Paleti Krishnasai
CED18I039

HPC LAB - Sum of N Numbers MPI

Name: Paleti Krishnasai
Roll No: CED18I039
Programming Environment: MPI
Problem:Sum of N numbers

Hardware Configuration:
PU NAME: Intel(R) Core(TM) i5-8300H CPU @ 2.30GHz
Number of Sockets: 1
Cores per Socket: 4
Threads per core: 2
L1d cache: 128 KiB
L1i cache: 128 KiB
L2 cache: 1 MiB
L3 cache: 8 MiB

```
paleti@paleti-Lenovo-ldeapad-330-15ICH:~$ likwid-topology
--------------------------------------------------------------------------------
CPU name:       Intel(R) Core(TM) i5-8300H CPU @ 2.30GHz
CPU type:       Intel Coffeelake processor
CPU stepping:   10
********************************************************************************
Hardware Thread Topology
********************************************************************************
Sockets:                1
Cores per socket:       4
Threads per core:       2
--------------------------------------------------------------------------------
HWThread        Thread          Core            Socket          Available
0               0               0               0               *
1               0               1               0               *
2               0               2               0               *
3               0               3               0               *
4               1               0               0               *
5               1               1               0               *
6               1               2               0               *
7               1               3               0               *
--------------------------------------------------------------------------------
Socket 0:               ( 0 4 1 5 2 6 3 7 )
--------------------------------------------------------------------------------
********************************************************************************
Cache Topology
********************************************************************************
Level:                  1
Size:                   32 kB
Cache groups:           ( 0 4 ) ( 1 5 ) ( 2 6 ) ( 3 7 )
--------------------------------------------------------------------------------
Level:                  2
Size:                   256 kB
Cache groups:           ( 0 4 ) ( 1 5 ) ( 2 6 ) ( 3 7 )
--------------------------------------------------------------------------------
Level:                  3
Size:                   8 MB
Cache groups:           ( 0 4 1 5 2 6 3 7 )
--------------------------------------------------------------------------------
********************************************************************************
NUMA Topology
********************************************************************************
NUMA domains:           1
--------------------------------------------------------------------------------
Domain:                 0
Processors:             ( 0 1 2 3 4 5 6 7 )
Distances:              10
Free memory:            3546.2 MB
Total memory:           7831.84 MB
--------------------------------------------------------------------------------
```

```
**************************************************
Graphical Topology
**************************************************
Socket 0:
+-------------------------------------------------+
| +---------+ +---------+ +---------+ +---------+ |
| |  0 4    | |  1 5    | |  2 6    | |  3 7    | |
| +---------+ +---------+ +---------+ +---------+ |
| +---------+ +---------+ +---------+ +---------+ |
| |  32 kB  | |  32 kB  | |  32 kB  | |  32 kB  | |
| +---------+ +---------+ +---------+ +---------+ |
| +---------+ +---------+ +---------+ +---------+ |
| | 256 kB  | | 256 kB  | | 256 kB  | | 256 kB  | |
| +---------+ +---------+ +---------+ +---------+ |
| +---------------------------------------------+ |
| |                    8 MB                     | |
| +---------------------------------------------+ |
+-------------------------------------------------+
```

No of nodes: 12 (4 for each as written in the machine file).

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Serial Code:

```
#include "mpi.h"
#include <stdio.h>
#include <stdlib.h>
#include <float.h>
int main(int argc, char *argv[])
{
    double start,end;
    MPI_Init(&argc,&argv);
    start=MPI_Wtime();
    int i = 1, n = 100000;
    double a[n], sum = 0;
    for(i=0;i<n;i++)
    {
        a[i] = (i+1)*5.658;
        sum += a[i]
    }
    end=MPI_Wtime();
    printf("\nTime= %f",end-start);
    return 0;
}
```

