

## CS 416 Operating Systems

Prof Badri Nath  
<http://www.cs.rutgers.edu/~badri/416.html>  
Dept. of Computer Science  
Rutgers University

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## Computer System Overview

Chapter 1

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### Why are operating systems interesting?

- An Operating System makes the computing power available to users by controlling the hardware resources
- Services used by application programmers
- Provides an easy way to program a machine
- Reality-soul of any computer
  - Linux, palm-OS, WIN/NT, UNIX flavors

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### Why are they complex

- Code needed to control variety of devices
- Calls for detailed knowledge of hardware
- Provides various services for applications
  - Examples? –
- Components designed for performance

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## Course Goals

- Understand “what is an OS?”
  - Understand key OS components; management of resources
  - An OS as a control program, resource allocator and an environment
- Present interesting algorithms used in OS
- To outline some important features of modern OS
  - Linux, WIN/NT, Unix flavors, palm OS

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## Historical perspective

- 0th generation
  - Single users, toggle switches loaders
- 1<sup>st</sup> generation
  - 1950's batch operating systems
- 2<sup>nd</sup> generation
  - Early 60's multiprogramming
  - Efficient use of resources (memory + CPU)
- 3<sup>rd</sup> generation
  - mid 60s to mid 70s
  - Timesharing, interactive response
- 4<sup>th</sup> generation
  - Mid 70s to mid 80s
  - Smaller compact systems minis

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## Historical perspective

- 5<sup>th</sup> generation
  - Mid 80s to mid 90s
  - PCs, WINDOWS, LINUX
  - Networking, client server systems
- Current generation
  - Small compact OS. Cluster computing, NOW (network of workstations). Emphasis on availability
  - OS for special devices
  - Focus on communication and entertainment
  - OS for webTV, Replay TV, Cellular phones, palm
  - OS in your car

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## Current trends in OS

- Flexibility VS performance
  - Plug N play
- Exploit architecture features on which OS executes
- OS for specialty devices
- Consider application requirements

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## Basic Components

- Processor (CPU)
- Main Memory (aka physical memory, aka primary memory)
  - holds data in code
- I/O modules (I/O controllers, I/O channels, I/O processors...)
  - hardware (with registers called I/O ports) that moves data between cpu and peripherals like:
    - secondary memory devices (eg: hard disks)
    - keyboard, display...
    - communications equipment
- System interconnection (ie: Buses)
  - communication among processors, memory, and I/O modules

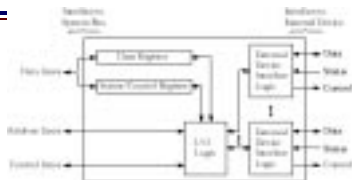
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## What's happening with CPU

- 8088 .5 MIPS
- 286 1 MIPS
- 386 5 to 10 MIPS
- 486 20 to 50 MIPS
- Pentium, power PC alpha 100 MIPS
- P6 200 to 300 MIPS
- Pentium III or AMD athlon 600 to 700 MIPS
  - 1 GHZ clock ( $10^{-9}$  sec)
  - <http://www.intel.com/mobile/performance/pentiumiii/index.htm>

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## I/O Module Structure



- Data to/from system bus are buffered in data register(s)
- Status/Control register(s) holds
  - current status information of the I/O operation
  - current control information from CPU
- I/O logic interact with CPU via control bus
- Contains logic specific to the interface of each device<sup>11</sup>

## CPU Registers (fast memory on cpu)

- Control & Status Registers
  - Generally not available to user programs
  - some used by CPU to control its operation
  - some used by OS to control program execution
- User-visible Registers
  - available to system (OS) and user programs
  - holds data, addresses, and some condition codes

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## Examples of Control & Status Registers

- Program Counter (PC)
  - Contains the address of the next instruction to be fetched
- Instruction Register (IR)
  - Contains the instruction most recently fetched
- Program Status Word (PSW)
  - A register or group of registers containing:
    - condition codes and status info bits
    - Interrupt enable/disable bit
    - Supervisor(OS)/user mode bit

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## User-Visible Registers

- Data Registers
  - can be assigned by the user program to perform operations on data
- Address Registers
  - contain memory address of data and instructions
  - may contain a portion of an address that is used to calculate the complete address

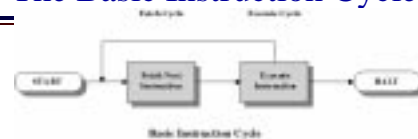
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## User-Visible Registers

- Condition Codes or Flags
  - Bits set by the processor hardware as a result of operations
  - Can be accessed by a program but not changed directly
  - Examples
    - sign flag
    - zero flag
    - overflow flag

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## The Basic Instruction Cycle

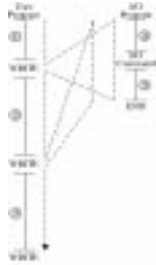


- The CPU fetches the next instruction (with operands) from memory.
- Then the CPU executes the instruction
- Program counter (PC) holds address of the instruction to be fetched next
- Program counter is automatically incremented after each fetch

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## Then CPU must wait for I/O to complete!

