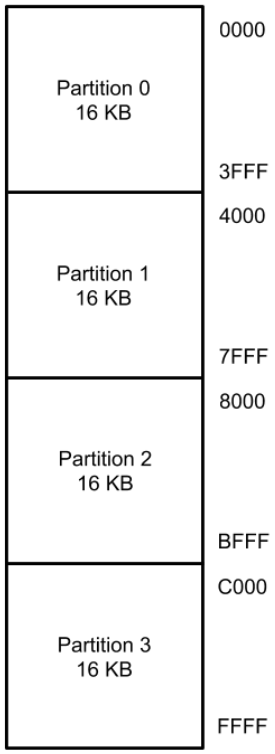
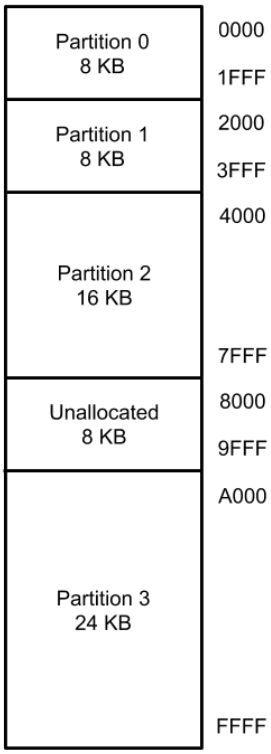
1. Memory management
    a. In a multiprogramming machine, memory dynamically allocated to OS and processes
        i. Multiprogramming – allows for multiple programs on a computer to be available to run at once
            1. Not running *simultaneously*, but gives the appearance of that
            2. Less waiting around if a program stalls
                a. Example – program needs something from RAM
        ii. Want more processes in RAM so that we have a bigger chance something is ready to execute
        iii. Could expand RAM, but this is expensive
    b. Swapping – move non-ready processes out of RAM onto disk into an intermediate queue
        i. *Swap* another process in from the long-term queue of processes that haven't been started yet
            1. Come back to intermediate queue later when something is ready
        ii. Disk I/O is slow, and so it's possible that doing this can make the problem worse
            1. In general, though, swapping is good, but there are better alternatives
    c. Partitioning – divide RAM into blocks, each process gets a block
    d. Fixed size partitioning – a given partition is always the same size
        i. Process gets placed into smallest available partition that holds it
        ii. Somewhat wasteful – extremely small processes may be allocated far more than it needs
            1. Larger processes may not get enough memory
    e. Variable size (dynamic) partitioning – process allocated exactly as much memory as it needs
        i. Memory fragments – small pockets of memory in non-contiguous chunks that are useless
            1. Too small to utilize or combine
        ii. Eventually memory becomes fragmented due to these small holes
            1. OS must spend CPU time *compacting* processes
            2. Do so by moving their partitions next to each other



Fixed size partitioning



Variable size partitioning with a memory fragment in the middle

2. Virtual versus physical addresses
    a. Discussed this with caches, now go into further depth
    b. Logical/virtual address – location relative to the start of the program
        i. You can imagine each process has an addressing space that starts at 0
            1. Exact start differs from OS to OS, though
        ii. Instructions only contain logical addresses
        iii. Programs start from 0 (in our example)
            1. Memory accesses are made based on that assumption
    c. Physical addresses – actual addresses in RAM
    d. Programs are always written/compiled to use virtual addresses!
        i. What would happen if we wrote a program in terms of physical addresses?
            1. Imagine we move the process through compaction
            2. Move from partition 1 to 0 in the variable example above
        ii. References in the instructions would reference wrong data now!
            1. 0x2015 is the physical address when the process is in partition 1
            2. 0x0015 is the physical address when the process is in partition 0
    e. Base address – where a process starts in RAM
        i. Virtual address + base address = physical address
        ii. Base address can change if we change where the process resides in memory
            1. May change because of compaction, for example
    f. MMU – memory management unit
        i. MMU converts every virtual address access to the corresponding physical address
        ii. Must do this for every single virtual address
        iii. This is the cost of having a physically addressed cache versus a virtual one