

Processes and Threads

- Processes and their scheduling
- Threads and scheduling
- Multiprocessor scheduling
- Distributed Scheduling/migration



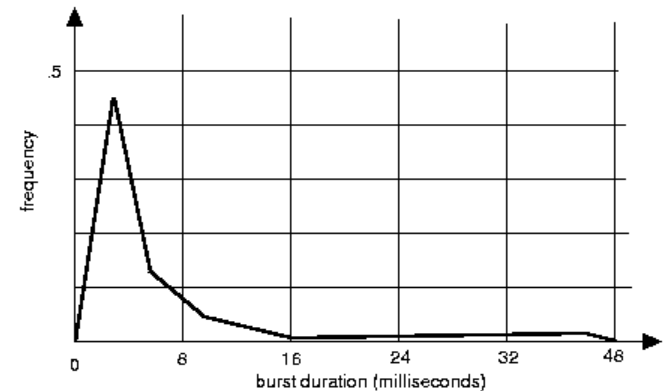
Module 1: Processes Review

- Multiprogramming versus multiprocessing
- Kernel data structure: process control block (PCB)
- Each process has an address space
 - Contains code, global and local variables..
- Process state transitions
- Uniprocessor scheduling algorithms
 - Round-robin, shortest job first, FIFO, lottery scheduling, EDF
- Performance metrics: throughput, CPU utilization, turnaround time, response time, fairness



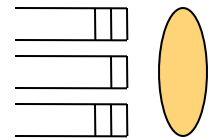
Process Behavior

- Processes: alternate between CPU and I/O
- CPU bursts
 - Most bursts are short, a few are very long (high variance)
 - Modeled using *hyperexponential* behavior
 - If X is an *exponential* r.v.
 - $\Pr [X \leq x] = 1 - e^{-\mu x}$
 - $E[X] = 1/\mu$
 - If X is a *hyperexponential* r.v.
 - $\Pr [X \leq x] = 1 - p e^{-\mu_1 x} - (1-p) e^{-\mu_2 x}$
 - $E[X] = p / \mu_1 + (1-p) / \mu_2$



Process Scheduling

- Priority queues: multiples queues, each with a different priority
 - Use strict priority scheduling
 - Example: page swapper, kernel tasks, real-time tasks, user tasks
- Multi-level feedback queue
 - Multiple queues with priority
 - Processes dynamically move from one queue to another
 - Depending on priority/CPU characteristics
 - Gives higher priority to I/O bound or interactive tasks
 - Lower priority to CPU bound tasks
 - Round robin at each level



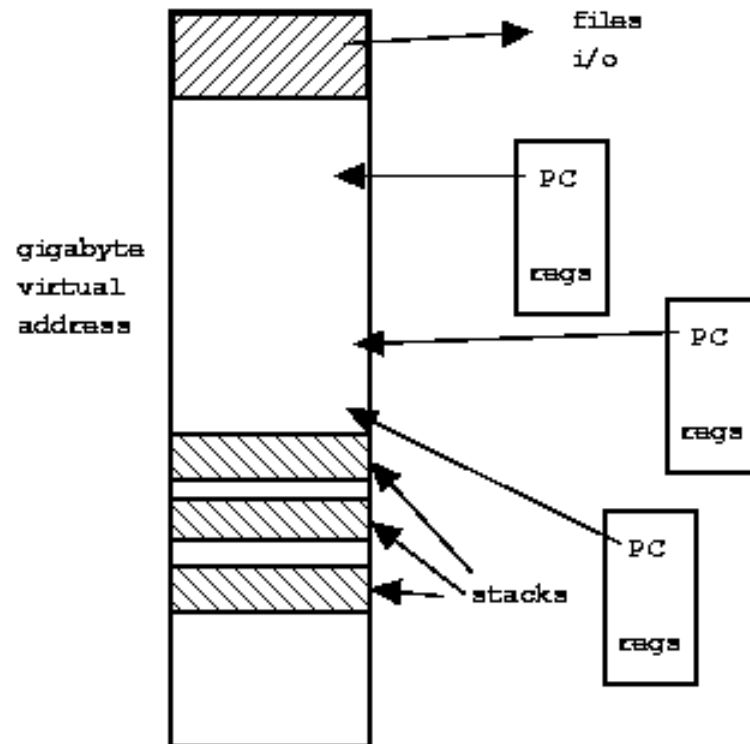
Module 2: Threads Intro

- Traditional process
 - One thread of control through a large, potentially sparse address space
 - Expensive communication (IPC requires context switching)
 - Including shared address space with other processes
 - Collection of systems resources (files, semaphores)
- Thread (light weight process)
 - A flow of control through an address space
 - Each address space can have multiple concurrent control flows
 - Each thread has access to entire address space
 - Potentially parallel execution, minimal state (low overheads)
 - May need synchronization to control access to shared variables



Threads

- Each thread has its own stack, PC, registers
 - Share address space, files,...



