GWDG – Kurs
Parallel Programming with MPI

Collective Operations Exercises

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Outline

- Synchronization
  - How to synchronize
- Broadcast
  - An example to distribute input data
- Gathering
  - Ways to combine local data of different sizes
- Reduction
  - Example: Monitor progress of processes
    Accumulate data from all processes

Exercise 1: Synchronization

(Source code in : **`mpiexercises/[f,c,py]/MPI-coll`**)

```
call MPI_BARRIER(comm,ierr)
MPI_Barrier(comm)
Comm.Barrier
```

Determine the time needed for synchronization for different number of processes (use **`synch.f`** **(make synch)**, **`synch.py`**)

Exercise 1: Synchronization

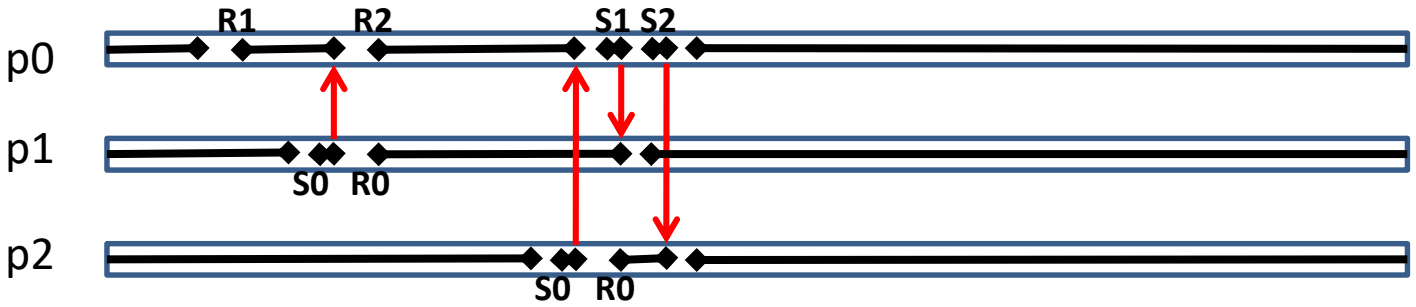
Program your own barrier using point-to-point communication:

(complete the program **`synch_s.(f,c,py]`**)

all tasks except task 0 send a message to task 0

task 0 sends a message to all other tasks

possible pattern for process execution times



Solution for Exercises

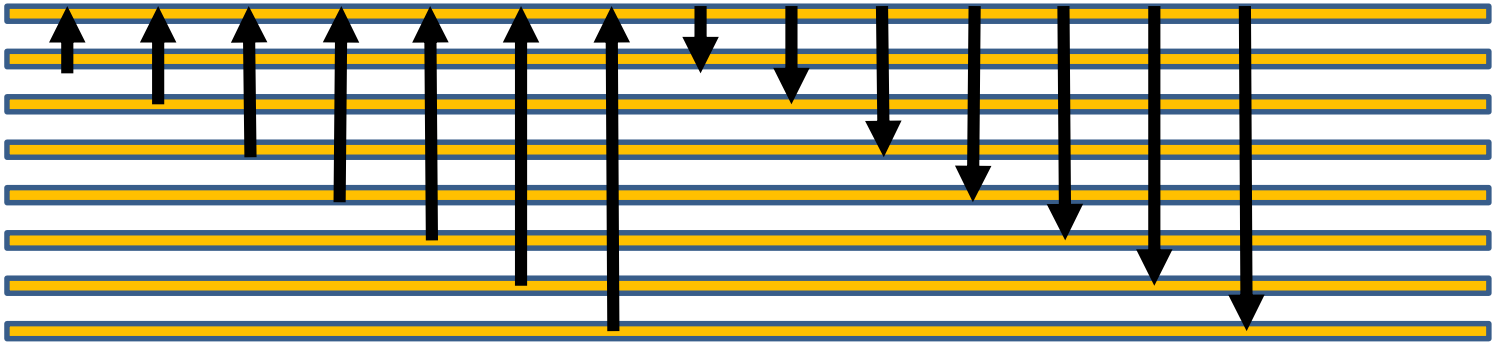
If you have tried hard to perform the required exercises and the programs still don‘t work, you are allowed to look into the directories

