
Computer Architecture

Virtual Memory

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Confession

- ✿ *Most of the materials have been collected from Internet.*
- ✿ *Images are taken from Internet.*
- ✿ *Various books are used to make these slides.*
- ✿ *Various slides are also used.*
- ✿ *References & credit:*
 - *Atanu Shome, Assistant Professor, CSE, KU.*
 - *Computer Organization and Design: the Hardware/Software Interface - Textbook by David A Patterson and John L. Hennessy.*
 - *Computer Organization and Architecture - Book by William Stallings*

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Virtual Memory

Main memory can act as cache for secondary memory. This is called Virtual Memory.

Why?

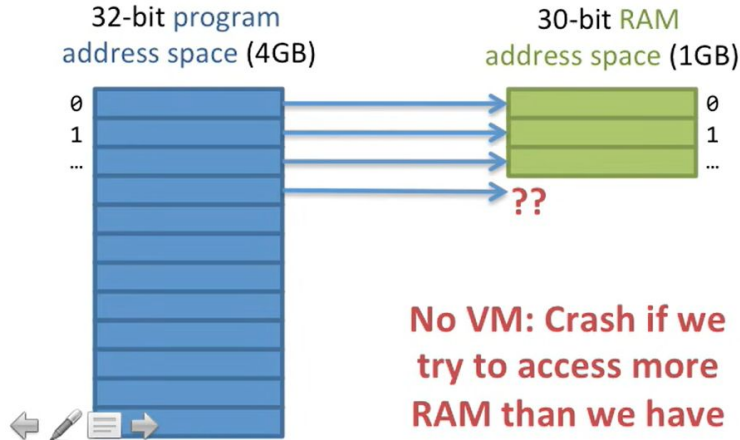
- ◆ Efficient and Safe memory share among programs.
- ◆ Go beyond limited RAM.
- ◆ Not enough adjacent space.

