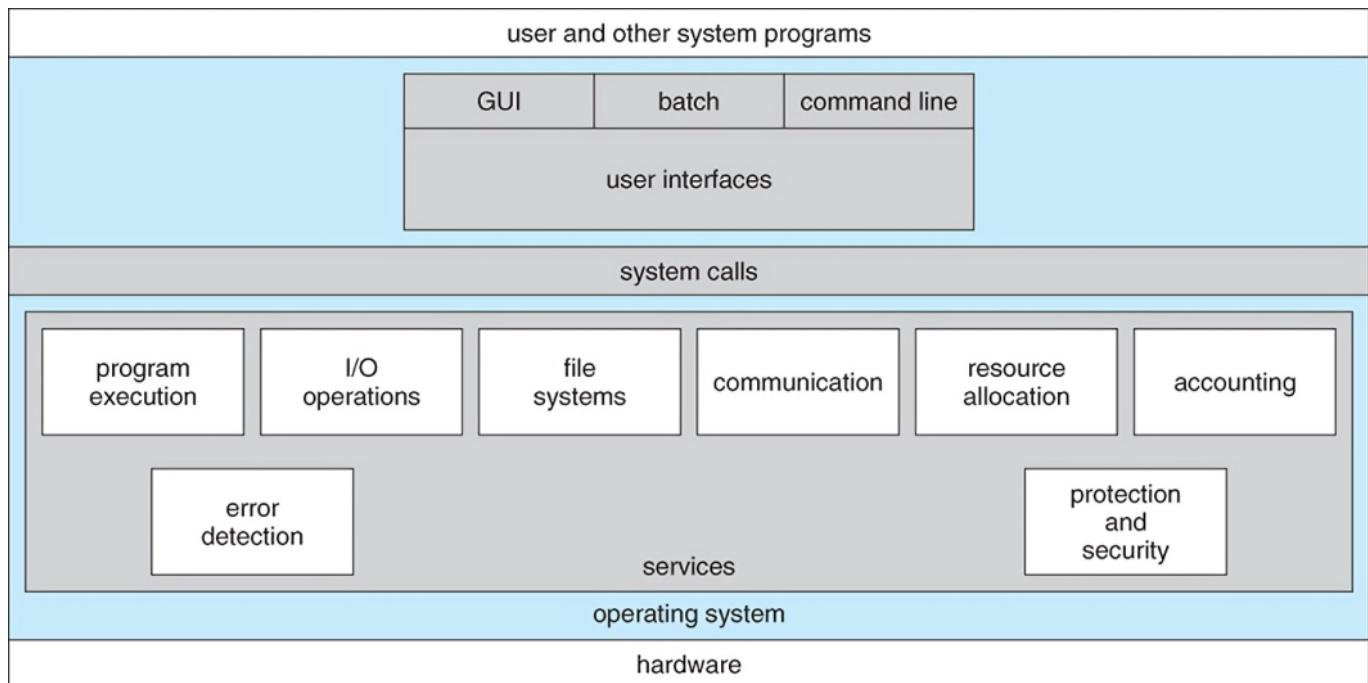


# CH1 OS system types

- OS
  - 沒有一個很明確通用的正式定義
  - 最接近的說法: "Everything a vendor ships when you order an operating system"
  - Kernel definition: "The one program running at all times on the computer" is the kernel, part of the operating system
  - everything else is either a **system program** or an **application program**
    - system program: ships with the operation system, but not part of the kernel
    - application program: all programs not associated with the operation system
- os
  - os user interface
    - user interface to 人
      - Command line->[MS-DOS,UNIX,Linus](#)
      - GUI->[Mac OS,windows](#)
      - Touch screen->[ios,Android](#)
    - system call to applications
  - kernel

