Module Title: Distributed and Cloud Systems Programming (5CS022)

Subject Title: Workshop 01

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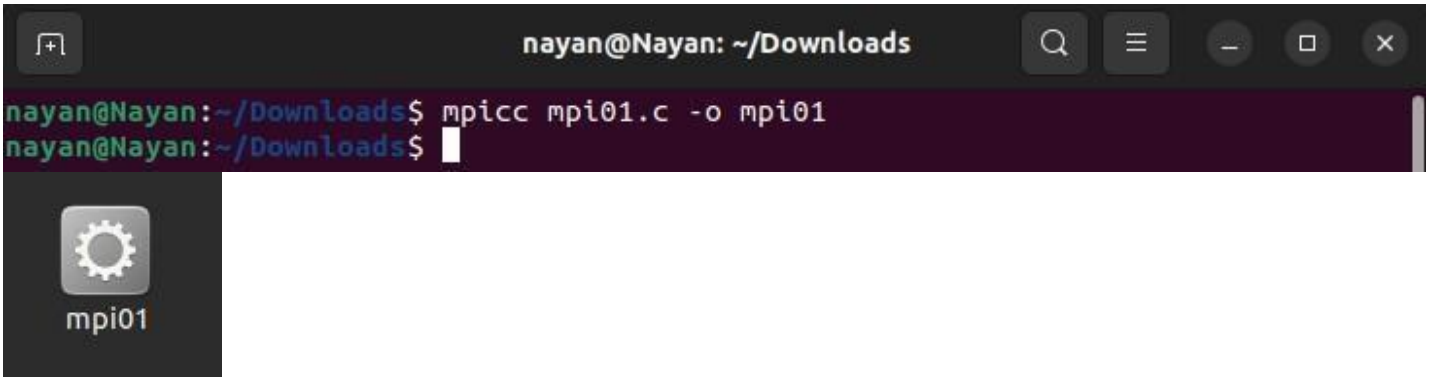
5CS022 Distribute and Cloud Systems Programming Week 1 Workshop

Tasks

1. Download the sample MPI programs from Canvas into your Linux system. Compile and run the program mpi01.c. To compile it, run the following command in the terminal:

```
mpicc mpi01.c -o mpi01
```



Now run it with the following:

```
mpiexec ./mpi01
```

This will (probably) only run only one process, which is not very interesting. Run it again with the following command:

```
mpiexec -n 4 -oversubscribe ./mpi01
```

Note the output this time. It should indicate that 4 processes have run and they all have different process IDs.

Experiment with higher and higher numbers of processes until it stops running. Then have a look at the error message and try and work out why it stop working.

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec -n 1000 ./mpi01
[proxy:0:0@Nayan] HYDU_create_process (utils/launch/launch.c:21): pipe error (To
o many open files)
[proxy:0:0@Nayan] launch_procs (pm/pmiserv/pmip_cb.c:730): create process return
ed error
[proxy:0:0@Nayan] HYD_pmcd_pmip_control_cmd_cb (pm/pmiserv/pmip_cb.c:906): launc
h_procs returned error
[proxy:0:0@Nayan] HYDT_dmxu_poll_wait_for_event (tools/demux/demux_poll.c:76): c
allback returned error status
[proxy:0:0@Nayan] main (pm/pmiserv/pmip.c:169): demux engine error waiting for e
vent
[mpiexec@Nayan] control_cb (pm/pmiserv/pmiserv_cb.c:206): assert (!closed) faile
d
[mpiexec@Nayan] HYDT_dmxu_poll_wait_for_event (tools/demux/demux_poll.c:76): cal
lback returned error status
[mpiexec@Nayan] HYD_pmci_wait_for_completion (pm/pmiserv/pmiserv_pmci.c:160): er
ror waiting for event
[mpiexec@Nayan] main (ui/mpich/mpiexec.c:325): process manager error waiting for
 completion
```

There is a maximum number of processes a computer can access. If this maximum is exceeded, the OS will generate an error message signaling that many files are opened at once.

2. Compile and run the program mpi02.c. Try running it with 2, 3 and 4 processes. Eg.:

mpiexec -n 2 -oversubscribe ./mpi02 mpiexec -n 3 -oversubscribe ./mpi02 mpiexec -n 4 -oversubscribe ./mpi02

Note what happens. It doesn't let you run the program with anything other than 3 processes.

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpicc mpi02.c -o mpi02
nayan@Nayan:~/Downloads$
```


```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec -n 2 ./mpi02
This program needs to run on exactly 3 processes
nayan@Nayan:~/Downloads$ mpiexec -n 3 ./mpi02
Process 1 received 9
Process 2 received 17
nayan@Nayan:~/Downloads$ mpiexec -n 4 ./mpi02
This program needs to run on exactly 3 processes
nayan@Nayan:~/Downloads$
```

3. Now change the code so that you remove the check for only 3 processes. Now run it with 2, then 3, then 4 and then more processes.

