



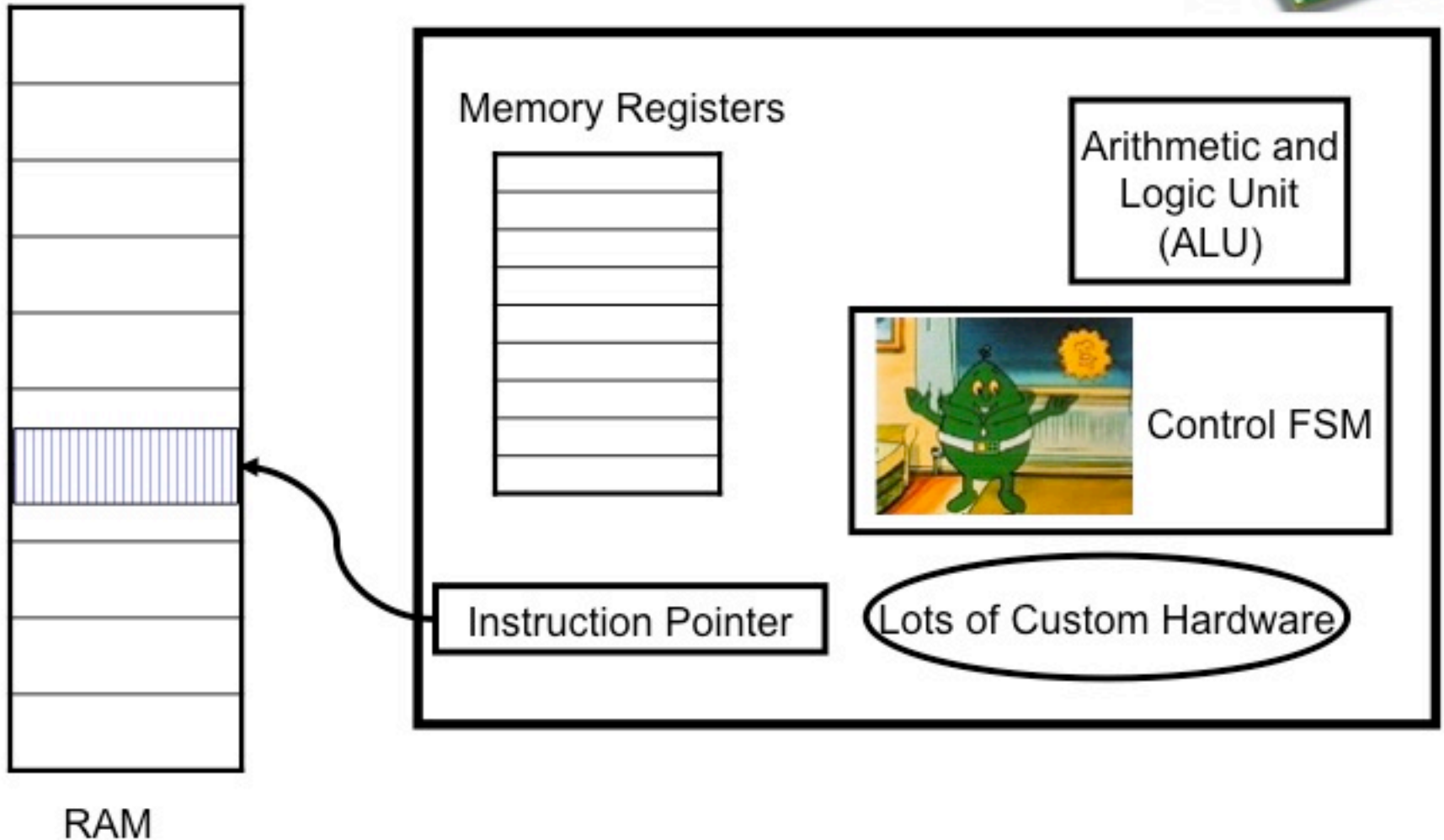
How to streamline your life (lessons from computer architecture).

