

COMP 3511 Operating System



Operating System Concepts – 9th Edition

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Lecture, Tutorials and Grading Scheme

- Lecture notes and tutorial materials
 - Download course materials before class
 - Homework and programming assignments will be put online

- Grading is based on
 - Four Written Assignments – 20% (5% each)
 - Two Programming Assignments – 25% (10% and 15%)
 - Midterm Exam - 20%
 - Final Exam - 35%

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Lecture Format

- Lectures:
 - Slides are available before class
 - It is important to attend the lectures (not all materials and concepts can be covered in slides)
 - If you miss any lectures, learn from the lecture notes and textbook

- Tutorials
 - Supplement the lectures with more examples
 - Some exercises
 - Unix environment, editor, how to compile and run programs, Makefile
 - **Nachos**

- Reading the corresponding materials in the textbook
 - Slides do not cover everything

- Chapter summary
 - Comprehensive summary at the end of each chapter

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Lectures and Tutorials

- L-1
 - Instructor: Bo Li
 - Lectures: Tuesday and Thursday 10:30 am – 11:50 am
 - Venue: Room 2502

- Lab sessions:
 - Lab 1A Monday 3:00 pm - 4:50 pm Room 4214
 - Lab 1B Wednesday 10:30 am - 12:20 pm Room 4214

- Web site: <http://course.cs.ust.hk/comp3511/>

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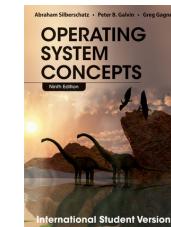
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Textbook

- Operating System Concepts, A. Silberschatz, P. B. Galvin and G. Gagne, 9th Edition



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Course Prerequisite

- COMP 2611 or equivalent
 - Basic computer organization knowledge, computer system, CPU, memory hierarchy, interrupt, DMA, storage, I/O devices

- Programming
 - UNIX environment
 - C/C++ programming

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Assignments

- Written assignments
 - Due by time specified
 - Contact TAs directly for any disputes on the grading
 - Re-grading requests will only be granted within **one week** after the homework grades are released
 - Late policy: 15% reduction, only one day delay is allowed.

- Programming assignments
 - Individual projects
 - Due by time specified
 - Run on Unix
 - Submit it using CASS – You need to register for an account
 - Re-grade policy will be announced
 - Late policy : 15% reduction, only one day delay is allowed.

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Midterm and Final Examinations

- Midterm Exam
 - March 31, 2015 (Week #9, Tuesday) 7:00 pm - 8:30 pm
 - Venues: 3006 and 3007

- Final Exam
 - TBD

- All exams are closed-book, closed-notes

- No make-up exams will be given unless
 - under very unusual circumstances, e.g., sickness, with letters of proof
 - Instructor must be informed beforehand

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Tips for Learning

- Attend lectures
 - Download lecture notes prior to lectures
 - Important concepts are explained
- Complete homework alone
 - This is an exercise to test your knowledge
- Spend 30 minutes each week to review the content
 - Weekly summary can help
 - This will save you lots of time later when you prepare for exams
 - You can not expect to learn everything two days before exams no matter how smart you are
 - Knowledge is accumulated incrementally
- Start your project earlier
 - Have a plan for the project
- Raise questions!
 - Do not delay your questions until exams

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What you are suppose to learn

- Define the fundamental principles, strategies and algorithms used in the design and implementation of operating systems
- Analyze and evaluate operating system functions
- Analyze the structure of an operating system kernel, and identify the relationship between the various subsystems
- Identify the typical events, alerts, and symptoms indicating potential operating system problems
- Recognize and evaluate the source code of the NACHOS operating system
- Design and implement programs for basic operating system functions and algorithms

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Chapter 1: Introduction

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Chapter 1: Introduction

- Computer-System Architecture
- What Operating Systems Do
- Operating-System Structure
- Operating-System Operations
- Computing Environment

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Computer System Structure

- Computer system can be divided into *four* components
 - **Hardware** – provides basic computing resources
 - CPU, memory, I/O devices
 - **Operating system**
 - Controls and coordinates use of hardware among various applications and users
 - **System and application programs** – define the ways in which the system resources are used to solve the computing problems of the users
 - Word processors, compilers, web browsers, database systems, video games
 - **Users**
 - People, machines, other computers

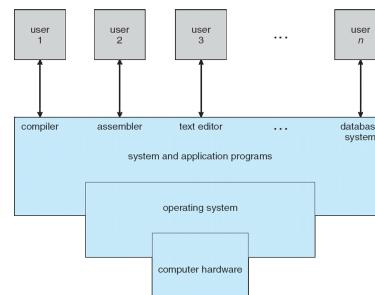
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Four Components of a Computer System