Why use Threads?

- Large multiprocessors/multi-core systems need many computing entities (one per CPU or core)
- Switching between processes incurs high overhead
- With threads, an application can avoid per-process overheads
 - Thread creation, deletion, switching cheaper than processes
- Threads have full access to address space (easy sharing)
- Threads can execute in parallel on multiprocessors



Why Threads?

- *Single threaded process*: blocking system calls, no concurrency/parallelism
- *Finite-state machine* [event-based]: non-blocking with concurrency
- *Multi-threaded process*: blocking system calls with parallelism
- Threads retain the idea of sequential processes with blocking system calls, and yet achieve parallelism
- Software engineering perspective
 - Applications are easier to structure as a collection of threads
 - Each thread performs several [mostly independent] tasks



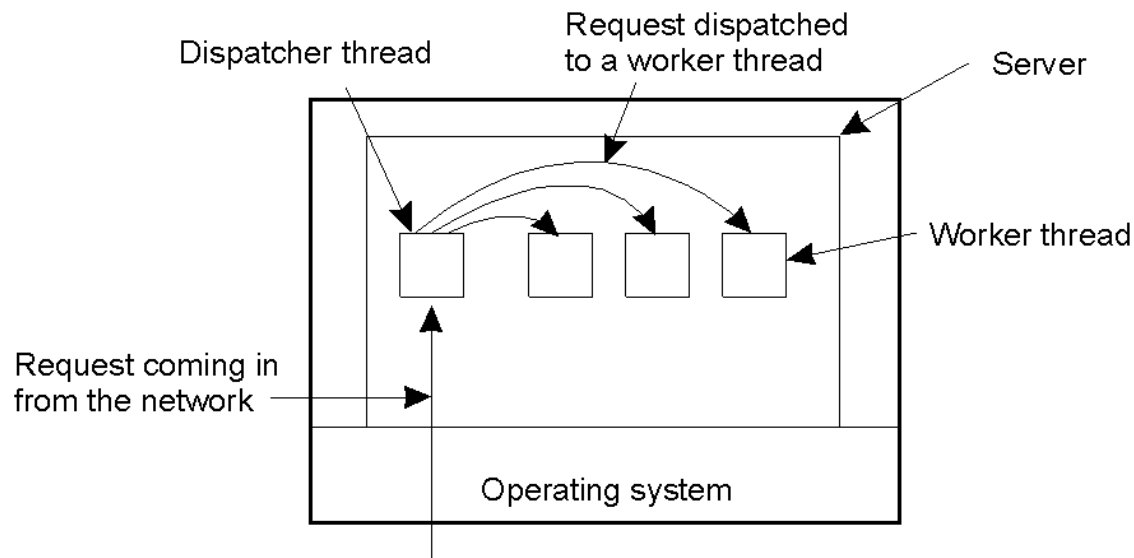
Multi-threaded Clients Example : Web Browsers

- Browsers such as IE are multi-threaded
- Such browsers can display data before entire document is downloaded: performs multiple simultaneous tasks
 - Fetch main HTML page, activate separate threads for other parts
 - Each thread sets up a separate connection with the server
 - Uses blocking calls
 - Each part (gif image) fetched separately and in parallel
 - Advantage: connections can be setup to different sources
 - Ad server, image server, web server...



Multi-threaded Server Example

- Apache web server: pool of pre-spawned worker threads
 - Dispatcher thread waits for requests (“master slave” architecture)
 - For each request, choose an idle worker thread
 - Worker thread uses blocking system calls to service web request



Thread Management

- Creation and deletion of threads
 - Static versus dynamic
- Critical sections
 - Synchronization primitives: blocking, spin-lock (busy-wait)
 - Condition variables
- Global thread variables
- Kernel versus user-level threads



Module 3: User-level versus kernel threads

- *Key issues:*
- Cost of thread management
 - More efficient in user space
- Ease of scheduling
- Flexibility: many parallel programming models and schedulers
- Process blocking – a potential problem



User-level Threads

- Threads managed by a threads library
 - Kernel is unaware of presence of threads
 - Many (*threads*)-to-one (*scheduling entity*) approach
- Advantages:
 - No kernel modifications needed to support threads
 - Efficient: creation/deletion/switches don't need system calls
 - Flexibility in scheduling: library can use different scheduling algorithms, can be application dependent
- Disadvantages
 - Need to avoid *blocking* system calls [all threads block]
 - Threads compete with each other
 - Process cannot take advantage of multiprocessors [no real parallelism]



