Exercise 1: MPI-Parallelization of a Jacobi Solver

Task 1:

1) The advantages and disadvantages of a 2-D decomposition, as compared to a 1-D decomposition are:

Advantages	**Disadvantages**
(1) It is easier to handle complex geometries which are irregular or intricate in shape as it decomposes the domain into smaller subdomains thar can be handled and distributed evenly across individual processes. (2) It provides clear representation of discontinuous properties and interfaces, thus making it easier to apply various numerical methods and boundary conditions leading to more accurate simulations. (3) In a 2-D decomposition, each region can independently control and generate its own mesh, that provides more efficient mesh generation. (4) The neighbouring grid points close to each other are assigned the same MPI process which helps in better cache utilization and more data locality. (5) Conservative methods of physical quantities can be employed because they can be applied to individual regions independently.	1) Due to less connectivity of information between the neighbouring processes, it can become more challenging to implement and handle communication between neighbouring processes, which in turn lead to more complexity and potential errors. 2) In some cases when the grid size is large in 2-D decomposition, it can result in increased communication volume as the information is to be exchanged in both dimensions. 3) Storing stencil coefficients for each control volume within each MPI process can lead to increased memory usage, when the grid size is large and reduce scalability.

2) In a Domain decomposition, the order of computations within a single Jacobi iteration does not change and remains consistent as each MPI process independently updates the values of grid points within the assigned sub-domain which are based on the values of previous iteration from the neighbouring grid points. Also, because the computations proceed sequentially within each segment and subdomain, each grid point is updated one after the other in the decompositions leading to numerically identical result.

3) Using a wider layer to perform multiple independent iterations before setting up a communication of the ghost layers can be advantageous in many ways in the cases when the bandwidth between MPI processes is high, domain is large and the latency is low, so this decreases the time spent on communication compared to that of computation.

   It will result in better utilization of the resources and improved performance of the Jacobi solver. Also, all processes can proceed in a similar pace and reduce communication delays ensuring more balanced progress across the entire domain.

4) In the IUE-cluster, it has,

Regular Compute node:- (10 X)

2x Intel Xeon Gold 6248 each with 20C (20 Cores)

Each CPU has 1MB of L2 cache per core

So, total L2 cache per regular compute node =

$$\frac{20 \text{ Cores}}{\text{CPU}} \times 1\,\text{MB/core} \times \frac{2 \text{ CPU's}}{\text{node}}$$

$= 40$ MB/node

Now, total L2 cache for regular Compute nodes (10 X)

= L2 cache per node X 10 nodes

= 40MB/node X 10 nodes

$= \underline{400\ MB}$

Fat Compute node (2X) :-

2X Intel Xeon Gold 6248, each with 20C.

L2 cache per CPU core = 1MB

Total L2 cache per Fat Compute node =

$$\frac{20 \cancel{\text{Cores}}}{\cancel{\text{CPU}}} \times \frac{1\ MB}{\cancel{\text{Core}}} \times \frac{2\ \cancel{\text{CPUs}}}{\text{node}}$$

$= 40\ MB/\text{node}$

Now, total L2 cache for Fat Compute node (2X)

$= L2$ Cache per node X 2 nodes.

$$= \frac{40 MB}{\cancel{\text{node}}} \times 2\ \cancel{\text{nodes}}$$

$= \underline{80\ MB}$

Login/Storage Node (1X) :- 2X Intel Xeon Gold, 5217, 8C.

Total L2 Cache per Login/Storage node

$$= \frac{8\ \cancel{\text{cores}}}{\text{CPU}} \times \frac{1\ MB}{\cancel{\text{core}}} \times \frac{2\ \text{CPU}}{\text{node}}$$

$= 8\ MB/\text{node} \times 2 = 16\ MB/\text{node}$

The total L2 cache for login/storage node (1x)

$$= \text{L2 cache per node} \times 1 \text{ node}$$

$$= \frac{16 \text{ MB}}{\cancel{\text{node}}} \times 1 \cancel{\text{node}}$$

$$= \underline{16 \text{ MB}}$$

Total L2 cache for the IVE cluster

$$= 400 + 88 + 16$$

$$= 496 \text{MB}$$