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
  – Address space may be shared with other processes (shared mem)
  – 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 set up 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

- 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 for one another
  - Does not 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
  - Better scheduling decisions, more expensive
  - Better for multiprocessors, more overheads for uniprocessors
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 of kernel events
  - Provides data structures for saving thread context
- Kernel makes up-calls: CPU available, I/O is done etc.
- Library informs kernel: create/delete threads
  - N:M mapping: n user-level threads onto M kernel entities
  Performance of user-level threads with behavior of kernel threads
Light-weight Processes

- Several LWPs per heavy-weight process
- User-level threads package
  - Create/destroy threads and synchronization primitives
- Multithreaded applications – create multiple threads, assign threads to LWPs (one-one, many-one, many-many)
- 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
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