Operating System Principles

操作系统原理

Memory Management

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Objectives

- No Memory Abstraction
- Basic Memory Management
- ~~*Virtual Memory Management*~~

Parkinson's law

Programs expand to fill the memory available to hold them!

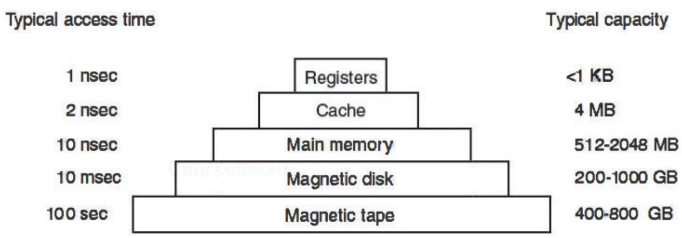
Memory Management

- Memory is an important resource that must be carefully managed

While the average home computer nowadays has a thousand times as much memory as the IBM 7094, the largest computer in the world in the early 1960's

- Memory hierarchy
  - *Volatile* cache memory
    - a small amount,very fast,expensive
  - Volatile main memory(RAM)
    - tens of megabytes, medium-speed, medium-price
  - Nonvolatile disk storage
    - tens or hundreds of gigabytes, slow, cheap

Memory Hierarchy



Memory Management

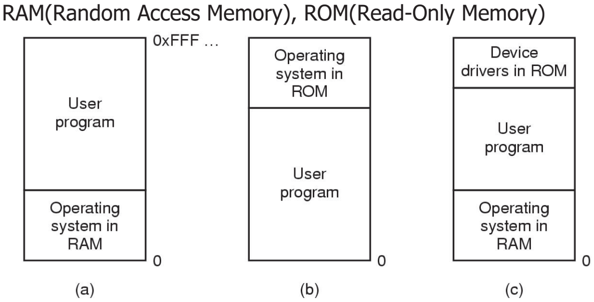
- 1. extend main memory
- 2. control data transmission between main memory and storage
- 3. main memory allocation and revoke
- 4. main memory share and protection

No Memory Abstraction

No Memory Abstraction

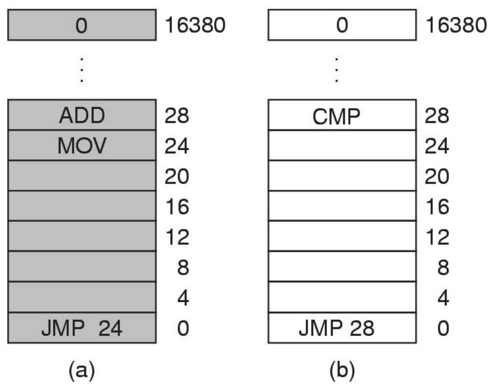
- early mainframe computers (<1960)
- early minicomputers (<1970)
- early personal computers (<1980)

RAM(Random Access Memory), ROM(Read-Only Memory)



Three simple ways of organizing memory with an operating system and one user process.

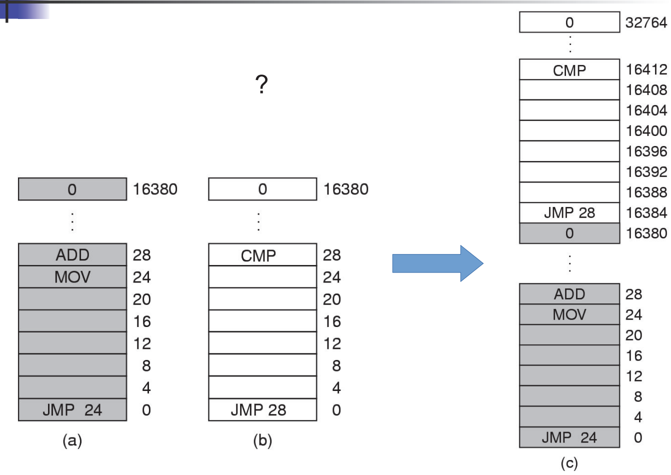
Issues of No Memory Abstraction



Two Processes

Issues of No Memory Abstraction

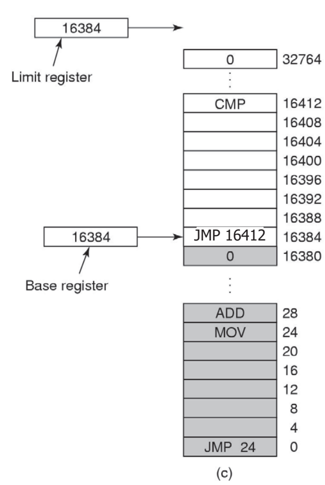
?



