Beyond Physical Memory: Mechanisms

- Remove the assumption that an address space is small enough to fit in physical memory.
    - To do this add a level in the memory hierarchy.
    - To support large address spaces the OS needs a place to store portions of the address space that currently aren't in high use.
        - The space should have more capacity than memory.
        - Generally slower than memory.
        - Usually done on hard disk drives.

21.1 Swap Space

- Swap space is reserved space on disk for moving pages back and forth.
    - Assume that the OS can read and write to swap space in page sized units.
- The size of the swap space is important.
    - It determines the maximum number of memory pages that can be used by a system at a given time.

21.2 The Present Bit

- Running processes generate virtual memory references.
    - The hardware translates them into physical addresses before fetching from memory.
    - The hardware extracts the VPN from the virtual address.
        - Checks the TLB for a match.
    - If the VPN is not found in the TLB the hardware locates the page table in memory.

- Swapping pages to disk requires more machinery.
  - When the hardware looks in the PTE the page may not be present in physical memory.
  - This is determined through a present bit in the page table entry.
    - If present bit is set to 1 it means the page is present in physical memory.
  - Page fault is the act of accessing pages not in physical memory.
    - The page-fault hander deals with page faults.

21.3 The Page Fault

- With TLB misses there are two types of systems.
  - Hardware managed and software managed.
- If the page is not present and has been swapped to disk the OS will need to swap the page into memory.
  - The page table is a place to store the information.
- When the disk I/O completes the OS will update the page table.
  - Marks the page as present.
  - Updates the PFN field of the entry.
- While the I/O is occuring the process will be blocked.

21.4 Memory Full

- There may not be enough space in memory to page in from swap space.
  - In this case room must be made by a page out of one or more pages.
  - The process of determining which page to replace is known as page-replacement policy.

21.5 Page Fault Control Flow

- There are three important cases to understand when a TLB miss occurs.
    - First: Page is both present and valid.
        - The TLB miss handler can grab the PFN from the PTE and retry the instruction.
    - Second: Page fault handler must be run.
        - Legitimate page to access but it's not in memory.
    - Third: The access is to an invalid page.
        - Hardware traps an invalid process and the OS trap handler runs.

21.6 When Replacments Really Occur

- There are many reasons for an OS to keep a small part of memory free.
- To keep memory free most operating systems have some kind of high watermark and low watermark to decide when to start swapping pages.
    - When the OS notices that there are fewer than low watermark pages available.
        - A thread responsible for freeing memory removes pages until the high watermark number of pages is present.
        - The thread is called a swap daemon or page daemon.
- Doing a number of replacements at the same time allows for better efficiency.