Paleti Krishnasai
CED18I039

HPC LAB - Vector Multiplication MPI

Name: Paleti Krishnasai
Roll No: CED18I039
Programming Environment: MPI
Problem: Vector Multiplication
Date: 21-10-2021

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-ideapad-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 machine file).

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Serial Code:

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

#define VSIZE 1000
#define MASTER 0
#define FROM_MASTER 1
#define FROM_WORKER 2

//serial code
int main(int argc, char *argv[]){
        double start,end;
    MPI_Init(&argc, &argv);
        start=MPI_Wtime();
    int i;
    long double a[VSIZE], b[VSIZE], c[VSIZE];
    for (i = 0; i < VSIZE; i++){
                a[i] = i * 156.678;
                }
        for (i = 0; i < VSIZE; i++){
                b[i] = i * 2.0078;
                }
        for (i = 0; i < VSIZE; i++)
            c[i] = a[i] * b[i];
        printf("\nResultant Vector:\n");

        for (i = 0; i < VSIZE; i++)
            printf("\n%Lf +%Lf = %Lf   ", a[i],b[i],c[i]);

        printf("\nFinished.\n");
    end=MPI_Wtime();
    printf("\nTime= %f",end-start);
    return 0;
    }
```

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Parallel Code: [Point to Point]

```
#include <mpi.h>

#include <stdio.h>

#include <stdlib.h>



#define VSIZE 1000

#define MASTER 0

#define FROM_MASTER 1

#define FROM_WORKER 2


int main(int argc, char *argv[])

{

    int numtasks, taskid, numworkers, source, dest, mtype, segment,
aveseg, extra, offset, i, j, k, rc;

    long double a[VSIZE], b[VSIZE], c[VSIZE];

    MPI_Status status;

    double start,end;



    MPI_Init(&argc, &argv);

    start=MPI_Wtime();

    MPI_Comm_rank(MPI_COMM_WORLD, &taskid);

    MPI_Comm_size(MPI_COMM_WORLD, &numtasks);
```

```
    if (numtasks < 2)

    {

        printf("Need atleast two MPI tasks. Quiting...\n");

        MPI_Abort(MPI_COMM_WORLD, rc);

        exit(1);

    }



    char pro_name[MPI_MAX_PROCESSOR_NAME];

    int name_len;

    MPI_Get_processor_name(pro_name,&name_len);



    printf("-From from  %s, rank %d, out of %d
processors\n",pro_name,taskid,numtasks);

    numworkers = numtasks - 1;



    //master task:



    if (taskid == MASTER)

    {

        for (i = 0; i < VSIZE; i++){
```

```
                a[i] = i * 156.678;

                }

        for (i = 0; i < VSIZE; i++){

                b[i] = i * 2.0078;

                }



        aveseg = VSIZE / numworkers;

        extra = VSIZE % numworkers;

        offset = 0;

        mtype = FROM_MASTER;

        for (dest = 1; dest <= numworkers; dest++)

        {

            segment = (dest <= extra) ? aveseg + 1 : aveseg;



            MPI_Send(&offset, 1, MPI_INT, dest, mtype, MPI_COMM_WORLD);

            MPI_Send(&segment, 1, MPI_INT, dest, mtype, MPI_COMM_WORLD);

            MPI_Send(&a[offset], segment, MPI_LONG_DOUBLE, dest, mtype,
MPI_COMM_WORLD);

            MPI_Send(&b[offset], segment, MPI_LONG_DOUBLE, dest, mtype,
MPI_COMM_WORLD);

            offset = offset + segment;
```

```
        }



        //receive from worker:



        mtype = FROM_WORKER;

        for (i = 1; i <= numworkers; i++)

        {

            source = i;

            MPI_Recv(&offset, 1, MPI_INT, source, mtype, MPI_COMM_WORLD,
&status);

            MPI_Recv(&segment, 1, MPI_INT, source, mtype, MPI_COMM_WORLD,
&status);

            MPI_Recv(&c[offset], segment, MPI_LONG_DOUBLE, source, mtype,
MPI_COMM_WORLD, &status);