COS 116, Spring 2012
Adam Finkelstein

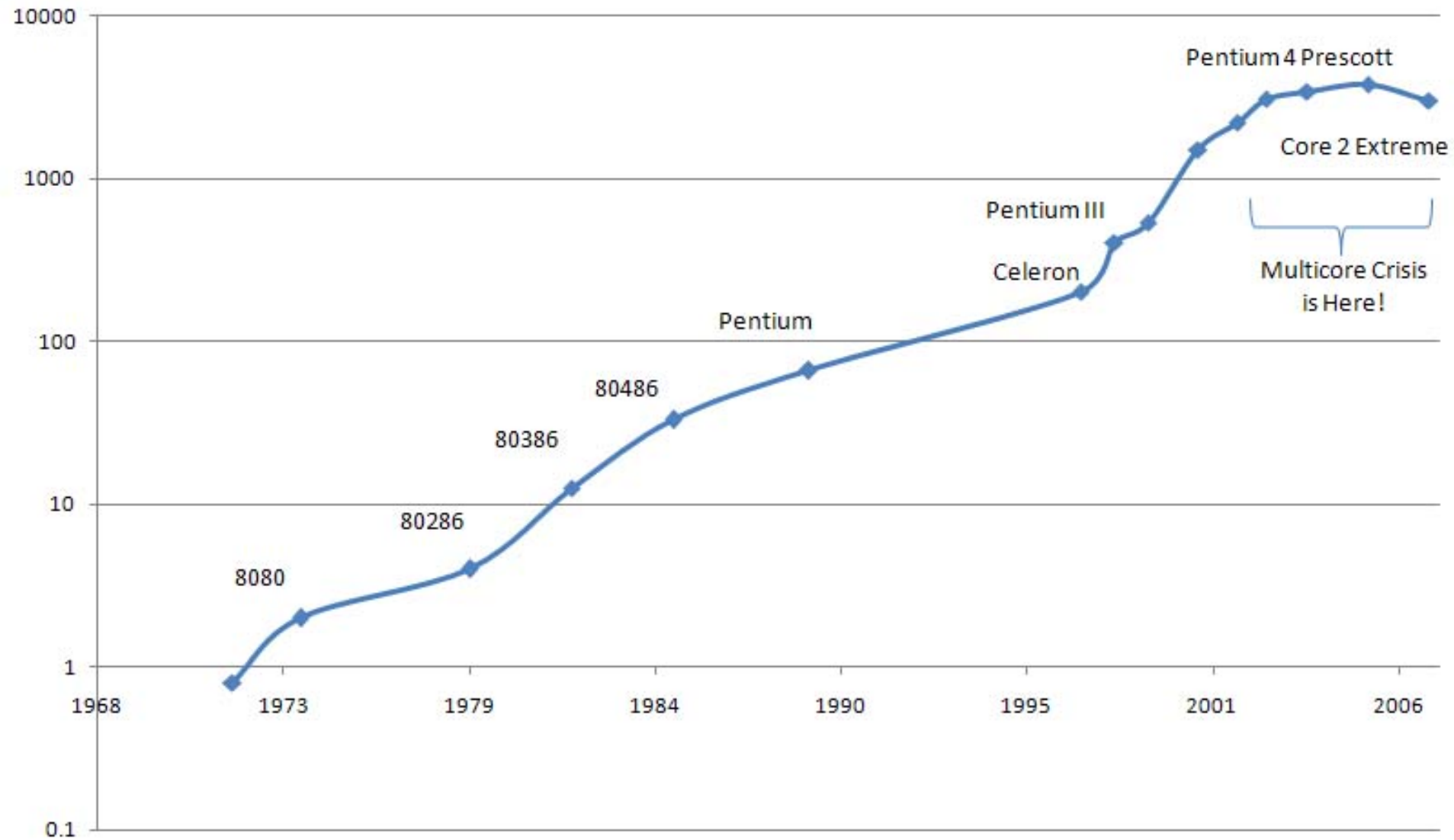
Greatly simplified view of modern CPUs.



Program (in binary)
stored in memory



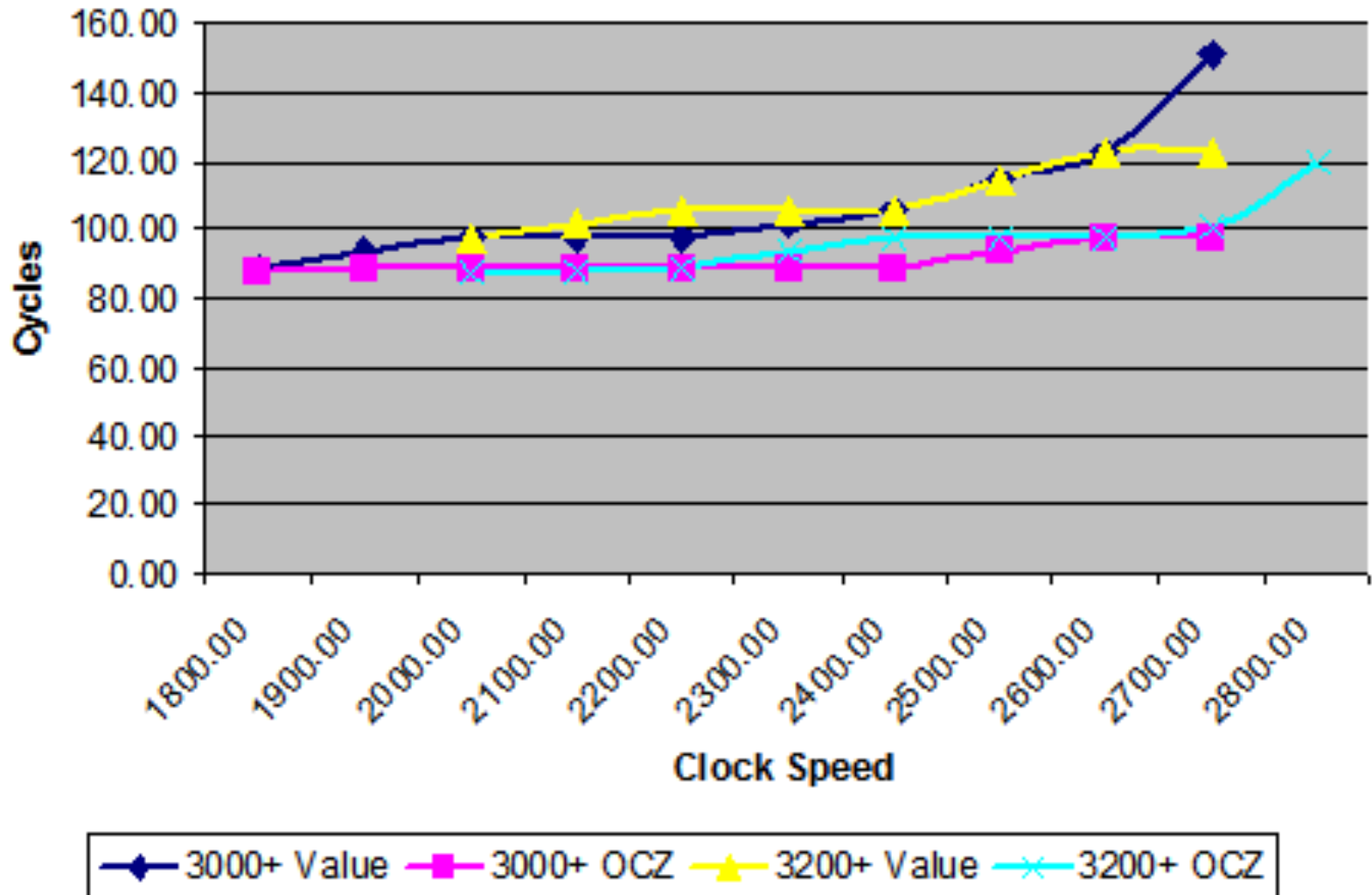
Intel Processor Clock Speed (MHz)