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Course Outline

- Overview (1.5 week)
 - Basic OS concept
 - System architecture
- Process and Thread (6 weeks)
 - Process and thread (2 weeks)
 - CPU scheduling (1 week)
 - Synchronization (2 weeks)
 - Deadlock (1 week)
- Memory and storage (5 weeks)
 - Memory management (1.5 weeks)
 - Virtual memory (1.5 weeks)
 - File system (1 week)
 - Secondary storage and I/O (1 weeks)

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Computing Devices Everywhere

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Computer Startup

- **Bootstrap program** is loaded at power-up or reboot time
 - Typically stored in ROM or EPROM, generally known as **firmware**
 - Initializes all aspects of the system
 - Loads operating system kernel and starts execution

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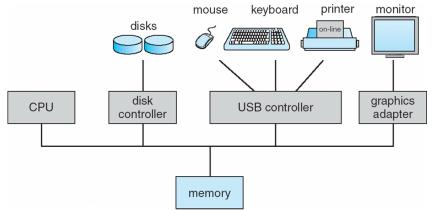
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Computer System Organization

- Computer-system operation
 - One or more CPUs, device controllers connect through common bus providing access to shared memory
 - Concurrent execution of CPUs and devices competing for memory cycles

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Computer-System Operation

- I/O devices and the CPU can execute concurrently
- Each device controller is in charge of a particular device
- Each device controller has a local buffer
- CPU moves data from/to main memory to/from local buffers
- I/O is from the device to local buffer of controller
- Device controller informs CPU that it has finished its operation by causing an **interrupt**

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Interrupts

- Interrupt transfers control to the **interrupt service routine** generally, through the **interrupt vector**, which contains the addresses of all the service routines or called interrupt handlers
- Interrupt architecture must save the address of the interrupted instruction
- Determines which type of interrupt has occurred:
 - polling**
 - vectored interrupt system**
- Incoming interrupts are **disabled** while another interrupt is being processed to prevent a *lost interrupt*
- A **trap** or **an exception** is a software-generated interrupt caused either by an error (e.g., division by zero) or a user request for operation system service
- Operating systems are **interrupt driven**

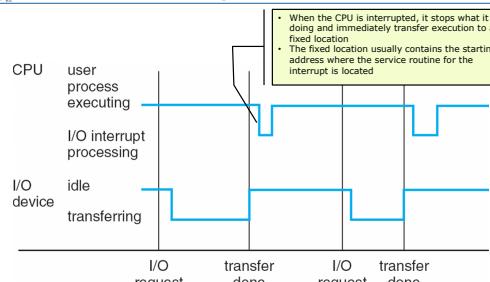
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Interrupt Timeline

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Storage Definitions and Notation Review

The basic unit of computer storage is the **bit**. A bit can contain one of two values, 0 and 1. All other storage in a computer is based on collections of bits. Given enough bits, it is amazing how many things a computer can represent: numbers, letters, images, movies, sounds, documents, and programs, to name a few. A **byte** is 8 bits, and on most computers it is the smallest convenient chunk of storage. For example, most computers don't have an instruction to move a bit but do have one to move a byte. A less common term is **word**, which is a given computer architecture's native unit of data. A word is made up of one or more bytes. For example, a computer that has 64-bit registers and 64-bit memory addressing typically has 64-bit (8-byte) words. A computer executes many operations in its native word size rather than a byte at a time. Computer storage, along with most computer throughput, is generally measured and manipulated in bytes and collections of bytes. A **kilobyte**, or **KB**, is 1,024 bytes; a **megabyte**, or **MB**, is 1,024 KB; a **gigabyte**, or **GB**, is 1,024 MB; a **terabyte**, or **TB**, is 1,024 GB; and a **petabyte**, or **PB**, is 1,024 TB. Computer manufacturers often round off these numbers and say that a megabyte is 1 million bytes and a gigabyte is 1 billion bytes. Networking measurements are an exception to this general rule; they are given in bits (because networks move data a bit at a time).

