GWDG – Kurs
Parallel Programming with MPI

Point-to-Point Communication Exercises

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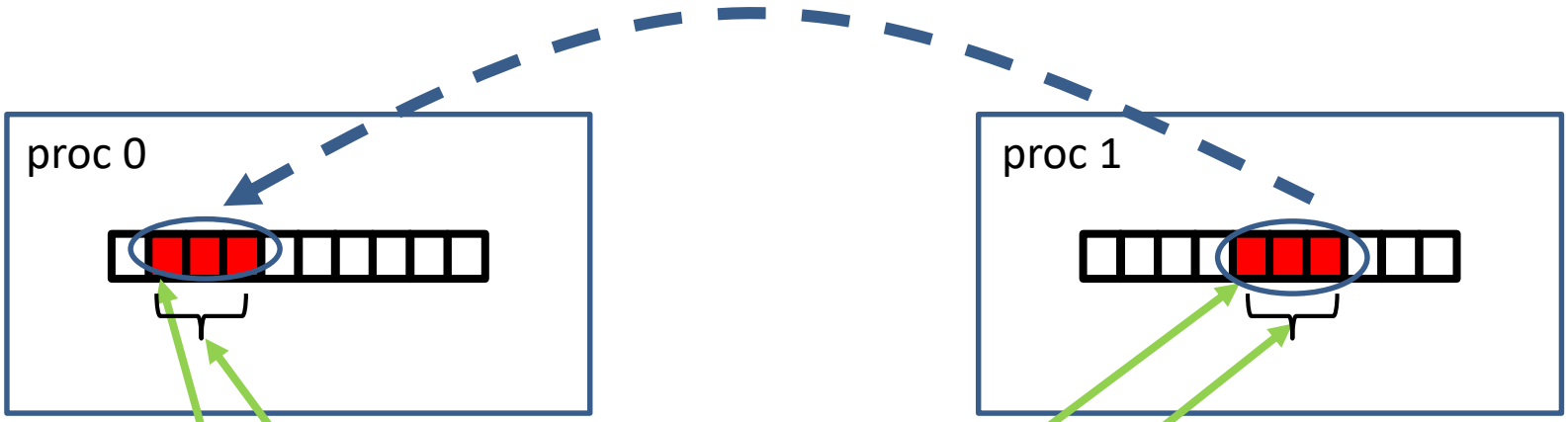
Exercise 1: Passing a Message




```
double precision vec(10); integer tag = 0, nsend = 3, nrecv = 3
```

```
MPI_RECV( vec(2), nrecv, MPI_DOUBLE_PRECISION, MPI_ANY_SOURCE,
    MPI_ANY_TAG, MPI_COMM_WORLD, MPI_STATUS_IGNORE, ierr)
```

```
MPI_SEND( vec(5), nsend, MPI_DOUBLE_PRECISION, 0, tag,
      MPI_COMM_WORLD, ierr)
```

Exercise 1:

Source code in directory

`mpiexercises/[f,c,py]/MPI-p2p`

Message passing programs

`p2p_vector.f p2p_vector.c  p2p_vector.py`

Exercise 1: Comments to `p2p_vector.f`

- types of send and receive buffers must coincide
- MPI datatypes must conform to types of these buffers

```
double precision vec(10)

MPI_SEND(vec(...),..., MPI_DOUBLE_PRECISION,...

MPI_RECV(vec(...),..., MPI_DOUBLE_PRECISION,...
```

Exercise 1: Comments to `p2p_vector.c`

- types of send and receive buffers must coincide
- MPI datatypes must conform to types of these buffers
- Address of buffers as first arguments : **`&vec[...]`**
  (parameter passing by value in C)

```
double vec[10];

MPI_Send(&vec[...],...,MPI_DOUBLE,...

MPI_Recv(&vec[...],...,MPI_DOUBLE,...
```

Exercise 1: Comments to p2p_vector.py

Datatype information is attached to the numpy object instanciated by

```
vec = myid*np.arange(1,11,dtype = np.float64)
```

The array section object **vec[startsend:startsend+nsend]** includes information about datatype and number of elements, therefore no count and datatype arguments in mpi4py calls to send and receive:

```
comm.Send(vec[startsend:startsend+nsend],
          dest=0,tag=11)

comm.Recv(vec[startrecv:startrecv+nrecv,
         source=MPI.ANY_SOURCE,tag=MPI.ANY_TAG)
```

Exercise 1:

What happens if nrecv < nsend?

