6.033 - Operating Systems + Virtual Memory
Lecture 3
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0. Previously
  - Modularity reduces complexity
  - Naming is necessary for modularity

1. Operating Systes
  - Job: enforce modularity on a single machine
    - Also: multiplexing, isolation, cooperation, portability, performance, ...
  - To enforce modularity on a single machine, need to:
    - protect programs' memory from each other
    - allow programs to communicate
    - allow programs to share a single CPU
  - Virtualization is how we do that
  - Today: virtualize memory. assume one CPU per program and that programs don't need to communicate.

2. Virtual memory
  - Two components: main memory, CPU
  - CPU holds instruction pointer (EIP)
  - Naive method: two programs can just point to each other's memory (bad)
  - Another method: force programs to only use particular blocks of memory by having them address only part of the space. Complicated.
  - Virtual memory addressing: let each program address the full 32-bit space. MMU translates virtual to physical addresses.

3. Page tables
  - Idea 1: Store physical addresses, use virtual addresses as an index into that table
  - Problem: table is too big
  - Solution: virtual address = page number + offset. MMU maps virtual page numbers to physical page numbers. Keeps offset the same.
  - Page table entries contain other stuff. Among that stuff:
    - Present bit
      - This bit lets us know if a page resides in RAM or storage. That's how the OS deals with not actually having 2^32 * (number of programs) physical addresses in RAM: pages can live on disk when necessary.
    - R/W bit
    - U/S bit
    - These bits let the OS know when to trigger page faults

4. Hierarchical Page Tables
  - "Normal" page tables (described above) still use a lot of space

- Page tables have to be allocated all at once or not at all
- Hierarchical page tables solve this by creating a hierarchy of page tables and allocating each table only when it's needed.
  - Virtual addresses get divided into multiple parts, one part per level in the hierarchy + an offset.
- Downside? Speed. Multiple lookups instead of one. More page faults.

5. Kernel
   - Virtualized memory doesn't protect the page table
   - Kernel mode vs. user mode does this
   - Switch between user and kernel modes via interrupts

6. Abstraction
   - Some things can't be virtualized (disk, network, ..)
   - OS abstractions (system calls) make these things portable
   - System calls are implemented as interrupts

7. Virtual memory as naming
   - Virtual memory is just a naming scheme
   - Gives us hiding, controlled sharing, indirection

Next lectures: get rid of our initial assumptions (one CPU per program, etc.)