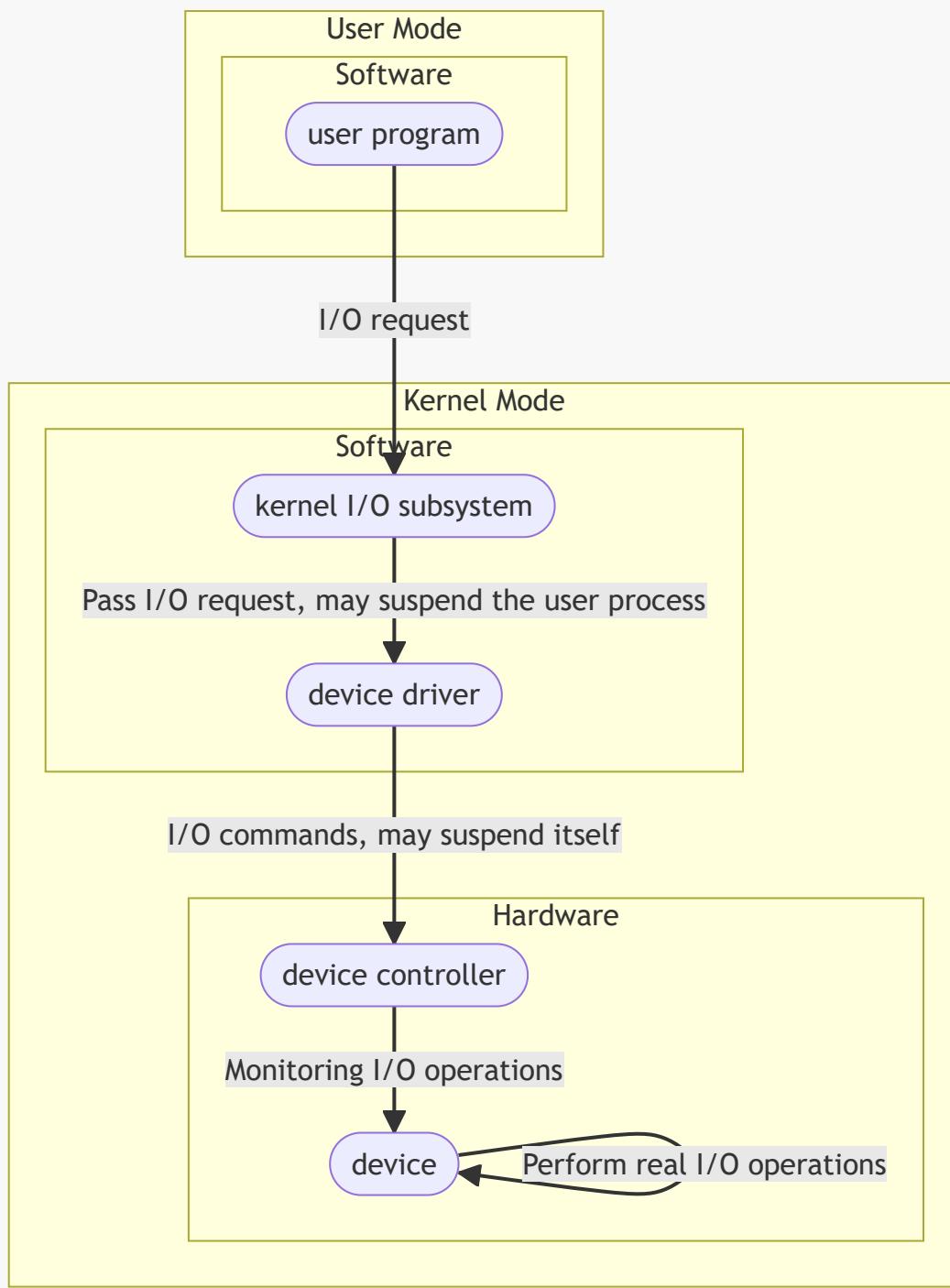


- what os roles
  - 使用者關心的是方便使用電腦以及好的使用效能
    - users want convenience, ease of use and good performance
  - os是一個資源分配的管理者,希望他能有效運用硬體資源
    - os is a resource allocator making efficient use of HW
  - os也負責指揮控制監督程式的執行,確保安全,防止意外或者故意的操作所造成的系統重大危害

- control program for managing execution of user programs for protection and security purpose
- 提供一個讓user program容易執行的環境
  - provides many system calls to be used by the user process. such as I/O operation, process control and IPC,etc
- system types
  - Multiprogramming
  - Time-sharing(Multitasking)
    - virtual memory
    - spooling technique
  - Multiprocessor(Tightly-Coupled system)
    - Benefits
      - Increased throughput
      - Economy of scale
      - Increased reliability
    - ASMP(Asymmetric Multiprocessing)
      - Master-Slave architecture
    - SMP(Symmetric Multiprocessing)
  - Distributed system(Loosely-Coupled system)
    - Client-server model
    - peer-to-peer model
  - Real-time system
    - Hard real-time system
    - Soft real-time system
  - Mobile computing
  - Batch system