        }



        printf("\nResultant Vector:\n");



        for (i = 0; i < VSIZE; i++)

            printf("\n%Lf +%Lf = %Lf   ", a[i],b[i],c[i]);



        printf("\nFinished.\n");
```

```
    end=MPI_Wtime();

    printf("\nTime= %f",end-start);

    }

    //Worker task:



    if (taskid > MASTER)

    {

        mtype = FROM_MASTER;

        MPI_Recv(&offset, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,
&status);

        MPI_Recv(&segment, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,
&status);

        MPI_Recv(&a, segment, MPI_LONG_DOUBLE, MASTER, mtype,
MPI_COMM_WORLD, &status);

        MPI_Recv(&b, segment, MPI_LONG_DOUBLE, MASTER, mtype,
MPI_COMM_WORLD, &status);



        //mat multiplication



        for (i = 0; i < segment; i++)

            c[i] = a[i] * b[i];
```

```
        mtype = FROM_WORKER;

        MPI_Send(&offset, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD);

        MPI_Send(&segment, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD);

        MPI_Send(&c, segment, MPI_LONG_DOUBLE, MASTER, mtype,
MPI_COMM_WORLD);

    }

    MPI_Finalize();
    return 0;
}
```

Observations: [Point to Point]

Processes(n)	Runtime	Speedup (s)
1	0.042741	1
2	0.064913	0.6584351363
4	0.066917	0.6387166191
6	0.089911	0.4753700882
8	0.119081	0.3589237578
10	0.106206	0.4024348907
12	0.147787	0.2892067638
16	0.2249	0.1900444642
32	1.046669	0.04083525928