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Parallel Code : [MPI_Reduce]

```
#include <mpi.h>
#include <stdio.h>
#include <math.h>
#include <stdlib.h>

#define ARRAY_SIZE 100000

int main(int argc, char *argv[])
{
int myid, numprocs, s;
double vector1[ARRAY_SIZE + 50], sum = 0, vector1Receive[ARRAY_SIZE + 50],
fSum =
0;
MPI_Init(&argc, &argv);
MPI_Comm_size(MPI_COMM_WORLD, &numprocs);
MPI_Comm_rank(MPI_COMM_WORLD, &myid);
double start = MPI_Wtime();
for (int i = 0; i < ARRAY_SIZE; i++)
vector1[i] = i + 1;
if (myid == 0)
s = (int)floor(ARRAY_SIZE / numprocs);
MPI_Bcast(&s, 1, MPI_INT, 0, MPI_COMM_WORLD);
MPI_Scatter(vector1, s, MPI_DOUBLE, vector1Receive, s, MPI_DOUBLE, 0,
MPI_COMM_WORLD);
for (int i = 0; i < s; i++)
sum += vector1Receive[i];
MPI_Reduce(&sum, &fSum, 1, MPI_DOUBLE, MPI_SUM, 0, MPI_COMM_WORLD);
if (myid == 0)
{
for (int i = s * numprocs; i < ARRAY_SIZE; i++)
fSum += vector1[i];
printf("%f\n", fSum);
double end = MPI_Wtime();
printf("%f\n", end - start);
}
MPI_Finalize();
}
```

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Observations : [MPI_Reduce]

Processes (n)	Runtime	Speedup (s)
1	0.000698	1
2	0.017489	0.03991080107
4	0.086921	0.00803028037
6	0.121665	0.005737064891
8	0.124371	0.005612240796
10	0.110482	0.006317771221
12	0.126299	0.005526567906
16	0.278594	0.002505438021
20	0.325962	0.0021413539
32	0.602774	0.001157979608
64	1.246792	0.0005598367651
128	3.013827	0.0002315992258

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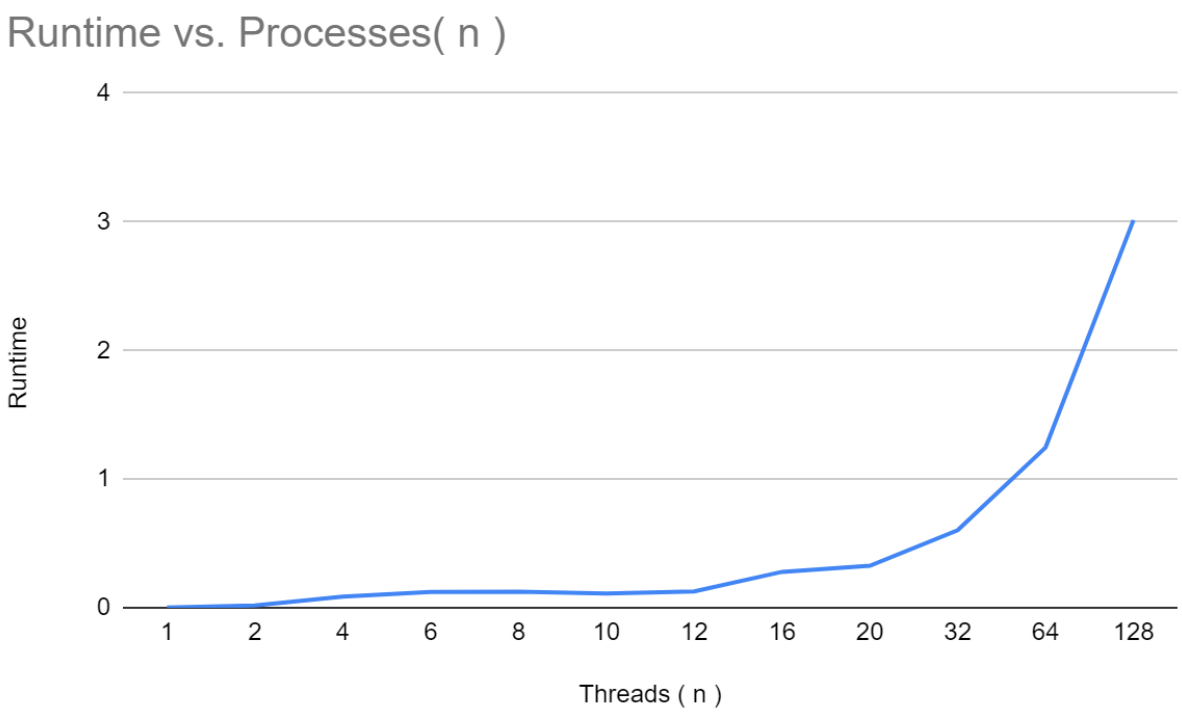