## CH2 I/O operations, Hardware resource protection

---



- I/O operators
  - Polling I/O
    - **byte-transfer**
  - Interrupted I/O
    - sense interrupt-request line **before** Instruction Fetch
    - device controller raises an interrupt by asserting a signal on the interrupt-request line
  - DMA(Direct Memory Access)
    - **block-transfer**
  - Nonblocking and Asynchronous I/O
    - Blocking=Synchronous
      - process suspended until I/O complete

- Synchronous
- Nonblocking
  - I/O call returns as much as available
  - returns quickly with count of bytes read or written
- Asynchronous
  - process runs while I/O executes
  - I/O subsystem signals process when I/O complete
- Hardware Resource Protection
  - infrastructure
    - Dual mode operation
      - user mode
      - kernel mode
    - Privileged Instruction
      - executed only in kernel mode
        - e.g. the instr. to switch to kernel mode, I/O instr., disable interrupts, clear memory, modify the base/limit registers, modify the value of timer for cpu
  - Hardware Resource Protection
    - I/O protection
      - purpose: 防止user process誤用I/O devices, 降低使用I/O devices複雜度
      - mechanism: all I/O instr. are set as "privileged instr.", so they can be executed only in kernel mode
    - Memory protection
      - purpose: 防止user process非法存取其他process or kernel memory area
      - mechanism: modify the base/limit registers must be privileged instruction
    - CPU protection
      - purpose: we must ensure that the os maintains control over the CPU. We can't allow a user program to get stuck in an infinite loop or to fail to call system services and never return control to the os
      - mechanism: modify the value of timer for cpu must be privileged instruction

## CH3 System call, OS structures, Virtualization

---

- system call
  - parameters passing of system call
    - registers
    - memory
    - stack
- mechanism
  - how
  - use time to be cpu protection
- policy

- what
- determin MAX cpu time quantum
- Monolithic kernel
  - Linux
  - UNIX
  - Solaris
  - Windows
- Microkernel
  - Mach
- Modules(loadable kernel modules(LKMs))
  - Linux
  - Solaris(先鋒)
  - UNIX
  - MacOS
  - Windows
- Hybrid system
  - Linux
  - Solaris
  - Windows
  - MacOS
  - iOS
  - Android
- Virtual Machine
  - Host
  - Vitual Machine Manager(VMM)
  - Guest
  - different types
    - type 2 use mode
    - type 1 OS(kernel mode)
    - type 0 HardWare
  - implementation of VMMS
    - Pure VM
    - Paravirtualization
    - Programming-environment virtualization
      - Java Virtual Machine(JVM)
    - Emulators
    - Application containment
      - container
  - Cloud Computing
    - Software as a Service(SaaS)

- office365, salesforce, gmail, google drive, dropbox,...
- Platform as a Service(PaaS)
  - 金流API, 物流API, 地圖API,...
- Infrastructure as a Service(IaaS)
  - AWS, Azure,...

## CH4 Process Management, Thread Management

---

### Process

#### process state diagram

- New
- Ready
- Running
- Waiting
- Terminal

### PCB

1.Process state 2.Program counter 3.CPU registers 4.CPU-scheduling information 5.Memory-management information 6.Accounting information 7.I/O status information (8.Process ID)

### scheduler 之種類

- Long-Term scheduler
  - Batch system採用
  - Real-time system, Time-sharing system不採用
- Medium-Term scheduler
- Short-Term scheduler

### scheduling criteria

- CPU utilization
- Throughput
- Turnaround time
- Waiting time
- Response time

### CPU Scheduling Algorithm

- **FCFS**
- SJF
  - Non-preemptive SJF->**SJF**
  - Preemptive SJF->**SRJF**
- **RR**
- **priority**
  - aging

- **multilevel queues**
- **multilevel feedback queues**

## Multiple-Processor scheduling

- ASMP(沒什麼好設計的)
- SMP
  - load balancing
    - push migration
    - pull migration
  - processor affinity
    - soft affinity
    - hard affinity

## Real-Time system scheduling

若有Priority Inversion,用Priority Inheritance解決

- Hard real-time(preemptive kernel)
  - Rate-Monotonic scheduling
  - EDF scheduling
- Soft real-time(preemptive kernel)
  - 不提供aging

