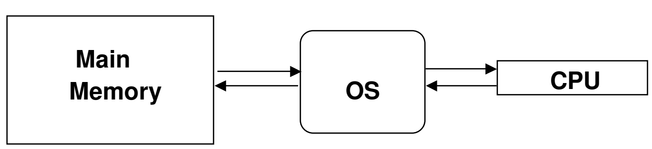
Chapter 11

Memory Management

Memory Management

Main memory is a resource that must be allocated and deallocated



Memory Management Techniques determine:

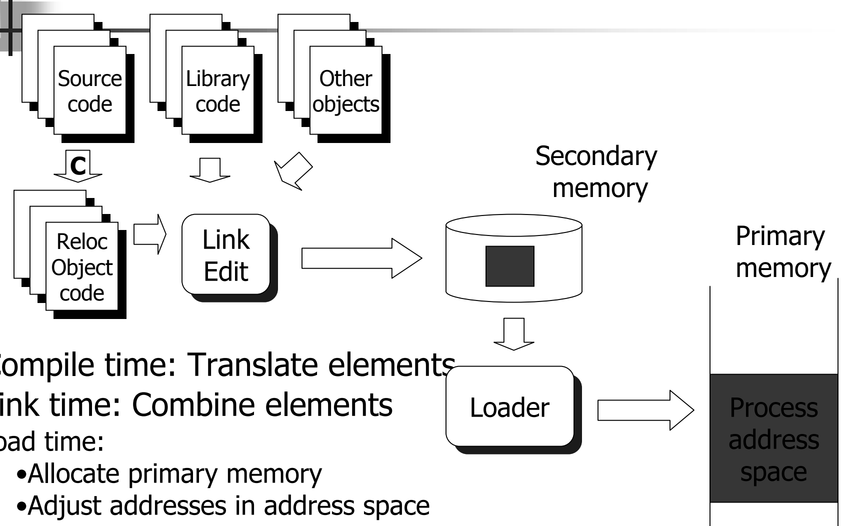
- **Where and how a process resides in memory**
- **How addressing is performed**

Binding:

identifiers --> compiled relative addresses (relative to 0)

--> physical addresses

Building the Address Space



- Compile time: Translate elements
- Link time: Combine elements
- Load time:
  - Allocate primary memory
  - Adjust addresses in address space
  - Copy address space from secondary to primary memory

Memory Management Techniques

1) **Single Contiguous**
2) **Overlays**
3) **Fixed (Static) Partitions**
4) **Relocation (Dynamic) Partitions**
5) **Paging**
6) **Demand Paging**
7) **Segmented**
8) **Segmented / Demand Paging**

For each technique, observe:

- **Algorithms**
- **Advantages / Disadvantages**
- **Special Requirements**

I. Single Contiguous

```
While ( job is ready ) Do
        If ( JobSize <= MemorySize )
            Then  Begin
                  Allocate Memory
                  Load and Execute Job
                  Deallocate Memory
                  End
            Else  Error
```


I. Single Contiguous…

☺ ***Advantages:***

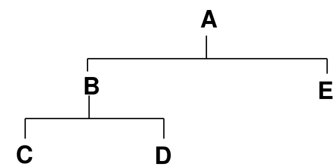
- Simplicity
- No special hardware

☹ ***Disadvantages:***

- CPU wasted
- Main memory not fully used
- Limited job size

II. Overlays

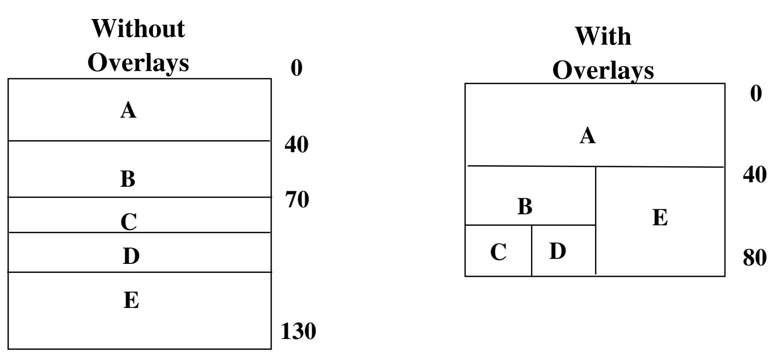
- Programs can be sectioned into modules
- Not all modules need to be in main memory at the same time



- **Programmer specifies which modules can overlay each other**
- **Linker inserts commands to invoke the loader when the modules are referenced**
- **The "parent" must stay in memory**
- **Used in DOS as an alternative to Expanded Memory.**

