Operating Systems II
Review on OS I

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Outline

1 Introduction + Quick Review on OS
   - The hardware
   - Computer systems architecture
   - OS Structure

2 Process Management
Abstract view of the components of a system
Setting up the place

Operating System (OS)
Intermediary between the user and the machine hardware

- User point of view => (ease of use)
- Hardware point of view => (resource allocation)

Definition
Operating System is everything that provides
- an environment for the programs to run
- resource management
Hardware

<table>
<thead>
<tr>
<th></th>
<th>CPU</th>
<th>Cache</th>
<th>Mem</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>sram</td>
<td>sram</td>
<td>dram</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2000:</th>
<th></th>
<th>1982:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1ns</td>
<td>1ns</td>
<td>200ns</td>
<td>200ns</td>
<td></td>
</tr>
<tr>
<td>3ns</td>
<td>3ns</td>
<td>200ns</td>
<td>200ns</td>
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<td>10ns</td>
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<tr>
<td>150ns</td>
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<tr>
<td>5 000 000ns</td>
<td></td>
<td>10 000 000ns</td>
<td></td>
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</tbody>
</table>
## Computer systems architecture

<table>
<thead>
<tr>
<th>Single CPU</th>
<th>Multi-CPU</th>
<th>Clusters</th>
</tr>
</thead>
</table>

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Why do we need parallel computers?

- **Speed**: We want to calculate e.g. simulations faster
- **Space**: We want to handle *larger amounts of data*

Parallel computers offer a cost effective solution, not bounded by the laws of physics
What’s more important than performance?

- Correctness
- Simplicity
- Maintainability
- Cost (programmer time)
- Stability, Robustness
- Features, Functionality
- Modularity (local changes rather than across the whole code)
- User-friendliness (HUGE growth in the 90's)
- Security (important since year 2k)
Why is it hard to program in parallel?

Or: Why are not more of the contemporary software and hardware parallel?

Two main problems:

1

2

our focus

There is no standard for parallel computer systems. A great spectra of architectures exists. It is “impossible” to construct general efficient parallel programs.
Structuring an Operating System

- Monolithic (MS-DOS, Original Unix)
- Layered (Unix)
- Microkernel (Mach)
- Modular (Solaris)
Not so much structure

Most functionality in the least space.

<table>
<thead>
<tr>
<th>Kernel interface to the hardware</th>
<th>System-call interface to the kernel</th>
<th>(the users)</th>
</tr>
</thead>
<tbody>
<tr>
<td>terminal controllers terminals</td>
<td>file system</td>
<td>shells and commands</td>
</tr>
<tr>
<td>device controllers disks and tapes</td>
<td>CPU scheduling page replacement demand paging virtual memory</td>
<td></td>
</tr>
<tr>
<td>memory controllers physical memory</td>
<td></td>
<td>compilers and interpreters system libraries</td>
</tr>
</tbody>
</table>

- terminal controllers
- terminals
- device controllers
- disks and tapes
- memory controllers
- physical memory
- Kernel
  - signals terminal handling
  - character I/O system
  - terminal drivers
Layered Approach
Microkernel

application environments and common services

kernel environment

BSD

Mach
Modular Approach

- device and bus drivers
- scheduling classes
- file systems
- loadable system calls
- executable formats
- STREAMS modules
- miscellaneous modules
Outline

1. Introduction + Quick Review on OS

2. Process Management
   - Definition
   - States
   - PCB & Queues
   - Transitions
   - Communication
   - Threads
   - Scheduling
Process Management

Resources (CPU time, memory, files, I/O) are either
- given at creation or
- allocated while running.

Definition (Process)

Unit of work in the system. For both user and system.

- Call sequence that executes independently of others. Maintains bookkeeping and control for this activity.

- Creating / Deleting / Suspending / Resuming
- Mechanism for process synchronization
- Mechanism for process communication
- Mechanism for deadlock handling (prevention, avoidance, reparation, ...)

OS Review
OS2’09 | OS2 (Review on OS I)
What characterizes a process?