## Threads

- private
  - program counter
  - CPU registers set
  - stack
  - local variables
  - thread ID
- shared
  - code section
  - data section(global data)
  - heap
  - static local variables
  - other OS resources(open files, signals, I/O resources,etc.)
- Benefits
  - **responsiveness**
  - **resource sharing**
  - **economy**
  - **scalability**(utilization of multiprocessors architecture)
- Thread management

- user thread
  - provide a library entirely in user space with no kernel support
  - implement a kernel-level library supported directly by the OS
- kernel thread
- multithreading models
  - Many-to-One model
  - One-to-One model
  - Many-to-Many model
- 2 strategies of creating multiple threads
  - Asynchronous threading(父,兒之thread concurrently execute)
  - Synchronous threading(父thread要等兒thread做完)
- Pthreads library
  - Pthreads is a specification
  - Run on UNIX
  - Can't run on windows os

## CH5 Deadlock Management

---

- necessary conditions
  - **mutual exclusion**
  - **hold and wait**
  - **no preemption**
  - **circular wait**
- resource-allocation graph
  - no cycle, no deadlock
  - 有cycle不一定有deadlock
    - if every resource only has exactly one instance, 有cycle就有deadlock
- methods for handling deadlocks
  - **deadlock prevent**
    - 破除mutual exclusion條件(辦不到)
    - 破除hold and wait條件
    - 破除no preemption條件
    - 破除circular wait條件: resource ordering
  - **deadlock avoidance**
    - banker's algorithm( $O(n^2m)$ , n: process, m: resource)
    - if system consisting of **m** resources of the same type with **n** processes running in the system
      - $1 \leq MAX_i \leq m$
      - $\sum_{i=1}^n MAX_i < n + m$

- **deadlock detection and recovery**
  - detect it, and recover(允許系統進入deadlock)
  - detection algorithm( $O(n^2m)$ ,n: process,m: resource)
- **ignore deadlock**
- Recovery from deadlock
  - process and thread termination
    - abort all deadlocked processes
    - abort one process at a time until the deadlock cycle is eliminated(盲目地砍一個)
  - resource preemption

## CH6 Process Synchronization, IPC(InterProcess Communication)

---

- synchronization: process因某些事情之發生 or 不發生,而被迫停頓,要等其他process do something 之後,才可往下進行.
  - Producer-Consumer problem
  - Readers/Writers problem
    - First variation
    - Second variation
  - The Sleeping barber problem
  - The dinning philosophers problem
- 執行中程式可有兩種型態:
  - independent processes
    - 我的結果不會影響你,你的結果不會影響我
  - cooperation processes
    - 有某種程度的資訊交換
    - 允許process cooperation之理由
      - information sharing
      - computation speedup
      - modularity
- 2 fundamental models of IPC
  - **Shared Memory**
  - **Message Passing**

## Shared Memory

- Race Condition problem
  - several processes access and manipulate the same data concurrently and the outcome of the execution depends on the particular order in which the access takes place.
  - resolve race condition problem 2 strategy

- **disable interrupt**

- **critical section design**

- 每個process內, access shared data之程式碼片段稱為critical section
- c.s.須滿足3性質
  - mutual exclusion
  - progress
  - bounded waiting
- critical section是要設計Entry section以及Exit section

```
while(true){  
    Entry section;  
    C.S.  
    Exit sectin;  
    R.S.  
}
```

- 程式語言level
  - monitor
- OS SW tools(sys. call)level
  - mutex lock, semaphore
- 基礎
  - C.S. design
    - SW solution
      - peterson solution
    - HW support
      - memory barriers
      - test&set(&lock)
      - compare&set(&lock,0,1)
  - 非C.S. design
    - disable interrupt

- **peterson solution**

<pre>Pi while(true){     flag[i]=true; /*表明有意*/     turn=j; /*禮讓對方*/     while(flag[j] &amp;&amp; turn==j);     /*當對方有意且權杖在對方身上,則我等 */     C.S.     flag[i]=false; /*手放下*/     R.S. }</pre>	<pre>Pj while(true){     flag[j]=true; /*表明有意*/     turn=i; /*禮讓對方*/     while(flag[i] &amp;&amp; turn==i);     /*當對方有意且權杖在對方身上,則我等 */     C.S.     flag[j]=false; /*手放下*/     R.S. }</pre>
---	---