Illustration of Overlays

Program Component:	A	**B**	**C**	**D**	**E**
Memory:	**40K**	**30K**	**10K**	**10K**	**40K**



Overlays …

☺ ***Advantages:***

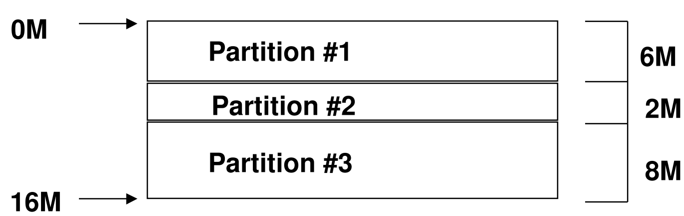
- **Reduced memory requirements**

☹ ***Disadvantages:***

- Overlap map must be specified by programmer
- Programmer must know memory requirements
- Overlapped modules must be completely disjoint

Fixed (Static) Partitioning with Absolute Translation

- Earliest attempt at multiprogramming
- Partition memory into fixed sized areas:



Fixed (Static) Partitioning with <u>Absolute </u>Translation …

- Each partition can hold <u>ONE</u> process
- Code generated using an <u>ABSOLUTE</u> address reflecting the starting address of the partition in which it is supposed to execute
  (relative to 0, 6M, or 8M in picture)
- Queue of processes waiting for each partition

Fixed (Static) Partitioning with Absolute Translation

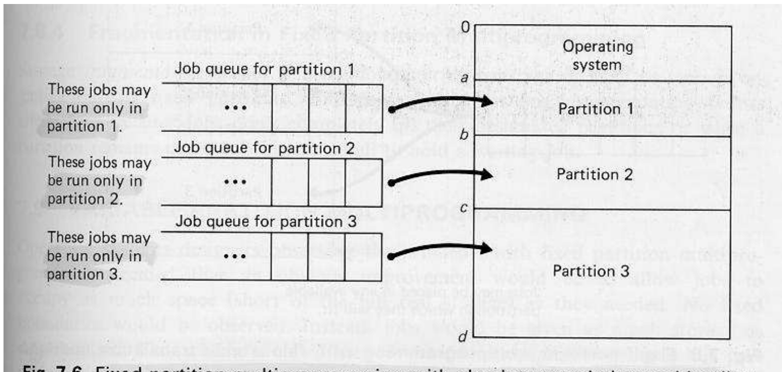


Fig. 7.6 Fixed partition multiprogramming with absolute translation and loading.

Fixed (Static) Partitioning with Absolute Translation…

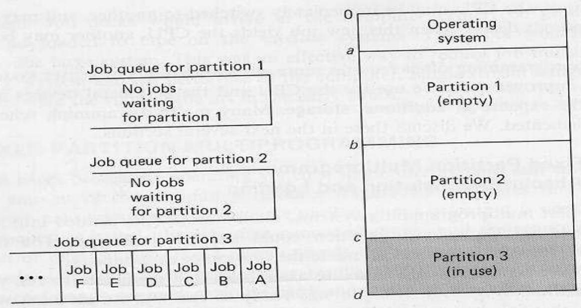


Fig. 7.7 An extreme example of poor storage utilization in fixed partition multiprogramming with absolute translation and loading. Jobs waiting for partition 3 are small and could "fit" in the other partitions. But with absolute translation and loading, these jobs may run only in partition 3. The other two partitions remain empty.

Fragmentation- Definitions

Fragmentation **is a situation in which the free cells in main memory are not contiguous.**

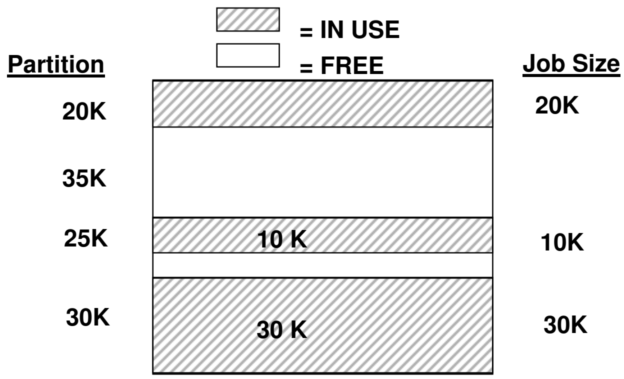
Internal fragmentation:

A situation in which free memory cells are within the area allocated to a process

External fragmentation:

A situation in which free memory cells are not in the area allocated to any process