What if nrecv > nsend?

Exercise 2: Retrieving Message Properties

Retrieving Message Properties from **`stat`**

	C	Fortran	mpi4py
type	`MPI_Status stat`	`integer stat(MPI_STATUS_SIZE)`	`stat = MPI.Status()`
source	`stat.MPI_SOURCE`	`stat(MPI_SOURCE)`	`stat.Get_source()`
tag	`stat.MPI_TAG`	`stat(MPI_TAG)`	`stat.Get_tag()`
error	`stat.MPI_ERROR`	`stat(MPI_ERROR)`	`stat.Get_error()`
count	`MPI_Get_count (&stat,datatype,&count)`	`call MPI_GET_COUNT (stat,datatype,count,ierr)`	`stat.Get_elements (datatype)`
size	---	---	`stat.Get_size()`

Exercise 2: Retrieving Message Properties

Source code in directory

`mpiexercises/[f,c,py]/MPI-p2p`

Message passing programs

`p2p_status.f p2p_status.c  p2p_status.py`

- Includes call to MPI_ GET_COUNT to retrieve number of received elements .
- Complete code to retrieve source and tag of received message

Exercise 3: Using MPI_PROBE

Retrieve number of elements in the pending message with MPI_PROBE:

Copy **`p2p_status.<>`** to **`p2p_probe.<>`**

Modify **`p2p_probe.<>`**:

Call MPI_PROBE before calling MPI_RECEIVE:

C
```
MPI_Probe(MPI_ANY_SOURCE,
          MPI_ANY_TAG, comm, &stat);
```

Fortran
```
call MPI_PROBE(MPI_ANY_SOURCE,
  MPI_ANY_TAG, comm, stat,  ierr)
```

mpi4py
```
comm.Probe(MPI.ANY_SOURCE,
           MPI.ANY_TAG, stat)
```

Exercise 3: Using MPI_PROBE

Determine **nrecv** parameter to be used in the MPI_RECV call from the number of elements in the pending message by

C
```
MPI_Get_count(&stat, MPI_DOUBLE, &nrecv);
```

Fortran
```
call MPI_GET_COUNT(stat,
                   MPI_DOUBLE_PRECISION, nrecv, ierr)
```