Virtual Memory

Virtual memory takes program addresses and maps them to Ram addresses

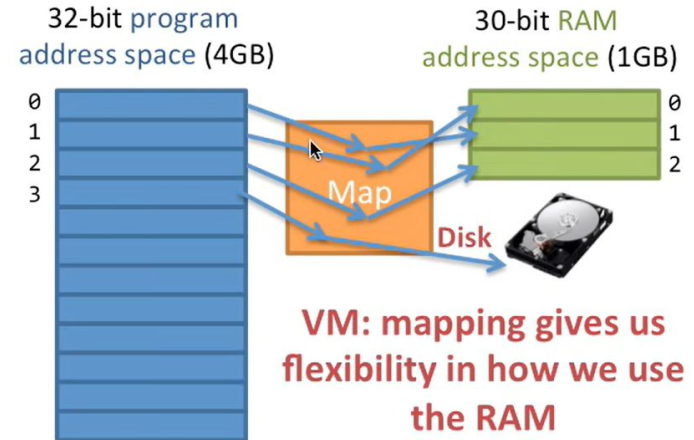
Without Virtual Memory

Program Address = RAM Address

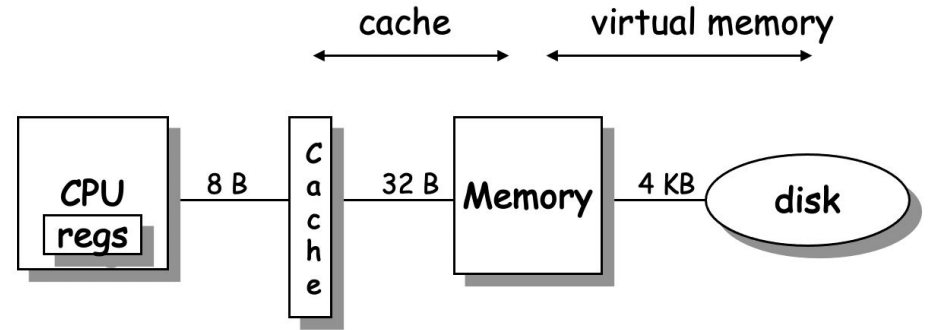


With Virtual Memory

Program Address Maps to RAM Address



Levels in Memory Hierarchy

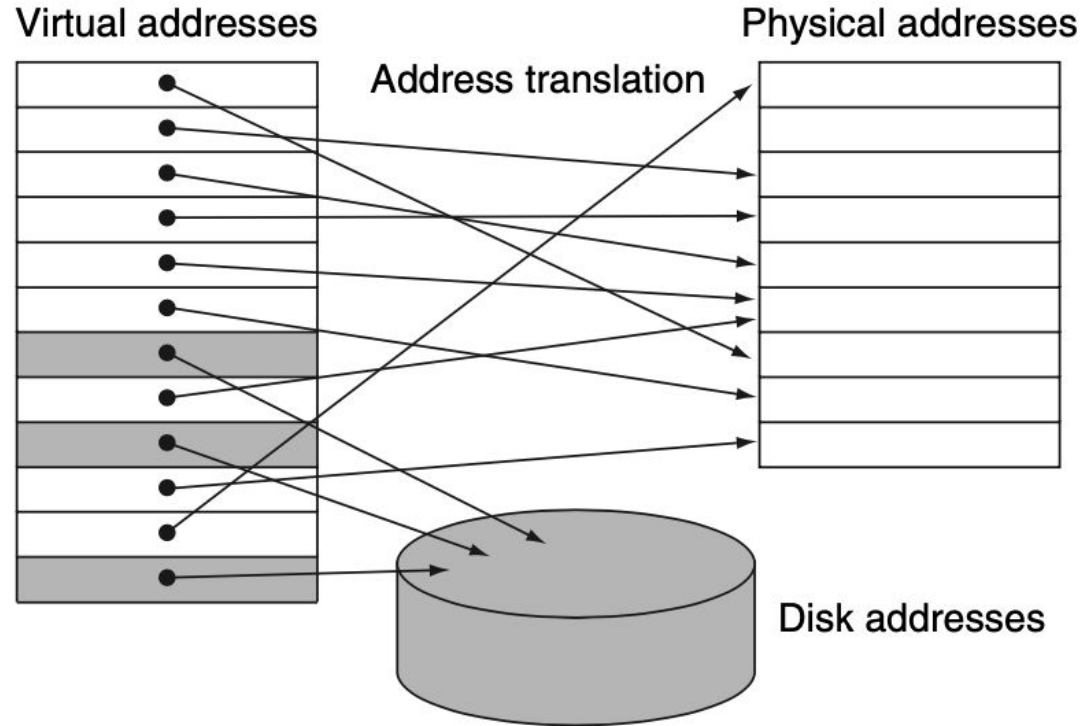


	Register	Cache	Memory	Disk Memory
size:	32 B	32 KB-4MB	128 MB	20 GB
speed:	2 ns	4 ns	60 ns	8 ms
\$/Mbyte:		\$100/MB	\$1.50/MB	\$0.05/MB
line size:	8 B	32 B	4 KB	

