Memory (Part I):
Historical Perspectives & Approaches to Memory Management

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Some slides & figures adapted from Stallings instructor resources.

Some slides adapted from Adam Bates's F'18 CS423 course @ UIUC
https://courses.engr.illinois.edu/cs423/sp2018/schedule.html

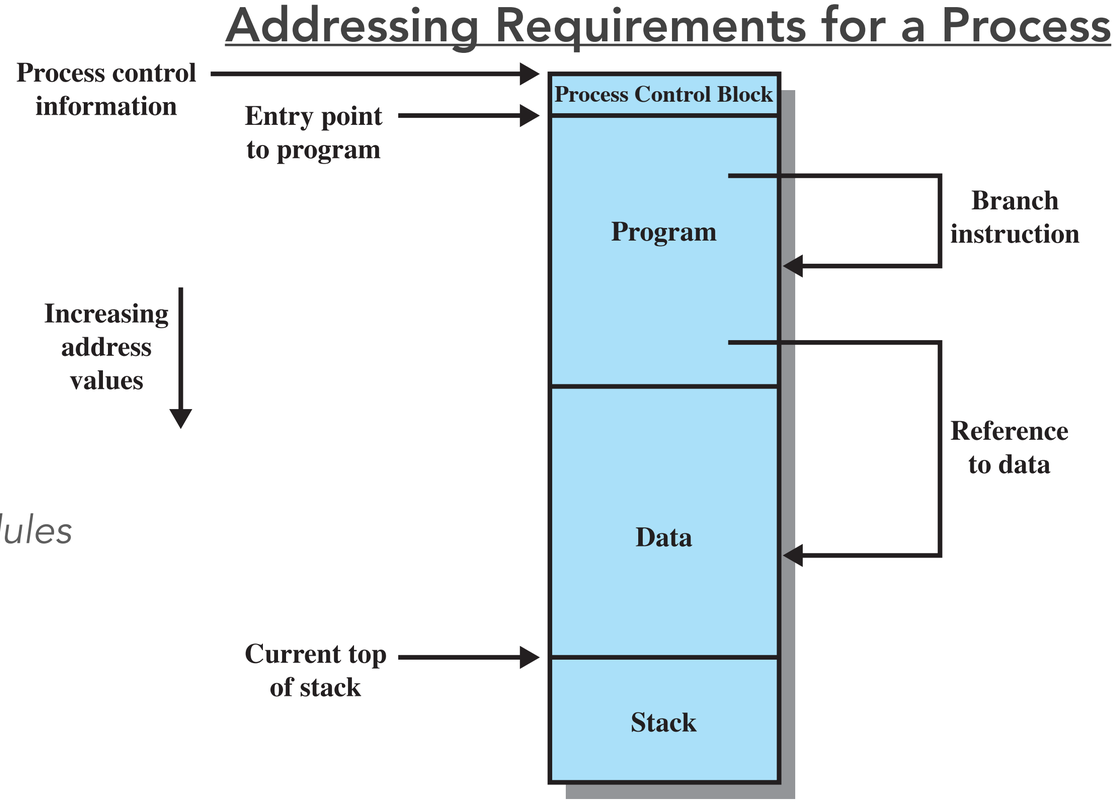
Goals for Today

Learning Objectives

- Understand basics of memory management, including
  - memory partitioning and common techniques
  - paging and segmentation — what they are, and their relative advantages and disadvantages
- Understand basics of loading and linking

Requirements for Memory Management

- Relocation
  ability to move program memory around
  (e.g., due to swapping)
- Protection
  *protection against unwanted interference by other processes (HW***)*
- Sharing
  controlled access to shared areas of memory
  (e.g., multiple instances of the same program)
- Logical Organization
  1-D/linear sequence of bytes; but most programs are organized as modules having different access permissions (R/W/X)
  - → *independent compilation*
  - → *different degrees of protection*
  - → *intuitive sharing mechanisms*
- Physical Organization
  2+ tiers of memory managed by the OS
  - → *main memory = faster, volatile*
  - → *secondary memory = slower, non-volatile, larger (relative to MM)*



