Computer Science 703

Advance Computer Architecture

2005 Semester I

Lecture Notes

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Computer Design Issues/Technology

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Reference

Hennessy & Patterson, *Computer Architecture: A Quantitative Approach* (3rd Ed.), 2003, Chapter 1.

Scaling of transistors, wires, & Power

- Feature size: minimum size of a transistor or wire in one dimension (today: 0.09 microns = 90 nm)
- Smaller features imply
  - lower voltage
  - increased speed
- But, wires do not scale! They get worse!

Power

- Major limit today:
  - delivering clean voltage to the chip
  - dissipating heat generated
- Two kinds of power, both getting worse
  - static (leakage)
  - dynamic (switching)

Integrated Circuit Economics

$$\text{Die yield} = \text{wafer yield} \times \left(1 + \frac{\text{Defects per unit area} \times \text{Die area}}{\alpha}\right)^{-\alpha}$$

For current CMOS, $\alpha \approx 4$

In practice, at cost-effective point,

$$\text{Die cost} \approx (\text{Die area})^2$$

Cost vs. Price

- Price often (not always) tracks cost
- Learning curve for each new generation
  - Costs plummet as processes are tuned
  - Volume is critical
- Integrated circuits: good dies/wafer
  - Expensive, infrequent
  - Larger wafer increases potential number
  - Larger die-size reduces potential number

Cost vs. Price (con't)

- Hardware is different than software!
  - High development cost, but
  - Manufacturing and testing (direct costs) are per unit
- Gross margins: 10-45%
- Corporate goal: component that is
  - Unique
  - High-volume

Rules of Thumb

- Every 3 years DRAMs increase in size by 4X. Gordon Moore
- Every 3 years transistor count on a chip increases 4X. Andy Glew
- Every 3 years chip speed increases by 2X. Andy Glew
- Every 10 years DRAMs get 30% faster. Andy Glew
- Every 3 years Disks increase in size by 2X. Andy Glew
- Every 10 years Disks get 30% faster. Andy Glew
- Programmers increase the size of programs 2X every year. Andy Glew
- 1Mb/s of I/O bandwidth is required per MIPS. Gene Amdahl
- Doubling volume reduces cost by 10% Gordon Bell

Amdahl's Law

You need to go 100 km, ½ by auto and ½ walking

Question: if you travel half way at 100km/hr and half way at 5km/hr, what is your average speed?

Answer: ~~$\frac{100+5}{2} = 52.5 km/hr$~~

Question: How long does it take to get there?

Answer: $\frac{50km}{100km/hr} + \frac{50km}{5km/hr} = 10.5hr$

Average speed: $\frac{100km}{10.5hours} = 9.5km/hr$

Amdahl's Law

- Even if first half is done instantly, average is still only 10 km/hour!
- Amdahl's Law: the performance improvement to be gained from using some faster mode of execution is limited by the fraction of the time the faster mode can be used.

Amdahl's Law

$$\text{Speedup} = \frac{\text{Performance for entire task using the enhancement when possible}}{\text{Performance for entire task without using the enhancement}}$$

Alternatively,

$$\text{Speedup} = \frac{\text{Execution time for entire task without using the enhancement}}{\text{Execution time for entire task using the enhancement when possible}}$$

Clocks per Instruction (CPI)

Execution time = # instructions
× average # clocks/instruction
× clock period

What is "average # clocks/instruction"? CPI