Issues of No Memory Abstraction

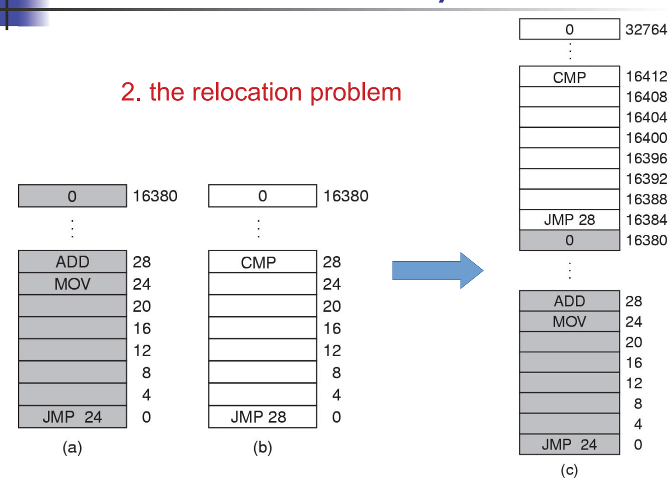
1.separate address space

Base register
Limit register



Issues of No Memory Abstraction

2. the relocation problem



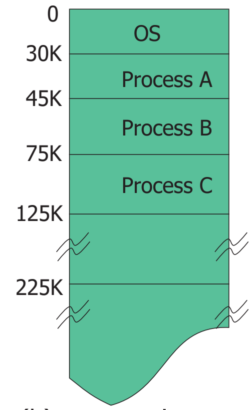
Basic Memory Management
- contiguous 连续 allocation

Multi-programming with Fixed Partitions

- Partition
  - Fixed, size

ID	Size (KB)	Start Addr (K)	State
1	15	30	used
2	30	45	used
3	50	75	used
4	100	125	available

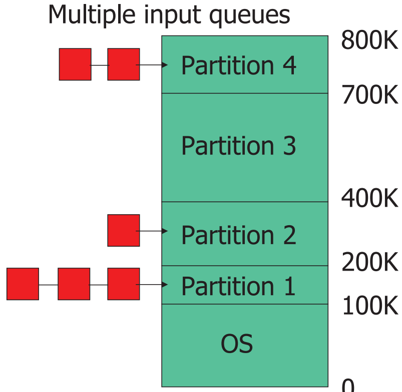
(a) partition desc table



(b) memory layout

Multi-programming with Fixed Partitions

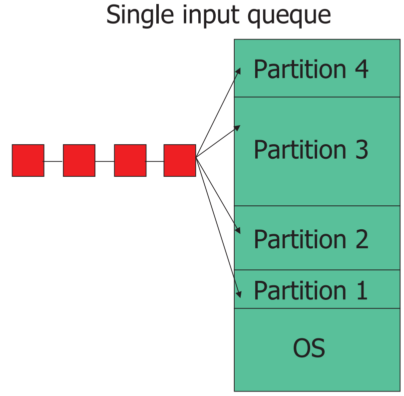
Multiple input queues



(a)

Multi-programming with Fixed Partitions

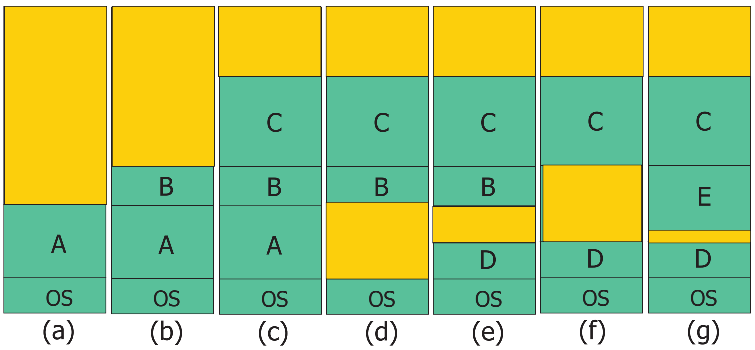
Single input queque



(b)

