High Performance Computing (Oct 1)

Question 1

Let's assume perfect parallelization. Processor A of a single core works at 2GHz with 1.5V, while Processor B of 8 cores works at 500MHz with 0.5V. Those two processors have the same theoretical peak performance. How many times is Processor B more power-efficient than Processor A?

Answer

The power consumption of Processor A in watt is calculated by

$$P_A = \alpha \times 2 \times 1.5^2 = 4.5\alpha$$

On the other hand, the power consumption of Processor B is calculated by

$$P_B = 8 \times \alpha \times 0.5 \times 0.5^2 = \alpha$$

because Processor B has 8 cores. Hence, Processor B is 4.5 times more power-efficient than Processor A in terms of theoretical peak performance per watt.

Note that this question assumes perfect parallelization and uses theoretical peak performance. It is worth mentioning that we cannot usually achieve N times higher effective performance by using N times more cores. Efficient parallel processing itself is a challenge but the question above shows the importance of it.

Question 2

Suppose that 95% of a program is parallelizable but 5% is not. Then, what is the maximum speedup ratio if we have an infinite number of processors?

Answer

Let T_{seq} and T_{par} be sequential and parallel execution times, respectively. Also, $\alpha = 0.95$ is the parallelization ratio. Then, the speedup ratio with using n processors is given by

$$S(n) = \frac{T_{seq}}{T_{par}} = \frac{T_{seq}}{(1-\alpha)T_{seq} + \alpha T_{seq}/n} = \frac{1}{(1-\alpha) + \alpha/n}$$

Thus,

$$\lim_{n\to\infty} S(n) = \frac{1}{1-\alpha} = \frac{1}{1-0.95} = 20$$

The maximum speedup ration with an infinite number of processors is 20.

For example. if the parallelization ratio increases only by 4%, the maximum speedup ratio becomes 100. A small increase in the parallelization ratio results in a significant increase in the maximum speedup ratio. This clearly indicates the importance of carefully considering the parallelization method.