

Section 9: Virtual Memory (VM)

- Overview and motivation
- Indirection
- VM as a tool for caching
- Memory management/protection and address translation
- Virtual memory example

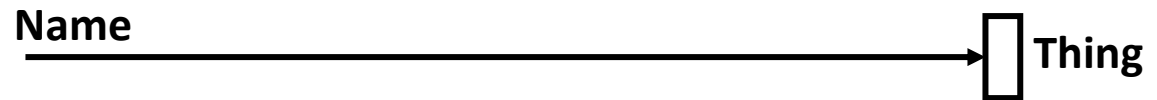
How would you solve those problems?

- **Fitting a huge memory into a tiny physical memory**
- **Managing the memory spaces of multiple processes**
- **Protecting processing from stepping on each other's memory**
- **Allowing processes to share common parts of memory**

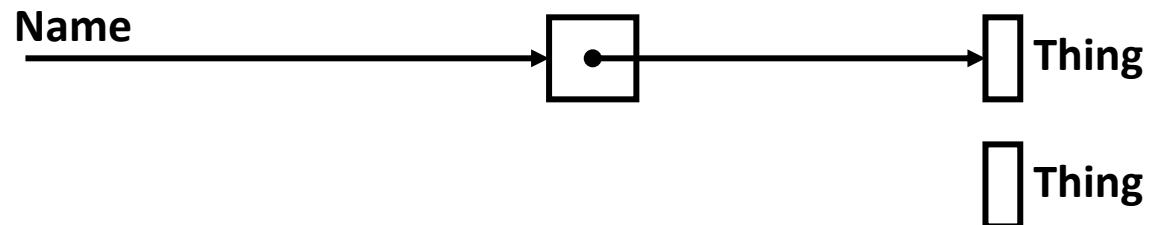
Indirection

- “Any problem in computer science can be solved by adding another level of indirection”

- Without Indirection

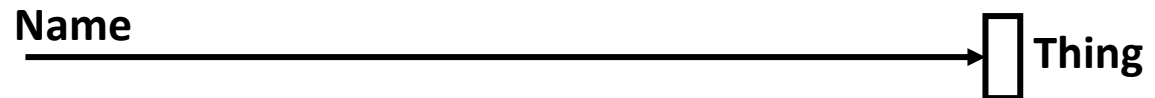


- With Indirection



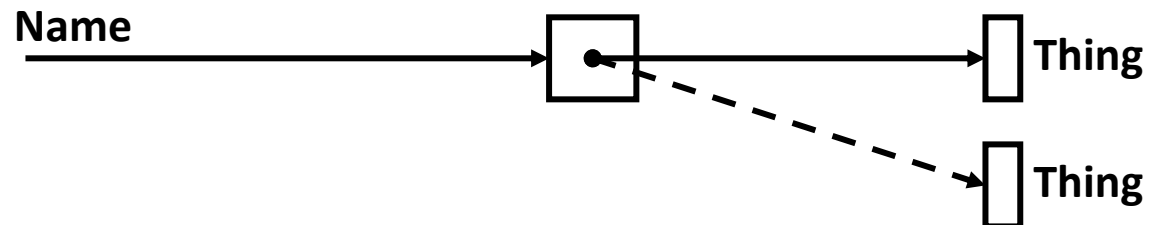
Indirection

- Indirection: the ability to reference something using a name, reference, or container instead the value itself. A flexible mapping between a name and a thing allows changing the thing without notifying holders of the name.