   CODE:

mpi02.c
~/Downloads

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

int main(int argc, char** argv) {
int size, rank;

  MPI_Init(NULL, NULL);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);

  if(rank ==0){
    int x = 9;
    int y = 17;
    MPI_Send(&x, 1, MPI_INT, 1, 0, MPI_COMM_WORLD);
    MPI_Send(&y, 1, MPI_INT, 2, 0, MPI_COMM_WORLD);
  } else {
    int number;
    MPI_Recv(&number, 1, MPI_INT, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
    printf("Process %d received %d\n", rank, number);
  }

  MPI_Finalize();

  return 0;
}
```

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OUTPUT:

```
mpiexec -n 2 -oversubscribe ./mpi02
```

mpiexec -n 3 -oversubscribe ./mpi02

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec -n 2 ./mpi02
Process 1 received 9
Abort(939149830) on node 0 (rank 0 in comm 0): Fatal error in internal_Send: Inv
alid rank, error stack:
internal_Send(120): MPI_Send(buf=0x7ffeefdf6060, count=1, MPI_INT, 2, 0, MPI_COM
M_WORLD) failed
internal_Send(78).: Invalid rank has value 2 but must be nonnegative and less th
an 2
nayan@Nayan:~/Downloads$
```

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec -n 3 ./mpi02
Process 1 received 9
Process 2 received 17
nayan@Nayan:~/Downloads$
```

mpiexec -n 4 -oversubscribe ./mpi02

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec -n 4 ./mpi02
Process 1 received 9
Process 2 received 17
```

4. When you try to run it with 4 or more processes, it probably runs and appear to work, but never ends. You will have to end with "Ctrl-C". Why do you think it doesn't end when you run it with more than 3 processes? Change it so that it will work with any number of processes.

The program continues to run because only the first two processes receive messages from the process waiting for input from process 0, leaving the remaining processes waiting endlessly.

CODE:

```c
/*
  - Process 0 sends x to process 1 and y to processes 2. "1, MPI_INT"
    indicates that the message consists of one integer.
  - Processes other than rank 0 wait to receive a message using MPI_Recv.
    The "0, 0" indicates that the message is expected from process 0 and
    should have the tag 0. The result is stored in the number variable.
*/

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

int main(int argc, char** argv) {
  int size, rank;

  MPI_Init(NULL, NULL);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);

  if(rank == 0) {
    int x = 9;
    int y = 17;
    for(int dest = 1; dest < size; dest++) {
      MPI_Send(&x, 1, MPI_INT, dest, 0, MPI_COMM_WORLD);
      MPI_Send(&y, 1, MPI_INT, dest, 0, MPI_COMM_WORLD);
    }
  } else {
    int number1, number2;
    MPI_Recv(&number1, 1, MPI_INT, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
    MPI_Recv(&number2, 1, MPI_INT, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
    printf("Process %d received %d and %d\n", rank, number1, number2);
  }

  MPI_Finalize();

  return 0;
}
```

OUTPUT:

```
nayan@Nayan:~/Downloads$ mpiexec -n 4 ./mpi02
Process 1 received 9 and 17
Process 2 received 9 and 17
Process 3 received 9 and 17
nayan@Nayan:~/Downloads$
```

5. Build and run the program mpi03.c. In this program Process 0 will wait for messages from Process 1 and Process 2. However, Process 1 end sup blocking Process 2 because it sleeps for 5 seconds. How would you change the code so that Process 1 does not block Process 2, even if it does sleep for 5 seconds?