64	3.7924277	0.01127008961
128	15.069948	0.002836174352

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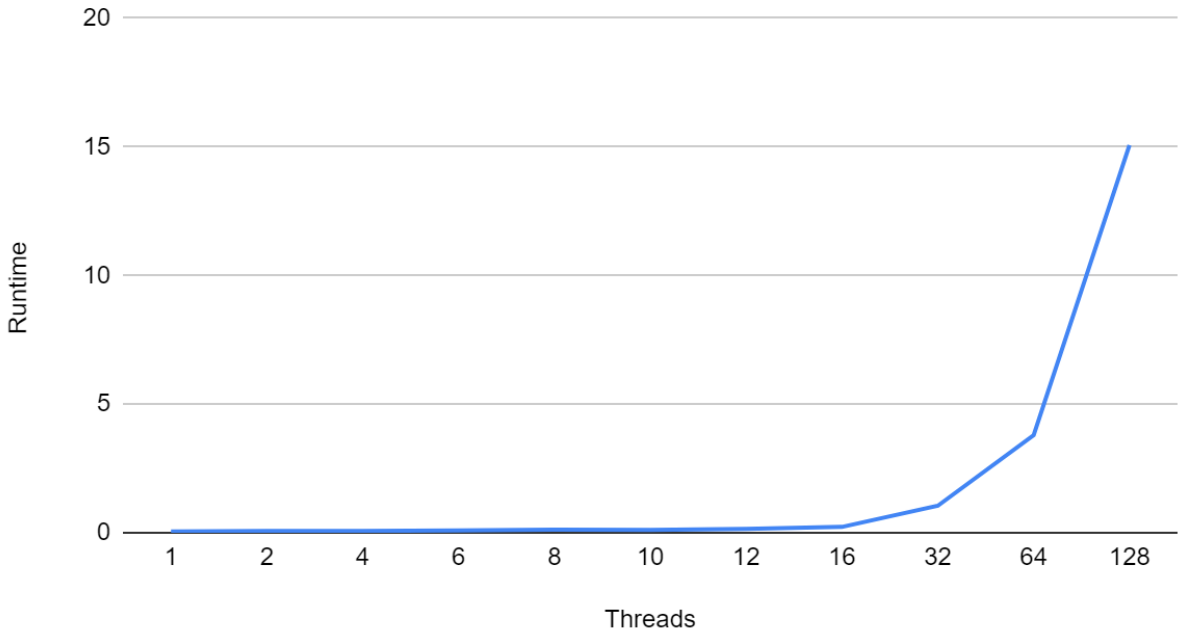
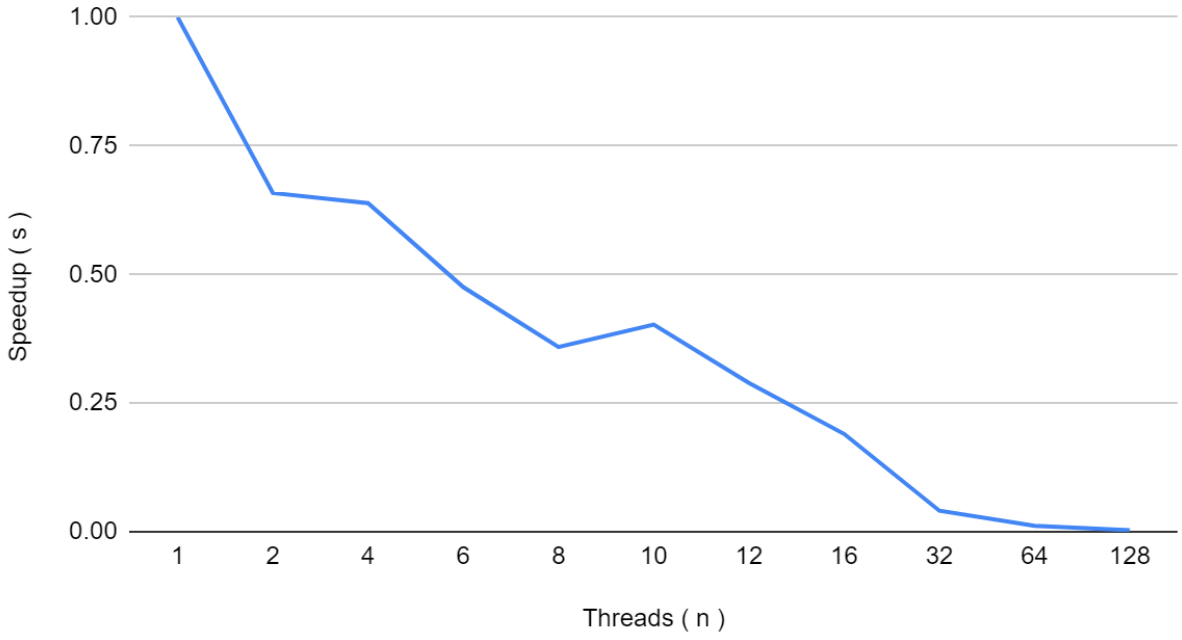
Runtime vs. Processes



Speedup (s) vs. Processes(n)



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Parallel Code: [Collective]

```
#include "mpi.h"
#include <stdio.h>
#include <math.h>
#include <stdlib.h>
int main(int argc, char *argv[]) {
     int myid, numprocs;
    double startwtime,
    endwtime;
    int  namelen;
    int ARRAY_SIZE = 100000;
    int vector1[ARRAY_SIZE];
    int vector2[ARRAY_SIZE];
    int vector3[ARRAY_SIZE];
     int i, j;
     int s, s0;
    double totalTime;
    double start, end;
    char processor_name[MPI_MAX_PROCESSOR_NAME];
    MPI_Init(&argc,&argv);
    start=MPI_Wtime();
    MPI_Comm_size(MPI_COMM_WORLD,&numprocs);
MPI_Comm_rank(MPI_COMM_WORLD,&myid);
MPI_Get_processor_name(processor_name,&namelen);
    fprintf(stderr,"Process %d on %s\n", myid, processor_name);
    fflush(stderr);
 // Vector 1 Reading
        for (i=0; i < ARRAY_SIZE; i++)
        vector1[i] =i * 156.678;
    // Vector 2 Reading
        for (i=0; i < ARRAY_SIZE; i++)
        vector2[i] =i * 2.0078;

if(myid == 0)
{
    MPI_Bcast(&ARRAY_SIZE, 1, MPI_INT, 0, MPI_COMM_WORLD);
    s = (int) floor(ARRAY_SIZE/numprocs);
    s0 = ARRAY_SIZE%numprocs;
    int vector1Receive[s];
    int vector2Receive[s];
```