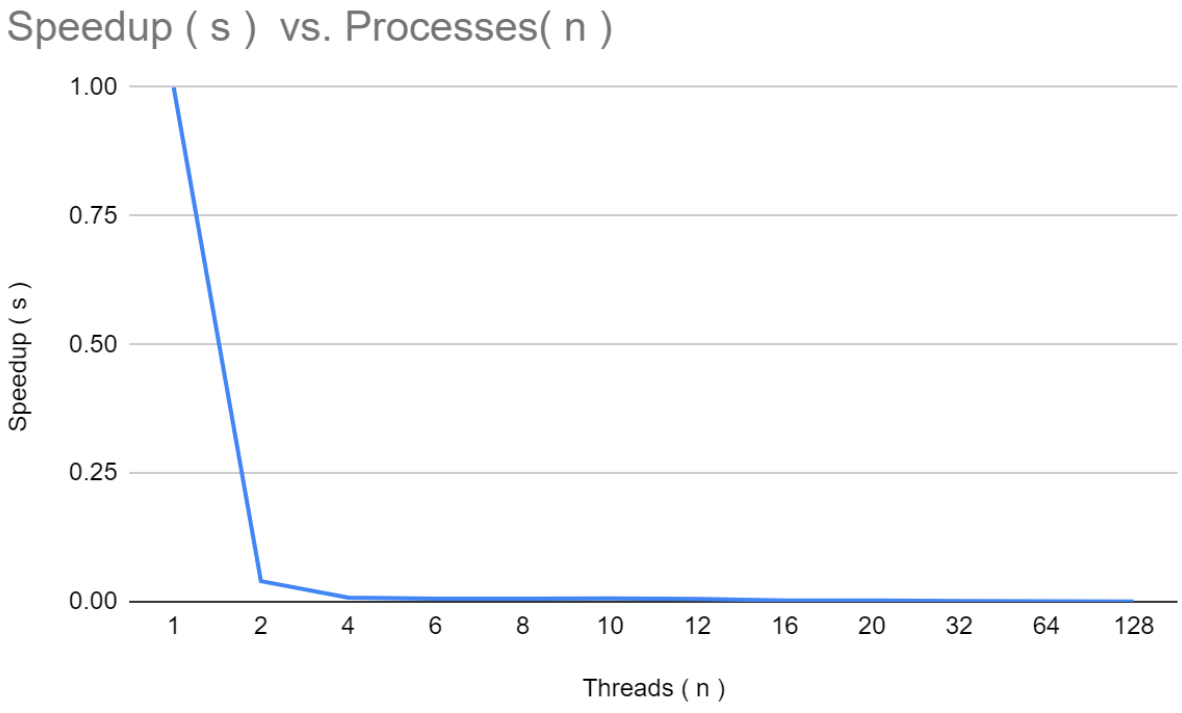

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Parallel Code : [Without MPI_Reduce]

```
#include <mpi.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

// size of array
#define n 10000

int a[10000];

// Temporary array for slave process
int a2[100000000];

int main(int argc, char* argv[])
{
    double start,end;
    int pid, np,
        elements_per_process,
        n_elements_recieved;
    // np -> no. of processes
    // pid -> process id

    MPI_Status status;

    // Creation of parallel processes
    MPI_Init(&argc, &argv);
    start=MPI_Wtime();
     for (int i = 0; i < 10000; i++)
            a[i] = (i + 1)*8.754;
    // find out process ID,
    // and how many processes were started
    MPI_Comm_rank(MPI_COMM_WORLD, &pid);
    MPI_Comm_size(MPI_COMM_WORLD, &np);

    // master process
    if (pid == 0) {
        int index, i;
        elements_per_process = n / np;
```

```
        // check if more than 1 processes are run
        if (np > 1) {
            // distributes the portion of array
            // to child processes to calculate
            // their partial sums
            for (i = 1; i < np - 1; i++) {
                index = i * elements_per_process;

                MPI_Send(&elements_per_process,
                         1, MPI_INT, i, 0,
                         MPI_COMM_WORLD);
                MPI_Send(&a[index],
                         elements_per_process,
                         MPI_INT, i, 0,
                         MPI_COMM_WORLD);
            }

            // last process adds remaining elements
            index = i * elements_per_process;
            int elements_left = n - index;

            MPI_Send(&elements_left,
                     1, MPI_INT,
                     i, 0,
                     MPI_COMM_WORLD);
            MPI_Send(&a[index],
                     elements_left,
                     MPI_INT, i, 0,
                     MPI_COMM_WORLD);