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpicc mpi03.c -o mpi03
nayan@Nayan:~/Downloads$
```

ERROR:

```
nayan@Nayan: ~/Downloads
nayan@Nayan:~/Downloads$ mpiexec ./mpi03
Abort(469377030) on node 0 (rank 0 in comm 0): Fatal error in internal_Recv: Inv
alid rank, error stack:
internal_Recv(127): MPI_Recv(buf=0x7ffdf0380d74, count=1, MPI_INT, 1, 0, MPI_COM
M_WORLD, status=0x1) failed
internal_Recv(78).: Invalid rank has value 1 but must be nonnegative and less th
an 1
nayan@Nayan:~/Downloads$
```

Process 0 is blocked and must wait for the sleep function to complete while it awaits a message from process 1 before proceeding to process 2.

By substituting non-blocking communication for blocking communication, the issue can be resolved.

CODE:

mpi03.c
~/Downloads

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

int main(int argc, char** argv) {
  int size, rank;

  MPI_Init(NULL, NULL);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  if(size != 3) {
    if(rank == 0) {
      printf("This program needs to run on exactly 3 processes\n");
    }
  } else {
    if(rank ==0){
      int x, y;
      MPI_Recv(&x, 1, MPI_INT, 1, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
      printf("Received %d from process %d\n", x, 1);
      MPI_Recv(&y, 1, MPI_INT, 2, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
      printf("Received %d from process %d\n", y, 2);
    } else {
      if(rank == 1){
        MPI_Request request;
        int number = rank + 10;
        MPI_Isend(&number, 1, MPI_INT, 0, 0, MPI_COMM_WORLD, &request);
        usleep(5000000);
        MPI_Wait(&request, MPI_STATUS_IGNORE);
      } else {
        int number = rank + 10;
        MPI_Send(&number, 1, MPI_INT, 0, 0, MPI_COMM_WORLD);
      }
    }
  }
  MPI_Finalize();
  return 0;
}
```

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OUTPUT:

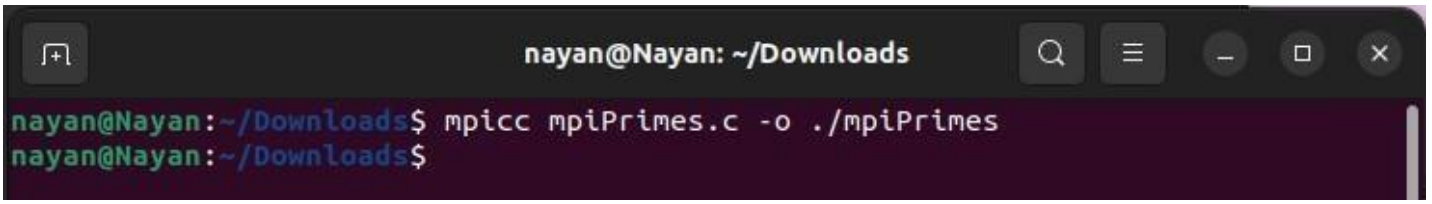
nayan@Nayan: ~/Downloads

```
nayan@Nayan:~/Downloads$ mpiexec -n 3 ./mpi03
Received 11 from process 1
Received 12 from process 2
```

6. The following is a simple program that looks for prime numbers between 1 to 10000:

```
 #include <stdio.h>
int main(int argc, char
 **argv)  {
 int i, c;
   int nstart=1, nfinish=10000;
   printf("%s : Prime numbers between %d and %d are :\n",
   nstart, nfinish);  for(i=nstart; i<=nfinish; i++)
   { for(c=2; c<=i-1; c++)
     { if ( i%c==0
       ) break;
     } if ( c==i ) printf("%s :
     %d\n",argv[0], i);
   } return
   0;
 }
```

Convert it to MPI so that it can run with different numbers of processes including just one process.



CODE:

mpiPrimes.c
~/Downloads

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

int main(int argc, char **argv)
{
    int i, c;
    int nstart = 1, nfinish = 10000;
    int rank, size;

    MPI_Init(&argc, &argv);
    MPI_Comm_rank(MPI_COMM_WORLD, &rank);
    MPI_Comm_size(MPI_COMM_WORLD, &size);

    int chunk_size = (nfinish - nstart + 1) / size;
    int start = nstart + rank * chunk_size;
    int end = start + chunk_size - 1;
    if (rank == size - 1) {
        end = nfinish;
    }

    printf("Process %d: Prime numbers between %d and %d are:\n", rank, start, end);
    for (i = start; i <= end; i++) {
        for (c = 2; c <= i - 1; c++) {
            if (i % c == 0) {
                break;
            }
        }
        if (c == i) {
            printf("Process %d: %d\n", rank, i);
        }
    }

    MPI_Finalize();
    return 0;
}
```

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OUTPUT:

nayan@Nayan: ~/Downloads

```
nayan@Nayan:~/Downloads$ mpiexec ./mpiPrimes
Process 0: Prime numbers between 1 and 10000 are:
Process 0: 2
Process 0: 3
Process 0: 5
Process 0: 7
Process 0: 11
Process 0: 13
```

. . .

```
Process 0: 9967
Process 0: 9973
nayan@Nayan:~/Downloads$
```