```
    int vector3Receive[s];
    if (s0 != 0)
    {
        s = s + 1;
        for(i=0; i < ((s * numprocs) - ARRAY_SIZE); i++)
        {
            vector1[ARRAY_SIZE + i] = 0;
            vector2[ARRAY_SIZE + i] = 0;
        }
    }
    MPI_Bcast(&s, 1, MPI_INT, 0, MPI_COMM_WORLD);
    MPI_Scatter(vector1, s, MPI_INT, vector1Receive, s, MPI_INT, 0,
MPI_COMM_WORLD);
    MPI_Scatter(vector2, s, MPI_INT, vector2Receive, s, MPI_INT, 0,
MPI_COMM_WORLD);
    for(i=0; i<s; i++)
    {
        vector3Receive[i] = vector1Receive[i] * vector2Receive[i];
    }
    MPI_Gather(vector3Receive, s, MPI_INT, vector3, s, MPI_INT, 0,
MPI_COMM_WORLD);

    for(i=0; i<ARRAY_SIZE; i++)
        printf("%d\n", vector3[i]);
}
else
{
    MPI_Bcast(&ARRAY_SIZE, 1, MPI_INT, 0, MPI_COMM_WORLD);
    MPI_Bcast(&s, 1, MPI_INT, 0, MPI_COMM_WORLD);
    int vector1Receive[s];
    int vector2Receive[s];
    int vector3Receive[s];
    MPI_Scatter(vector1, s, MPI_INT, vector1Receive, s, MPI_INT, 0,
MPI_COMM_WORLD);
    MPI_Scatter(vector2, s, MPI_INT, vector2Receive, s, MPI_INT, 0,
MPI_COMM_WORLD);
    for(i=0; i<s; i++)
    {
        vector3Receive[i] = vector1Receive[i] * vector2Receive[i];
    }
```

```
    MPI_Gather(vector3Receive, s, MPI_INT, vector3, s, MPI_INT, 0,
MPI_COMM_WORLD);