        }

        // master process add its own sub array
        int sum = 0;
        for (i = 0; i < elements_per_process; i++)
            sum += a[i];

        // collects partial sums from other processes
        int tmp;
        for (i = 1; i < np; i++) {
            MPI_Recv(&tmp, 1, MPI_INT,
```

```
                    MPI_ANY_SOURCE, 0,
                    MPI_COMM_WORLD,
                    &status);
            int sender = status.MPI_SOURCE;

            sum += tmp;
        }

        // prints the final sum of array
        printf("Sum of array is : %d\n", sum);
         end=MPI_Wtime();
        printf("\nTime_hello= %f",end-start);
    }
    // slave processes
    else {
        MPI_Recv(&n_elements_recieved,
                 1, MPI_INT, 0, 0,
                 MPI_COMM_WORLD,
                 &status);

        // stores the received array segment
        // in local array a2
        MPI_Recv(&a2, n_elements_recieved,
                 MPI_INT, 0, 0,
                 MPI_COMM_WORLD,
                 &status);

        // calculates its partial sum
        int partial_sum = 0;
        for (int i = 0; i < n_elements_recieved; i++)
            partial_sum += a2[i];

        // sends the partial sum to the root process
        MPI_Send(&partial_sum, 1, MPI_INT,
                 0, 0, MPI_COMM_WORLD);
    }
    // cleans up all MPI state before exit of process
    MPI_Finalize();
    return 0;
}
```

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Observations : [Without MPI_Reduce]

Processes (n)	Runtime	Speedup (s)
1	0.000698	1
2	0.008503	0.08208867459
4	0.014682	0.04754120692
6	0.036009	0.01938404288
8	0.04158	0.01678691679
10	0.078148	0.008931770487
12	0.082783	0.008431682833
16	0.290735	0.002400811736
20	0.334831	0.002084633741
32	0.873777	0.000798830823
64	3.385408	0.0002061789894
128	15.950274	0.00004376100373

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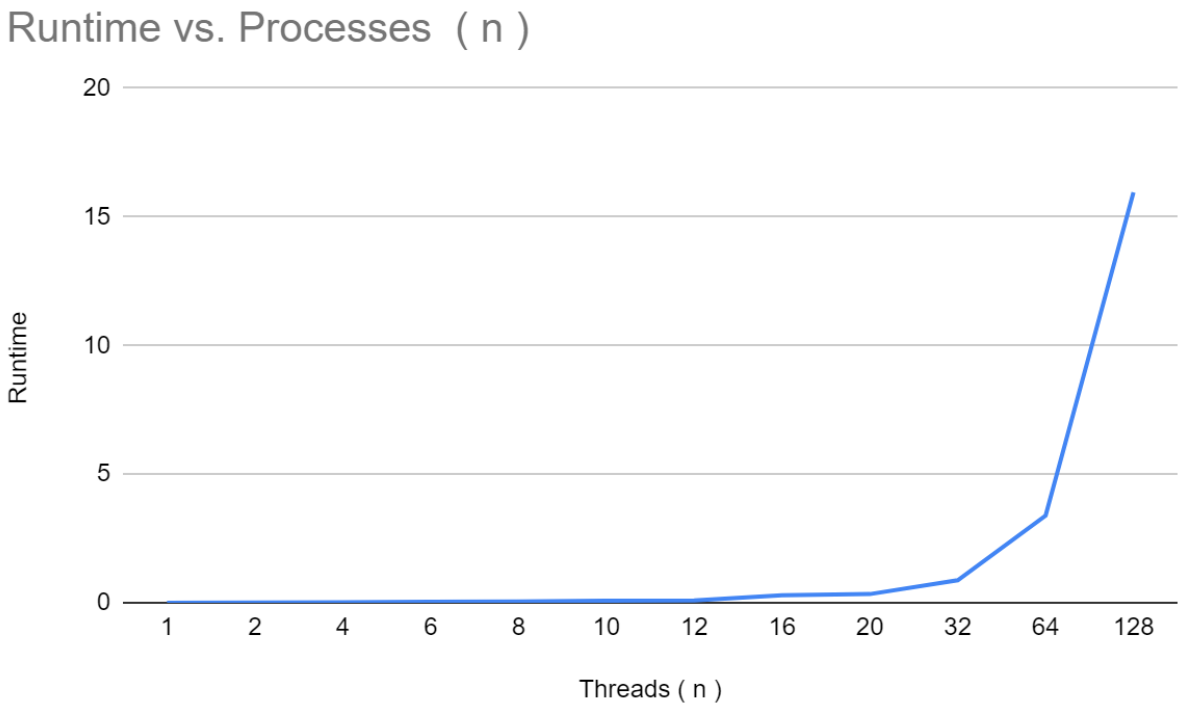

