Processes and Threads

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

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.
    - $\Pr [ X \leq x ] = 1 - e^{-\mu x}$
    - $E[X] = \frac{1}{\mu}$
  - If $X$ is a hyperexponential r.v.
    - $\Pr [ X \leq x ] = 1 - p e^{-\mu_1 x} - (1-p) e^{-\mu_2 x}$
    - $E[X] = \frac{p}{\mu_1} + \frac{(1-p)}{\mu_2}$

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
Processes and Threads

• 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 need many computing entities (one per CPU)
- 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 parallelism
- *Finite-state machine* [event-based]: non-blocking with parallelism
- *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
  – 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

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

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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
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