}
end=MPI_Wtime();
    printf("\nTime= %f",end-start);
MPI_Finalize();
}
```

Observations [Collective] :

Processes(n)	Runtime	Speedup (s)
1	0.042741	1
2	0.73142	0.05843564573
4	1.977666	0.02161183941
6	2.065529	0.02069251993
8	2.099447	0.02035821814
10	2.279888	0.01874697354
12	2.240546	0.01907615376
16	3.053671	0.01399659623
32	4.816833	0.008873257595
64	8.681692	0.004923118673
128	16.589044	0.002576459499

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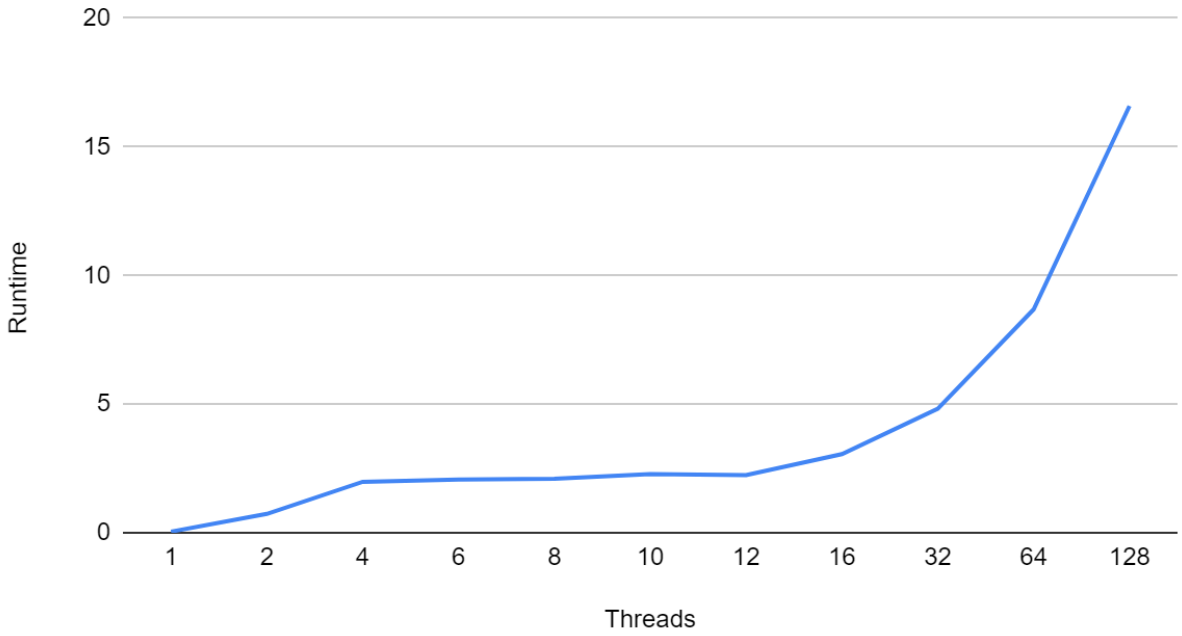
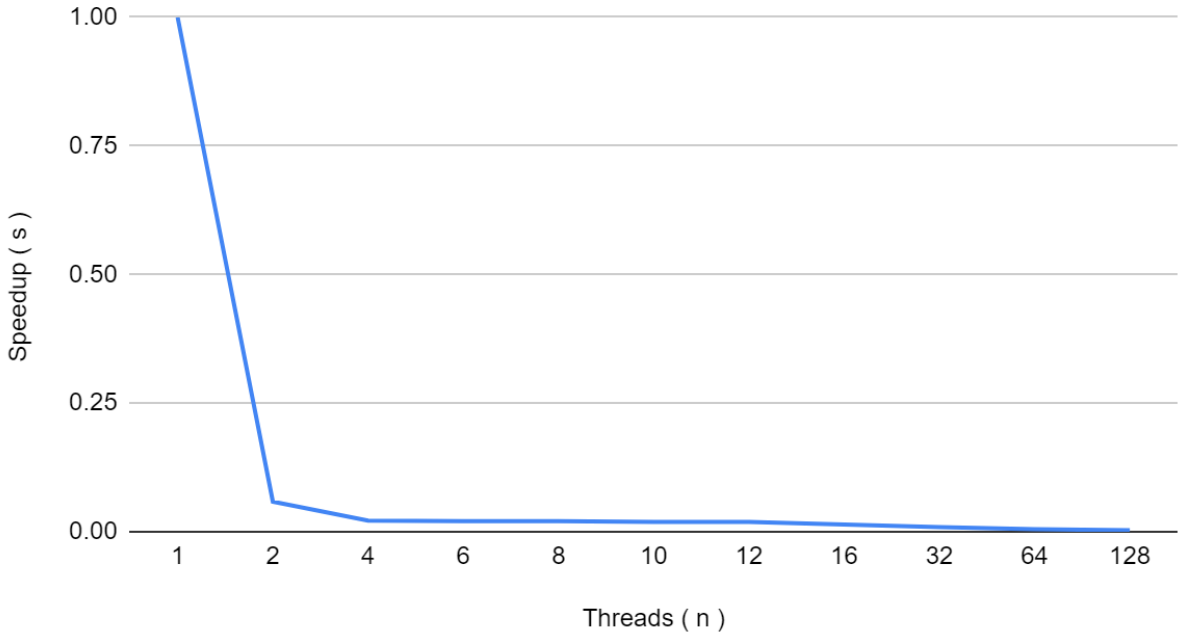
Runtime vs. Processes



Speedup (s) vs. Processes(n)



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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)