[Bob Warfield]

Memory Performance CPU-Z 1.30 Latency (Cycles)

[Jarred Walton]

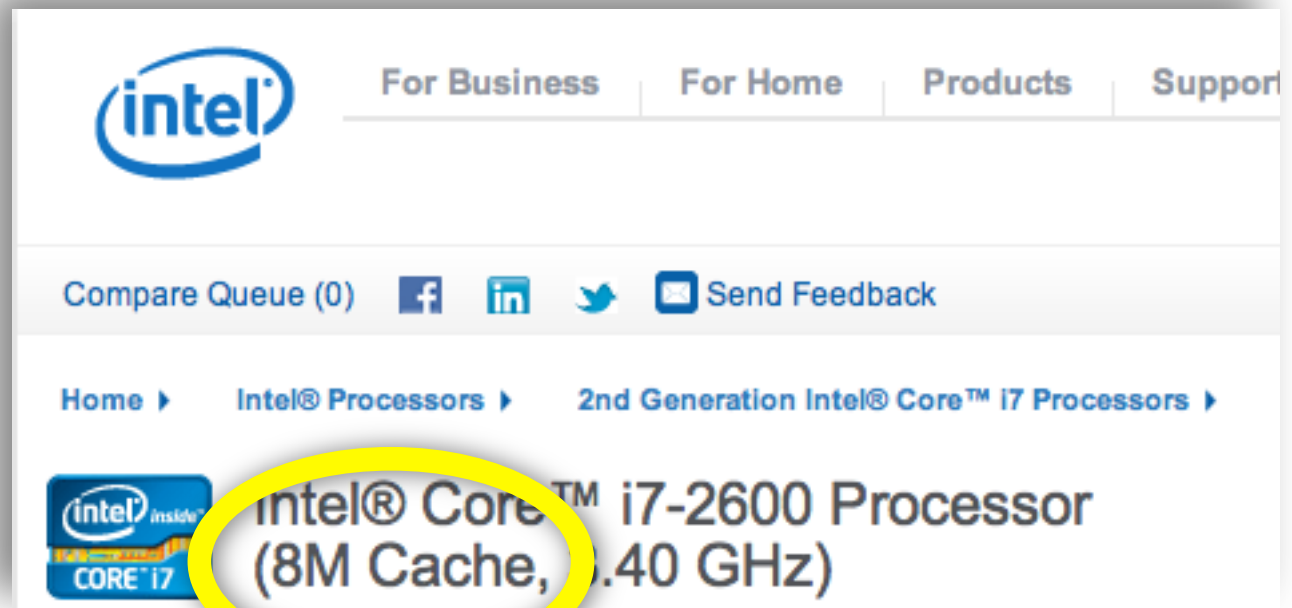


Problem:

Retrieval from memory is relatively slow.

Solution:

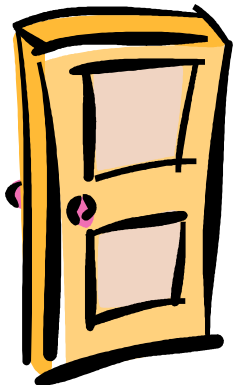
“Cache”



The image is a screenshot of the Intel website's product page for the Intel® Core™ i7-2600 Processor. The page features the Intel logo at the top left, followed by navigation links for 'For Business', 'For Home', 'Products', and 'Support'. Below the navigation is a 'Compare Queue (0)' and social media icons for Facebook, LinkedIn, and Twitter, along with a 'Send Feedback' button. The breadcrumb trail shows 'Home > Intel® Processors > 2nd Generation Intel® Core™ i7 Processors >'. The product name is 'Intel® Core™ i7-2600 Processor (8M Cache, 3.40 GHz)'. The text '(8M Cache, 3.40 GHz)' is circled in yellow.

the tired librarian

reserves



100 ft



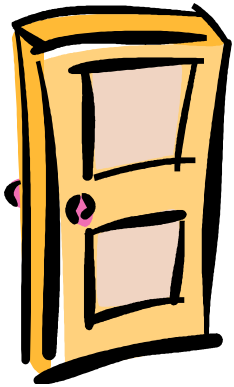
- 1000 checkouts or returns per day
- Distance covered:
 $100 \times 1000 = 100,000$ feet \sim 20 miles