Memory Partitioning: A Progression of Approaches

→ *Fixed Partitioning*

→ *Dynamic Partitioning*

→ *Paging*

→ *Segmentation*

→ *Paging **and** Segmentation*

Overview of Memory Management Techniques

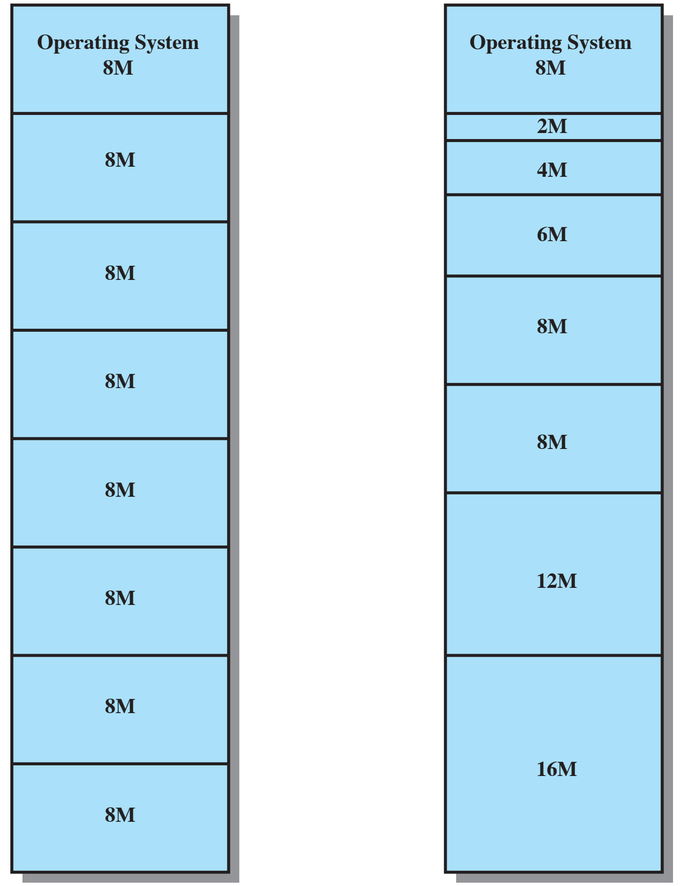
Technique	Description	Strengths	Weaknesses
Fixed Partitioning	Main memory is divided into a number of static partitions at system generation time. A process may be loaded into a partition of equal or greater size.	Simple to implement; little operating system overhead.	Inefficient use of memory due to internal fragmentation; maximum number of active processes is fixed.
Dynamic Partitioning	Partitions are created dynamically, so that each process is loaded into a partition of exactly the same size as that process.	No internal fragmentation; more efficient use of main memory.	Inefficient use of processor due to the need for compaction to counter external fragmentation.
Simple Paging	Main memory is divided into a number of equal-size frames. Each process is divided into a number of equal-size pages of the same length as frames. A process is loaded by loading all of its pages into available, not necessarily contiguous, frames.	No external fragmentation.	A small amount of internal fragmentation.
Simple Segmentation	Each process is divided into a number of segments. A process is loaded by loading all of its segments into dynamic partitions that need not be contiguous.	No internal fragmentation; improved memory utilization and reduced overhead compared to dynamic partitioning.	External fragmentation.
Virtual Memory Paging	As with simple paging, except that it is not necessary to load all of the pages of a process. Nonresident pages that are needed are brought in later automatically.	No external fragmentation; higher degree of multiprogramming; large virtual address space.	Overhead of complex memory management.
Virtual Memory Segmentation	As with simple segmentation, except that it is not necessary to load all of the segments of a process. Nonresident segments that are needed are brought in later automatically.	No internal fragmentation, higher degree of multiprogramming; large virtual address space; protection and sharing support.	Overhead of complex memory management.

Fixed Partitioning

- OS occupies a fixed portion of main memory.
  All other memory available for use by processes.

