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COMS 321
WA-1

Question 1.1

- Personal Computer - These computers are the best-known form of computing, which readers of this document have likely used extensively. Personal computers emphasize delivery of good performance to single users at low cost and usually execute third party software. This class of computing drove the evolution of many computing technologies.

- Servers - These computers are the modern form of what were once much larger computers and are usually accessed only via a network. Servers are oriented to carrying sizable workloads, which may consist of either single complex applications, usually a scientific or engineering application, or handling many small jobs, such as would occur in building a large web server. These applications are usually based on software from another source (such as a database or simulation system) but are often modified or customized for a particular function. Servers are built from the same basic technology as desktop computers, but provide for greater computing, storage, and input/output capacity. In general, servers also place a higher emphasis on dependability, since a crash is usually more costly that it would be on a single user PC.

- Supercomputers - These are computers which at present consist of tens of thousands of processors and many terabytes of memory, and cost tens to hundreds of millions of dollars. Supercomputers are usually used for high-end scientific and engineering calculations such as weather forecasting, oil exploration, protein structure determination, and other large-scale problems. Although such supercomputers represent the peak of computing capability, they represent a relatively small fraction of the servers and thus a proportionally tiny fraction of the computer market in terms of total revenue.

- Embedded Computers - These computers are the largest class of computers and span the widest range of applications and performance. Embedded computers include the microprocessor found in your car, the computers in a television set, and the networks of processors that control a modern airplane or cargo ship. Embedded computing systems are designed to run one application or one set of related applications that are normally integrated with the hardware and delivered as a single system. Thus, despite the large number of embedded computers, most users never really see that they are using a computer.

Question 1.3

- To speak directly to electronic hardware, we need to send electrical signals. The easiest signals for computers to understand are on and off, and so the computer alphabet is just two letters which are the number 0 and 1 or binary numbers.

- Computers execute our commands called 'instructions' which are just collections of bits that the computer can understand and obey. For example, the bits 1000110110100000 tell the computer to add two numbers.

- This process was too tedious for humans, so using the computer to help program the computer, the pioneers invented software that translates from symbolic notations to binary. The first of these programs was called an 'assembler'. For example, the programmer would write ADD A, B and the assembler would translate this notation into 1000110010100000. The binary language that the machine understands is the 'machine language'.

- While this was a tremendous improvement, assembly language requires the programmer to write one line for every instruction that the computer will follow, forcing the programmer to think like the computer.

- One of the great breakthroughs in the early days of computing was the recognition that a program could be written to translate a more powerful language into computer instructions. For example, the high-level programming language C.

- To put it concisely and break things down, a program written in a high-level language such as C is compiled into assembly language by the compiler, which is then translated into binary machine language by the assembler, which is directly executed by a computer processor.

Question 1.4

a. Given that each color uses 8 bits, and we are dealing with 3 colors per pixel, each pixel will use 24 bits. 1 byte is 8 bits, so each pixel will be using 24/8 = 3 bytes per pixel.

   The frame is of size 1280 * 1024, so total bytes that can fit in the frame:
   = 1280 * 1024 * 3
   = 3932160 bytes/frame

b. 100Mbits/s = 100*10^6 bits/s = 100000000 bits/s
   In bytes/s it would be 100000000/8 = 12500000 bytes/s Total

   time = 3932160 / 12500000 = 0.314 seconds

Question 1.5

Performance = Clock Rate / CPI

a. P1's Performance = 3GHz / 1.5
   $= 3*10^9/1.5$
   $= 2 * 10^9$ I/s

   P2's Performance = $2.5 * 10^9$ I/s

   P3's Performance = $1.818 * 10^9$ I/s

   Processor 2 (P2) has the highest performance.

b. Cycles = Clock Rate * Time
   Instructions = Cycles / CPI

   P1 Cycles = $3 * 10^9$ x 10 = $3 * 10^{10}$ cycles.
   P1 Instructions = $3 * 10^{10}$ / 1.5 = $2 * 10^{10}$ instructions

   P2 Cycles = $2.5 * 10^{10}$ cycles
   P2 Instructions = $2.5 * 10^{10}$ instructions

   P3 Cycles = $4 * 10^{10}$ cycles
   P3 Instructions = $1.818 * 10^{10}$ instructions

c. New Processor Speed = (Total Instructions * New CPI) / New Execution Time

   New CPI will be calculated by doing 1.2 * original CPI since it's given that there's an increase in the CPI by 20%.

