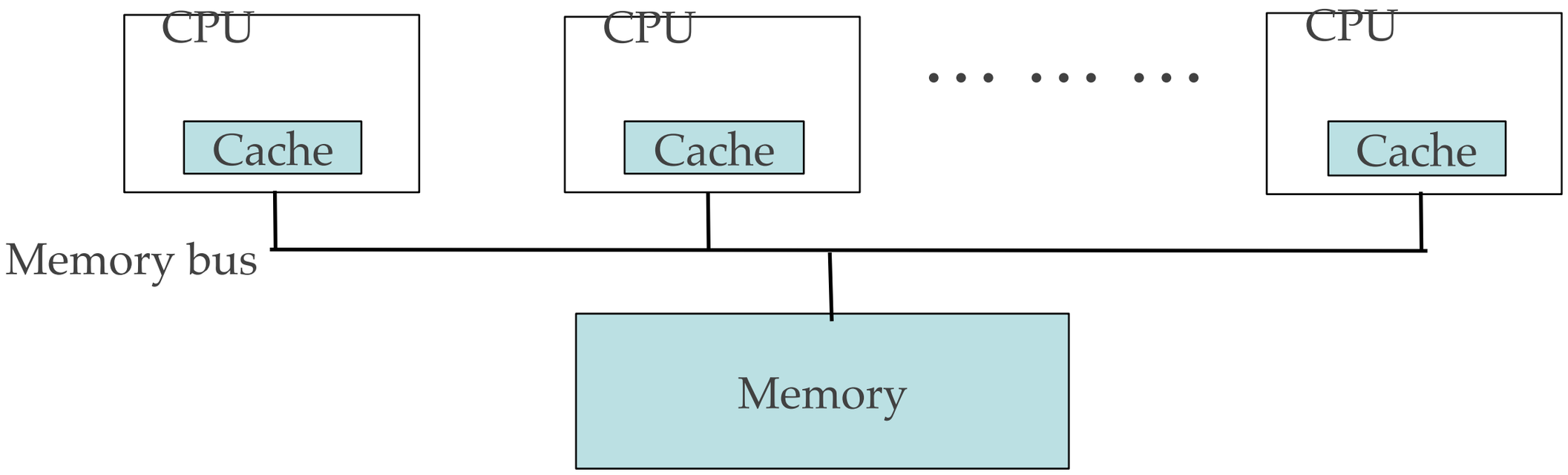
Outline

- Multiprocessor hardware
- Types of multi-processor workloads
- Operating system issues
  - Where to run the kernel
  - Synchronization
  - Where to run processes