- ***Simple Approach:***
  Divide memory into fixed-size partitions

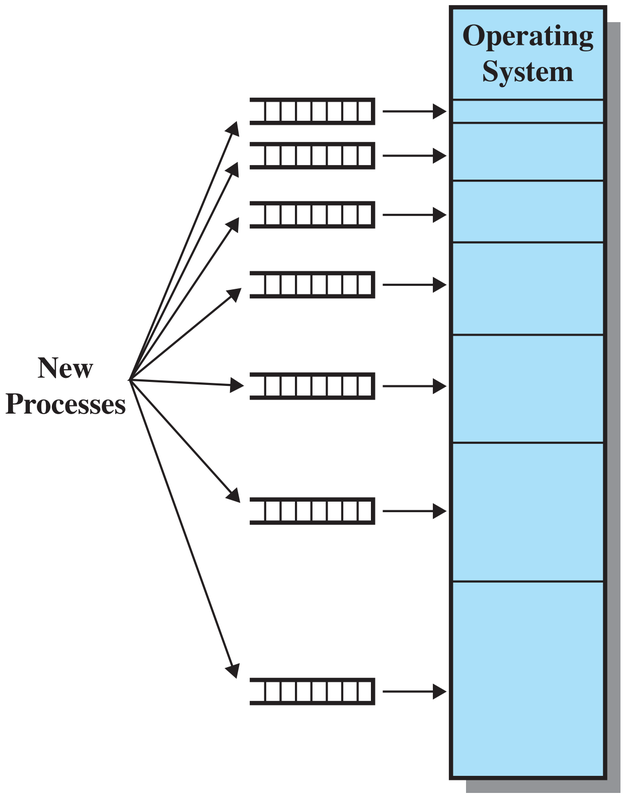
- **Example:** 64MB memory
  - *What if a program doesn't fit into a partition?*
    → ***overlaying***
  - *What if a program is much smaller than a partition?*
    → ***internal fragmentation***
  - *How does program get put into a partition?*
    → ***loading function*** *(later…)*
  - *Can we do better?*



equal partitions **vs.** ***unequal*** partitions

Placing Processes in Memory

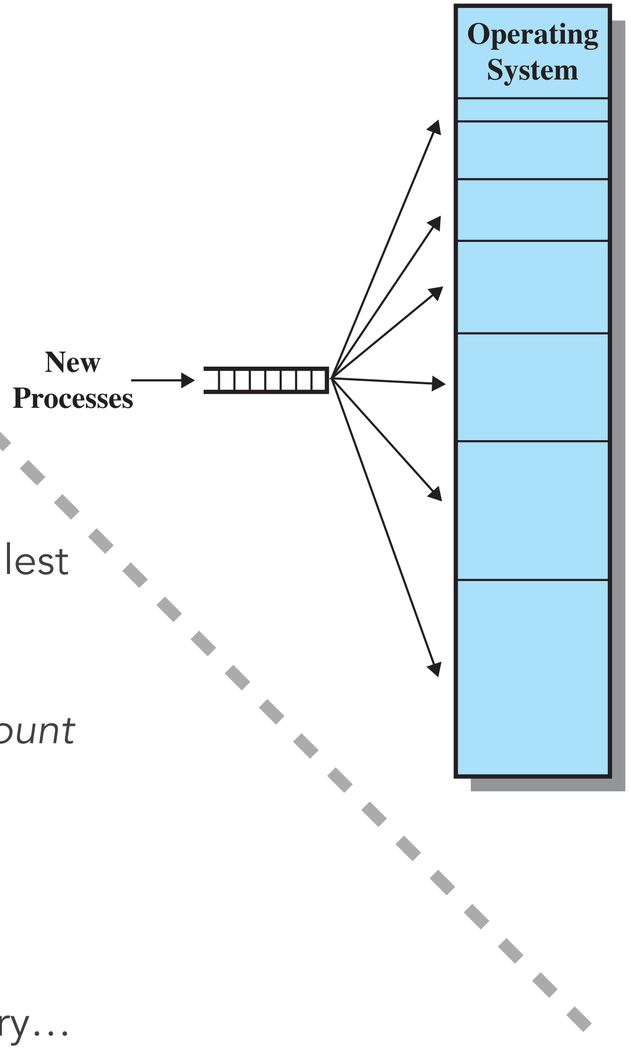
Placing processes in equal-sized fixed partitions is easy…
All partitions are equal. Pick one. Swap when needed. *(Recall **scheduling**!)*



Assign each process to the smallest partition within which it will fit.