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

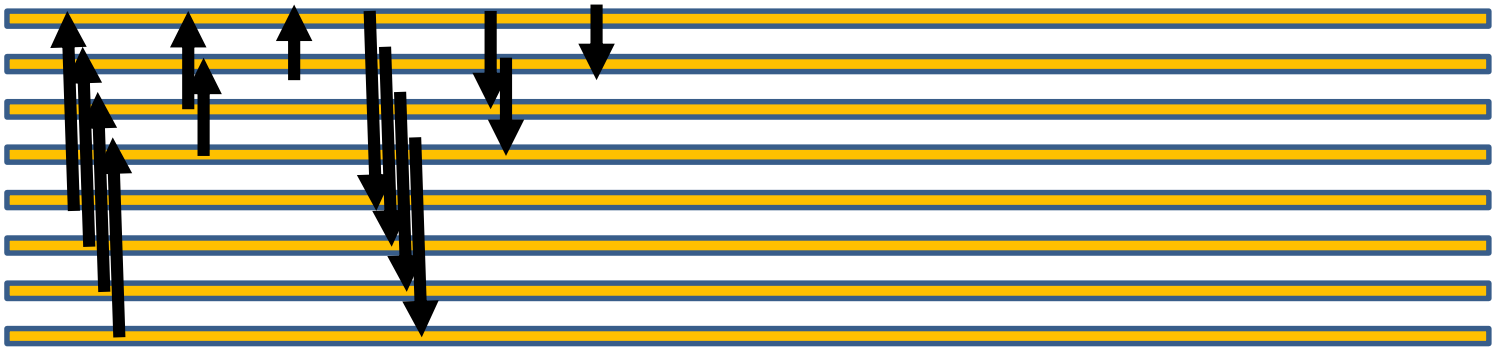
where you will find the completed programs for some exercises

Exercise 1: Synchronization

Sequential Synchronization (t~ np)



Partially Parallel Synchronization (t~ln (np))



Example implementation in program **`synch_casc.f`** (valid only for np =2^k)

Exercise 2: Broadcast

Modify program bcast (*distribution of input value n from process 0 to all other processes*) by using the broadcast function instead of the sequential send and receive operations

C:

```
MPI_Bcast( void *buf, int count,
           MPI_Type datatype, int root, MPI_Comm comm )
```

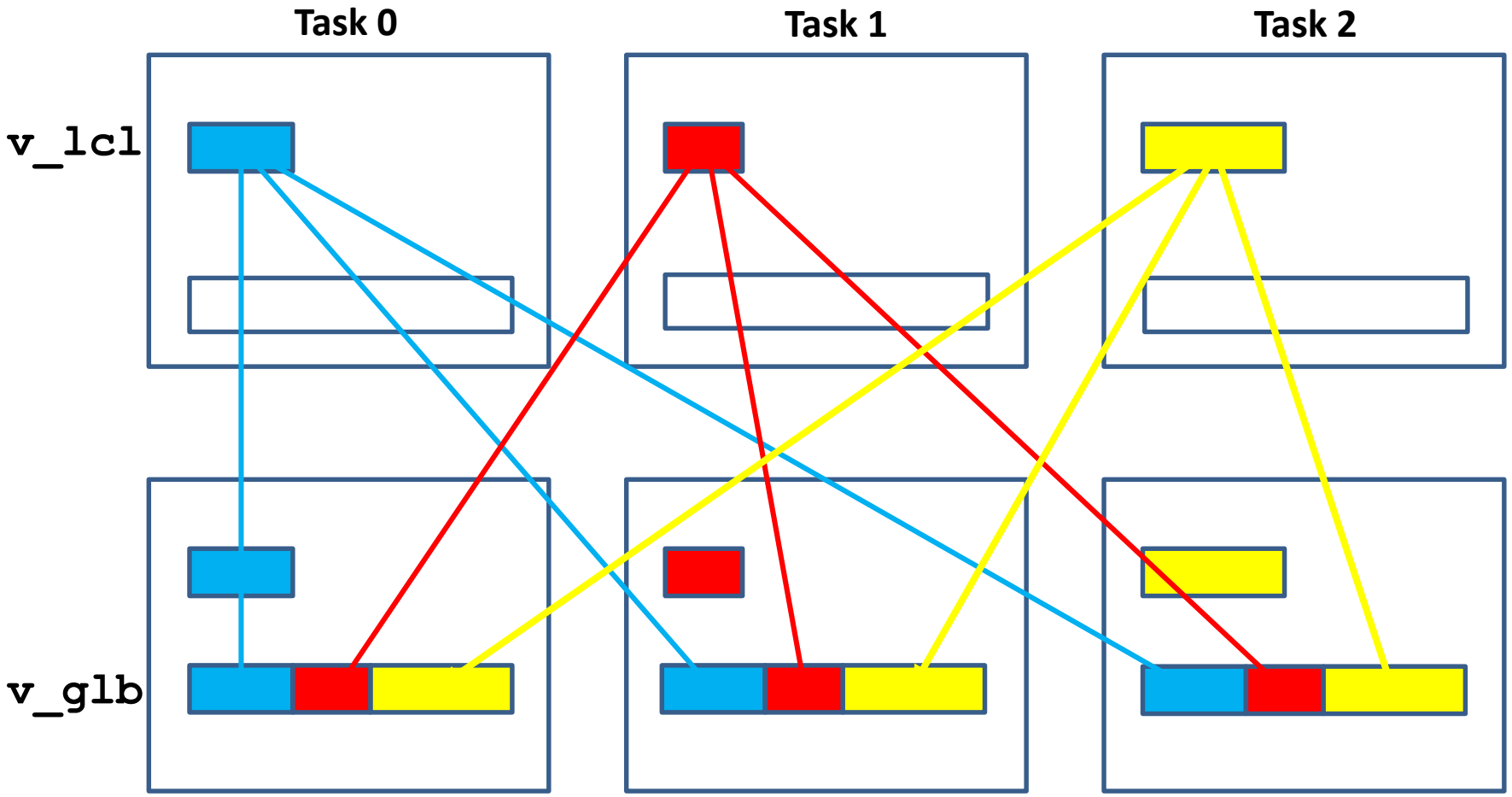
Fortran:

```
MPI_BCAST( buf, count, datatype, root, comm, ierror )
<type>buf(*), INTEGER count, datatype, root, comm,
ierror
```