Multiprocessor Hardware

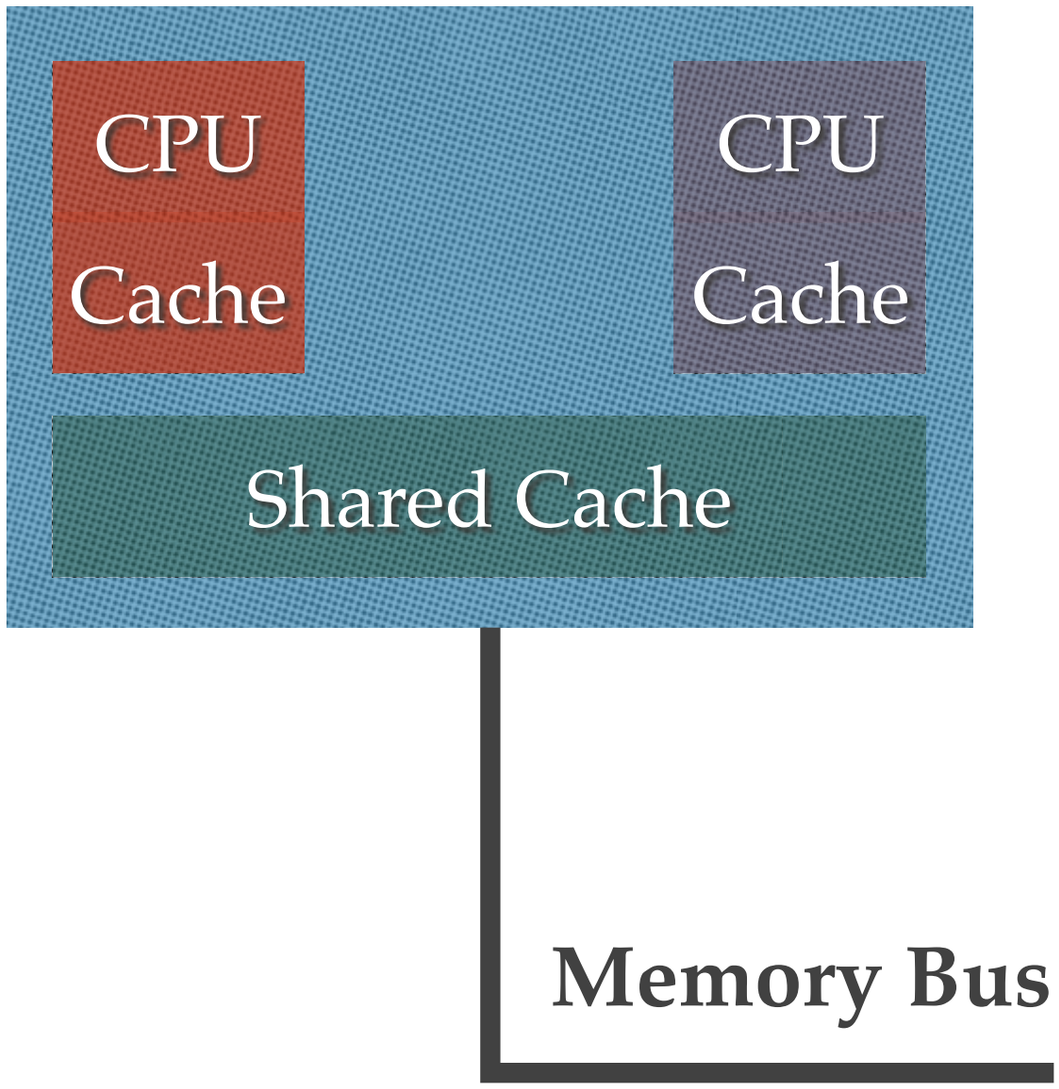
Multiprocessor Hardware

- System in which two or more CPUs share full access to the main memory
- Each CPU might have its own cache and the coherence among multiple caches is maintained