mpi4py
```
nrecv = stat.Get_elements(MPI.DOUBLE)
```

Exercise: Non-Blocking RECV

Source code in directory

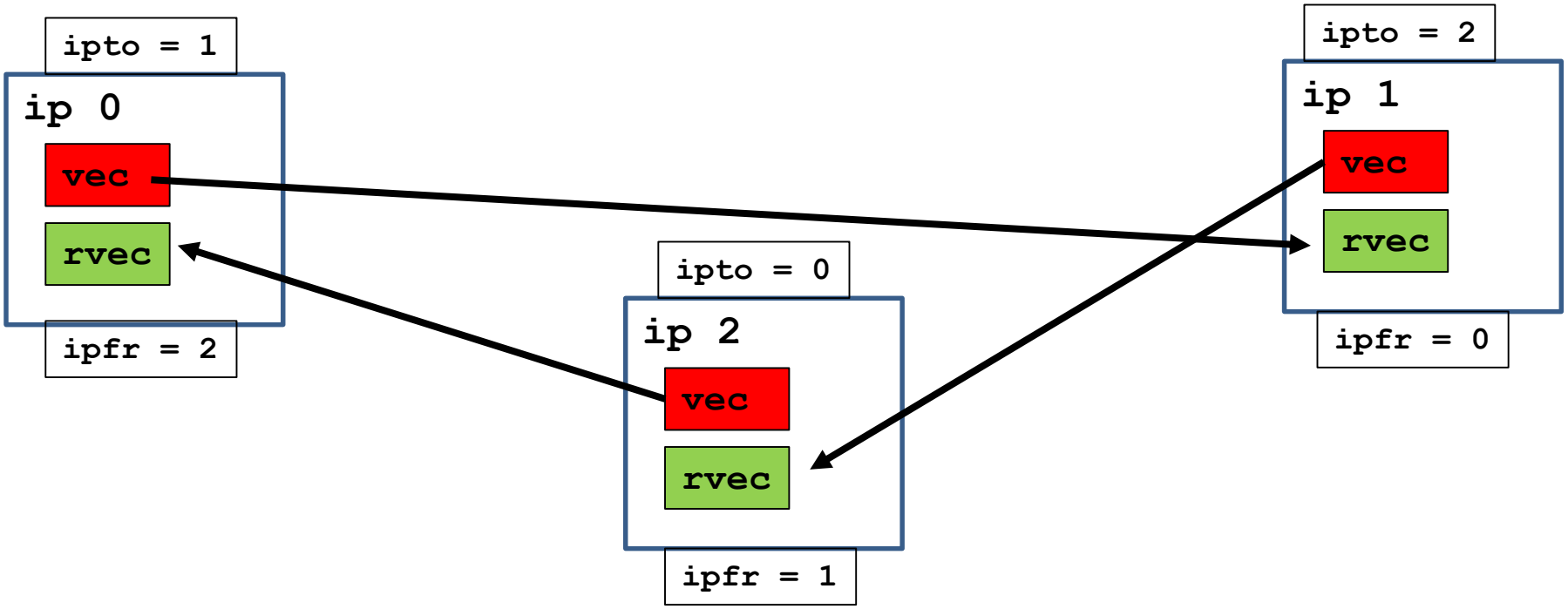
`mpiexercises/[f,c,py]/MPI-p2p`

Non-blocking recv in programs

`p2p_irecv.f p2p_irecv.c  p2p_iRcv.py`

- Inspect and run the program.
- Modify the program by using the MPI_WAIT function instead of MPI_TEST
- What happens, if you omit the MPI_WAIT ?

Exercise 4: Clockwise Ring Shift




```
call MPI_SEND( vec, nl, MPI_INTEGER, ipto, 0, MPI_COMM_WORLD, ierr )
call MPI_RECV( rvec, nl, MPI_INTEGER, ipfr, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE, ierr )
```

Exercise 4: Deadlock

Ring shift of long messages leads to deadlock:

`p2p_deadlock.f`
`p2p_deadlock.c`
`p2p_deadlock.py`

Run the example program and determine, at which size of the message a deadlock occurs.

Compare openmpi and intel-mpi

Replace MPI_SEND by MPI_SSEND

Exercise 4: Avoiding the Deadlock – Change order

1st solution: Change order of send and receive for one process.

Copy **p2p_deadlock.f** to **p2p_no_deadlock_1.f**

Use the following modification:

```
 if (myid.eq.0) then
    call MPI_RECV( rvec, nl, MPI_INTEGER, ipfr, 0,
:                  MPI_COMM_WORLD, MPI_STATUS_IGNORE, ierr )
    call MPI_SEND( vec, nl, MPI_INTEGER, ipto, 0,
:                  MPI_COMM_WORLD, ierr )
 else
    call MPI_SEND( vec, nl, MPI_INTEGER, ipto, 0,
:                  MPI_COMM_WORLD, ierr )
    call MPI_RECV( rvec, nl, MPI_INTEGER, ipfr, 0,
:                  MPI_COMM_WORLD, stat, ierr )
 end if
```

Exercise 4: Avoiding the Deadlock: BSEND

2nd solution: Using Buffered send:

Fortran:

Copy **p2p_deadlock.f** to **p2p_no_deadlock_2.f**
modify code, using:

```
integer temp(110000000)
integer bsize
bsize = 4*nl+MPI_BSEND_OVERHEAD
! Buffer Size in Byte including overhead
call MPI_BUFFER_ATTACH(temp,bsize,ierr)
...
call MPI_BSEND( vec, nl,...
...
call MPI_BUFFER_DETACH(temp,bsize,ierr)
```

Exercise 4: Avoiding the Deadlock: BSEND

2nd solution: Using Buffered send:

C:

Copy **p2p_deadlock.c** to **p2p_no_deadlock_2.c**
modify code, using:

```
  int temp[110000000];
  char *tempptr
  int bsize = 4*nl + MPI_BSEND_OVERHEAD
// Buffer Size in Byte including overhead
  MPI_Buffer_attach(temp,bsize);
        ..
  MPI_Bsend( vec, nl,...;
        ...
  MPI_Buffer_detach(&tempptr,&bsize);
```

Exercise 4: Avoiding the Deadlock: BSEND

2nd solution: Using Buffered send:

mpi4py:

Copy **p2p_deadlock.py** to **p2p_no_deadlock_2.py**
modify code, using:

```
    ntemp = nl + MPI.BSEND_OVERHEAD
# Buffer length including overhead
    temp = np.empty(ntemp,dtype = np.int)
    MPI.Attach_buffer(temp)
        ...
    comm.Bsend(vec,dest=ipto)
        ...
    MPI.Detach_buffer()
```

Exercise 4: Avoiding the Deadlock: SENDRECV

3rd solution using **SENDRECV**

Copy **p2p_deadlock.f** to **p2p_no_deadlock_3.f**

Modify code:

FORTRAN:

```
 call MPI_SENDRECV( vec,nl,MPI_DOUBLE_PRECISION,ipto,tag,
:                   rvec,nl,MPI_DOUBLE_PRECISION,ipfr,tag,
:                   MPI_COMM_WORLD,stat,ierr )
```

C:

```
 MPI_Sendrecv( vec,nl,MPI_DOUBLE,ipto,tag,
               rvec,nl,MPI_DOUBLE,ipfr,tag,
               MPI_COMM_WORLD, &stat);
```

mpi4py:

```
 comm.Sendrecv(sendbuf=vec,dest=ipto,
               recvbuf=rvec,source=ipfr)
```

Exercise 4: Avoiding the Deadlock: ISEND

4th solution: Using non-blocking ISEND:

Fortran:

Copy **p2p_deadlock.f** to **p2p_no_deadlock_4.f**
modify code, using:

```
integer req
 ...
call MPI_ISEND( sendvec, nl, MPI_DOUBLE_PRECISION,
ipto, tag, MPI_COMM_WORLD, req, ierr )
...
  no need to modify receive call
...
call MPI_WAIT( req, stat, ierr )
```

Exercise 4: Avoiding the Deadlock: ISEND

4th solution: Using non-blocking Isend:

C:

Copy **p2p_deadlock.c** to **p2p_no_deadlock_4.c**
modify code, using:

```
MPI_Request req;
  ...
MPI_Irecv( recvvec, nl, MPI_DOUBLE, ipfr, tag,
MPI_COMM_WORLD, &req);
...
  no need to modify send call
...
MPI_Wait( &req, &stat );
```

Exercise 4: Avoiding the Deadlock: ISEND

4th solution: Using non-blocking Isend:

mpi4py:

Copy **p2p_deadlock.py** to **p2p_no_deadlock_4.py**
modify code, using:

```
req = comm.Isend(sendvec,dest=ipto)
...
  no need to modify send call
...
MPI.Request.Wait(req)
```