mpi4py:

```
robj = comm.bcast(sobj, root= 0)
comm.Bcast(ar, root= 0)
```

Exercise 3: Gather Data(1)

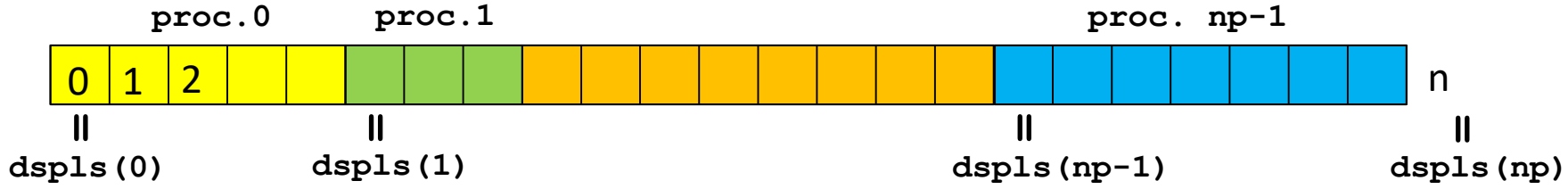


Exercise 3: Gather Data(2)

v_glb is a vector with **n** elements in **np** intervals

vector of interval sizes: **counts(0),...,counts(np-1)**

vector of start indices : **dspls(0),...,dspls(np)**



Length of local vectors on process ip :

counts(ip) = dspls(ip+1)-dspls(ip), ip=0,np-1

Length of global vector :

n = dspls(np)

Exercise 3: Gather Data(3)

Example:

Length of local vector on process ip is ip+3:

```
dspls(0) = 0
do ip = 1 , np
   dspls(ip) = dspls(ip-1)+ 3 +(ip-1)
   counts(ip-1) = dspls(ip) - dspls(ip-1)
end do
nglb = dspls(np)
```

Initialize the local vectors (such that v_glb(i) = i):

```
do i = 0 , counts(myid)-1
   v_lcl(i) = dspls(myid)+i
end do
```

Exercise 3: Gather Data(4)

Solution 1: gather with SEND / RECV

(**program collect_sendrecv**)

Every process sends its local vector to all other processes:

```
nlcl = counts(myid)
do ip = 0,np-1
  call MPI_SEND(v_lcl,nlcl,type,ip ...
```

Every process stores local vectors from other processes at the appropriate location in the global vector:

```
do ip = 0,np-1
    nrecv = counts(ip)
    call MPI_RECV(v_glb(dspls(ip)),nrecv,type,ip ...
```

Exercise 3: Gather Data(5)

Solution 2: with BCAST

(complete **`program collect_bcast`**)

Every process copies its **`v_lcl`** to its **`v_glb`**:

```
nlcl = counts(myid)
 do i = 1 , nlcl
     v_glb(dspls(myid)+i) = v_lcl(i)
```

Every process broadcasts this part of v_glb

Syntax for broadcast:

MPI_BCAST(buffer, count, datatype, root, comm)

comm.Bcast(buf, root = root)

Exercise 3: Gather Data(6)

Solution 3: with GATHERV (Fortran, C)
(complete **`program collect_gather`**)