Multi-programming with Variable Partitions

- Allocate a contiguous partition dynamically



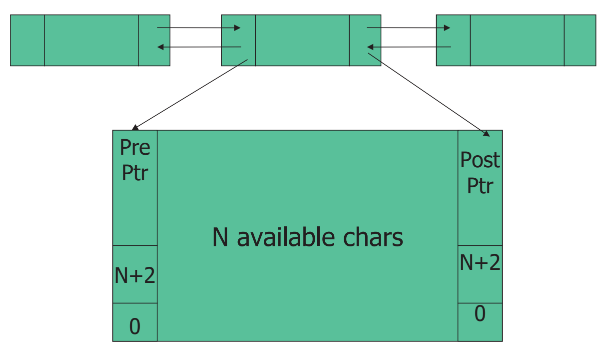
Multi-programming with Variable Partitions

- Structure
- Algorithm
- Allocating and Revoking Procedures

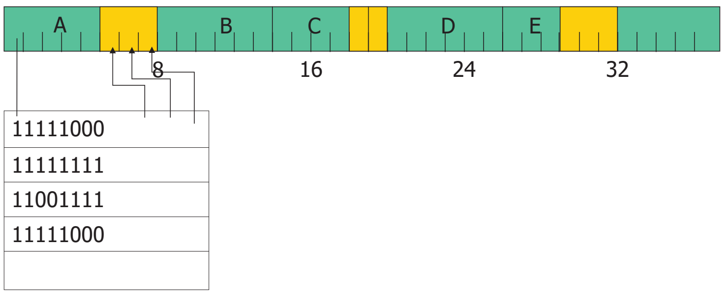
Variable Partitions: Partition Array Table

ID	Size (KB)	Start Addr (K)	state
1	64	44	available
2	24	132	available
3	40	210	used
4	30	270	available
5	…	…	…

Variable Partitions: Inline Linked Structure

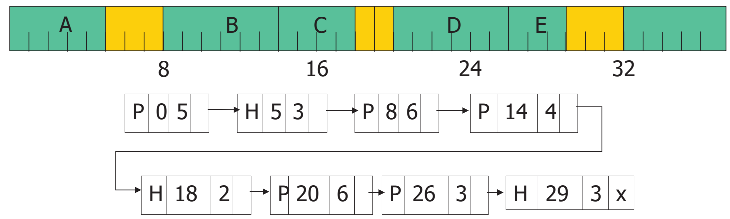


Variable Partitions: Bitmap 位图



Variable Partitions: Linked List

P: Process
H: Free space



Algorithms of Variable Partitions

- First Fit: FF
- Next FF
- Best Fit: BF
  - 最佳适应算法
  - external fragmentation
    - 碎片
- Worst Fit: WF

Algorithms of Variable Partitions

- Quick Fit
  - Multi-queues for 4KB, 8KB,16KB free contiguous space
  - Advantages
  - Disadvantage
    - Overhead of merging free partitions

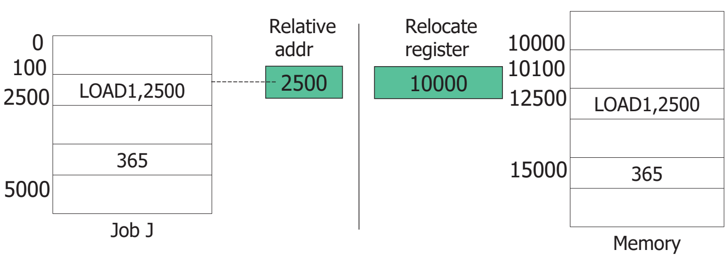
Algorithms of Variable Partitions

- Buddy memory allocation
  - 伙伴式的内存管理
  - 1963,Harry Markowitz,who won the 1990 Nobel Memorial Prize in Economics
  - each block is subdivided into two smaller blocks
  - 2^i
  - internal fragmentation