“80-20 rule”

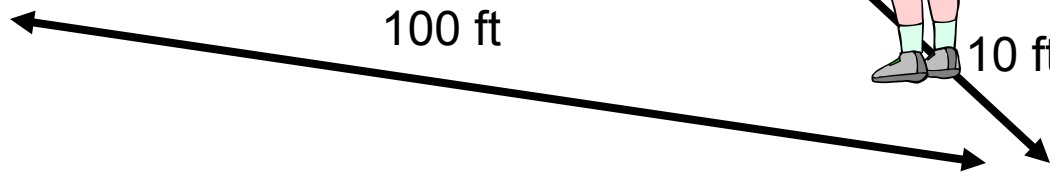
- “Pareto principle” Pareto [1906], Juran [1941]
- 80% of wealth held by 20% of the people
- 80% of work done by 20% of organization
- 80% of sales come from 20% of the clients
- 80% of computer crashes from 20% of bugs
- 80% of librarian work comes from 20% of books
- 80% of fetches are for 20% of computer memory

better arrangement

reserves



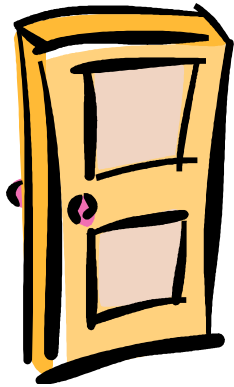
shelf with 20%
most popular books



- Distance covered:
 $20\% (100 \times 1000) + 80\% (10 \times 1000)$
 $= 28,000 \text{ feet} \sim 5 \text{ miles}$