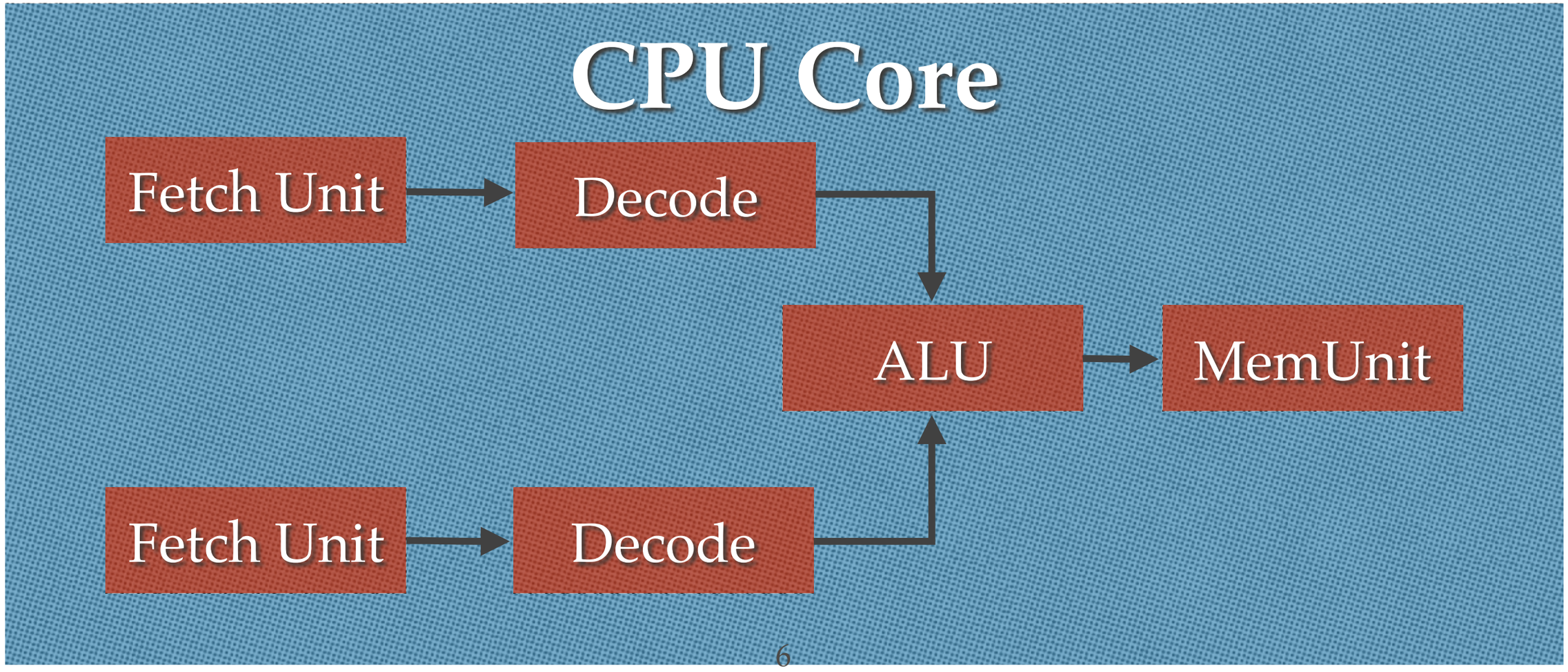
Multi-core Processor

- Multiple processors on “chip”
- Some caches shared
- Some not shared



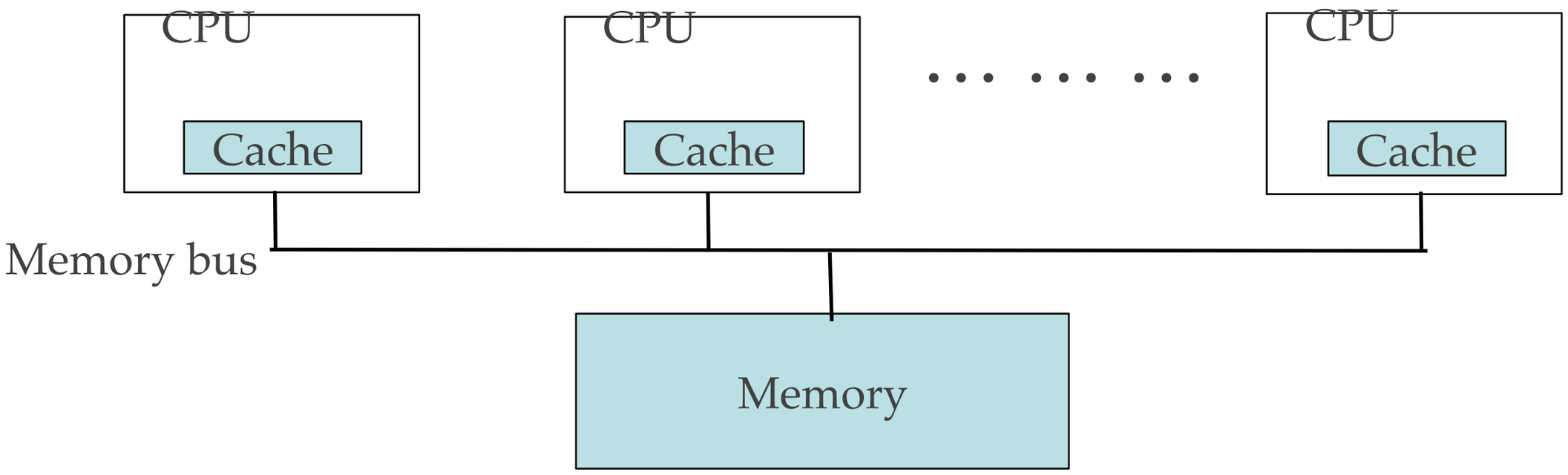
Hyper-Threading

- Replicate parts of processor; share other parts
- Create illusion that one core is two cores



Cache Coherency

- Ensure processors not operating with stale memory data
- Writes send out cache invalidation messages



Non Uniform Memory Access (NUMA)

- Memory clustered around CPUs
- For a given CPU
- Some memory is nearby (and fast)
- Other memory is far away (and slow)

Multiprocessor Workloads

Multiprogramming

- Non-cooperating processes with no communication
- Examples
  - Time-sharing systems
  - Multi-tasking single-user operating systems
  - make -j<very large number here>

Concurrent Servers

- Minimal communication between processes and threads
- Throughput usually the goal
- Examples
  - Web servers
  - Database servers