- **memory barriers**

```

Pi
while(true){
    turn=j; /*禮讓對方*/
    memory_barrier();
    flag[i]=true; /*表明有意*/
    C.S.
    flag[i]=false; /*手放下*/
    R.S.
}

```

- **test&set(&lock),compare&set(&lock,0,1)**

- 是CPU特殊指令

```

boolean test_and_set(boolean *target){
    boolean ret=*target;
    *target=false;
    return ret;
}

```

```

int CAS(int *value, int expected, int new_value){
    int temp=*value;
    if(*value==expected)
        *value=new_value;
    return temp;
}

```

- test&set,CAS用於critical section problem

```

while(true){
    waiting[i]=true;
    key=true;
    while(waiting[i] && key)
        key=test_and_set(&lock); or key=CAS(&lock,0,1); //決一死戰,誰先搶到,誰
先win
    waiting[i]=false;//Pi不用等了,可進入C.S.
    C.S.
    j=(i+1)%n;
    while(j!=i && !waiting[j])//找出下一個想進入C.S.之process
        j=(j+1)%n;
    if(j==i)//此時無人想進入C.S.
        lock=false;//鑰匙掛高空,等人去搶
    else//Pj像進入C.S.
        waiting[j]=false;//Pj不用等了,可進入C.S.,此時lock為true
    R.S.
}

```

- mutex lock

```
while(true){  
    acquire lock;  
    C.S.  
    release lock;  
    R.S.  
}
```

- a mutex lock透過boolean variable: available, 用以指示the lock is available or not.
- 提供兩個atomic operations:
  - acquire()

```
acquire(){  
    while(!available); //if lock被取走就卡  
    available=false; //lock被Pi取走  
}
```

- release()

```
release(){  
    available=true;  
}
```

- 利用cpu硬體指令完成mutex lock

```
typedef struct{  
    int available; //0->lock is available, 1->lock is unavailable  
}lock;  
  
lock mutex;  
//使用CAS製作acquire  
void acquire(lock *mutex){  
    while(CAS(&mutex->available, 0, 1)!=0);  
    return;  
}  
//使用test_and_set製作acquire  
void acquire(lock *mutex){  
    while(test_and_set(&mutex->available)!=0);  
    return;  
}  
void release(lock *mutex){  
    mutex->available=0;
```

```
    return;  
}
```

- **semaphore**

- semaphore is a data type based on int
- semaphore只能透過兩個atomic operation來存取
  - wait() or P()

```
wait(s){  
    while(s<=0);  
    s--;  
}
```

- signal() or V()

```
signal(s){  
    s++;  
}
```

- 用於C.S. design

```
semaphore mutex=1;  
Pi  
wait(mutex);  
C.S.  
signale(mutex);  
R.S.
```

- **monitor**

- a monitor type is a ADT(Abstract Data Type),想像成class,包含三部分
  - 共享變數宣告
  - a set of programmer-defined operations
  - 初始區
- monitor本身已保證了互斥性質
  - the monitor construct ensures that only **one** process at a time is **active** within the monitor
    - 如此保證了monitor內的shared variables不會發生race condition problem
    - 代表programmer無需煩惱race condition problem,只需專心解決synchronization
- condition變數
  - 為了讓programmer可以用monitor解決synchronization problem,需提供一種特殊形態變數,即condition type variables

- 宣告格式:

```
condition x,y;
```

- 此變數只有兩種operation提供呼叫:

- x.wait()
  - 類似block() sys. call
- x.signal()
  - 類似wakeup() sys. call
  - default is FIFO Queue

## liveness (是一個好性質,但沒考過)

- system 必須滿足確保processes make progress during their execution life cycle

## Message Passing IPC

- 無須共享相同的位址空間,在分散式系統中特別有用.
- 兩個processes要溝通,步驟如下:
  - 建立communication link
  - messages 相互傳輸
  - 傳輸完畢, release communication link
- OS提供至少兩種system calls
  - send(message)
  - receive(message)
- messages sent by a process can be either **fixed** or **variable** in size.
- message passing
  - direct communication
    - symmetric
      - 收送雙方皆須相互指名對方process ID才能建立通訊鏈結
      - send(Q, message)
      - receive(P, message)
    - asymmetric(跟e-mail很像)
      - 只有sender需指名recipient的process ID
      - send(Q, message)
      - receive(id, message)
  - indirect communication
    - 收送雙方是透過共享的mailbox來溝通, each mailbox有自己獨一無二的ID
    - send(mailbox, message)
    - receive(mailbox, message)

