The Compute : Communicate Ratio

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1D Compute-to-Communicate Ratio

In the above drawing, Compute : Communicate is 4 : 2

where N is the number of compute cells per core
How do more Cores Interact with the Compute-to-Communicate Ratio?

In this case, with 4 cores, Compute : Communicate = 4 : 2

In this case, with 8 cores, Compute : Communicate = 2 : 2

Think of it as a Goldilocks and the Three Bears sort of thing. :-)

Too little Compute : Communicate and you are spending all your time sharing data values across threads and doing too little computing.

Too much Compute : Communicate and you are not spreading out your problem among enough threads to get good parallelism.

It’s difficult to find the “sweet spot” without running experiments.
Performance as a Function of Number of MPI Processors

Heat Transfer using Multiprocessors

MegaElements/Sec

NUM_ELEMENTS: 1024 8192

Number of MPI Processors

Increasing Compute Power
Too Much Communication Required
Too Much Communication Required
Performance as a Function of NUM_ELEMENTS

- Performance measured in MegaElements Computed Per Second
- Number of Elements to Compute vs. Number of Cores

Graph showing performance trends with varying numbers of elements and cores.
Performance as a Function of Number of Cores

MegaElements Computed Per Second

# of Cores

NUM_ELEMENTS
2D Heat Transfer Equation

\[ \rho C \frac{\partial T}{\partial t} = k \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) \]

\[ \frac{\Delta T}{\Delta t} = \frac{k}{\rho C} \left( \frac{\Delta^2 T}{\Delta x^2} + \frac{\Delta^2 T}{\Delta y^2} \right) \]

\[ \Delta T_{i,j} = \left( \frac{k}{\rho C} \right) \left( \frac{T_{i-1,j} - 2T_{i,j} + T_{i+1,j}}{(\Delta x)^2} + \frac{T_{i,j-1} - 2T_{i,j} + T_{i,j+1}}{(\Delta y)^2} \right) \Delta t \]
2D Compute-to-Communicate Ratio

Intracore computing

Intercore communication

Compute : Communicate ratio = \( N^2 : 4N = N : 4 \)

where \( N \) is the dimension of compute nodes per core

The 2D Compute : Communicate ratio is sometimes referred to as Area-to-Perimeter
3D Heat Transfer Equation

\[ \rho C \frac{\partial T}{\partial t} = k \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) \]

\[ \Delta T_{i,j,k} = \left( \frac{k}{\rho C} \frac{T_{i-1,j,k} - 2T_{i,j,k} + T_{i+1,j,k}}{(\Delta x)^2} + \frac{T_{i,j-1,k} - 2T_{i,j,k} + T_{i,j+1,k}}{(\Delta y)^2} + \frac{T_{i,j,k-1} - 2T_{i,j,k} + T_{i,j,k+1}}{(\Delta z)^2} \right) \Delta t \]

\[ \frac{\Delta T}{\Delta t} = \frac{k}{\rho C} \left( \frac{\Delta^2 T}{\Delta x^2} + \frac{\Delta^2 T}{\Delta y^2} + \frac{\Delta^2 T}{\Delta z^2} \right) \]
3D Compute-to-Communicate Ratio

Compute : Communicate ratio = $N^3 : 6N^2 = N : 6$

where $N$ is the dimension of compute nodes per core

In 3D the Compute : Communicate ratio is sometimes referred to as *Volume-to-Surface*