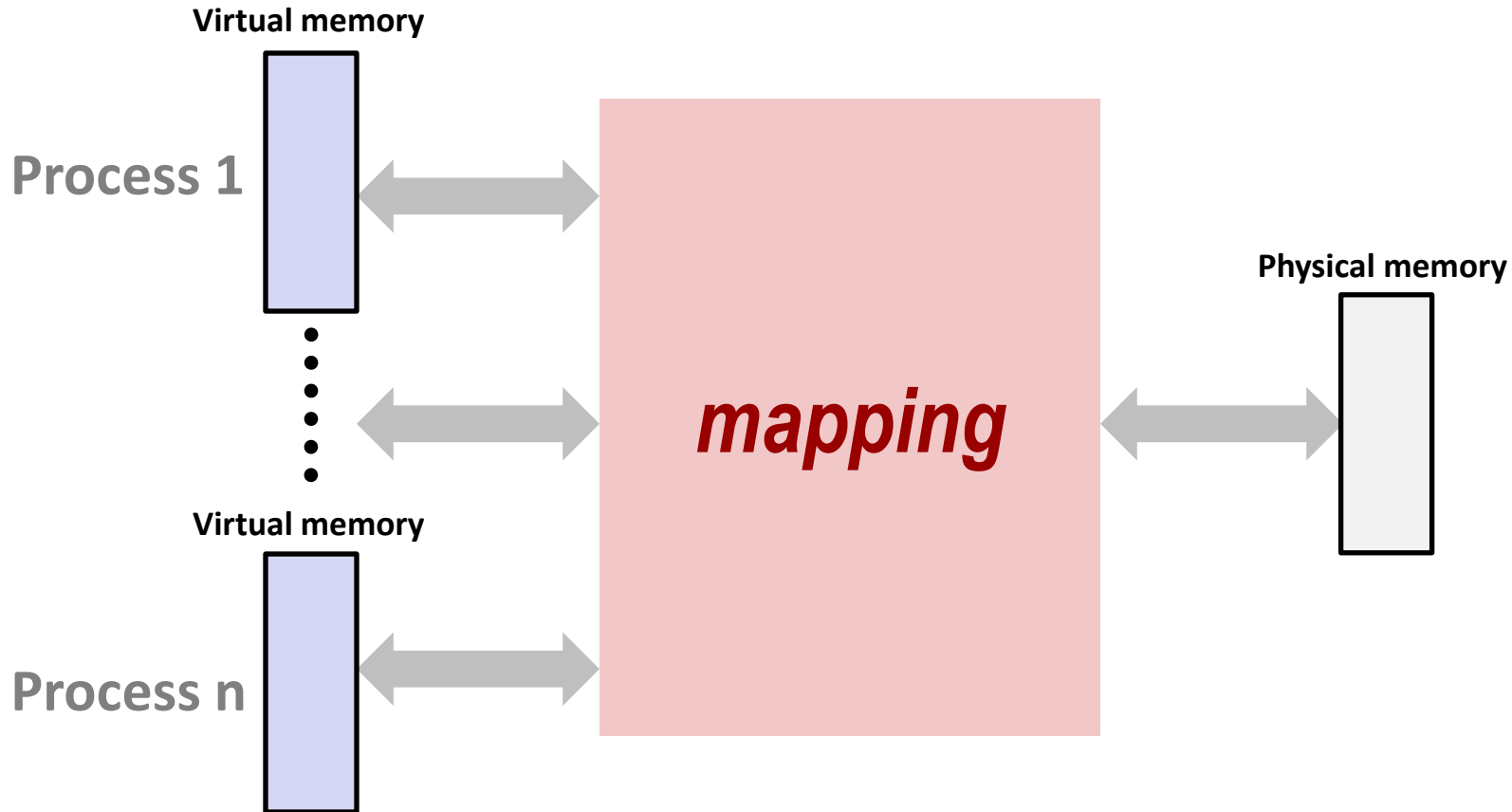
- Without Indirection

- With Indirection



- Examples:
Domain Name Service (DNS) name->IP address, phone system (e.g., cell phone number portability), snail mail (e.g., mail forwarding), 911 (routed to local office), DHCP, call centers that route calls to available operators, etc.