Assumes we know the max. amount of memory…

→ Minimizes ***internal fragmentation!***
→ Could lead to unused memory…



Use a single queue of processes…

Assign each to the smallest available partition…

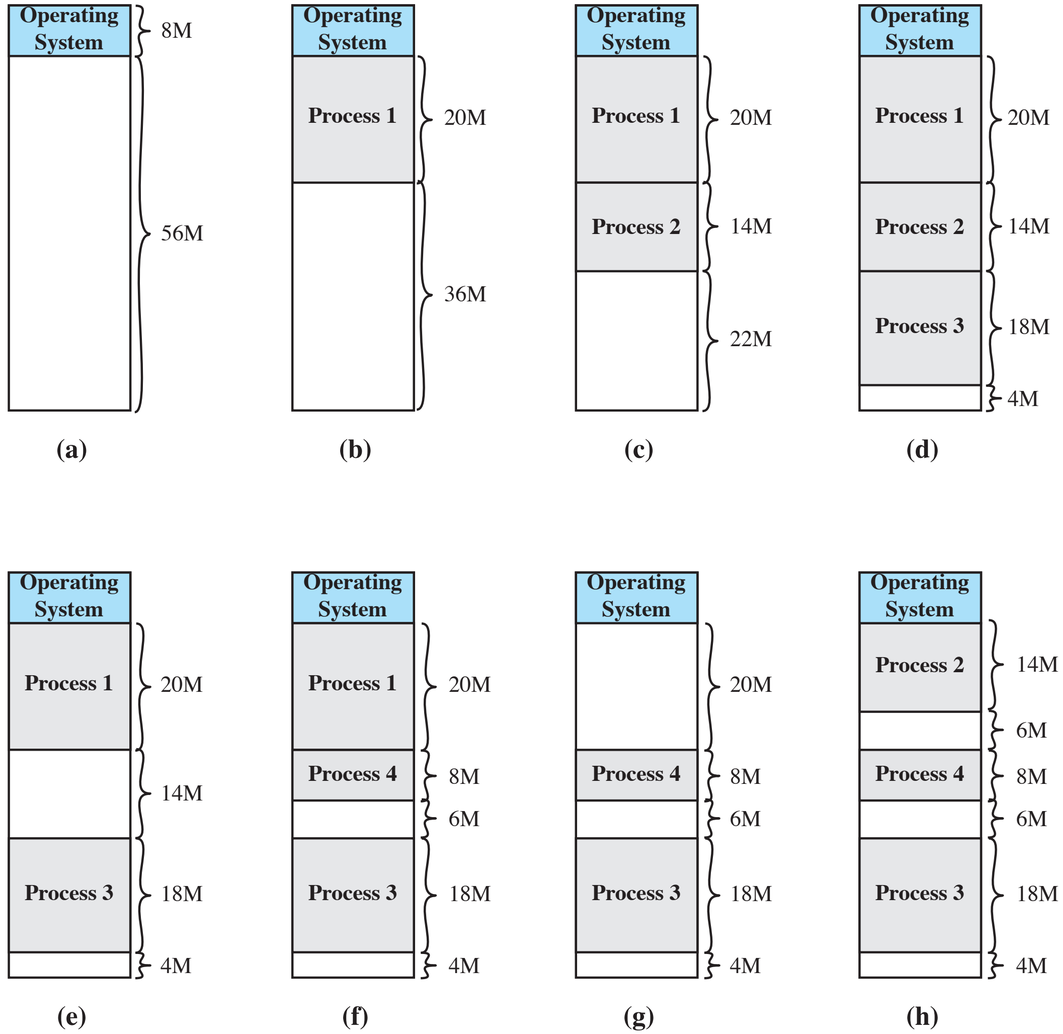
Resort to swapping when no partitions are available.

Swap based on…

- smallest partition?
- partition with lowest priority process?
- partition w/ a blocked process?

Dynamic Partitioning

→ *partitions are of variable length & number*
→ *each process allocated exactly as much memory as it needs*



→ Quickly leads to **external *fragmentation***!

→ One solution is **compaction**… *but this solution is time consuming and wasteful of processor time.*

→ How to best place processes in (available) memory?

Placement Algorithms

→ How to best place *(fit)* processes in available memory?
(Recall: we'd like to avoid having to perform compaction often)

Example: How to place a request for a 16MB block?

- Best-Fit
  scan all available memory blocks;
  select block that is closest in size to the request
  Usually The Worst!

- First-Fit
  scan memory from start;
  select the first available block that is large enough
  Simplest. Usually Best & Fastest.

- Next-Fit
  scan memory from location of the last placement;
  select the next available block that is large enough
  Tends To Be Worse Than First-Fit…