even better arrangement

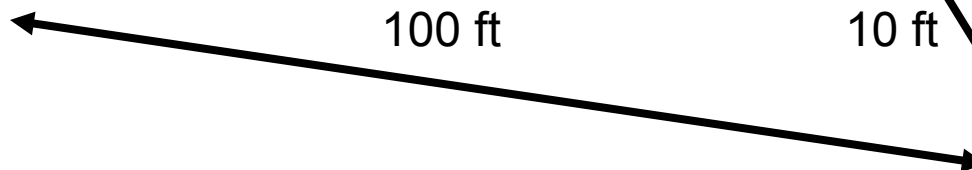
reserves



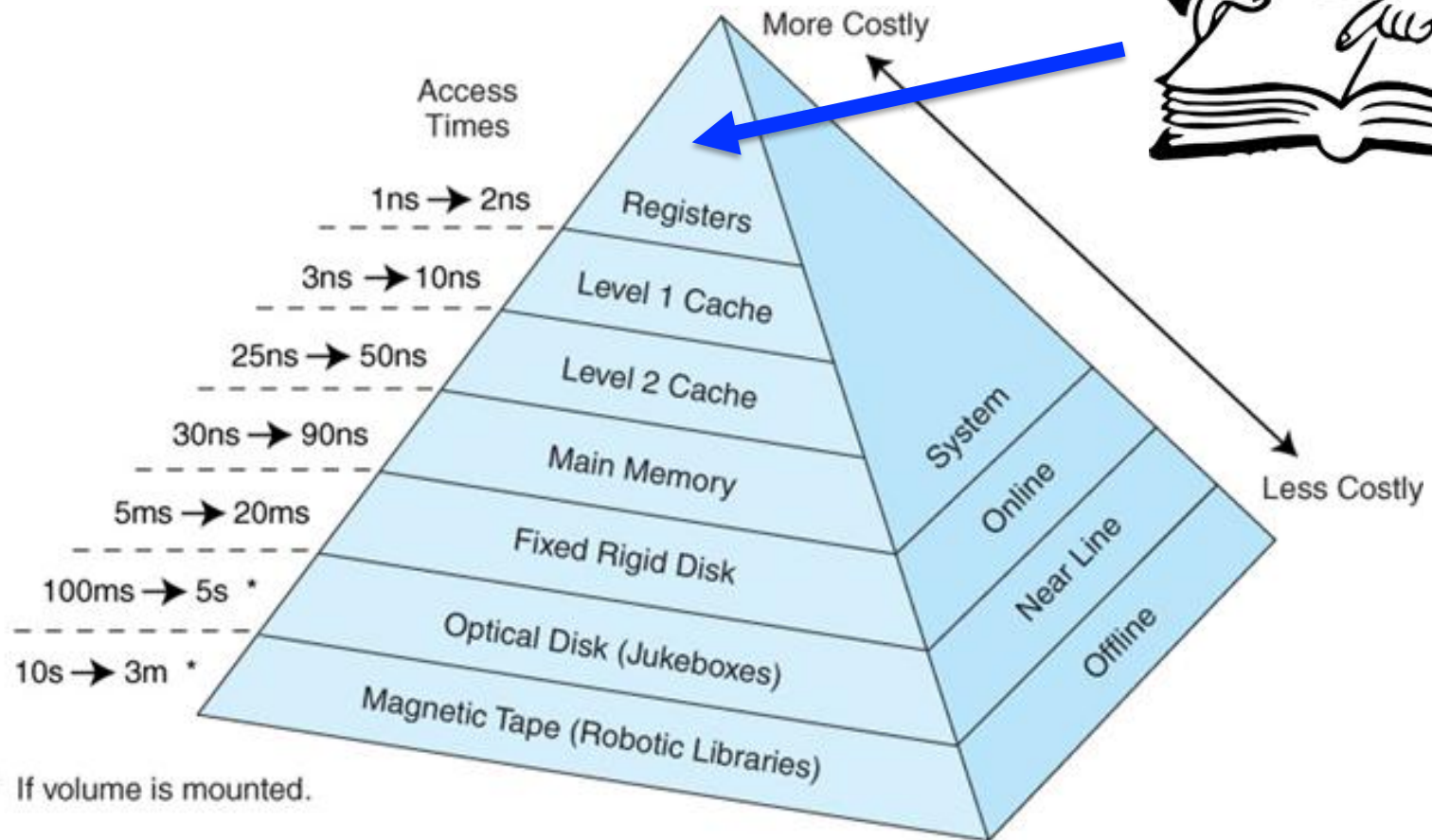
shelf with 20%
most popular books



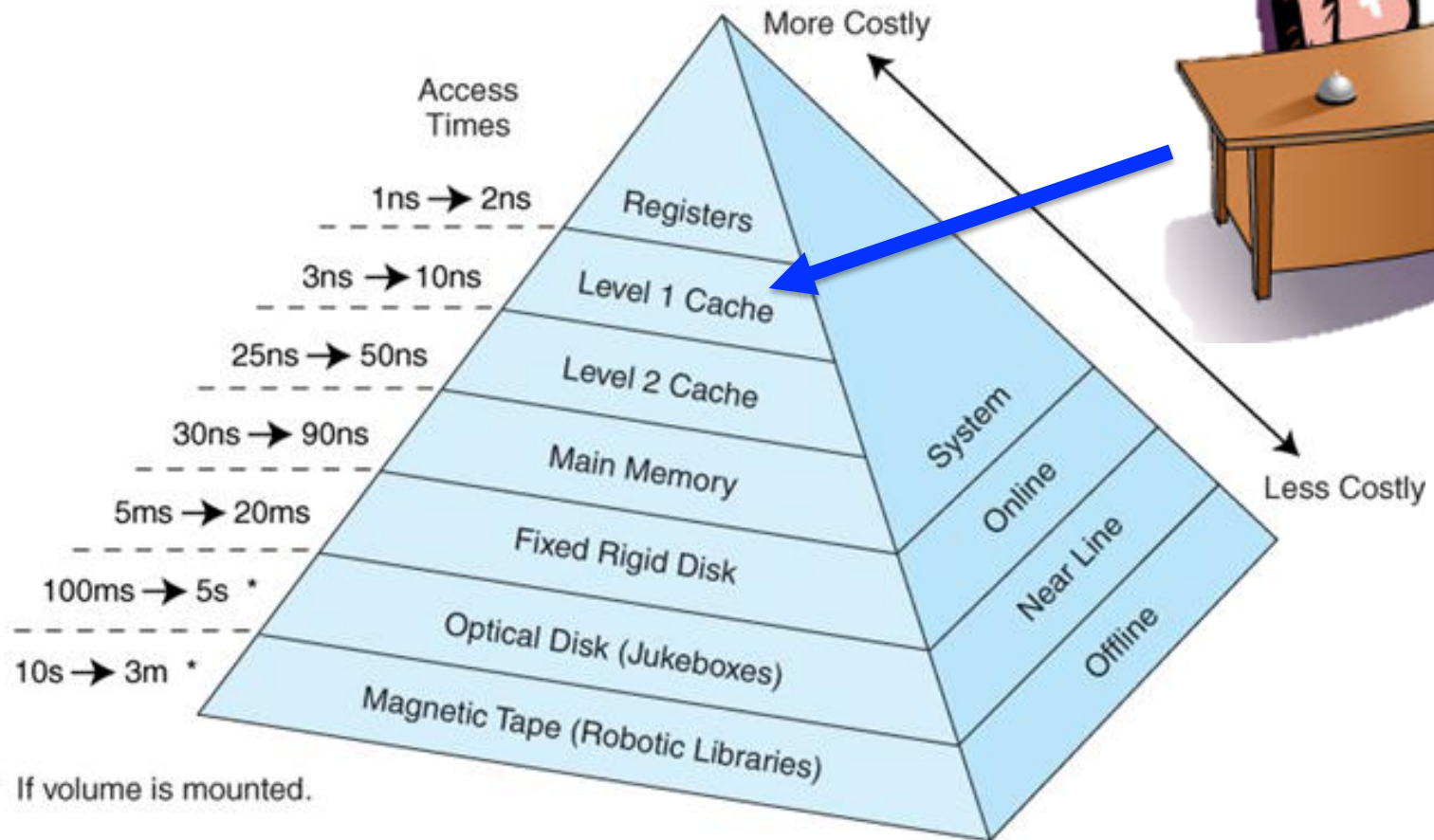
top 4%
(0 ft)