User-level threads

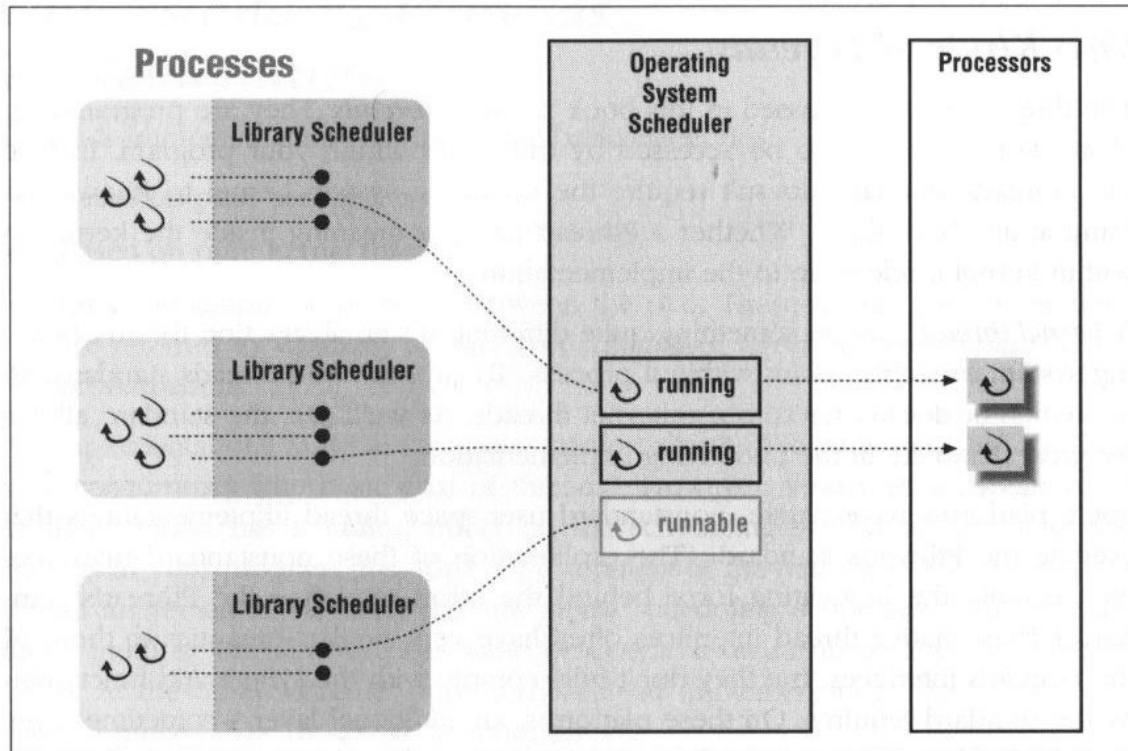


Figure 6-1: User-space thread implementations

Kernel-level threads

- Kernel aware of the presence of threads
 - One-to-one: each thread is schedulable independently
 - Better scheduling decisions, more expensive
 - Better for multiprocessors, more overheads for uniprocessors

