Linux

CS 256/456

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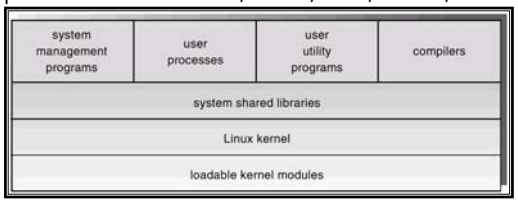
History

- Linux is a modem, free operating system based on UNIX standards.
- First developed as a small but self-contained kernel in 1991 by Linus Torvalds, with the major design goal of UNIX compatibility.
- The core Linux operating system kernel is entirely original, but it can run much existing free UNIX software, resulting in an entire UNIX-compatible operating system free from proprietary code.
- Its history has been one of collaboration by many users from all around the world, corresponding almost exclusively over the Internet.

Linux Kernel/System/Distribution

- Kernel
  - the OS code that runs on privileged mode
- System
  - essential system components, but runs in user mode
  - compilers & system libraries
- Linux distribution
  - extra system-installation and management utilities
  - precompiled and ready-to-install tools & packages
  - popular distributions: Redhat, Debian, SuSE, Caldera, …



Kernel Modules

- Sections of kernel code that can be compiled, loaded, and unloaded independent of the rest of the kernel.
- A kernel module may typically implement a device driver, a file system, or a networking protocol.
- The module interface allows third parties to write and distribute, on their own terms, device drivers or file systems (that could not be distributed under the GPL).
- Kernel modules allow a Linux system to be set up with a standard, minimal kernel, without any extra device drivers built in.

Processes and Threads

- Linux uses the same internal representation for processes and threads; a thread is simply a new process that happens to share the same address space as its parent.
- A distinction is only made when a new thread is created by the **clone** system call.
  - a process is a task with its own entirely new context (including address space)
  - a thread is a task with its own identity, but not an dedicated address space
- The **clone** system call allows fine-grained control over exactly what is shared between two threads.
  - open files, memory space, page tables

Linux Task Scheduling

- Linux uses two task-scheduling classes:
  - A time-sharing class for fair preemptive scheduling between multiple tasks.
  - A real-time class that conforms to POSIX real-time standard. (FIFO/RR)
- A prioritized, epoch-based algorithm for time-sharing
  - Each task has a static priority (default=20) and an dynamic quantum (initially set to priority)
  - Scheduling is prioritized based on "quantum+priority"
  - Quantum of the running task decrements by one at every clock tick
  - Recrediting when no runnable tasks have any quantum (end of an epoch):

$$\text{initial quantum in new epoch} = \frac{\text{remaining quantum}}{2} + \text{priority}$$

  - This quantum crediting system automatically prioritizes interactive or I/O-bound tasks.

Linux Task Scheduling: O(1) Scheduler

- Linux O(1) scheduler
  - the scheduling overhead is constant, which is independent of the number of processes in the system
- Main operations in Linux scheduler
  - schedule(), quantum recalculation, wakeup()
- Using two priority arrays
  - one for active array, one for those whole quantum has been used up (called "expired")
  - O(1) operation to find the highest priority in a particular array: use array index bitmap and BSFL
  - problem: have to use static priority since array index indicates the priority and it is too costly to move tasks in the array

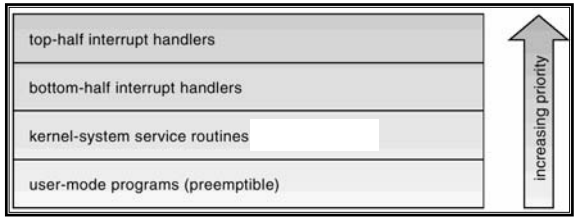
Kernel Synchronization

- When kernel-mode execution occurs?
  - system call or software trap.
  - hardware interrupts.
- Kernel synchronization: allow the kernel's critical sections to run without interruption by conflicting critical section.
  - disabling the interrupts

Kernel Synchronization (Cont.)

- To avoid performance penalties, Linux's kernel uses a synchronization architecture that allows long service routines to run without having interrupts disabled for the critical section's entire duration.
- Kernel routines (often interrupt service routines) are separated into a *top half* (urgent) and a *bottom half* (not so urgent).
  - The top half runs with interrupts disabled.
  - The bottom half is run, with all interrupts enabled.
  - Bottom halves do not interrupt themselves.

Interrupt Protection Levels



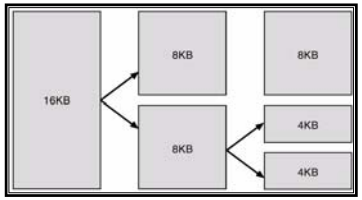
- Each level may be interrupted by code running at a higher level, but will never be interrupted by code running at the same or a lower level.

Multiprocessor

- Linux 2.0 was the first Linux kernel to support SMP hardware; separate processes or threads can execute in parallel on separate processors.
- To preserve the kernel's nonpreemptible synchronization requirements, SMP imposes the restriction, via a single kernel spinlock, that only one processor at a time may execute kernel-mode code.
- The nonpreemptible restriction is removed in recent kernels.

Managing Physical Memory

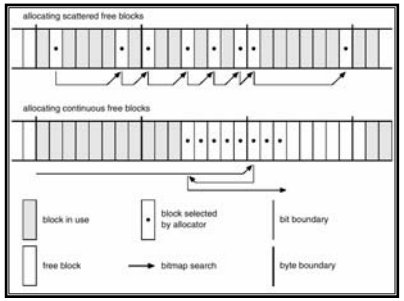
- Keep track of free memory?
- Linux page allocator can allocate ranges of physically-contiguous pages on request.
- The allocator uses a *buddy-heap* algorithm to keep track of available physically-contiguous memory regions.



- A free region list is maintained for each region size

Ext2fs Block-Allocation Policies

- Ext2fs uses allocation policies designed to place logically adjacent blocks of a file into physically adjacent blocks on disk, so that it can submit an I/O request for several disk blocks as a single operation.



The Linux /proc File System

- The **proc** file system does not store data, rather, its contents are computed on demand according to user file I/O requests.
  - When data is read from one of these files, **proc** collects the appropriate information, formats it into text form and places it into the requesting process's read buffer.

Prefetching and I/O Scheduling

- File prefetching/read-ahead
  - Linux prefetching sequences
- Disk I/O scheduling
  - seek-reduction scheduling: SSTF, LOOK, SCAN
  - non-work conserving scheduling: anticipatory scheduling with deadline to prevent starvation

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