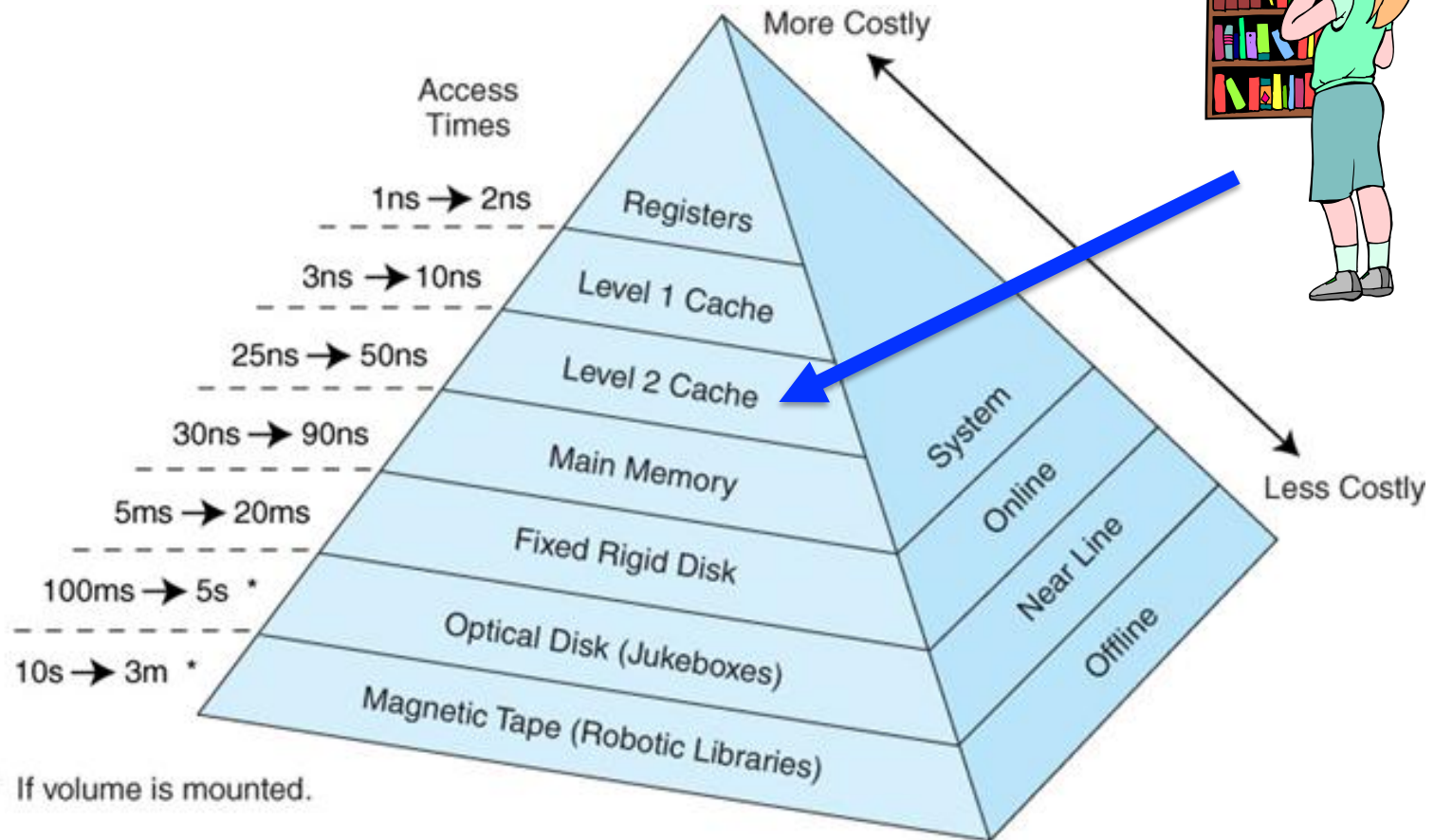
memory cache hierarchy



memory cache hierarchy

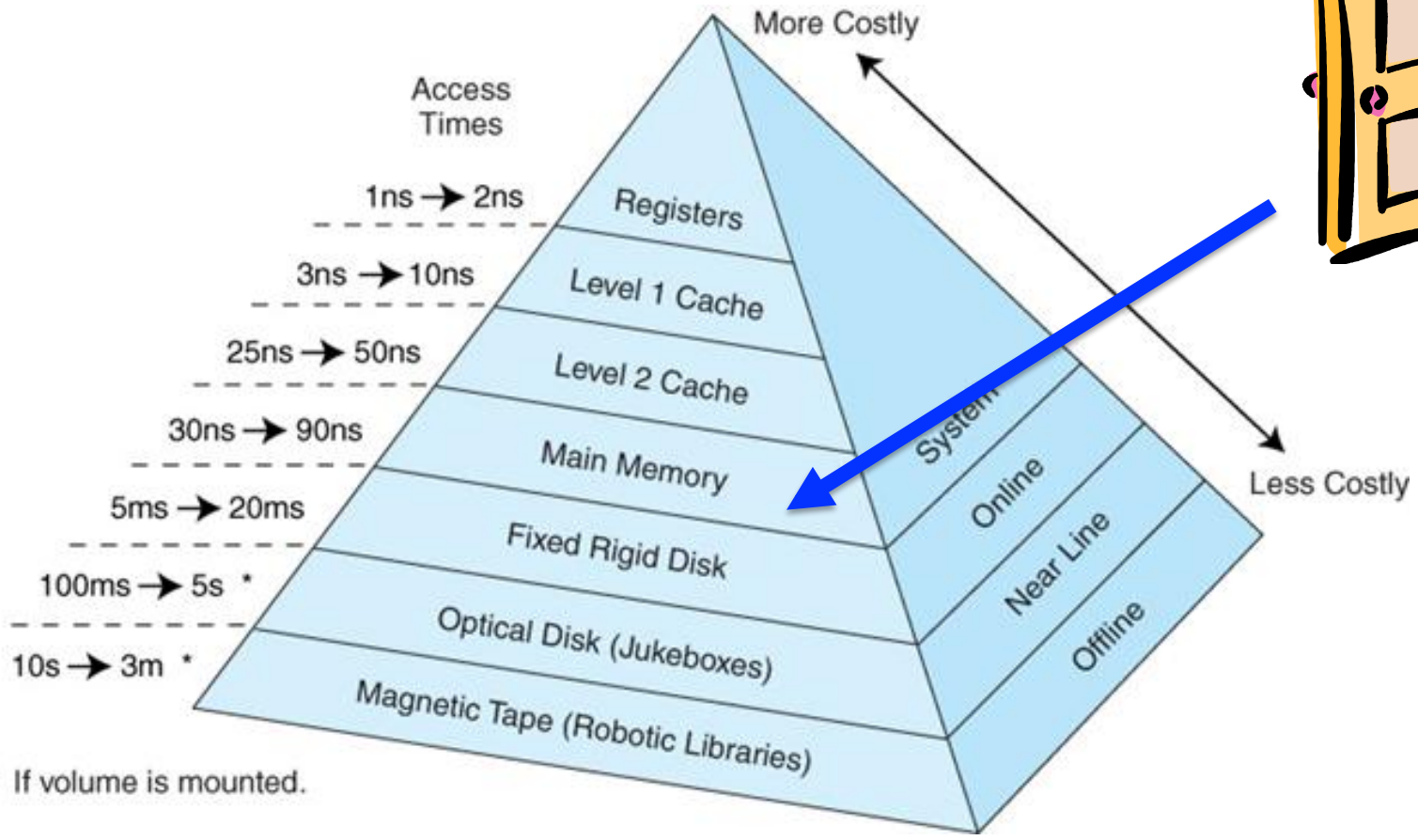
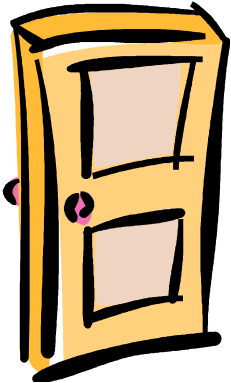


memory cache hierarchy



memory cache hierarchy

reserves



Why this Organization?

- Speed vs cost of various memories
(as of a few years ago)

| | Cost: \$ / GB | Speed: GB/s |
|-----------------------------------|---------------|-------------|
| Hard drive | 0.10 | 0.1 |
| Flash (e.g., SSD, USB stick) | 2 | 0.25 |
| RAM | 10 | 10 |
| On-chip memory for CPU (L2 Cache) | 40000 | 20 |



Cache benefit

■ Performance:

- Speed is close to that of fastest memory (cache)
- Overall capacity is that of largest memory (disk)

encyclopedia assignment

1000 questions like these:

- What is the capital city of Albania?
- Who was the fourth Roman Emperor?
- Who is the prime minister of India?
- What is the population of Argentina?