Case: buddy memory allocation

Step	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K
1	2^4															
2.1	2^3								2^3							
2.2	2^2				2^2				2^3							
2.3	2^1		2^1		2^2				2^3							
2.4	2^0	2^0	2^1		2^2				2^3							
2.5	A: 2^0	2^0	2^1		2^2				2^3							
3	A: 2^0	2^0	B: 2^1		2^2				2^3							
4	A: 2^0	C: 2^0	B: 2^1		2^2				2^3							
5.1	A: 2^0	C: 2^0	B: 2^1		2^1		2^1		2^3							
5.2	A: 2^0	C: 2^0	B: 2^1		D: 2^1		2^1		2^3							
6	A: 2^0	C: 2^0	2^1		D: 2^1		2^1		2^3							
7.1	A: 2^0	C: 2^0	2^1		2^1		2^1		2^3							
7.2	A: 2^0	C: 2^0	2^1		2^2				2^3							
8	2^0	C: 2^0	2^1		2^2				2^3							
9.1	2^0	2^0	2^1		2^2				2^3							
9.2	2^1		2^1		2^2				2^3							
9.3	2^2				2^2				2^3							
9.4	2^3								2^3							
9.5	2^4															

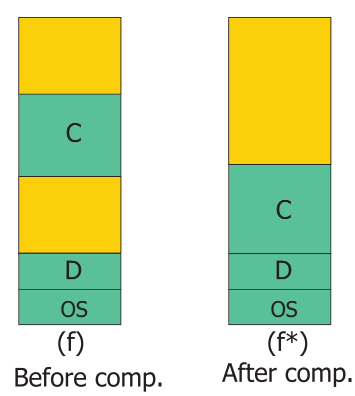
Dynamical Relocation



Memory Compaction

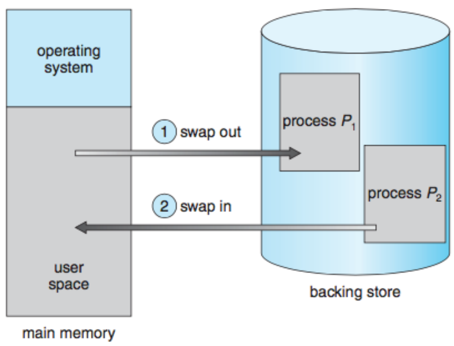
- 紧凑

?fragmentation



Swapping 交换

- bring in each process in its entirety, running it for a while, then putting it back on the disk

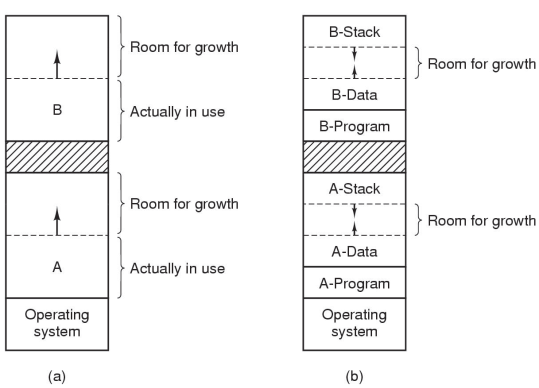


Overlay 覆盖

- Replacement of a block of stored instructions or data with another
- a way to describe sections which are to be loaded as part of a single memory image but are to be run at the same memory address

```
OVERLAY [start] : [NOCROSSREFS] [AT ( ldaddr )]
  {
    secname1
      {
        output-section-command
        output-section-command
        ...
      } [:phdr...] [=fill]
    secname2
      {
        output-section-command
        output-section-command
        ...
      } [:phdr...] [=fill]
    ...
  } [>region] [:phdr...] [=fill] [,]
```


Issues of Variable Partitions



(a) Allocating space for growing data segment.

(b) Allocating space for growing stack, growing data segment.