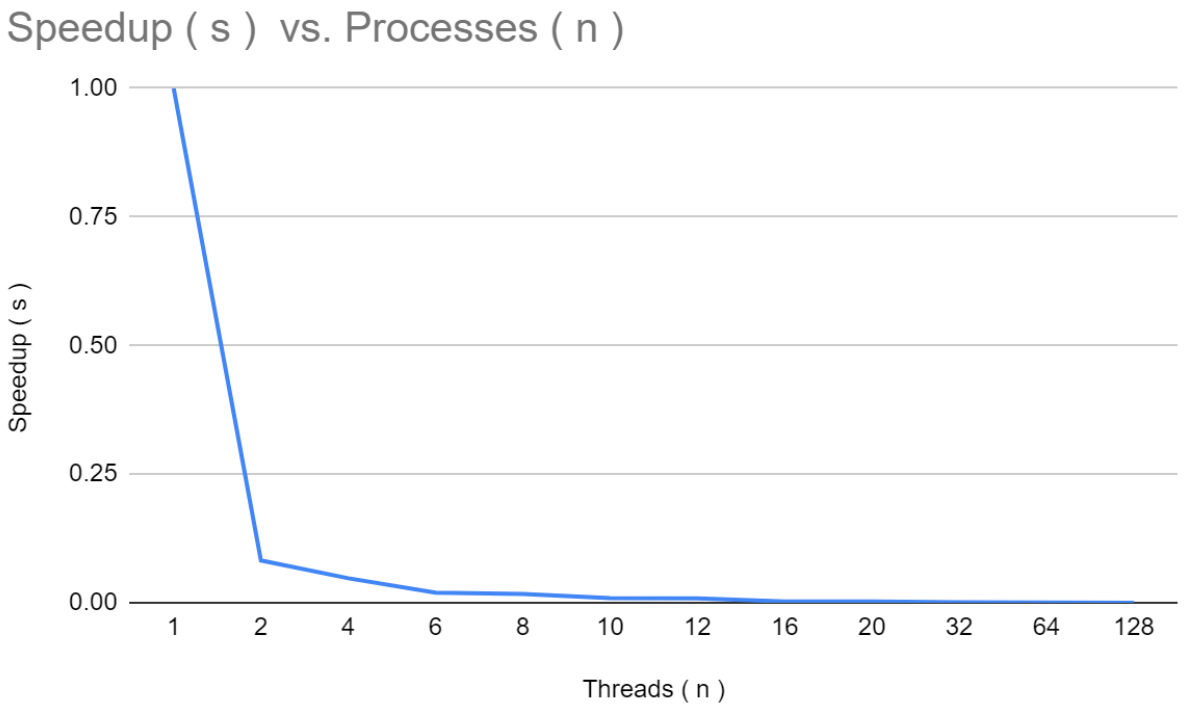

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Inference: (**Note**: Execution time, graph, and inference will be based on hardware configuration)

- Since MPI is a distributed memory architecture, the communication overhead between nodes causes the parallel code to run slower compared to serial code (running in 1 node or only in master).

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