larger, slower, cheaper



A System with Virtual Memory

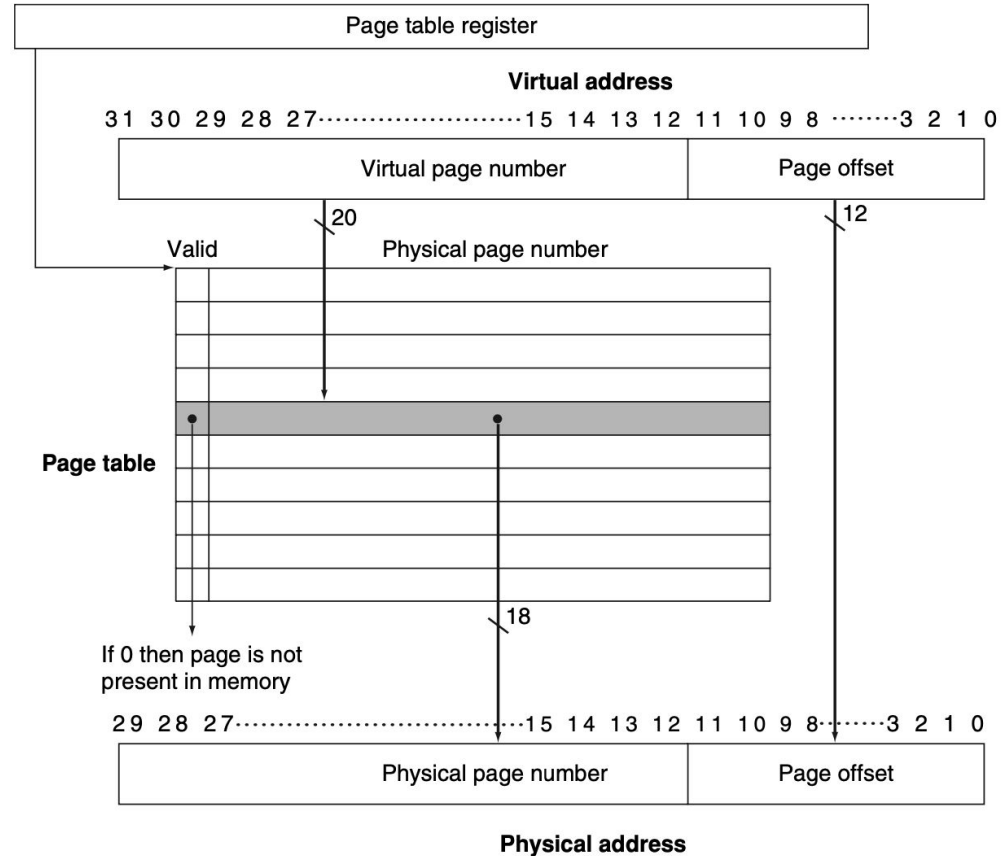


Virtual Memory

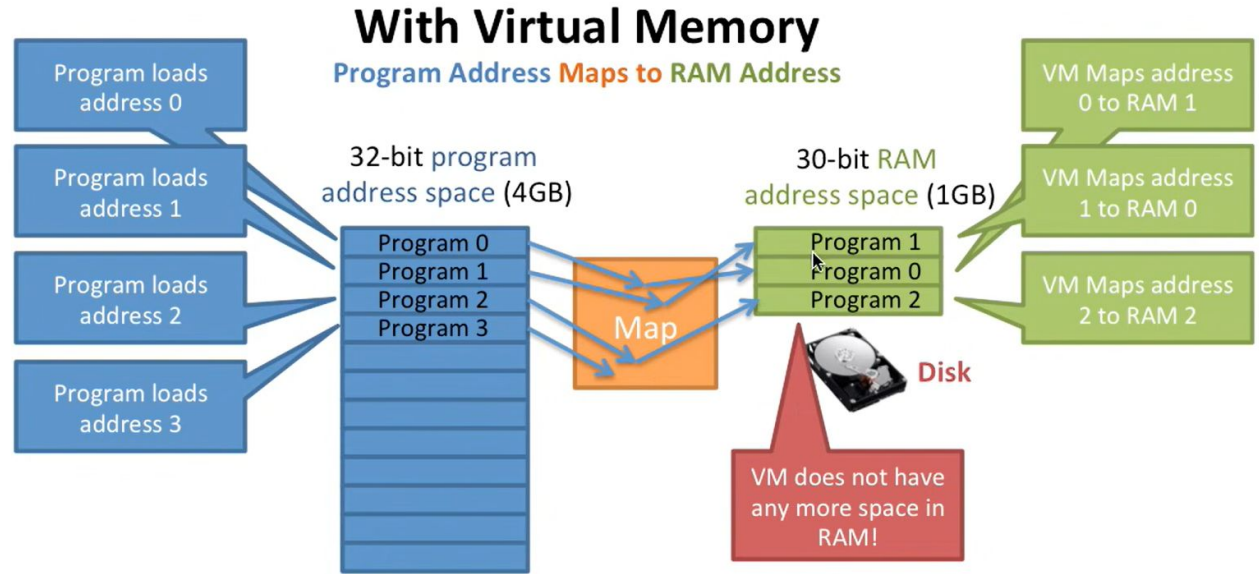
-
- ◆ Page
 - ◆ Page Fault
 - ◆ Virtual Address



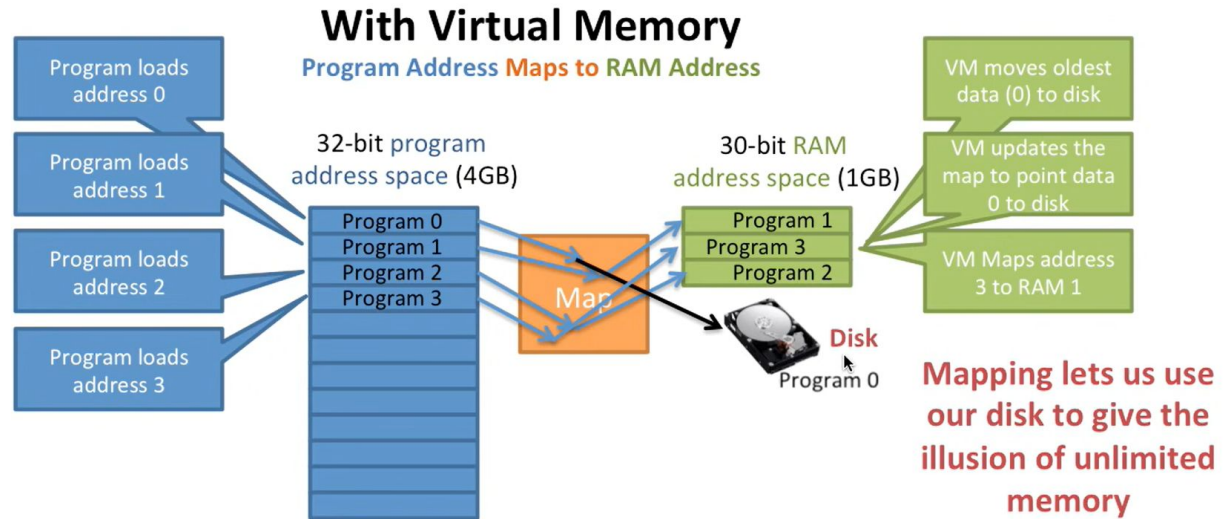
Address Translation via Page Table



Not Enough Memory



Not Enough Memory



Virtual Memory

Q: What is going to happen to the program performance when the data it needs is on the disk and not in memory?