   New Execution Time would be 0.7 * 10 = 7 seconds since we want it to run in 30% less time.

   P1 New Speed = ($2.0 * 10^{10}$ * 1.8) / 7 = 5.143 GHz P2 New Speed = ($2.5 * 10^{10}$ * 1.2) / 7 = 4.286 GHz P3 New Speed = ($1.8 * 10^{10}$ * 2.64) / 7 = 6.789 GHz

Question 1.9.1

CPU Execution Time = Clock Cycles / Clock Rate

- 1 Processor

  $((1 * 2.56 * 10^9) + (12 * 1.28 * 10^9) + (5\ 2.56 * 10^8))\ /\ 2 * 10^9$ = 9.6 seconds

- 2 Processors

  $(((1 * 2.56 * 10^9) + (12 * 1.28 * 10^9))/(0.7 * 2) + (5 * 2.56 * 10^8)\ )/\ 2 * 10^9$ = 7.04 seconds

  Relative Speedup = 9.6 / 7.04 = 1.36

- 4 Processors

  $(((1 * 2.56 * 10^9) + (12 * 1.28 * 10^9))\ /\ (0.7 * 4) + (5 * 2.56 * 10^8)\ )\ /\ 2 * 10^9$ = 3.84 seconds

  Relative Speedup = 9.6 / 3.84 = 2.5

- 8 Processors

  $(((1 * 2.56 * 10^9) + (12 * 1.28 * 10^9))\ /\ (0.7 * 8) + (5 * 2.56 * 10^8)\ )/\ 2 * 10^9$ = 2.24 seconds

  Relative speedup = 9.6 / 2.24 = 4.29

Question 1.9.2

- 1 Processor

  $((2 * 2.56 * 10^9) + (12 * 1.28 * 10^9) + (5 * 2.56 * 10^8)) / 2 * 10^9$
  10.88 seconds

  Relative slowdown = 10.88 / 9.6 = 1.13

- 2 Processors

  Using the same formula we get,
  7.95 seconds

  Relative Slowdown = 1.13

- 4 Processors

  Using the same formula we get,
  4.3 seconds

  Relative Slowdown = 1.12

- 8 Processors

  Using the same formula we get,
  2.47 seconds

  Relative Slowdown = 1.1

Question 1.9.3

Execution Time must be 3.84 seconds.

Clock cycles = $2 * 10^9 * 3.84 = 7.68$

Therefore, CPI new = $(7.68 * 10^9 - 3.84 * 10^9) / 1.28 * 10^9 = 3$

Question 1.11.1

CPI = (CPU Execution Time) / Instruction * Clock Cycle Time
= $750 / 2.389 * 10^{12} * 0.333 * 10^{-9}$
= 0.94

Question 1.11.4

CPU Execution Time: Instructions * CPI * Clock Cycle Time

New CPU Execution Time = 1.1 * Instructions * 1.05 * CPI * Clock Cycle
= 1.155 * Old Execution Time
= 866.25

Therefore, the increase would be approximately 116.25 seconds

Question 1.11.6

CPU Execution Time = Instructions * CPI * Clock Cycle Time CPI =
Clock Rate * CPU Execution Time / Instructions
= $4 * 10^9$ 8 700 / 0.85 * $2.389 * 10^{12}$
= $2.8 * 10^{12} / 2.03 * 10^{12} = 1.38$

Question 1.11.11

It is given that the CPI has been reduced by 15% and the CPU time by 20%.

New Clock Rate = Instructions * CPI * 0.85 / CPU Execution Time * 0.8
= Old Clock rate * 0.85 / 0.8
= 4 * 0.85 / 0.8
= 4.2GHz

Question 1.12.1

Execution time for P1: $0.9 * 5 * 10^9 / 4 * 10^9 = 1.125$ seconds
Execution time for P2: $0.75 * 1 * 10^9 / 3 * 10^9 = 0.25$ seconds

Execution time of P2 is lesser than P1, so P2 has a better performance than P1, therefore this statement is false.