Fixed Partition Fragmentation



External fragmentation: 35K partition

Internal fragmentation: 25-10 => 15K wasted inside 25K partition

Fixed Partitioning with Absolute Translation: Pros/Cons

☺ *Advantages:*

- Simplicity
- Multiprogramming now possible
- Works with *any* hardware (8088, 68000, etc)

Fixed Partitioning with Absolute Translation: Pros/Cons …

☹ *Disadvantages:*

- Job Size <= Max Partition Size <= MM Size
- Storage wasted due to *internal fragmentation*:

    process size < partition size

- Storage wasted due to *external fragmentation:*

    A partition may be idle because none of the jobs assigned to it are being run

- Once compiled a job can *only* be executed in designated partition

Fixed (Static) Partitions with Relative Address Translation

- Allows process to run in any free partition

- ALL Code generated using addresses *relative to* **zero**

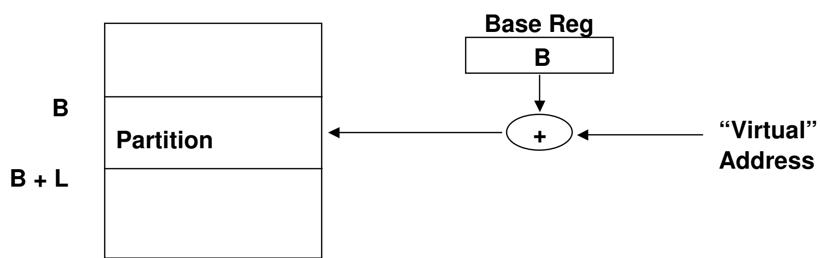
Fixed Partitions with Relative Address Translation…

Illustration:

Let:

B denote base (absolute) address of a partition

L denote partition length



QTP: Would Pointers work?

Multiprogramming Protection

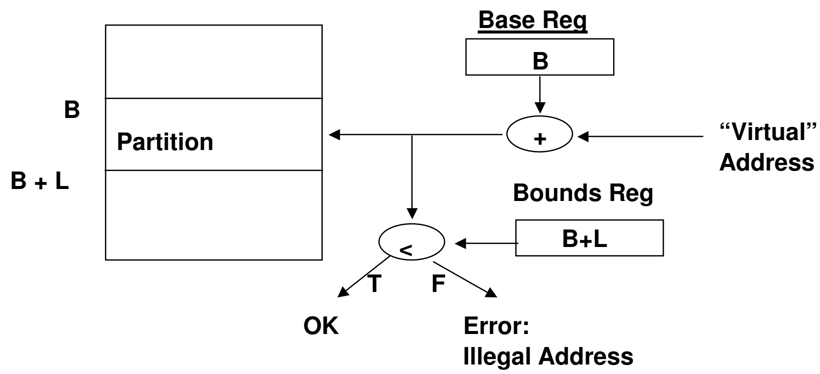
Fixed partitions with relative addressing supports multiprogramming protection

=> Ensure that one process does not access memory space dedicated to another process

Method:

Each relative address is compared to the **bounds register**

Multiprogramming Protection…



Fixed Partitioning with Relative Addressing: Pros/Cons

☺ *Advantage compared to absolute addressing:*

- Dynamic allocation of programs to partitions improves system performance

☺ *Still some disadvantages:*

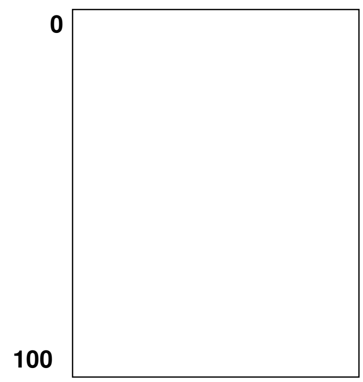
- Partition sizes are fixed at boot time
- Can't run process larger than largest partition
- Partition selection algorithm affects system performance
- Still has internal and external fragmentation

IV. Dynamic Partitions

Consider following scenario (100K memory):

1. **Job 1 arrives; size= 22 K**
2. **Job 2 arrives; size= 24 K**
3. **Job 3 arrives; size= 30 K**
4. **Job 4 arrives; size=10 K**
5. **Job 1 terminates**
6. **Job 3 terminates**
7. **Job 5 arrives; size=12K**

Where should job 5 be put?