- Program in execution
- Stack (Temporary data, function parameters,...)
- Heap
- Data section (Global variables)
- CPU Registers
- Program Counter (PC)

- Program code = Text section
- Program in execution = text section (executable file) loaded in memory
States

- **New**  The process is being created
- **Running**  Instructions are being executed
- **Waiting**  for some event to occur (I/O completion, signal...)
- **Ready**  Waiting to be assigned to a processor
- **Terminated**  Finished its execution
States

- new
- admitted
- ready
- running
- waiting
- I/O or event completion
- scheduler dispatch
- I/O or event wait
- terminated
- interrupt
- exit
### & Queues

#### Job Queue
- Linked list of PCBs
  - (main) job queue
  - ready queue
  - device queues

####Schedulers
- (loads from disk)
- (dispatches from ready queue)
Who is in control?

- To increase CPU utilization:
  - Job pool (in memory)
  - Interaction
  - The OS provides each user with a slice of CPU and main memory resources.

- (hardware error detection)
  - Generated asynchronously by external devices and timers
  - Example: The I/O is complete or timers have expired

- (software errors, illegal instructions)

- (interface to ask the OS to perform privileged tasks)
What happens at a transition?

- process \( P_0 \)
- operating system
- process \( P_1 \)

**Interrupt or system call**
- save state into \( PCB_0 \)
- ...
- reload state from \( PCB_1 \)

**Idle**
- executing

**Executing**
- interrupt or system call
- save state into \( PCB_1 \)
- ...
- reload state from \( PCB_0 \)

**Idle**
- executing
Interprocess Communication (IPC)

2 models

- Message Passing
- Shared Memory

Benefits

- Small amount to exchange
  => Message Passing, because no conflict to avoid
- Shared Memory
  => Working at the speed of memory – faster
Recall that the OS prevents processes to share memory
⇒ Agreement on relaxing restriction

Example (Producer-Consumer)

Unbounded buffer and bounded buffer
Shared Memory

Requires:
- Synchronisation
  (No consumption of unproduced items)
- Waiting
Message Passing

No shared space.
Can be distributed across network

Example
Chat program

- send(m)
- receive(m)

Requires a communication link
- direct or indirect (mailbox/ports)
- synch. or async. (blocking or non-blocking)
- automatic or explicit buffering (info on the link)
From process flaws

Heavy-weight vs Light-weight...

Example (Web server)

We want to serve more than one client at a time

- 1 process. If incoming request, new process created => costly!
- 1 process. If same task as other one, why overhead? ⇒ better to multithread

On Solaris:

- Time for creating a process = 30 × time for creating a thread
- Time for context switching = 5 × time for switching a thread
Threads

single-threaded process

multithreaded process
Benefits

- Resource sharing
- Economy
- Utilization of multiprocessor architectures
Recall – Abstract view

System and Application Programs

Operating System

Computer Hardware

Compiler  Assembler  Text Editor  ...  Database System

User_1  User_2  User_3  ...  User_n
User vs Kernel Mode: Hardware protection

```c
#include <stdio.h>
int main ()
{
    ...
    printf ("Greetings");
    ...
    return 0;
}
```

- User mode
- Kernel mode
- Standard C library
- `write()` system call
Multithread Models

Deals with correspondence between

- threads in
- threads in

One to One  Many to One  Many to Many
Important note

Note that...
On Operating Systems which support threads, it is kernel-level threads – not processes – that are being scheduled.

However, process scheduling ≈ thread scheduling.
CPU and IO Bursts

: load, store, add, store, read from file
  Wait for IO
store, increment, branch, write to file
  Wait for IO
load, store, read from file
  Wait for IO
:

Intervals with no I/O usage

Waiting time
Sum of time waiting in queue
How do we select the next process?

- CPU as busy as possible
- Number of processes that are completed per time unit
- Time between submission and completion
- Scheduling affects only waiting time
- Time between submission and first response
Algorithms

- **FCFS**: Non-preemptive, Treats ready queue as FIFO.
  - Problem: Convoy effect...
- **SJF**: Shortest next cpu burst first
  - Problem: Difficult to know the length of the next CPU burst of each process in Ready Queue.
  - Solution: Guess/predict based on earlier bursts.
- **SJF with Preemption**: When a process arrives to RQ, sort it in and select the SJF including the running process, possibly interrupting it.
- **Priority Scheduling**: Can be preemptive or not
  - Problem: Starvation (or Indefinite Blocking)
  - Solution: Aging
- **Round-Robin**: FCFS with Preemption. Ready Queue treated as circular queue
  - Problem: Quantum $\gg$ Context-switch
- **Multi-Level Feedback Queue**