- WRITE transfer control to the printer driver (I/O pgm)
- I/O pgm prepare I/O module for printing (4)
- CPU has to WAIT for I/O command to complete
- Long wait for a printer
- I/O pgm finishes in (5) and report status of operation



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## Interrupts

- Computers now permit I/O modules to INTERRUPT the CPU.
- For this the I/O module just assert an interrupt request line on the control bus
- Then CPU transfer control to an **Interrupt Handler Routine** (normally part of the OS)

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## Instruction Cycle with Interrupts!



- CPU checks for interrupts after each instruction
- If no interrupts, then fetch the next instruction for the current program
- If an interrupt is pending, then suspend execution of the current program, and execute the **interrupt handler**

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## Interrupt Handler

- Is a program that determines nature of the interrupt and performs whatever actions are needed
- Control is transferred to this program
- Control must be transferred back to the interrupted program so that it can be resumed from the point of interruption
- This point of interruption can occur anywhere in the program
- Thus: must save the state of the program (content of PC + PSW + registers + ...)

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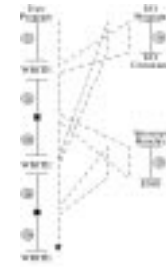
## Simple Interrupt Processing



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## Interrupts improve CPU usage

- I/O pgm prepares the I/O module and issues the I/O command (eg: to printer)
- I/O pgm branches to user pgm
- User code gets executed during I/O operation (eg: printing): no waiting
- User pgm gets interrupted (x) when I/O operation is done and branches to interrupt handler to examine status of I/O module
- Execution of user code resumes



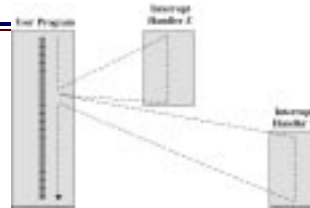
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## Classes of Interrupts

- I/O or Hardware Interrupts
  - signals normal completion of operation or error
- Program Exception
- An unusual condition resulting from the execution of an instruction – caused by the running process (need attention of OS)
  - Traps – occurs at end of instruction (special instructions or overflows)
- Other types of exceptions
- try to execute illegal instruction (beginning of instruction)
  - Fault Vs abort (can occur in the middle of executing an instruction)
  - Fault: exception that can be cleared (Page fault)
  - Abort: exception that cannot be cleared (reference outside user's memory space)
- Timer
  - preempts a program to perform another task
- Hardware failure (eg: memory parity error)
- Software interrupts –signals (independent of running process)

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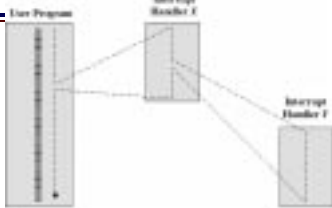
## Multiple interrupts: sequential order



- Disable interrupts during an interrupt
- Interrupts remain pending until the processor enables interrupts
- After interrupt handler routine completes, the processor checks for additional interrupts

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## Multiple Interrupts: priorities



- Higher priority interrupts cause lower-priority interrupts to wait
- Causes a lower-priority interrupt handler to be interrupted
- Example: when input arrives from communication line, it needs to be absorbed quickly to make room for more input

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## Multiprogramming

- When a program **reads** a value on a I/O device it will need to wait for the I/O operation to complete
- Interrupts are mostly effective when a single CPU is shared among several concurrently active processes.
- The CPU can then switch to execute another program when a program waits for the result of the read operation.

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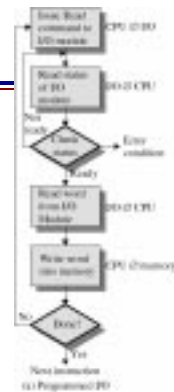
## I/O communication techniques

- 3 techniques are possible for I/O operation
  - **Programmed I/O**
    - Does not use interrupts: CPU has to wait for completion of each I/O operation
  - **Interrupt-driven I/O**
    - CPU can execute code during I/O operation: it gets interrupted when I/O operation is done.
  - **Direct Memory Access**
    - A block of data is transferred directly from/to memory without going through CPU

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## Programmed I/O

- I/O module performs the action, on behalf of the processor
- But the I/O module does not interrupt the CPU when I/O is done
- Processor is kept busy checking status of I/O module

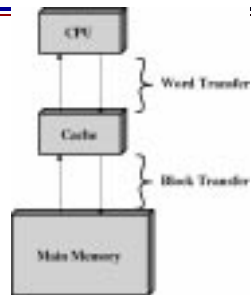


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## Cache Memory

- Small cache of expensive but very fast memory interacting with slower but much larger memory
- Invisible to OS and user programs but interact with other memory management hardware
- Processor first checks if **word** referenced to is in cache
- If not found in cache, a **block** of memory containing the word is **moved to the cache**



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## Locality of reference

- Memory reference for both instruction and data tend to cluster over a long period of time.
- Example: once a loop is entered, there is frequent access to a small set of instructions.
- Hence: **once a word gets referenced, it is likely that nearby words will get referenced often in the near future.**
- Thus, the hit ratio will be close to 1 even for a small cache.

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## What's happening with network

- Ethernet 10 to 100 Mbps
- Fast ethernet 70 to 100 Mbps
- Switched ATM or gigabit ethernet 100 to 1000 Mbps
- Wireless
  - Cellular 9.2 Kbps
  - Wireless LAN 2 to 10 Mbps

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