Gather local Data v_lcl of all processes in v_glb in process 0:

```
call MPI_GATHERV( v_lcl, counts(myid), sendtype,
   v_glb, counts, dspls, recvtype, 0, comm, ierr )
```

BCAST v_glb from process 0 to all processes

```
call MPI_BCAST(v_glb,nglb,type,0,comm, ierr )
```

Combine the two steps with: **`MPI_ALLGATHERV`**

Exercise 3: Gather Data(7)

Solution 3: with GATHERV (mpi4py)
(complete **`program collect_gather`**)

Gather local Data v_lcl of all processes in v_glb in process 0:

```
comm.Gatherv( sendbuf, recvbuf, root=0)
```

where:

```
sendbuf = v_lcl
recvbuf =[v_glb,counts,dspls[0:nproc],MPI.DOUBLE]
```

BCAST v_glb from process 0 to all processes

```
comm.Bcast(v_glb, root=0)
```

Alternatively : Combine the two steps with: **`MPI_ALLGATHERV`**

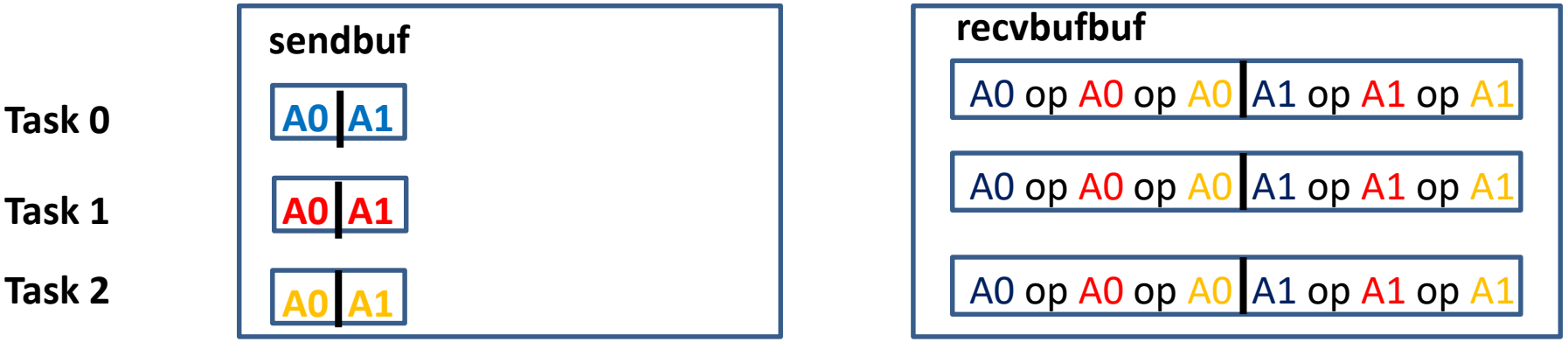
Exercise 4: Monitoring Program Execution

Signaling an error in one process to all other processes

- Look at the program **`errexit.f, errexit.py`** ,
  find out its behaviour
- Combine MPI_REDUCE + MPI_BCAST to MPI_ALLREDUCE

Syntax:

MPI_ALLREDUCE(sendbuf, recvbuf, count, datatype, op, comm)
recvbuf= comm.reduce(*sendobj* = sendbuf, *recvobj*=None, *op*=op)



Exercise 5: Reduce: MPI_SUM

- Generate a program to distribute the summation of integers from 1 to N.
- Hint: Calculate partial sums on every process and combine them to the total result with MPI_REDUCE using the operation MPI_SUM
- Modify the sequential code in
- **`intsum.[f,c,py]`**

Syntax of MPI_REDUCE

```
call MPI_REDUCE(suml,sum,1,MPI_INTEGER, MPI_SUM,
   :                    0,MPI_COMM_WORLD, ierr )
sum = comm.reduce(suml,op=MPI.SUM,root=0)
comm.Reduce(suml,sum,op=MPI.SUM,root=0)
```

Exercise 6: Reduce

Modify step 7 in program piapp_mpi (*add up all local **res** to the total results **pia** on process **0***) by using the reduce function instead of the sequential send and receive operations

C:

```
MPI_Reduce( void *sendbuf, void *recvbuf, int count,
            MPI_Type datatype, MPI_Op op, int root,
            MPI_Comm comm )
```

Fortran:

```
MPI_REDUCE( sendbuf, recvbuf, count, datatype, op,
root, comm, ierror )
<type>sendbuf(*), recvbuf
INTEGER count, datatype, op, root, comm, ierror
```

mpi4py:

```
rbuf = comm.reduce(sbuf,op=oper root= 0)
```