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Direct Memory Access

- The problem with interrupt-based I/O operations
 - The speed mismatch between CPU, memory and I/O device
- Used for high-speed I/O devices able to transmit information at close to memory speeds
- Device controller transfers blocks of data from buffer storage directly to main memory **without** CPU intervention
- Only one interrupt is generated per block, rather than the one interrupt per byte, so CPU can be released to execute instructions for other process or program

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Storage Hierarchy Structure

- Storage systems organized in hierarchy
 - Speed
 - Cost
 - Volatility

Main memory is a volatile storage device that loses its contents when power is turned off
- Cache – fast memory close to CPU
- Main memory – only large storage media that the CPU can access directly
- Secondary storage – extension of main memory that provides large nonvolatile storage capacity
- Magnetic disks – rigid metal or glass platters covered with magnetic recording material

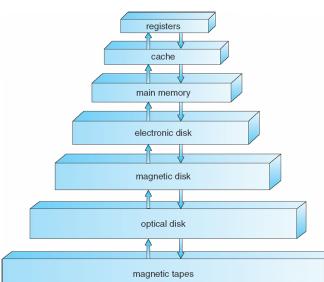
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Storage-Device Hierarchy

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Caching

- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily
- Faster storage (cache) first checks to determine if information is there
 - If it is, information used directly from the cache (fast)
 - If not, data copied from slower storage to cache and used there
- Cache smaller than storage being cached
 - Cache management important design problem
 - Cache size and replacement policy

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Performance of Various Levels of Storage

- The performance data is updated constantly

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000,000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

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How do We Tame Complexity?

- Every piece of computer hardware is different
 - Different CPU
 - Pentium, PowerPC, ColdFire, ARM, MIPS
 - Different amounts of memory, disk, ...
 - Different types of devices
 - Mice, Keyboards, Sensors, Cameras, Fingerprint readers
 - Different networking environment
 - Cable, DSL, Wireless, Firewalls,...
- Questions:
 - Does every program have to be altered for every piece of hardware?
 - Does a faulty program crash everything?
 - Does every program have access to all hardware?
 -

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What does Operating System Do?

- OS is a **resource allocator**
 - Manages all resources
 - Decides between conflicting requests for efficient and fair resource use
 - Prevent errors and improper use of the computer
- OS is a **facilitator**
 - Provides facilities that everyone needs
 - Standard Libraries, Windowing systems
 - Make application programming easier, faster, less error-prone

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Operating System Definition

- No universally accepted definition
- "Everything a vendor ships when you order an operating system" is good approximation
 - But varies wildly
- "The one program running at all times on the computer" is the **kernel**
 - Everything else is either a system program (ships with the operating system) or an application program

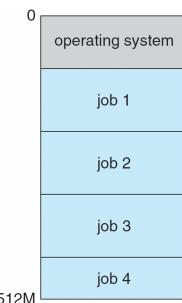
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Memory Layout for Multiprogrammed System

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Operating-System Operations

- Dual-mode** operation allows OS to protect itself and other system components
 - User mode and kernel mode, or supervisor mode, system mode
 - Mode bit provided by hardware
 - Provides ability to distinguish when system is running user code or kernel code
 - Some instructions designated as **privileged**, only executable in kernel mode
 - System call changes mode to kernel, return from call resets it to user

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What is an Operating System?

- A program that acts as an intermediary between a user of a computer and computer hardware
- Operating system goals:
 - Control and coordinate the use of system resources (hardware and software)
 - Make the computer system convenient to use for users
 - Use the computer hardware in an efficient and protected manner

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Operating System Structure

- Multiprogramming** needed for efficiency
 - Single user cannot keep CPU and I/O devices busy at all times
 - Multiprogramming organizes jobs (code and data) so CPU always has one to execute
 - A subset of total jobs in system is kept in memory
 - One job selected and run via **job scheduling**
 - When it has to wait (for I/O for example), OS switches to another job
- Timesharing (multitasking)** is logical extension in which CPU switches jobs so frequently that users can interact with each job while it is running, creating **interactive computing**
 - Response time should be < 1 second
 - Each user has at least one program executing in memory ⇒ **process**
 - If several jobs ready to run at the same time ⇒ **CPU scheduling**
 - If processes don't fit in memory, **swapping** moves them in and out to run
 - Virtual memory** allows execution of processes not completely in memory

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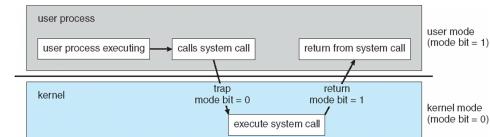
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Dual-mode Operation

- Transitions from user mode to kernel mode:
 - System Calls, Interrupts, Other exceptions

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Timer

- Must ensure the OS maintains control over the CPU
- Must prevent a user program from getting stuck in an infinite loop or never returning control to the OS
- Timer** is used to prevent infinite loop / process hogging resources
 - Set interrupt after specific period
 - Operating system decrements counter
 - When counter zero generate an interrupt
 - Set up before scheduling process to regain control or terminate program that exceeds allotted time

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Computing Environments - Traditional

- Stand-alone general purpose machines
- But blurred as most systems interconnect with others (i.e. the Internet)
- Portals** provide web access to internal systems
- Network computers (thin clients)** are like Web terminals
- Mobile computers interconnect via **wireless networks**
- Networking becoming ubiquitous – even home systems use **firewalls** to protect home computers from Internet attacks