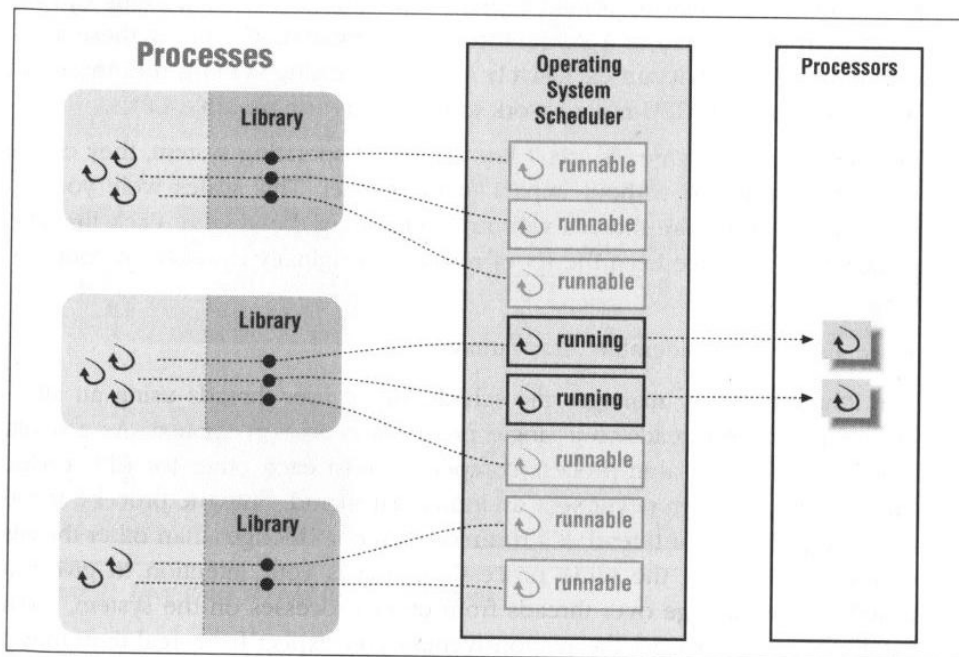


Figure 6-2: Kernel thread-based implementations



Light-weight Processes

- Several LWPs per heavy-weight process (many-to-many)
- User-level threads package
 - Create/destroy threads and synchronization primitives
- Multithreaded applications – create multiple threads, assign threads to LWPs
- Each LWP, when scheduled, searches for a runnable thread [*two-level scheduling*]
 - Shared thread table: no kernel support needed
- When a LWP thread block on system call, switch to kernel mode and OS context switches to another LWP



Scheduler Activation

- User-level threads: scheduling both at user and kernel levels
 - user thread system call: process blocks
 - kernel may context switch thread during important tasks
- Need mechanism for passing information back and forth
- Scheduler activation: OS mechanism for user level threads
 - Notifies user-level library to switch to next thread
 - Provides data structures for saving thread context
- User-level library/kernel communication
 - Library informs kernel: create/delete threads
 - Kernel makes up-calls: thread blocked, I/O is done etc.



LWP Example

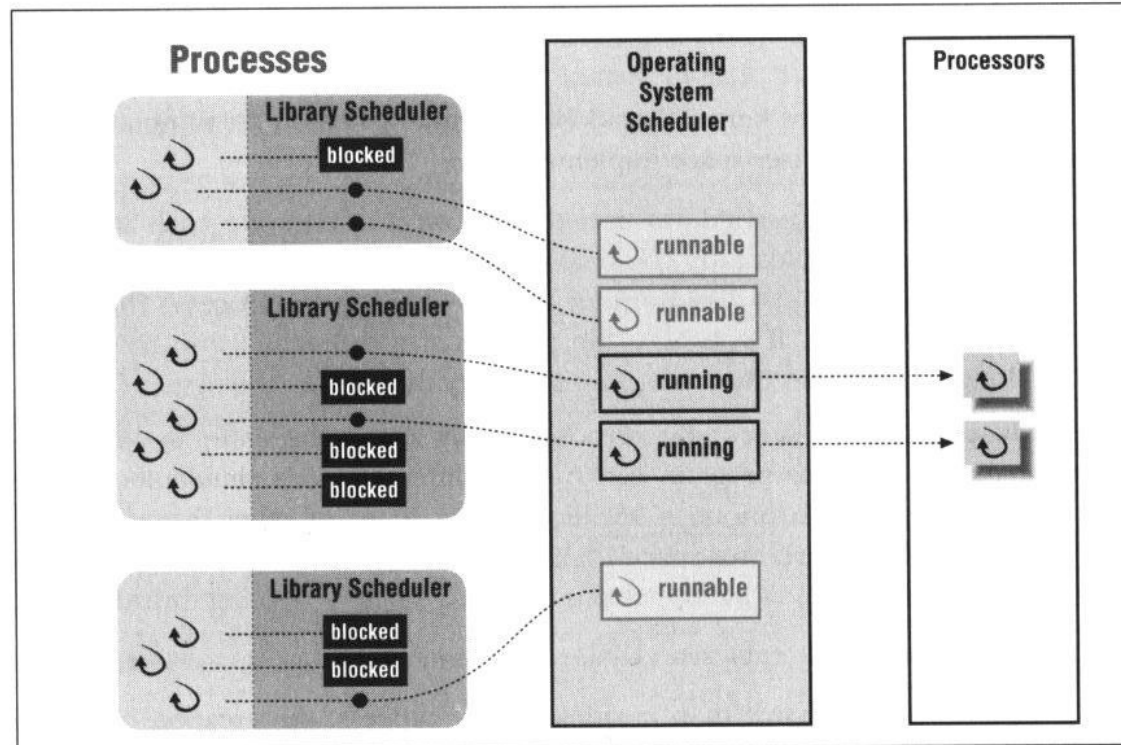


Figure 6-3: Two-level scheduler implementations



Thread Packages

- Posix Threads (pthreads)
 - Widely used threads package
 - Conforms to the Posix standard
 - Sample calls: `pthread_create`,...
 - Typical used in C/C++ applications
 - Can be implemented as user-level or kernel-level or via LWPs
- Java Threads
 - Native thread support built into the language
 - Threads are scheduled by the JVM