Parallel Programs

- Use parallelism to speed up computation
- Significant data sharing between processes and threads
- Examples
  - Gaussian Elimination
  - Matrix multiply

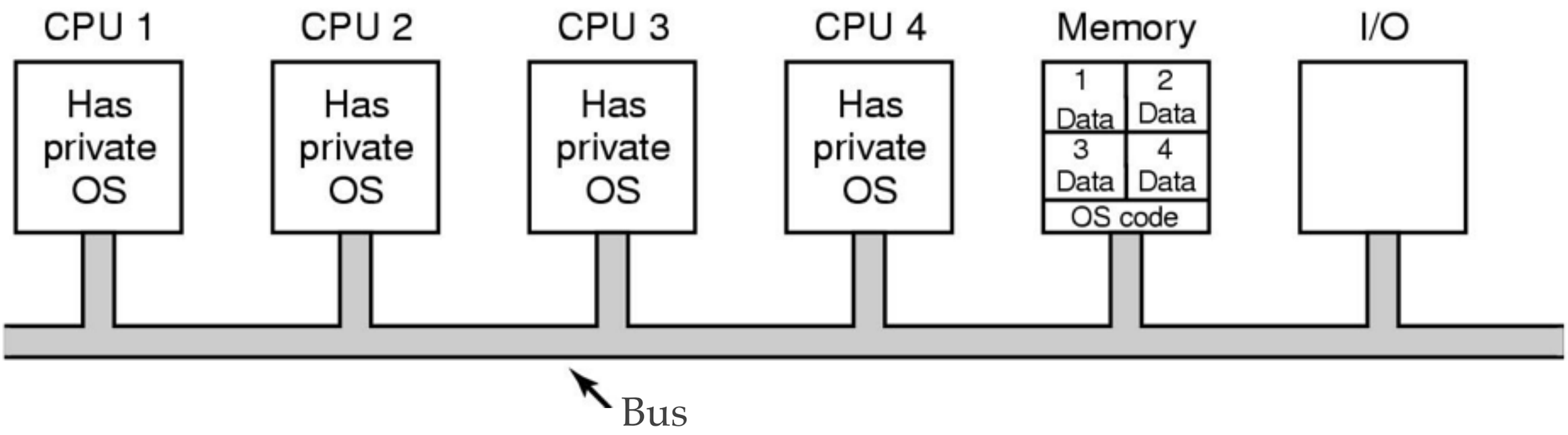
Operating System Issues

Three Challenges

- Where to run the OS
- How to do synchronization
- Where to schedule processes

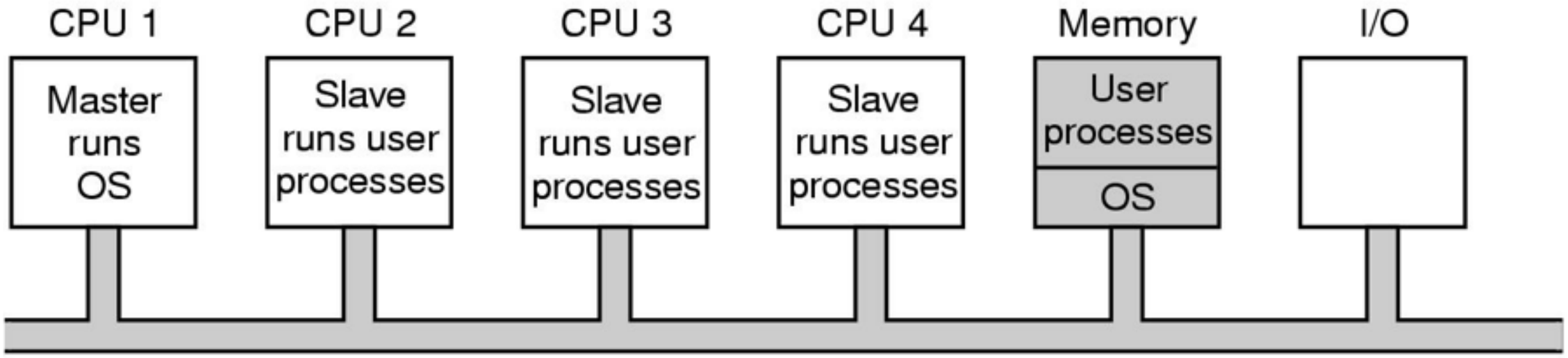
Where to Run the OS?