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Computer-System Architecture

- Most systems use a single general-purpose processor (PDAs through mainframes)
 - Most systems have special-purpose processors as well
- Multiprocessors** systems growing in use and importance
 - Also known as **parallel systems, tightly-coupled systems**
 - Advantages include:
 - Increased throughput
 - Economy of scale
 - Increased reliability – graceful degradation or fault tolerance
- Two types:
 - Asymmetric Multiprocessing** – one master CPU distributes tasks among multiple slave CPUs
 - Symmetric Multiprocessing**

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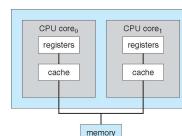
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A Dual-Core Design

- UMA and NUMA** architecture variations
 - Uniform Memory Access and Non Uniform Memory Access Architectures
- Multi-chip and multicore**

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Clustered Systems

- Like multiprocessor systems, but multiple systems working together
 - Usually sharing storage via a **storage-area network (SAN)**
 - Provides a **high-availability** service which survives failures
 - Asymmetric clustering** has one machine in hot-standby mode
 - Symmetric clustering** has multiple nodes running applications, monitoring each other
 - Some clusters are for **high-performance computing (HPC)**
 - Applications must be written to use **parallelization**
 - Some have **distributed lock manager (DLM)** to avoid conflicting operations

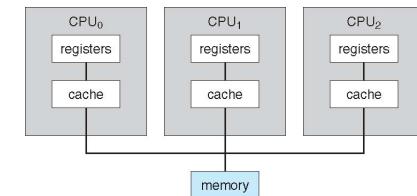
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Symmetric Multiprocessing Architecture

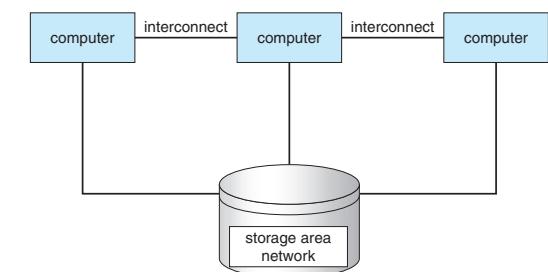
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Clustered Systems

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Computing Environments – Distributed

- Distributed**
 - Collection of separate, possibly heterogeneous, systems networked together
 - Network** is a communications path, **TCP/IP** most common
 - Local Area Network (LAN)**
 - Wide Area Network (WAN)**
 - Metropolitan Area Network (MAN)**
 - Personal Area Network (PAN)**
 - Network Operating System** provides features between systems across network
 - Communication scheme allows systems to exchange messages
 - Illusion of a single system

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Computing Environments - Mobile

- Handheld smartphones, tablets, etc
- What is the functional difference between them and a “traditional” laptop?
- Extra feature – more OS features (GPS, gyroscope)
- Allows new types of apps like **augmented reality**
- Use IEEE 802.11 wireless, or cellular data networks for connectivity
- Leaders are **Apple iOS** and **Google Android**

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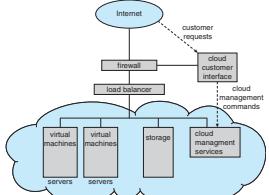
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Computing Environments – Cloud Computing

- Cloud compute environments composed of traditional OSes, VMMs (virtual machine management), plus cloud management tools
 - Internet connectivity requires security like firewalls
 - Load balancers spread traffic across multiple applications



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Computing Environments – Cloud Computing

- Delivers computing, storage, even apps as a service across a network
- Logical extension of virtualization as based on virtualization
 - Amazon **EC2** has thousands of servers, millions of VMs, PBs of storage available across the Internet, pay based on usage
- Many types
 - **Public cloud** – available via Internet to anyone willing to pay
 - **Private cloud** – run by a company for the company's own use
 - **Hybrid cloud** – includes both public and private cloud components
 - Software as a Service (**SaaS**) – one or more applications available via the Internet (i.e. word processor)
 - Platform as a Service (**PaaS**) – software stack ready for application use via the Internet (i.e. a database server)
 - Infrastructure as a Service (**IaaS**) – servers or storage available over Internet (i.e. storage available for backup use)

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Open-Source Operating Systems

- Operating systems made available in source-code format rather than just binary **closed-source**
- Counter to the **copy protection** and **Digital Rights Management (DRM)** movement
- Started by **Free Software Foundation (FSF)**, which has "copyleft" **GNU Public License (GPL)**
- Examples include **GNU/Linux**, **BSD UNIX** (including core of **Mac OS X**), and **Sun Solaris**

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End of Chapter 1



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