- synchronization
  - message passing 可以是blocking(synchronous) or nonblocking(asynchronous)
    - Blocking send
    - Nonblocking send
    - Blocking receive
    - Nonblocking receive
  - 如果收送雙方皆是採用Blocking\_send()即blocking\_receive(), 則此同步模式叫:rendezvous
- Buffering(message queue's size)
  - zero capacity
    - also called rendezvous
  - bounded capacity
  - unbounded capacity
    - the sender doesn't have to be blocked

## CH7 Main Memory

---

### Binding Time

- compile time
- loading time
- execution time

### Memory Management methods in OS

#### • **Contiguous Memory Allocation**

- external fragmentation
  - First Fit
  - Best Fit
  - Worst Fit

#### • **Page**

- internal fragmentation
- page table
  - hierarchical paging
  - hashed page table
  - inverted page table

#### • **Segment**

- external fragmentation
- Base and Limit

#### • Paged Segment

## CH8 Virtual Memory

---

- 實現Virtual Memory 技術: Demand Paging -pure demand paging -prepaging

## Page Replacement Algorithm(沒有最差，只有最佳)

- **FIFO**(belady's anomaly)
- **OPT**(stack property)
- **LRU**(stack property)
- LRU-approximation(stack property)
  - **Additional reference bits usage**
  - **Second chance**
  - **Enhanced second chance**
- **LFU**(belady's anomaly)
- **MFU**(belady's anomaly)
- **Thrashing**
  - CPU utilization down
  - Paging I/O devices 異常忙碌
  - processes spends more time on paging I/O than normal execution
    - technique to handle Thrashing
      - **decrease multiprogramming degree**(已經thrashing)
      - **page fault frequency control**
      - **working set model**
- Allocation Kernel Memory
  - Buddy system
  - Slab allocation(has no internal, external fragmentation)

## CH9 Massive Storage System

---

### Hard Disk

- cylinder
- tracks
- sectors(磁碟控制器控制read, write之基本單位)
- Disk Access Time
  - Seek Time
  - Rotational latency
  - Transfer Time

### Free-Space Management

- Bit vector
- Linked List
  - Grouping

- Counting

## File Allocation Methods

- Contiguous Allocation
- Linked Allocation
  - 變形: FAT
- Indexed Allocation
  - Linked scheme
  - Multilevel index
  - Combined scheme(UNIX i-Node structure)

## HDD scheduling(沒有最好與最差之法則)

- **FCFS**
- **SSTF**
- **SCAN**
  - elevator
- **C-SCAN**
- **LOOK**
  - elevator
- **C-LOOK**

## RAID

- improvement of reliability via redundancy
  - mirror
  - parity check
- improvement in performance via parallelism
  - data striping
    - bits-level
    - block-level
- RAID0(N部)
  - block-level striping
- RAID1(mirror)(N/2部)
- RAID2(ECC-Error-Correcting Code)
  - 沒有實際產品
- RAID3(ECC-Error-Correcting Code)(N+1部)
  - bit-level striping
  - parity check
- RAID4(ECC-Error-Correcting Code)(N+1部)

- block-level striping
- parity check
- RAID5(ECC-Error-Correcting Code)(N+1部)
- RAID6(ECC-Error-Correcting Code)(N+2部)
- RAID1+RAID0(更好)
- RAID0+RAID1

## File Directory Structure

- Tree-structured Directory
- Acyclic Graph Directory
- General Graph Directory(允許有cycle)

## File Access Control

- Owner, Group, Other
- RWX(Read, Write, eXecute)
- command: `chmod 755 file`

## Consistency Semantic

- UNIX semantic
  - 訂票系統
- Session semantic
  - 網站上的檔案提供下載讓user填寫
- Immutable-Shared-Files semantic
  - 總經理公告文件第3009號

## NAS(Network-Attached Storage)

- File-based operation
- 會占用網路頻寬

## SAN(Storage-Area Network)

- Block-based operation
- private network
- 不佔用一般網路頻寬