Question 1.12.2

We can equate the Execution Times of P1 and P2 to figure this out

$1 * 10^9 * 0.9 / 4 = I * 0.75 / 3$, where I is the instructions

$IP2=0.9*3*10^9/4*0.75$
$= 2.7*10^9/3$
$= 0.9 * 10^9$ instructions

Question 1.12.3

MIPS = Clock rate / CPI * 10^6
MIPS P1 = $4 * 10^9 / 0.9 * 10^6 = 4.44 * 10^3$
MIPSP2=$3*10^9/0.75*10^6=4*10^3$

MIPS P1 is greater than MIPS P2, but Performance P1 < Performance of P2 Therefore, this statement is false.

Question 1.12.4

Execution time for P1 = 1.125 seconds
Execution Time for P2 = 0.25 seconds

MFLOPS P1 = $0.4 * 5 * 10^9 / (1.125 * 10^6) = 2 * 10^3 / 1.125$
$= 1.78 * 10^3$ MFLOPS / second
MFLOPS P2 = $0.4 * 1 * 10^9 / (0.25 * 10^6)$
$= 1.6 * 10^3$ MFLOPS / second

Question 1.13.1

Time spent on FP operations after reducing 20% = 56 seconds

Total time now would be 250 - (70 - 56) = 236 seconds

Question 1.13.2

Time spent initially = 250 - (70 + 85 + 40) = 55 seconds

Time spent after reduction = 250 * 0.8 - (70 + 85 + 40) = 5

Reduction as a percentage would be 50 / 55 = 90.9%

Question 1.13.3

Branch Instruction occupy 40 / 250 = 16% of total time

Removing all branch instructions would only decrease total time by 16%, Therefore we cannot reduce the total time by 20% by adjusting branch instructions.

Question 1.15

- 1 Processor

  Execution Time = 100 seconds

- 2 Processors

  Execution time = 100/2 + 4 = 54 seconds
  Execution time / processor = 27 seconds
  Relative Speedup = 1.852
  Ideal Speedup = 2
  Ratio = 0.926

- 4 Processors

  Execution time = 100/4 + 4 = 29 seconds
  Execution time / processor = 29 /4 = 7.25 seconds
  Relative speedup = 100/29 = 3.44
  Ideal Speedup = 100/ (29 -4) = 4
  Ratio: 3.4483 / 4 = 0.862

- 8 Processors

  Execution time = 100/8 + 4 = 16.5 seconds
  Execution time / processor = 16.5 / 8 = 2.06 seconds
  Relative speedup = 100/16.5 = 6.06
  Ideal Speedup = 100/ (16.5 -4) = 8
  Ratio: 6.06 / 8 = 0.7575

- 16 Processors

  Execution time = 100/16 + 4 = 10.25 seconds
  Execution time / processor = 10.25/ 16 = 0.64 seconds
  Relative speedup = 100/10.25 = 9.75
  Ideal Speedup = 100/ (10.25 -4) = 16
  Ratio: 9.756 / 16 = 0.61

- 32 Processors

  Execution time = 100/32 + 4 = 7.125 seconds
  Execution time / processor = 7.125 / 32 = 0.22 seconds
  Relative speedup = 100/7.125 = 14.03
  Ideal Speedup = 100/ (7.125 -4) = 32
  Ratio: 14.0351 / 32 = 0.4375

- 64 Processors

  Execution time = 100/64 + 4 = 5.56 seconds
  Execution time / processor = 5.5625 / 64 = 0.08 seconds
  Relative speedup = 100/5.5625 = 17.977 Ideal Speedup =
  100/ (5.5625 - 4) = 64
  Ratio: 17.97753 / 64 = 0.28

- 128 Processors

  Execution time = 100/128 + 4 = 4.78 seconds
  Execution time / processor = 4.78/ 128 = 0.03 seconds
  Relative speedup = 100/4.78 = 20.92
  Ideal Speedup = 100/ (4.78 - 4) = 128
  Ratio: 20.92 / 128 = 0.16