Basic Memory Management - discrete allocation

Discrete Memory Allocation

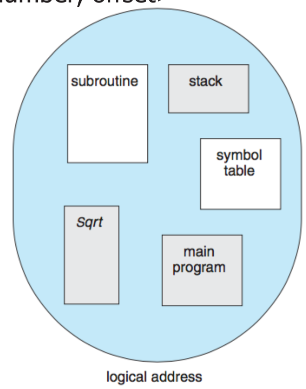
- Segmentation
  - 分段
- Paging
  - 分页

Segmentation 分段

two tuple:<segment-number, offset>

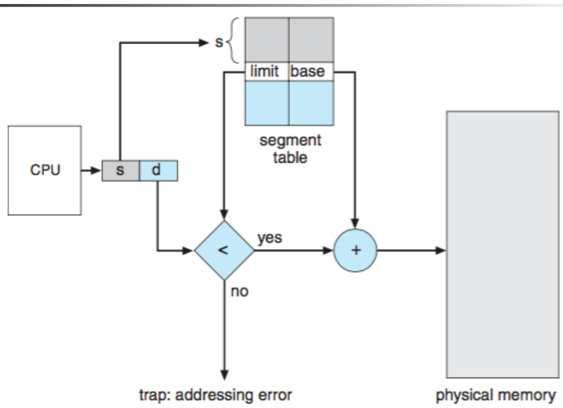
- Logical Segmentation
  - 1. The code
  - 2. Global variables
  - 3. The heap, from which memory is allocated
  - 4. The stacks used by each thread
  - 5. The standard C library

?fragmentation



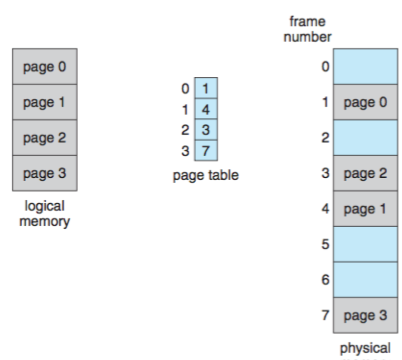
Programmer's view of a program

Segmentation



Segmentation hardware

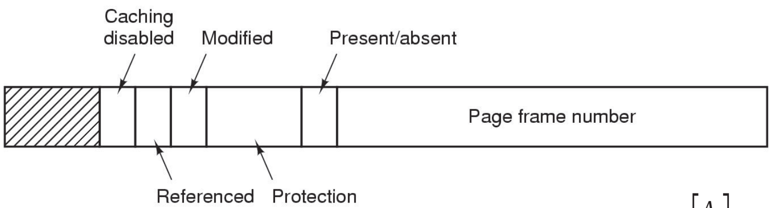
Paging 分页



- Page
- Frame
- Page Table

Paging model of logical and physical memory

Paging: page table



Address= (Page number, offset)

One Tuple

?fragmentation

$$PageNum = INT\left[\frac{A}{L}\right]$$

$$offset = [A]\, MOD\ L$$

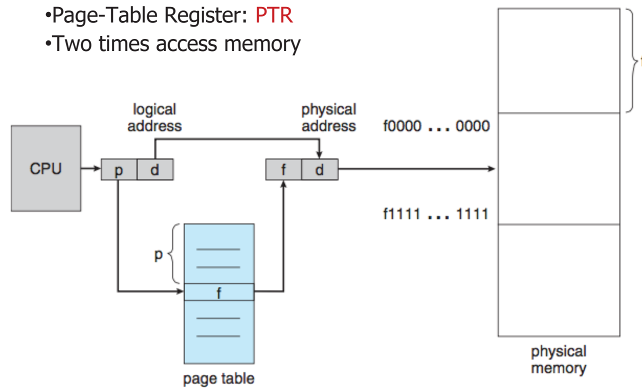
A:Logical Address

L:Page Size

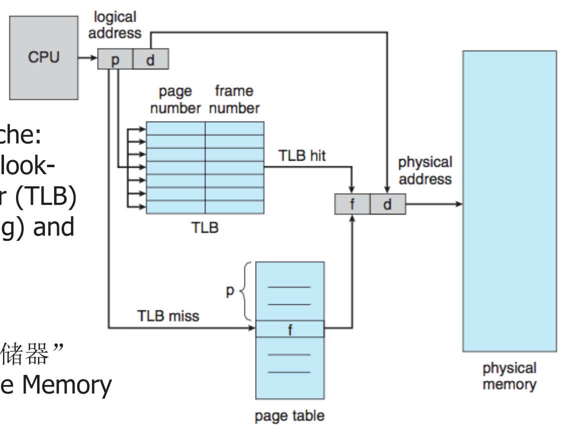
Paging: hardware

•Page-Table Register: PTR

•Two times access memory



Paging: hardware with TLB



hardware cache:

- translation look-aside buffer (TLB)
  - key (or tag) and value

- 快表 *,
- “ 联想存储器”
  Associative Memory

快表

- 在操作系统中，为了提高系统的存取速度，在地址映射机制中增加一个小容量的联想寄存器，即快表，用来存放当前访问最频繁的少数活动页面的页号。
  - 当某用户需要存取数据时，根据数据所在的逻辑页号在快表中找到其对应的内存块号，再联系页内地址，形成物理地址。如果在快表中没有相应的逻辑页号，则地址映射仍可以通过内存中的页表进行，得到空闲块号后须将该块号填入快表的空闲区中。如果快表中没有空闲块，则根据淘汰算法淘汰某一行，再填入新的页号和块号。
  - 快表查找内存块的物理地址消耗的时间大大降低了，使得系统效率得到了极大的提高。

CPU 中的缓存

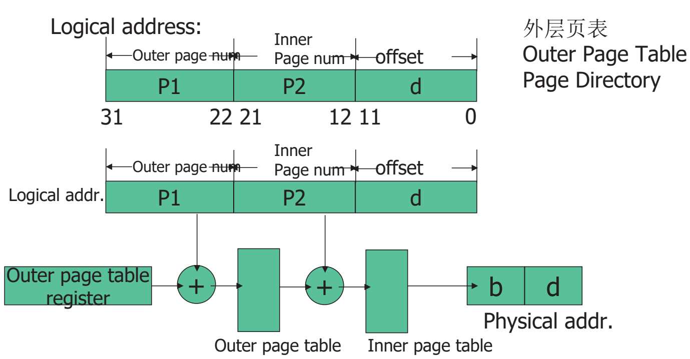
- 典型案例是高速缓冲存储器 Cache
- 随着计算机硬件的发展， CPU 的执行速度越来越快，系统架构越来越先进，而主存的结构和存取速度改进则较慢，因此高速缓存技术将越来越重要。
- 高速缓冲存储器 Cache 是位于 CPU 与内存之间的临时存储器，它的容量比内存小但交换速度快。在 Cache 中的数据是内存中的一小部分，但这一小部分是短时间内 CPU 即将访问的。当 CPU 调用大量数据时，就可避开内存直接从 Cache 中调用，从而加快读取速度。

Paging: hardware with TLB

Valid	Virtual page	Modified	Protection	Page frame
1	140	1	RW	31
1	20	0	R X	38
1	130	1	RW	29
1	129	1	RW	62
1	19	0	R X	50
1	21	0	R X	45
1	860	1	RW	14
1	861	1	RW	75

