Programming Techniques for Supercomputers Tutorial

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Assignment 5 – Task 1

Multicore power envelope a) Overclocking

- Assumptions
  - No static power consumption $W(0) = 0$
  - W_d Dynamic power consumption at $f = f_0$
  - Δf Clock frequency change ($\Delta f = f - f_0$)
  - Power consumption of one chip: $W = W_d(1 + \Delta f / f_0)^2$

- What is W when $\Delta f / f_0 = 0.4$?

$$\boldsymbol{W} = W_d(1 + 0.4)^2 = \boldsymbol{W_d \cdot 1.96}$$

Assignment 5 – Task 1

Multicore power envelope b) Multicore

- Denote $\Delta v = \Delta f / f_0$

We want to keep W_d fixed!

$$W(m) = m \cdot W_d (1 + \Delta v)^2 = W_d$$

$$\Rightarrow \boldsymbol{m = (1 + \Delta v)^{-2}}$$

$$\boldsymbol{m} = (1 - 0.5)^{-2} = \mathbf{4}$$

c) Performance extrema

- Assume $m = 4$ cores
- Minimum performance gain?
  - **Speedup: 1**. Memory bound codes would not benefit from additional cores
- Maximum performance gain?
  - **Speedup:** $m \cdot (-\Delta v) = 4 \cdot 0.5 = \mathbf{2}$. Compute bound codes benefit here

Assignment 5 – Task 2

Optimal energy to solution

- W_d Dynamic power consumption of a running core
- n cores used (of n_{max} available)
- W_0 Baseline power consumption of the chip (all cores idle): $W(n=0) = W_0$

Power : $\boldsymbol{W(n,f) = W_0 + nW_d}$

- $P(1)$ Performance of serial program
- P_{limit} Maximum performance of parallel program
- $P(n)$ Performance of parallel program on n cores
- $T(n)$ Time to solution on n cores

Time to solution : $\boldsymbol{T(n) = 1/(\min(nP(1), P_{limit}))}$

Energy to solution : $\boldsymbol{E(n)} = W(n,f)T(n) = \boldsymbol{(W_0 + nW_d)/(\min(nP(1), P_{limit}))}$

