Assignment 1

How to run

```
python3 run.py
```

The folder contains the files:

1. run.py : allocates nodes and runs src.c for each N,P 5 times, generates the data files
2. plot.py : generates 4 plots corresponding to the process counts [16,36,49,64]
3. Makefile : compiles src.c
4. src.c : contains the source code

Code

Halo exchange functions

```
double halo_send(double** arr, int rank, int size)
double halo_packed(double** arr, int rank, int size)
double halo_type(double** arr, int rank, int size)
```

1. arr : pointer to process' copy of 2D data array
2. rank : process rank in MPI_COMM_WORLD
3. size : total number of processes in MPI_COMM_WORLD

```
double halo_send(double** arr, int rank, int size)
```

- Performs halo exchange via multiple MPI_Sends, each MPI_Send transmits 1 double.

```
double halo_packed(double** arr, int rank, int size)
```

- Use of MPI_Pack to pack data of one row(Top/Bottom) or column(Left/Right) into a buffer(*send_buff*) to send data to the respective neighbouring processes.
- Data is received in *recvp_buff*. MPI_Unpack used to store the data in *recv_buff*.

```
double halo_type(double** arr, int rank, int size)
```

- Use of MPI_Type_vector to create *coltype*

- Use of MPI_Type_contiguous to create *rowtype*
- For sending data from a column(Left/Right exchange) *coltype* is used.
- For sending data from a row(Top/Bottom exchange) *rowtype* is used.

Common logic in all methods:

- The processes are assumed to form an abstract square grid.
- Processes (i*p, i*p + p-1) form the i th row, where *p = sqrt(P)* and *P* is total number of processes.
- All the three methods send/receive data from 4 directions in the given order: Left -> Right -> Top -> Bottom
- If the process happens to be at a boundary, it does not send to/receive from the boundary direction.
- Received data is stored in *recv_buff* which is used to compute data for next time step by *avg_compute*.
- Data recieved from neighbour processes is stored in *recv_buff* in clockwise direction starting from Left neighbour. e.g. recv_buff[0] -> left neighbour, recv_buff[1] -> top neighbour ...

```
void avg_compute(int s, int pcol, int prow, double** arr, double** recv_buff)
```

1. s: s = sqrt(size), where size is total number of processes in MPI_COMM_WORLD
2. pcol: x-coordinate of process in process grid.
3. prow: y-coordinate of process in process grid.
4. arr: double** pointer to process' copy of data.
5. recv_buff: double** pointer to 4 x n (where n = sqrt(N), N=data size) array used to store received data.

Global variables

1. n: n = sqrt(N) where N=data size
2. num_time_steps: Total number of time steps for which halo exchange is performed.
3. rowtype: MPI_Type_vector for sending rows
4. coltype: MPI_Type_contiguous for sending columns