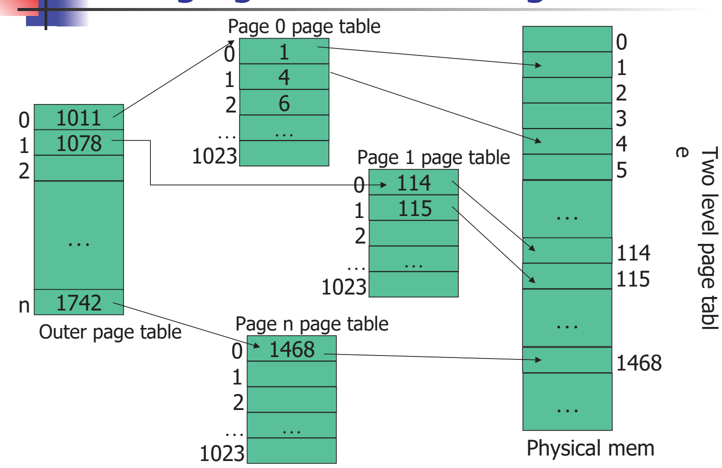
A TLB to speed up paging

Paging: Muti-level Page Table



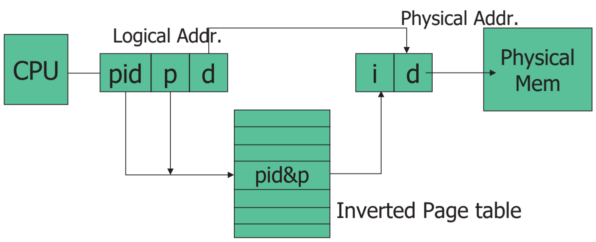
Two level page table

Paging: Muti-level Page Table

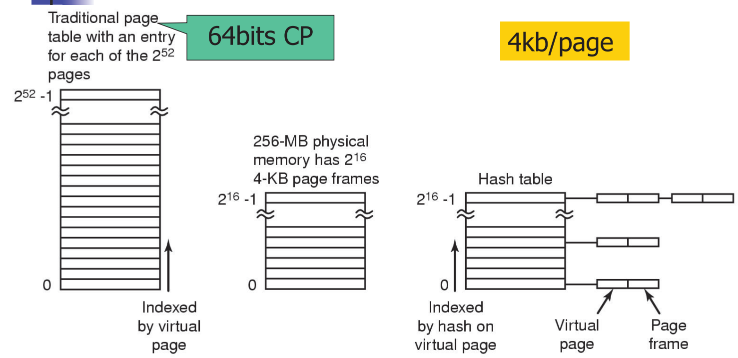


Inverted Page Tables 倒排页表

<process-id, page-number, offset>

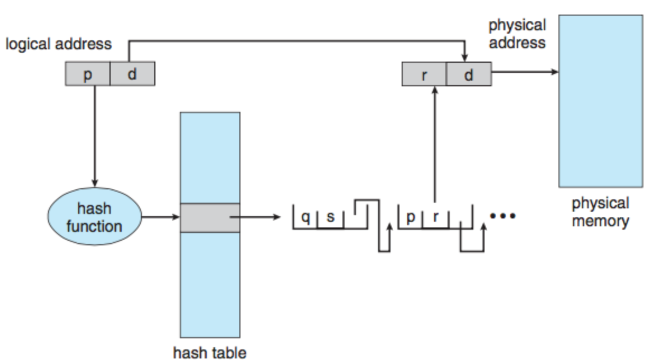


Inverted Page Tables



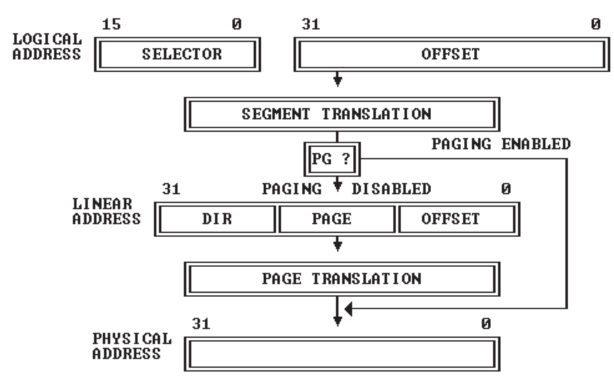
Comparison of a traditional page table with an inverted page table

Hashed Page Tables

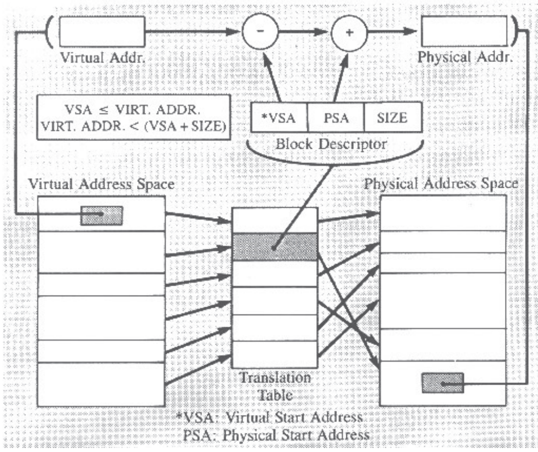


CURR MEMORY TRANSLATION

Logical Addr. -> (Virutal/)Linear Addr. -> Physical Addr.



CURR MEMORY TRANSLATION



Summary

- Memory Partitioning
- Swapping
- Segmentation
- Paging