Partition Selection Algorithms

- Implementation requires a *free block table*
- Sorting table in a particular manner results in a specific selection algorithm:

1) First Fit -- Table sorted by location, searched top to bottom
2) Best Fit -- Table Sorted by size (ascending)
   [don't break up big blocks]
3) Worst Fit -- Table sort by size (descending)
   [break up big blocks]
4) Next Fit

Where does Job 5 Go?
First Fit

a	FREE - 22 K
b	IN USE (J2) - 24 K
c	FREE - 30K
d	IN USE (J4) - 10 K
e	FREE - 14 K

:

:

7. Job 5 arrives; size=12K

Free List Table - First Fit

Start addr	**Length**
a	22
c	30
e	14

Where does Job 5 Go?
Best Fit

a	FREE - 22 K
b	IN USE (J2) - 24 K
c	FREE - 30K
d	IN USE (J4) - 10 K
e	FREE - 14 K

:

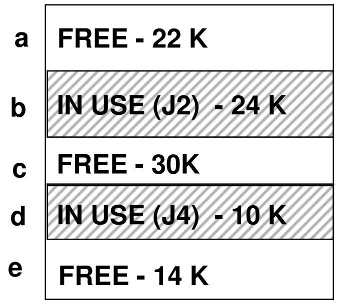
:

7. Job 5 arrives; size=12K

Free List Table - Best Fit

Start addr	**Length**
e	14
a	22
c	30

Where does Job 5 Go? Worst Fit



Free List Table ***- Worst Fit***

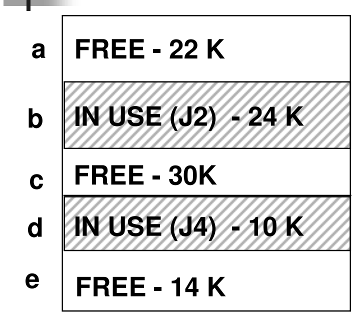
Start addr	Length
c	30
a	22
e	14

:

:

7. Job 5 arrives; size=12K

Where does Job 5 Go? Next Fit



Free List Table ***- Next fit***

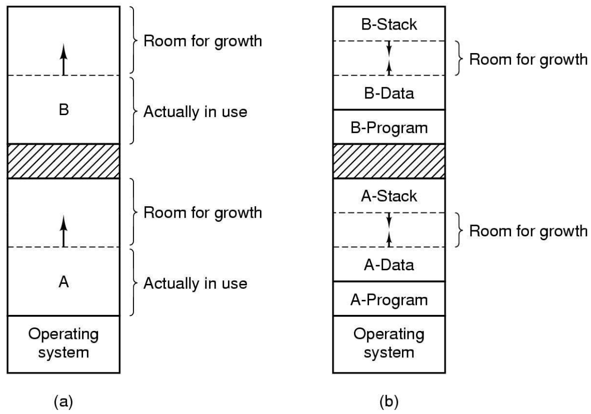
Start addr	Length
a	22
c	30
e	14

:

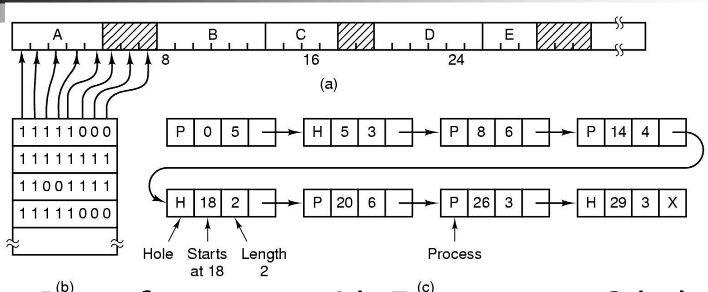
:

7. Job 5 arrives; size=12K

Dynamic partitions…

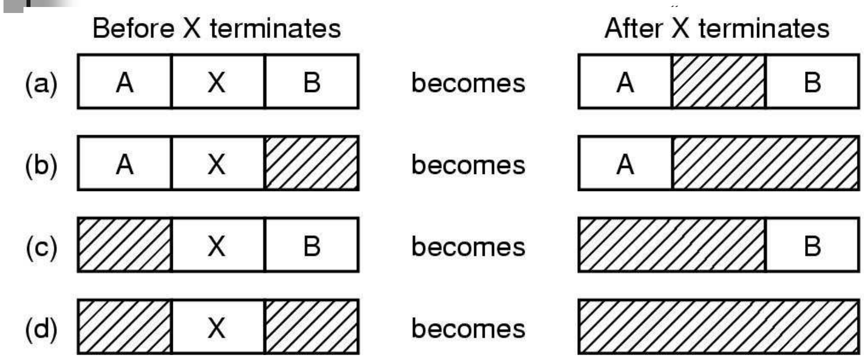


Memory Management with Bitmaps



- Part of memory with 5 processes, 3 holes
  - tick marks show allocation units
  - shaded regions are free
- Corresponding bit map
- Same information as a list

