Threads and Synchronization

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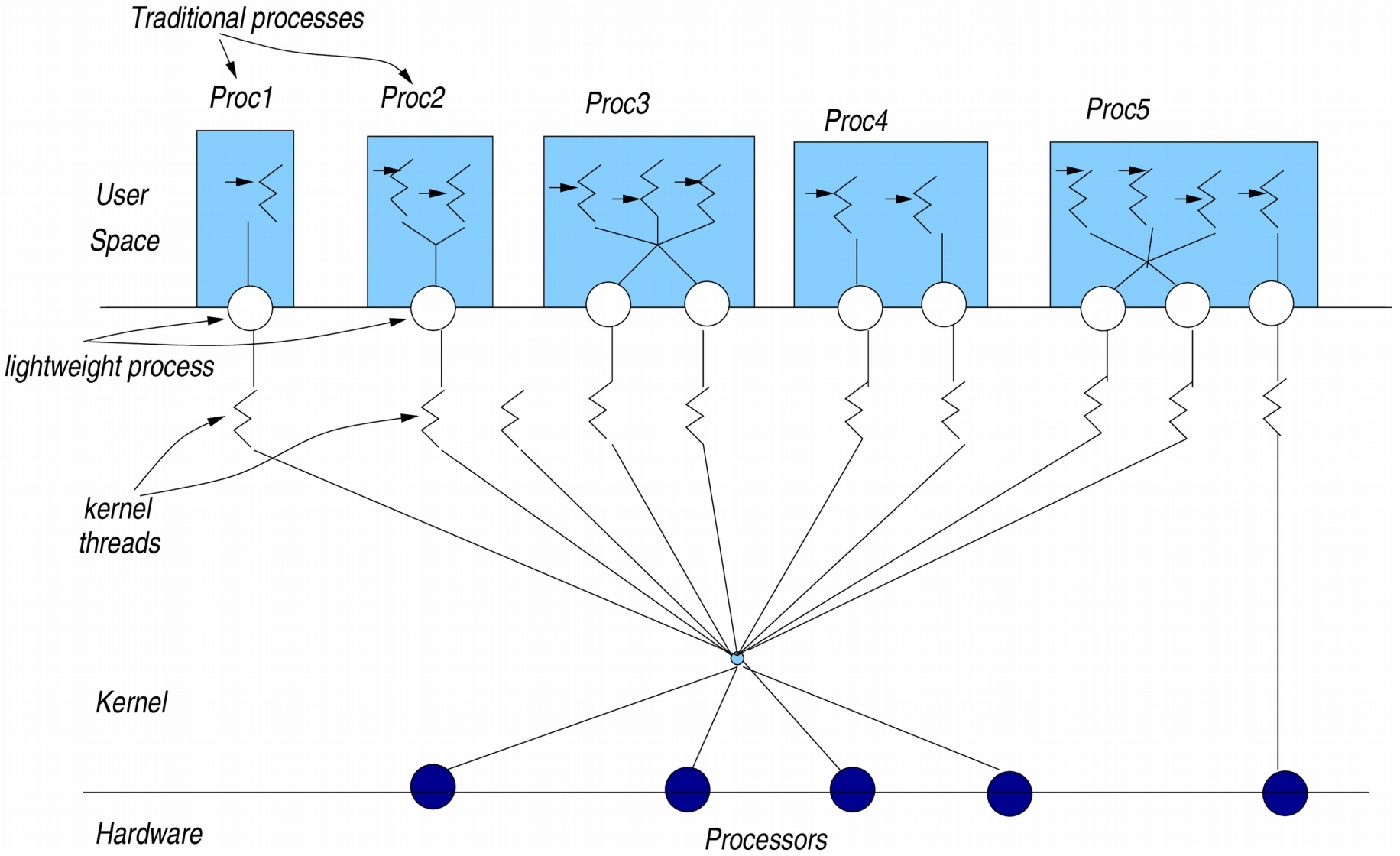
Threads

- A thread is an independent flow of control
  - i.e., an execution of a program
    - with its own instruction pointer
    - and stack, since that's determined by executed instructions
- Multiple threads may be in the same process
  - or in the kernel
  - they share everything else: heap, static area
- In a modern OS, threads (not processes) are the fundamental unit of scheduling/execution

User and Kernel-Level Threads



Synchronization

- Shared memory: parts of the address space are visible to two threads
- Can also be done with processes
  - just map the same physical pages in two address spaces
- Threads and processes are a continuum
  - shared memory can make processes be like threads
- Shared memory raises the need for synchronization
  - otherwise: *race conditions*

Mutex Locks

- Most common synchronization structure: *mutual-exclusion lock (mutex)*
- In two states: locked or unlocked
- Operations:
  - init: create, in unlocked state
  - lock/acquire:
    - if unlocked, *atomically* make it locked
    - else, no progress until it is unlocked and successfully acquired
  - unlock/release:
    - set mutex to unlocked
- See xv6 spinlock and sleeplock implementations

Condition Variables

- Used in combination with mutexes
  - *monitor-style programming*
- General-purpose waiting for long periods of time
- Operations:
  - init(): create, empty queue
  - wait(m):
    - *atomically* unlock mutex, put thread in “waiting” queue
    - when thread exits waiting queue, lock/acquire mutex
  - signal/notify:
    - remove one thread from waiting queue
- Typically in user space - kernel has modest needs
  - most general synchronization primitives, can implement all policies

Semaphores (Dijkstra ~1965)

- Like enhanced mutexes
  - mutexes = *binary semaphores*
- Instead of locked/unlocked, a counter
- Operations:
  - init(n): create, with counter n
  - down/P:
    - if counter positive, *atomically* decrement
    - else, no progress until it is positive
  - up/V:
    - increment counter
- Variations where increment/decrement are by >1

Applications

- Lots of textbook synchronization problems
  - bounded buffer
  - readers/writers
  - dining philosophers