Solution: Level Of Indirection

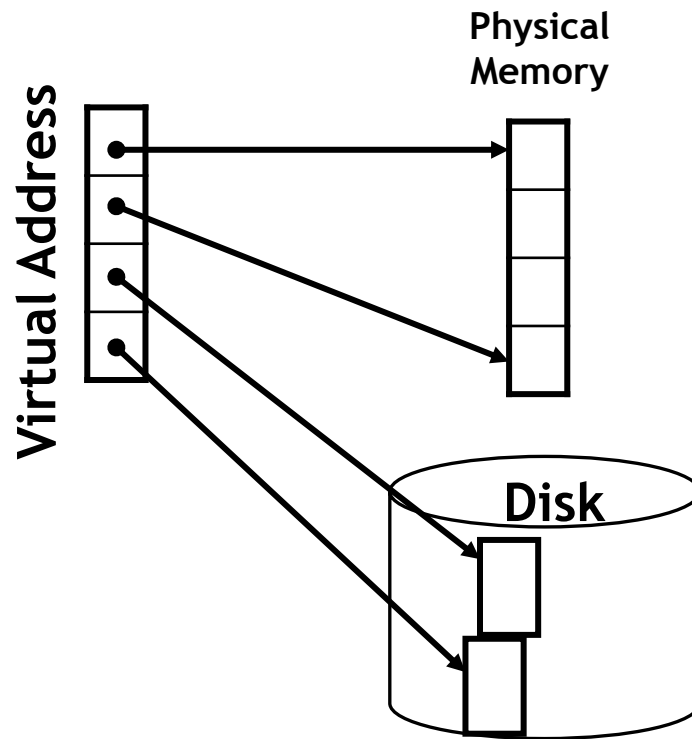


- Each process gets its own private virtual address space
- Solves the previous problems

Address Spaces

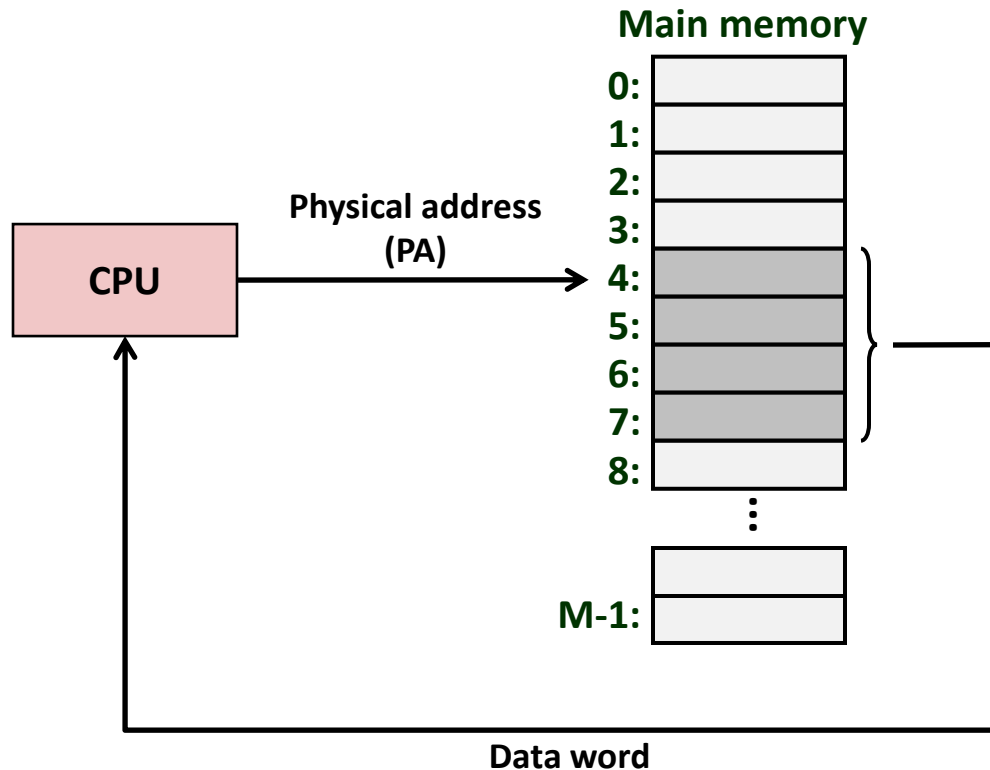
- **Virtual address space:** Set of $N = 2^n$ virtual addresses
 $\{0, 1, 2, 3, \dots, N-1\}$
- **Physical address space:** Set of $M = 2^m$ physical addresses ($n > m$)
 $\{0, 1, 2, 3, \dots, M-1\}$
- **Every byte in main memory:**
one physical address; zero, one, or more virtual addresses