Memory Management with Linked Lists



Dynamic Partitions

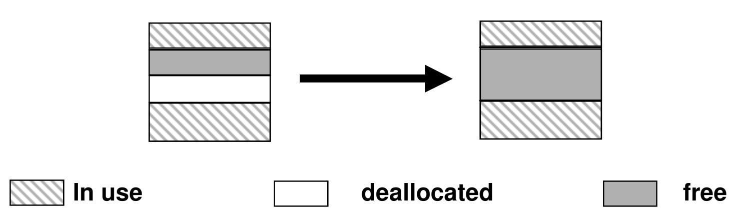
Requires two OS operations:

- *Allocation:*

  Form a partition from a free partition of ample size

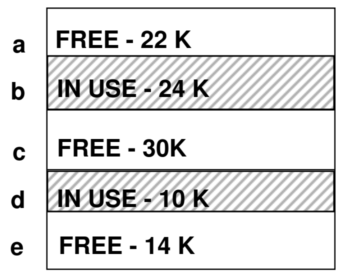
- *Deallocation:*

  Return partition to free table and *merge* where possible



Merge Example

Suppose b becomes free



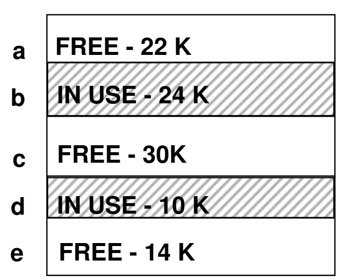
Free List Table - First Fit

Start addr	**Length**
a	**22**
c	**30**
e	**14**

What does Free List Table look like?

Merge Example

Suppose b becomes free



Free List Table - Best Fit

Start addr	**Length**
e	**14**
a	**22**
c	**30**

What does Free List Table look like?

Merge Example

Suppose b becomes free

a	FREE - 22 K
b	IN USE - 24 K
c	FREE - 30K
d	IN USE - 10 K
e	FREE - 14 K

Free List Table - *Worst Fit*

Start addr	Length
c	30
a	22
e	14

What does Free List Table look like?

Merge Example

Suppose b becomes free

a	FREE - 22 K
b	IN USE - 24 K
c	FREE - 30K
d	IN USE - 10 K
e	FREE - 14 K

Free List Table - *Next fit*

Start addr	Length
a	22
c	30
e	14

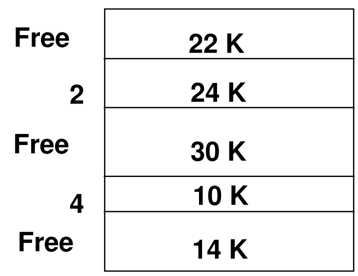
What does Free List Table look like?

What if we cannot find a big enough hole for an arriving job?

Suppose a 35K job arrives?

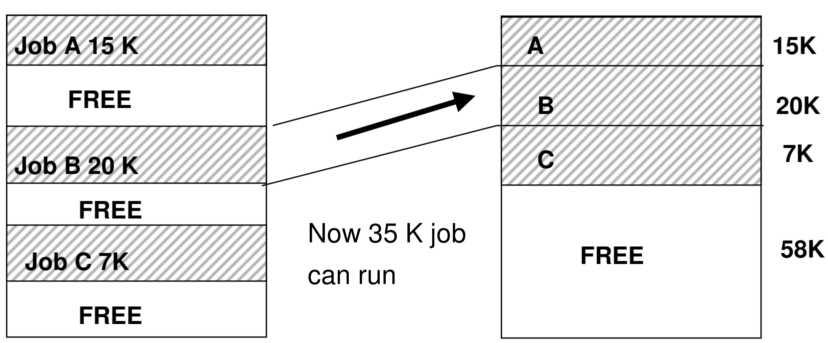
Suppose a 90K job arrives?

What do you do?



Compaction

Shuffle jobs to create larger contiguous free memory



QTP: How about <u>pointers</u>?

Pros/Cons of Dynamic Partitions

☺ ***<u>Advantages:</u>***

- Efficient memory usage

☹ ***<u>Disadvantages:</u>***

- Partition Management
- Compaction *<u>or</u>* external fragmentation
- Internal fragmentation (if blocks composing partions are are always allocated in fixed sized units -- e.g. 2k)