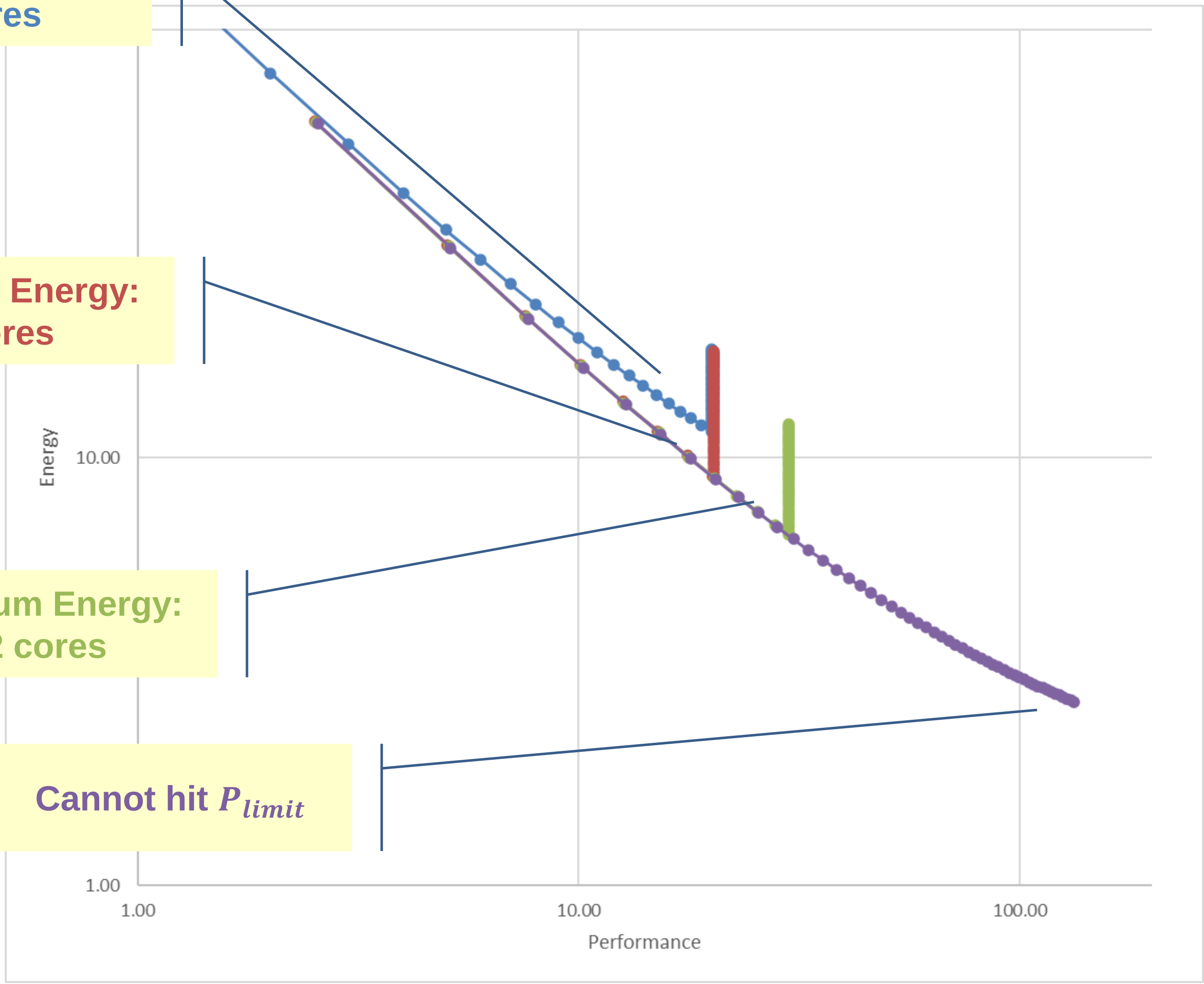
Assignment 5 – Task 2

Optimal energy to solution

a) $W_0 = 150[W], W_d = 4[W],$
$P(1) = 1[s^{-1}], P_{limit} = 20[s^{-1}]$

b) $W_0 = 150[W], W_d = 4[W],$
$\boldsymbol{P(1) = 2.5[s^{-1}]}, P_{limit} = 20[s^{-1}]$

c) $W_0 = 150[W], W_d = 4[W],$
$P(1) = 2.5[s^{-1}], \boldsymbol{P_{limit} = 30[s^{-1}]}$
$W_0 = 150[W], W_d = 4[W],$
$P(1) = 2.5[s^{-1}], \boldsymbol{P_{limit} = 200[s^{-1}]}$



Assignment 5 – Task 3

Balance

a) Double Precision `s = s + a[i];` $B_c = 8\ [B/F]$

b) Double Precision `s = s + a[i]*b[i];` $B_c = 8\ [B/F]$

c) Single Precision `a[i][j] = b[i][j]+ s*c[i][j];` $B_c = 8\ [B/F]$

d) Double Precision `a[i] = s*a[i];` $B_c = 16\ [B/F]$

e) Double Precision, int64 `x[i] = x[i] + s*v[index[i]];`

- Case 1:
  - **`index[i]=const`**, hence no extra traffic from **`v`** $\Rightarrow$ $B_c = 24[B]/2[F] = \mathbf{12}\ [B/F]$
- Case 2:
  - **`index[i]=i`**, means that **`v`** incurs $8\ [B] \Rightarrow$ $B_c = 32[B]/2[F] = \mathbf{16}\ [B/F]$
- Case 3:
  - **`index[i]=rand()`**, **`v`** incurs one, 64 $[B]$ CL $\Rightarrow$ $B_c = 88[B]/2[F] = \mathbf{44}\ [B/F]$