Multiprocessor OS



- Each CPU has its own operating system
  - quick to port from a single-processor OS
- Disadvantages
  - difficult to share things (processing cycles, memory, buffer cache)

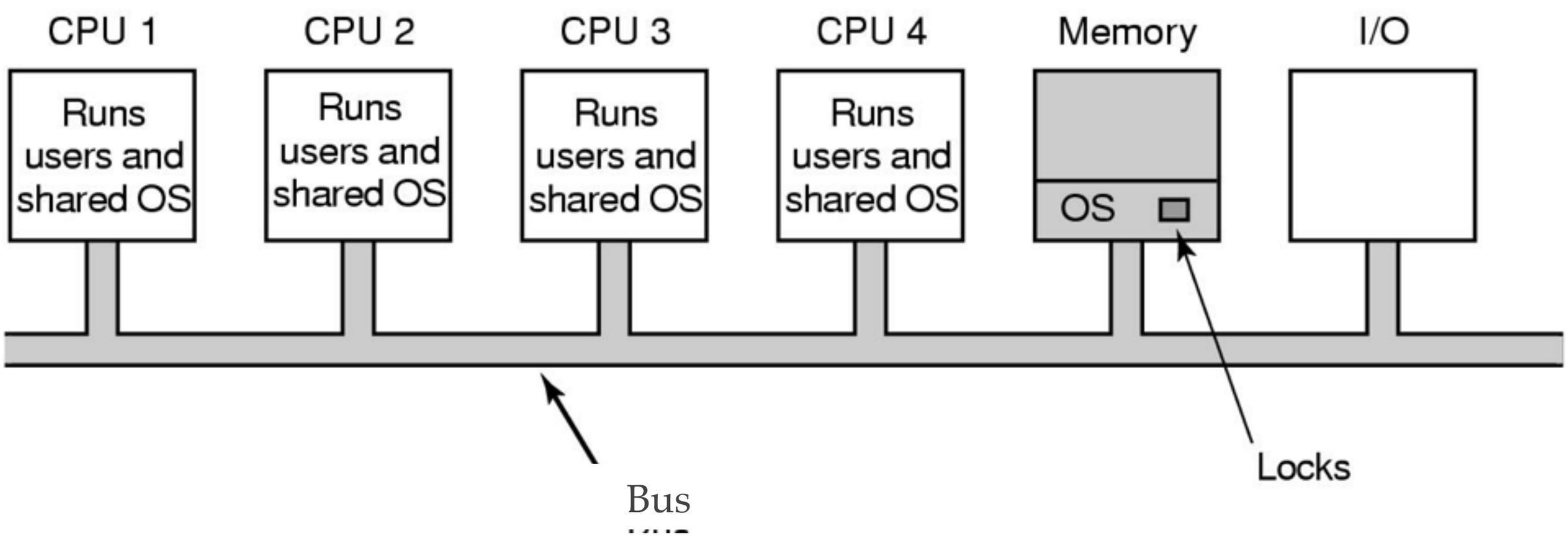
Multiprocessor OS – Master/Slave



- All operating system functionality goes to one CPU
  - no multiprocessor concurrency in the kernel
- Disadvantage
  - OS CPU consumption may be large so the OS CPU becomes the bottleneck (especially in a machine with many CPUs)

Multiprocessor OS – Shared OS

- A single OS instance may run on all CPUs
- The OS itself must handle multiprocessor synchronization
  - multiple OS instances from multiple CPUs may access shared data structure



Synchronization Issues

Synchronization

- Traditional atomic operations write memory
  - Atomic compare and swap
  - Atomic fetch and add
- This is very bad for multi-processors

Load-Linked and Store-Conditional

- Load-linked sets a bit in the cache line
- Cache invalidation clears bit
- Store-conditional checks that bit is still set in cache line
- Cleared bit means a cache invalidation occurred
- Which implies that another core wrote the memory
- Which implies that atomicity was violated

Performance Measures for Synchronization

- Latency
  - Cost of thread management under the best case assumption of no contention for locks
- Throughput
  - Rate at which threads can be created, started, and finished when there is contention

Synchronization (Fine/Coarse-Grain Locking)

- Fine-grain locking – lock only what is necessary for critical section
- Coarse-grain locking – locking large piece of code, much of which is unnecessary
- simplicity, robustness
- prevent simultaneous execution
  - simultaneous execution is not possible on uniprocessor anyway