Observations

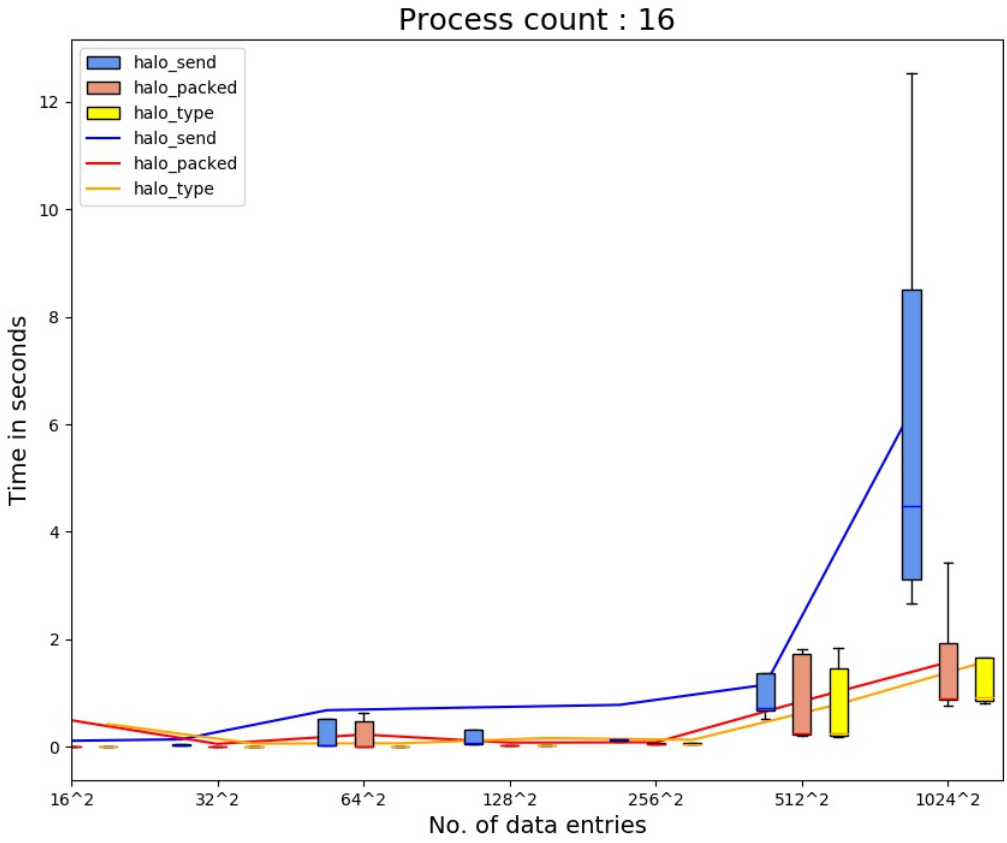
We generate 4 plots corresponding to each process count. The plot contains three line graphs respectively for halo_send(blue), halo_packed(red) and halo_type(orange) indicating mean execution time for 5 iterations. These line graphs are generated using the mean of the 5 execution times for each N,P. For a particular no. of data entries(N), the boxplots are created using the 5 data points generated by 5 independent executions of the communication function.

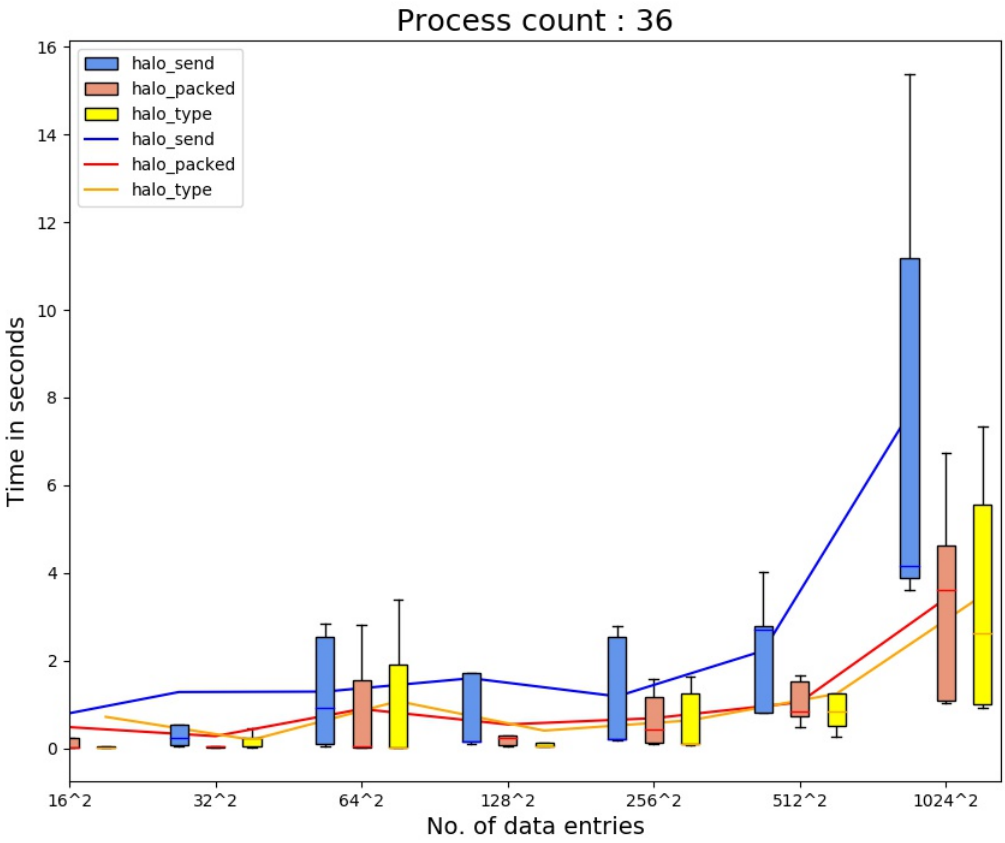
- We observe that the execution time of halo_send is invariably more than that of halo_packed and halo_type for fixed P,N.
- Time taken for all three methods increases with the number of processes keeping data size fixed.
- Execution time for all three methods increases with the increase in data size.
- The increase in time for any fixed number of processes and fixed communication method (change in slope of line graph) is sharpest when going from 256^2 to 512^2 and/or 512^2 to 1024^2.