- Which team won the 1968 World Series?
- ...etc.

encyclopedia assignment

Does cache help?

- Cache works ok.
- Needed volume is often at librarian's desk.
- Lucky when questions are in same volume.





Discussion Time

- Is the librarian's problem solved?

How to predict the 20% most popular books for next day?

- In general, no easy solution
- In practice, use rules of thumb
 - Example: “Least Recently Used”. When you need to create space on the desk (or shelf), move out the book that was used least recently
 - Many others (LRU is computationally expensive)

Question



- How does the same program (.exe file) run on different PCs with different memory configurations?
- Answer: “Virtual Memory”
 - All programs live a fiction: allowed to pretend they each have 2^{32} or 2^{64} bytes of memory
 - Illusion is preserved by hardware

Virtual Memory

■ Program's view:

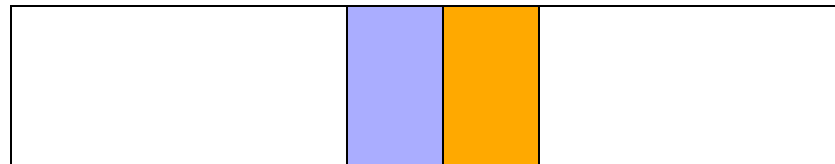
Powerpoint



Memory:

Lec14.ppt

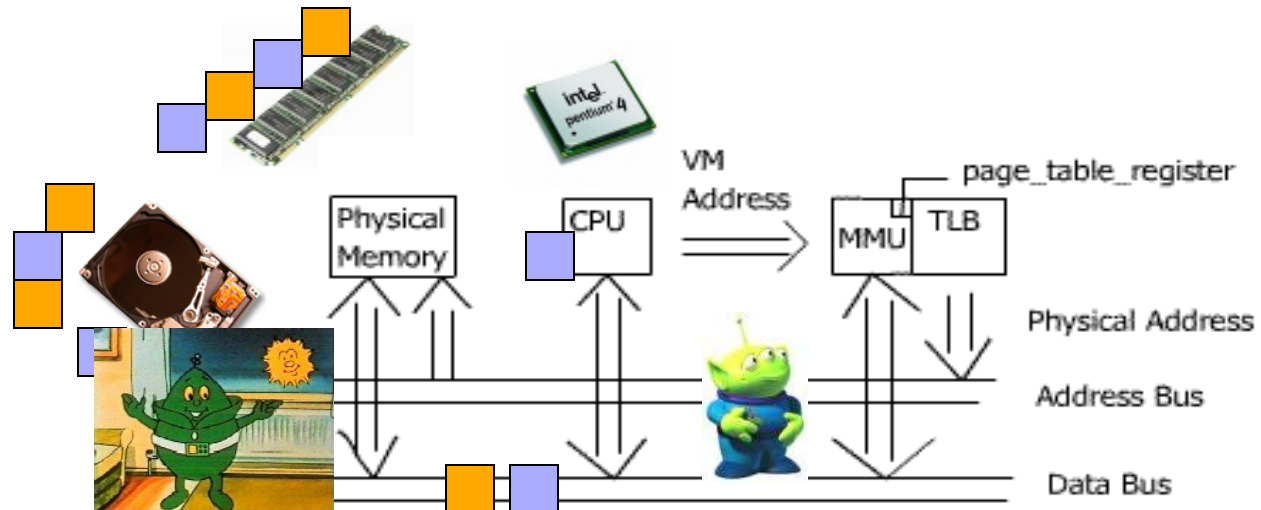
Lec15.ppt



Address 0

Address $2^{64} - 1$

■ Underneath:



Lesson 2: Multitasking

- “The Multitasking Generation”



An Evening's Tasks for a Gen-M'er

- Homework
- Listen to music
- Instant Messaging
- Call Mom (goes to bed by 11 PM!)
- Answer phone
- Read a bit more of Joyce's *Ulysses*
- Watch the Daily Show

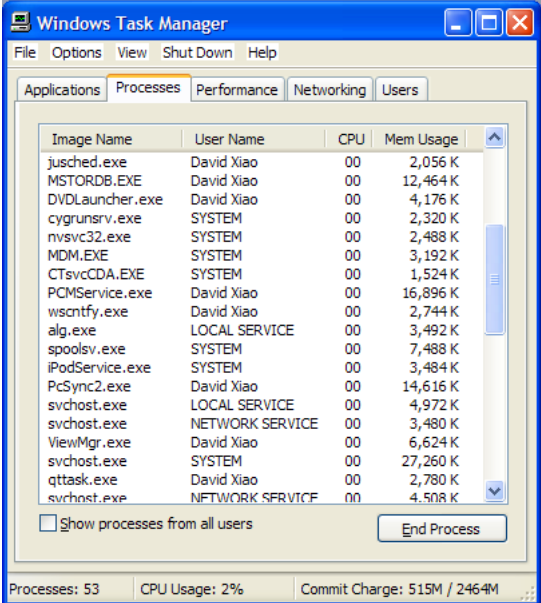


How do you do it all?!?

Tasks done by my PC last night

- Word processing
- Play CD
- Download news updates
- Download email
- Run clock
- Hidden tasks: handle network traffic, manage disk and RAM traffic, scheduler, etc.

Managed by “Operating System”
(Windows, Linux, MacOS, etc.)



| Image Name | User Name | CPU | Mem Usage |
|-----------------|-----------------|-----|-----------|
| jusched.exe | David Xiao | 00 | 2,056 K |
| MSTORDB.EXE | David Xiao | 00 | 12,464 K |
| DVDLauncher.exe | David Xiao | 00 | 4,176 K |
| cygrunsvr.exe | SYSTEM | 00 | 2,320 K |
| nsvsc32.exe | SYSTEM | 00 | 2,488 K |
| MDM.EXE | SYSTEM | 00 | 3,192 K |
| CTsvcCDA.EXE | SYSTEM | 00 | 1,524 K |
| PCMSvc.exe | David Xiao | 00 | 16,896 K |
| wscntfy.exe | David Xiao | 00 | 2,744 K |
| alg.exe | LOCAL SERVICE | 00 | 3,492 K |
| spoolsv.exe | SYSTEM | 00 | 7,488 K |
| iPodService.exe | SYSTEM | 00 | 3,484 K |
| PcSync2.exe | David Xiao | 00 | 14,616 K |
| svchost.exe | LOCAL SERVICE | 00 | 4,972 K |
| svchost.exe | NETWORK SERVICE | 00 | 3,480 K |
| ViewMgr.exe | David Xiao | 00 | 6,624 K |
| svchost.exe | SYSTEM | 00 | 27,260 K |
| qtask.exe | David Xiao | 00 | 2,780 K |
| svchost.exe | NETWORK SERVICE | 00 | 4,508 K |

Show processes from all users End Process

Processes: 53 CPU Usage: 2% Commit Charge: 515M / 2464M

Multitasking vs. Parallel Processing

Multitasking: A single CPU handles many tasks by switching rapidly among them.

(e.g., all Wintel machines since early 1990s; all Unix machines since the 1970s)


Parallel Processing: Multiple CPUs that do the work of a single CPU. (But, 4 CPUs do not necessarily mean 4x speed.)

XPS 420

Intel® Core™2 Q6600

Quad-Core (8MB L2

cache, 2.4GHz, 1066FSB)



Scheduler's objectives

- Fairness
- Timeliness
- Critical tasks processed promptly
- Low overhead

How can one achieve these
(often conflicting) goals?