Mapping



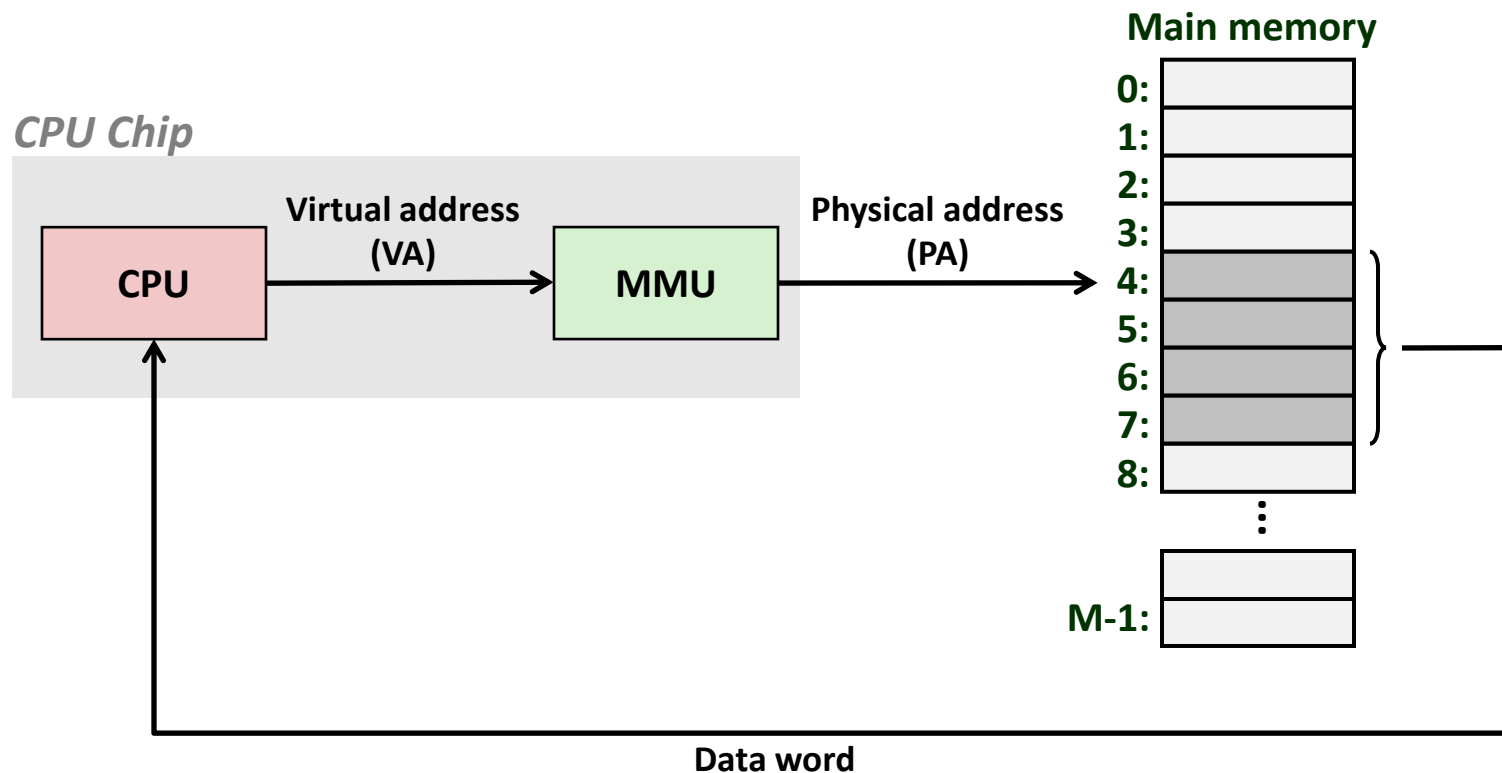
A virtual address can be mapped to either physical memory or disk.

A System Using Physical Addressing



- Used in “simple” systems like embedded microcontrollers in devices like cars, elevators, and digital picture frames

A System Using Virtual Addressing



- Used in all modern desktops, laptops, servers
- One of the great ideas in computer science