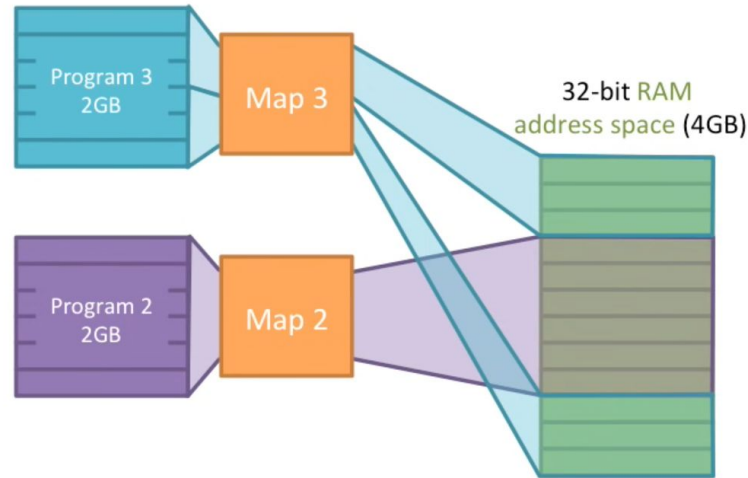
- ◆ Better performance: we can use more memory than we have
- ◆ Nothing: mapping to memory or disk is just as easy
- ◆ Worse performance: reading from disk is slower than RAM

A: Worse performance: reading from disk is slower than RAM

Remember that disks are 1000x slower than RAM. Any time you can't fit your data in memory and have to go to disk you pay a HUGE performance penalty! (This is why buying more RAM makes your computer faster.) 32-bit program address space (4GB) 30-bit RAM address space (1GB) Map Disk 15



Adjacent Space Not Required



With Virtual Memory

Program Address Maps to RAM Address

Each program has its own mapping.

Mappings lets us put our program data wherever we want in the RAM.

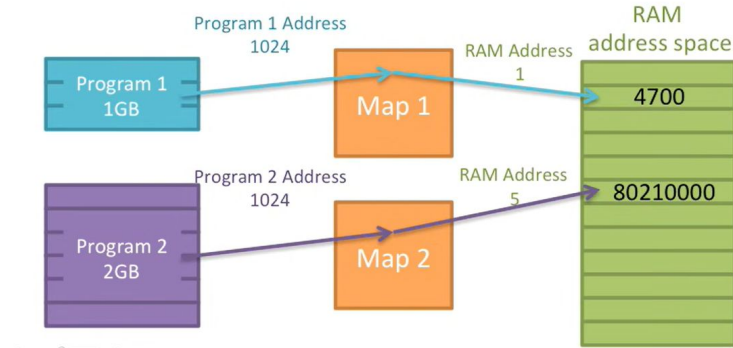
What about Security?



Keeping Program Secure

Program 1's and Program 2's addresses map to different Ram addresses

Because each program has its own address space, they cannot access each other's data: security and reliability.



With Virtual Memory

Program Address Maps to RAM Address

1. **Program 1** stores your bank balance at address 1024
1B. **VM maps** it to **RAM address 1**
2. **Program 2** stores your video game score at address 1204
2B. **VM maps** it to **RAM address 5**
3. **Neither can touch the other's data!**



Keeping Program Secure

Q: Virtual Memory lets us isolate programs so they can't share/corrupt data. What is a downside of complete isolation?

- ◆ Programs can't corrupt each other
- ◆ Programs can't share data with each other
- ◆ Programs use more space because they have their own address space
- ◆ Programs are slower because they always have to check the disk for data

A: Programs can't share data with each other

A lot of data is shared between programs. (Think about shared resources: fonts, graphics, scrollbars, icons and shared functionality: libraries, open/save dialog boxes, etc.)

However, we can use the same mapping to allow programs to share data by simply having their maps point to the same data! (Isn't indirection great?) Program 1 1GB Map 1 Program 2 2GB Map 2 RAM address space 4700 80210000 19



Thank You

