Due on
08/31/22

Comp Architecture - Assignment 1

Soln 1:

Power & Energy (30 Points)

→ Processor runs at: (CPU Bound assumption)

freq: 2 GHz

Voltage: 1.1 V

Total Power: 110 W

20 W Leakage Power

90 W Dynamic power

Time taken: 50 s

Assumption: Voltage & freq follow linear relation

V range (0.9V - 1.2V)

(i) Smallest time it takes to execute the program

→ Since, V & freq have a linear relation, if V ↑ then freq ↑ propotionally.

For min. time, freq should be max (under safety levels) $\left(freq \propto \frac{1}{\text{exec time}}\right)$

if V increases → 1.1V to 1.2V

$$freq_{new} = 2 \times \frac{1.2}{1.1} = 2.182 \text{ GHz}$$

$\therefore$ exec time (By inverse propotionality) $= 50 \times \frac{2}{2.182} = \boxed{45.83 \text{ secs}}$

min - exec time.

ii) Highest Power to execute the Program

Since Dynamic Power $\propto V^2 \times f$

To ↑ D.P, we would maximize V, hence f

As per previous part:

V : $1.1V \rightarrow 1.2V$

f : $2\text{ GHz} \rightarrow 2.182\text{ GHz}$ (proportional to V)

$$\frac{D.P_{old}}{D.P_{max}} = \frac{V_0^2 \times f_0}{V_{max}^2 \times f_{max}}$$

$$\frac{90}{D.P_{max}} = \frac{1.1 \times 1.1 \times 2}{1.2 \times 1.2 \times 2.182}$$

$$D.P_{max} = 116.84\text{ W}$$

Also,

Leakage Power $\propto$ Supply voltage

$$\text{Leakage Power}_{max} = 20 \times \frac{1.2}{1.1}$$

$$= 21.818\text{ W}$$

$$\text{Total max Power} = 116.84 + 21.818$$

$$= \boxed{138.66\text{ W}}$$

iii Lowest Energy to execute the Program

→ we use DVFS to minimize energy

$\therefore$ minimum V : 1.1 V → 0.9 V

Hence,

minimum f : $2 \times \frac{0.9}{1.1} = 1.636$ GHz

$$\frac{D.P_{old}}{D.P_{min}} = \frac{1.1 \times 1.1 \times 2}{0.9 \times 0.9 \times 1.636} = \frac{90}{D.P_{min}}$$

$D.P_{min} = 49.28$ W

Also,

L.P $\propto$ Supply V

$L.P_{min} = 20 \times \frac{0.9}{1.1} = 16.364$ W

Total $P_{min} = 49.28 + 16.364$

$= 65.64$ W

Since,

exec time $\propto \frac{1}{f}$

exec $time_{new} = 50 \times \frac{2}{1.636} = 61.125$ secs

Min energy $= T.P_{min} \times$ exec $time_{new}$

$= 65.64 \times 61.125$

$= \boxed{4012.25 \text{ J}}$

- Soln 2: Power & Energy (30 Pts)

→ Processor

$f = 3\,GHz$, $V = 1V$, $T = 100s$, $D.P = 80W$, $L.P = 20W$

Above values are baseline values.

Considering memory bound Y %

Y % of 100s (baseline time)

memory access time = $\frac{Y}{100} \times 100 = Y$ sec

CPU access time = $100 - Y$

Since freq ↓ to 1.5 GHz (Half)

CPU time will double = $2(100 - Y)$

memory time unaffected = Y

Baseline Energy = $(80 + 20) \times 100$

$= 10000\,J$

Now if frequency is halved (Applying DFS)

D.P : 80 W to 40 W

L.P will be constant

New T.P = $40 + 20 = 60\,W$

Eqn for minimum Y % memory bound such that energy is less than baseline

New Power × New time $< 10000\,J$

$$60 \times (2(100 - Y) + Y) < 10000\,J$$

$60 \times (200 - Y) < 10000$

$200 - Y < \frac{500}{3}$

$Y > 33.33$

The System should be > 33.33% memory bound to reduce energy than baseline

$\boxed{Y\% = \sim 34\%}$

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3) Sum of Execution times (20 pts)

	P	Q	R	S
Sys A (secs)	100	120	80	400
Sys B (secs)	120	80	100	300
Sys C (secs)	90	110	90	500

a) Sum of Execution time

Total exec time for B = 120 + 80 + 100 + 300
= 600 s

Total exec time for C = 90 + 110 + 90 + 500
= 790 s

$\text{Speedup (C to B)} = \frac{\text{exec time of B}}{\text{exec time of C}} = \frac{600}{790}$
$= 0.76$

∴ System C has 0.76 times the performance than B

b) Sum of weighted exec time

Ref machine = System A

For P, Normalize factor = $\frac{1}{100}$

For Q, Normalized factor = $\frac{1}{120}$

For R, " = $\frac{1}{80}$

For S, " = $\frac{1}{400}$

$$SWET(B) = \frac{1}{100} \times 120 + \frac{1}{120} \times 80 + \frac{1}{80} \times 100 + \frac{1}{400} \times 300$$
$$= 3.87$$

$$SWET(C) = \frac{1}{100} \times 90 + \frac{1}{120} \times 110 + \frac{1}{80} \times 90 + \frac{1}{400} \times 500$$
$$= 4.192$$

$$\text{Speedup} = \frac{3.87}{4.192} = 0.923$$

System C has speed up 0.923 times that of B

(less performance)

c) GM of execution times

$$GM = \sqrt[n]{T_1 \times T_2 \times \cdots T_n}$$

$$GM_{(B)} = \sqrt[4]{120 \times 80 \times 100 \times 300}$$

$$= 130.27$$

$$GM_{(C)} = \sqrt[4]{90 \times 110 \times 90 \times 500}$$
$$= 145.28$$

$$\text{speedup} = \frac{130.27}{145.28} = \underline{0.897}$$

System C has 0.897 times performance than B
(speed down)

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4 Performance eqn. (20 pts)

	P	Q	R	S	T
→ IPC_{old}	0.6	0.8	0.4	1.1	1.4
IPC_{new}	0.7	0.6	0.3	1.1	1.5

New laptop has 10 % ↑ clock speed

Same Binaries are run for same no. of cycles on each machine

Considering AM of IPCs

$$\text{AM IPCs old} = \frac{0.6+0.8+0.4+1.1+1.4}{5} = \frac{4.3}{5}$$

$$\text{AM IPCs new} = \frac{0.7+0.6+0.3+1.1+1.5}{5} = \frac{4.2}{5}$$

Clock speed of new = 1.1 if clock speed old = 1

$$\text{CPU time}_{old} = 1 \times \frac{4.3}{5} = \frac{4.3}{5}$$

$$\text{CPU time new} = 1.1 \times \frac{4.2}{5} = \frac{4.62}{5}$$

$$\text{Perf improvement} = \frac{4.62 - 4.3}{4.3} \times 100$$

$$= \underline{7.44\%}$$ increase in performance

or

$$\frac{4.62}{4.3} = 1.074$$ speed up.

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