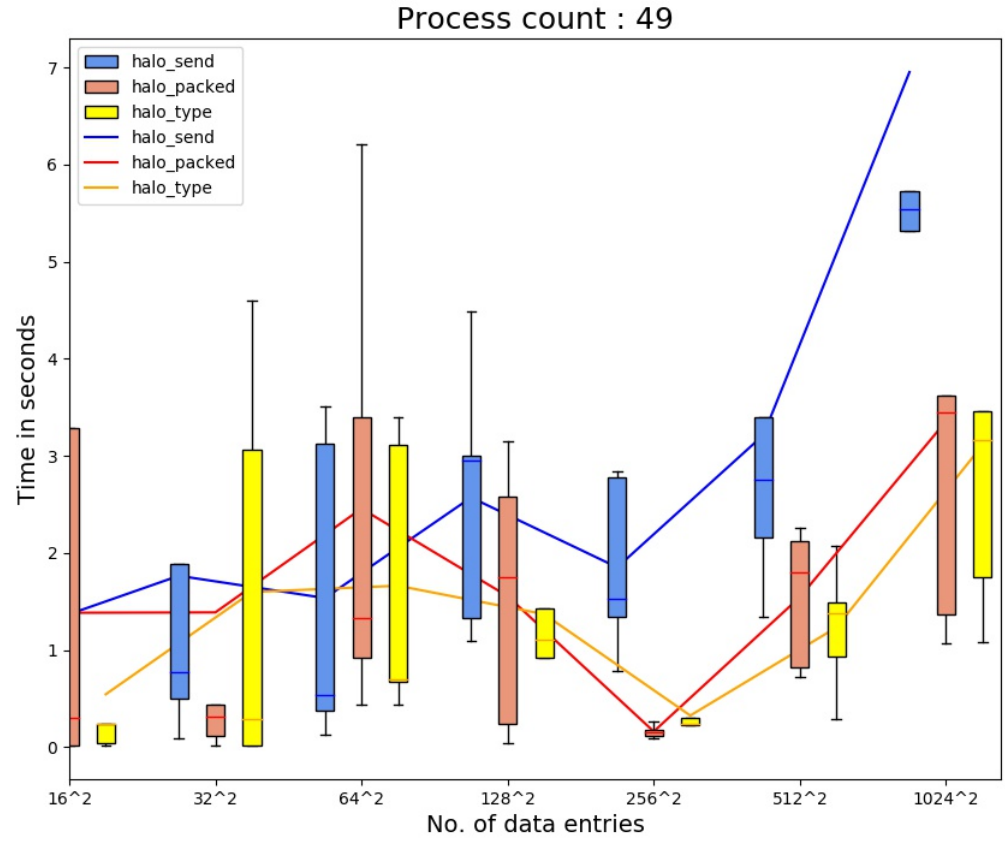
Problems faced

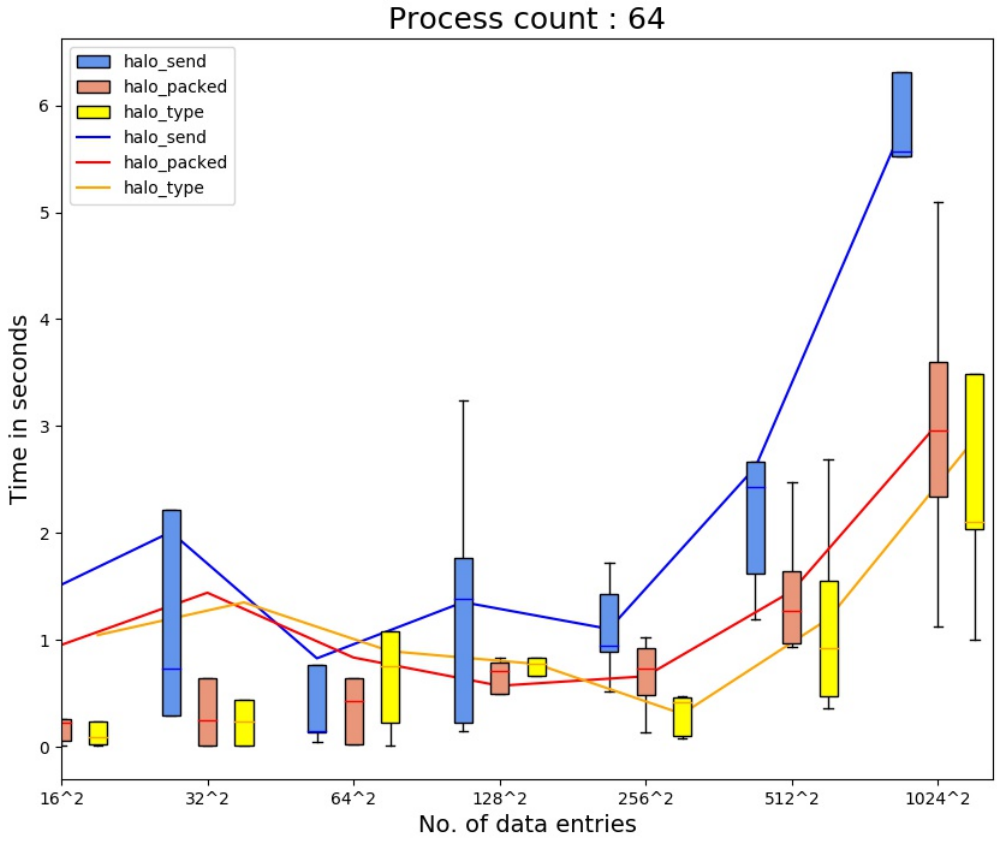
- For large data size (>=1024^2) the program gave segmentation fault upon static allocation of data and buffers due to the stack size limit of 8 MB. This issue was resolved by allocating large buffers dynamically using malloc.
- Installation of external libraries (Psutil, Numpy, Matplotlib) failed several times probably due to network issues on certain machines on the cluster.
- Long run times on several occasions probably due to high load on certain machines. Resolved to some extent by removing csews1-10 from ~/.eagle/hosts.txt.

Plots




Process count : 36
halo_send
halo_packed
halo_type
halo_send
halo_packed
halo_type
Time in seconds
No. of data entries
16^2
32^2
64^2
128^2
256^2
512^2
1024^2
0
2
4
6
8
10
12
14
16


Process count : 49
halo_send
halo_packed
halo_type
halo_send
halo_packed
halo_type
Time in seconds
No. of data entries
16^2
32^2
64^2
128^2
256^2
512^2
1024^2
0
1
2
3
4
5
6
7


Process count : 64
halo_send
halo_packed
halo_type
halo_send
halo_packed
halo_type
Time in seconds
0
1
2
3
4
5
6
16^2
32^2
64^2
128^2
256^2
512^2
1024^2
No. of data entries