Micro-Kernel OS

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Microkernel System Structure

- Microkernel structure:
  - Moves bunch of functionalities from the kernel into "user" space.
  - Tend to have more frequent kernel/user crossings.

- What must be in the kernel and what can be in user space?
  - Protection mechanisms (protecting hardware; protecting user processes from each other).
  - Resource management policies.
  - Examples in memory management, file system, networking, ...

- Benefits:
  - Modular design?
  - More reliable/secure (less code is running in kernel mode).

Microkernel OS: Mach

- Mach
  - developed at CMU in late 80s
  - bits/pieces leading to NeXT, the foundation of MacOS 10

- Micro-kernel design
  - OS functionalities are pushed to user-level servers (e.g., user-level memory manager)
  - user-level servers are trusted (often run as root)
  - protection mechanisms stay in kernel while resource management policies go to the user-level servers

Most modern OSes fall into this category!
User-level Memory Management

- User-level memory management
  - trusted/protected by the kernel
  - kernel provides the basic protection mechanism
  - user-level memory manager handles page loading; decides replacement policy

Inter-domain Communications

- Inter-domain communications in micro-kernel systems
  - between user-level applications and the kernel
  - between user-level applications and servers
  - between user-level servers and the kernel
    - down calls (normal system calls) and upcalls (calling from the kernel to user-level routines)
- Tend to have many inter-domain communications
  - resulting in large overhead

Virtual Message Passing

- Virtual message passing
  - mess around with memory map tables (page tables) to speed up message passing

Microkernel OS: Exokernel

- Exokernel
  - developed at MIT in early 90s
- Micro-kernel design
  - OS functionalities are pushed to library OSes linked with individual user-level processes
  - communication takes place between user/kernel modules using message passing
- Benefits:
  - more reliable/secure (less code is running in kernel mode).
  - more flexibility (different user program can use different VM page replacement policies) ⇒ better performance.
- Problem it introduces?
  - security and isolation
Library OS
- The kernel does not trust the library OS
- The library OS trusts the user program; so the library OS can be implemented without the concern of protection
- The library OS and the user program are linked together
  - low cost interaction between them
  - particularly helpful when applications and the OS interact frequently (application-assisted VM page replacement)
- Applications can link with customized library OS
  - flexibility
  - e.g., one process can use LRU page replacement and another can use MRU

The Kernel
- The kernel does not trust the library OS or user processes
  - must decide allocation/binding of resources to different library OSes and user processes
  - must enforce allocation/binding of resources to library OSes and user processes

Memory Management
- Two-level allocation
  - The kernel allocates memory among library OSes
  - Each library OS manages memory pages allocated to it
- The kernel enforces allocation among library OSes
- how does it work (for software-loaded TLBs)?
  - only the kernel can access the TLB, the kernel checks every TLB load to make sure a library OS (or a user process) doesn't access a page that it is not supposed to
  - who maintains the page table?
- how does it work (for hardware-loaded TLBs)?
Summary

- Microkernel structure:
  - Moves functionalities from the kernel into "user" space.

- Benefits:
  - More reliable/secure (less code is running in kernel mode)

- Disadvantage on performance:
  - Tend to have more frequent domain crossings.

- Two types of micro-kernels:
  - Running user-level OS in a trusted server - Mach
  - Running user-level OS within untrusted user processes - Exokernel
    - more flexibility, but problems on security and isolation

- Why aren't they taking over the world?