Exercise 4: Comparison of Solutions

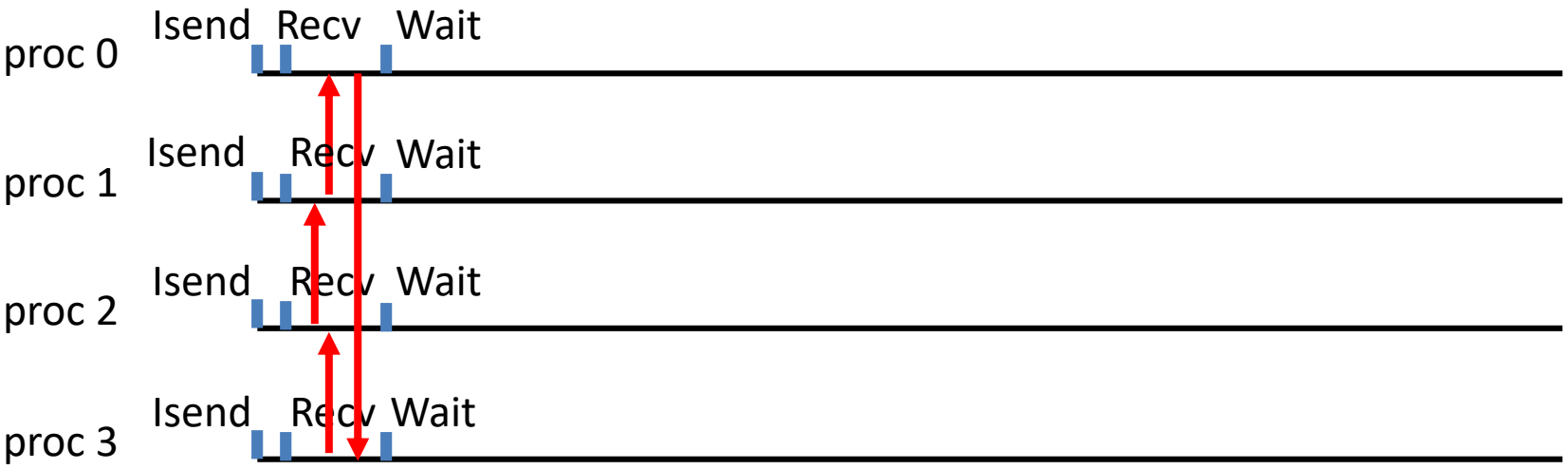
1th solution: Change order

serialized communication

time is linear in number of procs

Exercise 4: Comparison of Solutions

4th solution: Isend



simultaneous communication
time depends on network capabilities

Compare the performance of solutions 1 and 4
using the **`time`** command:

```
>time mpirun -n 4 ./a.out
```

Exercise 5: collect output in program prime_clct

In Program **prime_clct.<>** every process prints the number **nd** of divisors found in ist set of tested integers.

Modify the program **prime_clct.<>** : let process **0** collect and print the numbers **nd** of divisors found in the different processes.

- define an integer array **numdiv**
- every process sends its **nd** to process **0**:

```
call MPI_SEND(nd,1, MPI_INTEGER, 0,tag,
              MPI_COMM_WORLD, ierr )
```

- process 0 stores nd from process ip in numbers in **numdiv(ip)**

```
do ip = 0 , nproc-1
   call MPI_RECV(numdiv(ip),1,MPI_INTEGER,ip, tag,
                        MPI_COMM_WORLD,stat,ierr)
end do
```

- process **0** prints **numdiv**

Exercise 5: collect output in program prime_clct

What happens, if instead of standard send **`MPI_SEND`**
synchronous send **`MPI_SSEND`** is used ?

Complete Code for Exercises

If you have tried hard to perform the required exercises and the programs still don‘t work, you are allowed to look into the directories

~ohaan/mpisolutions/f
~ohaan/mpisolutions/c
~ohaan/mpisolutions/py

where you will find the completed programs for some exercises

Exercise 6: Speed and Latency of Communication

Point-to-Point Ping-Pong with **pp_mpi.f**

- Compile with **make pp**
- Communication parameters on local frontend node

```
mpirun –n 4 ./pp_mpi.exe
```

- Communication parameters between different cluster nodes

```
sbatch job.script
```

```
#!/bin/bash
#SBATCH -t 00:10:00
#SBATCH -N 2
#SBATCH --ntasks-per-node 2
#SBATCH -p medium
##SBATCH --reservation mpi-course

mpirun ./pp_mpi.exe
```