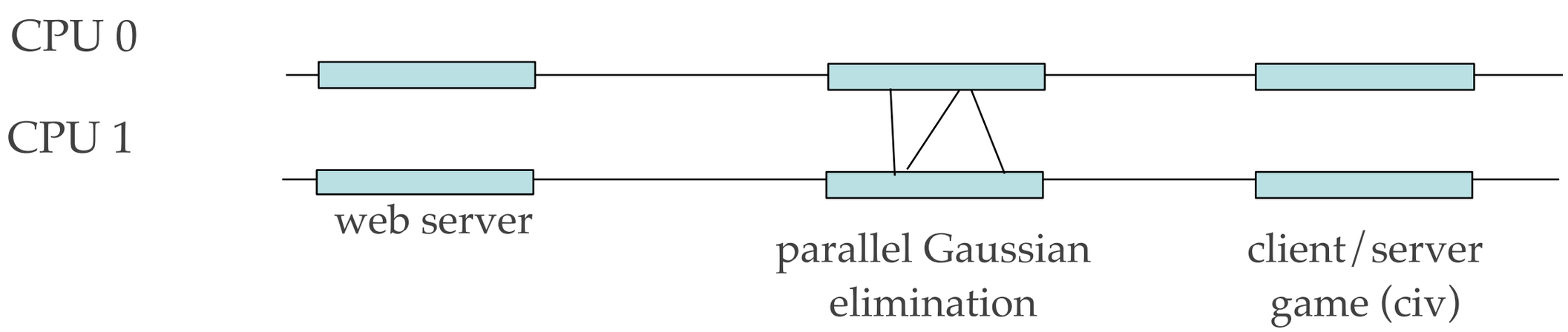
Synchronization Optimizations

- Avoid synchronization
  - Per-processor data structures
  - Lock-free data structures
- Use fine-grained locking to increase throughput
- Reuse (cache) data structures
  - Allocation/deallocation just a few pointer operations
  - Locks not held for very long

Where to Run Processes?

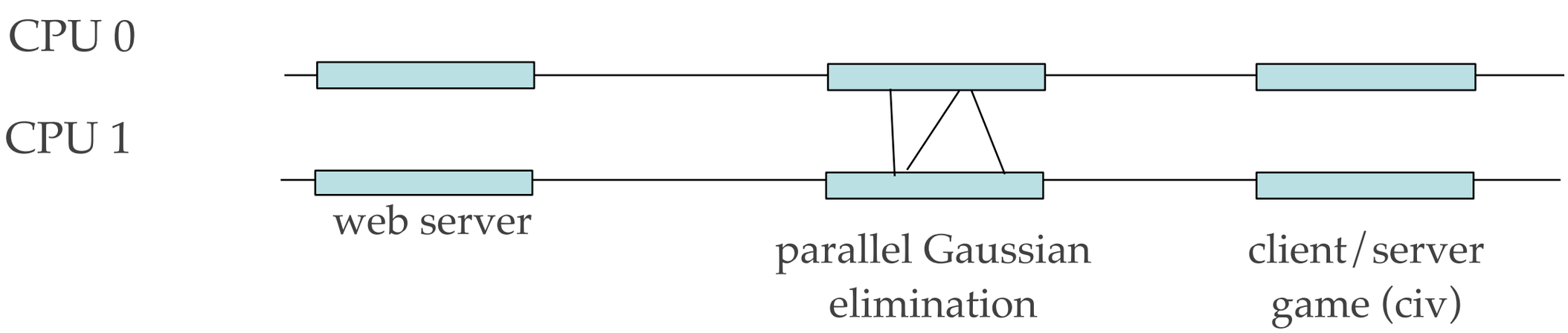
Multiprocessor Scheduling

- Affinity-based scheduling
  - Try to run each process on the processor that it last ran on
  - Takes advantage of cache locality



Multiprocessor Scheduling

- Gang/Cohort scheduling
  - Utilize all CPUs for one parallel/concurrent application at a time
  - Cache sharing and synchronization of parallel/concurrent applications



Resource Management To Date

- Capitalistic - generation of more requests results in more resource usage
  - Performance: resource contention can result in significantly reduced overall performance
  - Fairness: equal time slice does not necessarily guarantee equal progress

Fairness and Security Concerns

- Priority inversion
- Poor fairness among competing applications
- Information leakage at chip level
- Denial of service attack at chip level

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