

Topic: MPI Programming

Objective

- MPI basic functions
- MPI Collective functions/communication

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Template

program sample_mpi

Implicit none

Include 'mpif.h'

[other includes]

integer :: ierr, nproc, rank

[other declarations]

call mpi_init(ierr)

call mpi_comm_size(MPI_COMM_WORLD, nproc, ierr)

call mpi_comm_rank(MPI_COMM_WORLD, rank, ierr)

:

Main part of the code

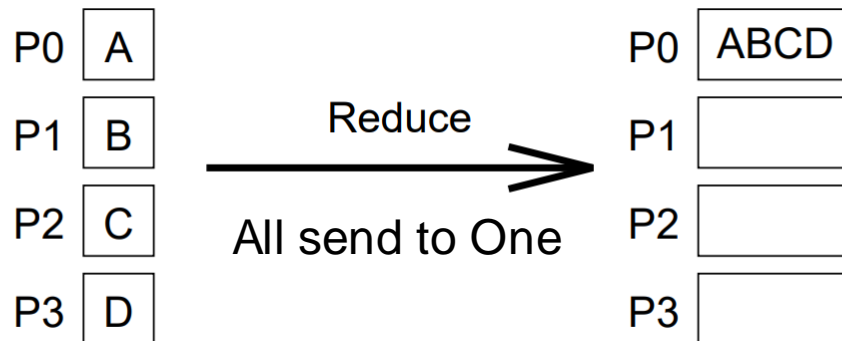
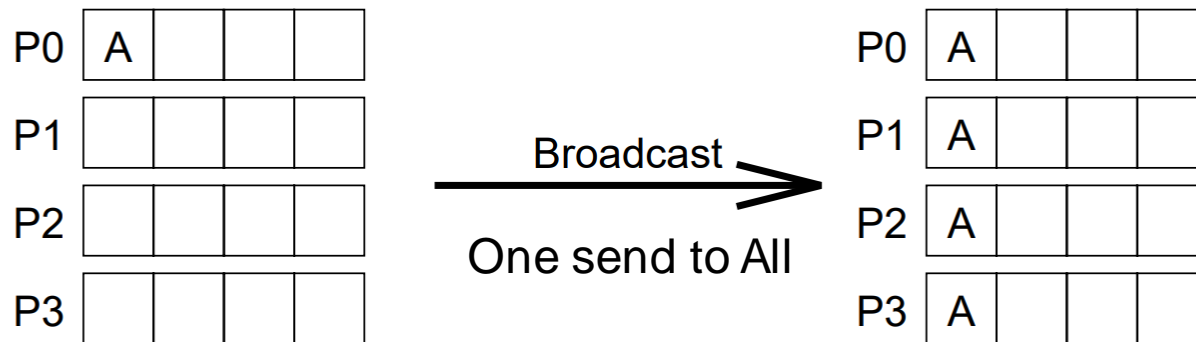
:

call mpi_finalize(ierr)

end program

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Collective communication - Broadcast and reduction



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Collective communication - Broadcast and reduction

```
MPI_Bcast(  
    data,  
    int count,  
    MPI_Datatype datatype,  
    int root,  
    MPI_Comm communicator, ierr)
```

MPI_Datatype: MPI_LOGICAL,
MPI_INTEGER, MPI_REAL,
MPI_DOUBLE_PRECISION

```
MPI_Reduce(  
    send_data,  
    recv_data,  
    int count,  
    MPI_Datatype datatype,  
    MPI_Op op,  
    int root,  
    MPI_Comm communicator, ierr)
```

MPI_Op: MPI_MAX, MPI_MIN,
MPI_SUM, MPI_PROD, etc

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Examples – MPI Broadcast

`MPI_Bcast(data, count, MPI_Datatype, root, MPI_Comm, ierr)`

Examples:

- `call MPI_Bcast(x, 1, MPI_Int, 0, MPI_Comm_World, ierr);`
- `call MPI_Bcast(numbers, 100, MPI_Double_Precision, 0, MPI_Comm_World, ierr);`

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Examples – MPI Reduce

`MPI_Reduce(send_data, recv_data, count, MPI_Datatype, MPI_Op, root, MPI_Comm, ierr)`

Examples:

- call `MPI_Reduce(avg_distance, new_avg_distance, 1, MPI_Real, MPI_Sum, 0, MPI_Comm_World, ierr)`
- call `MPI_Reduce(old, new, 100, MPI_Double_Precision, MPI_Sum, 0, MPI_Comm_World, ierr)`

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Fortran and C

Function Purpose	C Function Call	Fortran Subroutine Call
Initialize MPI	int MPI_Init (int *argc, char **argv)	integer ierror call MPI_Init (ierror)
Determine number of processes within a communicator	int MPI_Comm_size (MPI_Comm comm, int *size)	integer comm,size,ierror call MPI_Comm_Size (comm,size,ierror)
Determine processor rank within a communicator	int MPI_Comm_rank (MPI_Comm comm, int *rank)	integer comm,rank,ierror call MPI_Comm_Rank (comm,rank,ierror)
Exit MPI (must be called last by all processors)	int MPI_Finalize ()	CALL MPI_Finalize (ierror)
Send a message	int MPI_Send (void *buf,int count, MPI_Datatype datatype, int dest, int tag, MPI_Comm comm)	<type> buf(*) integer count, datatype,dest,tag integer comm, ierror call MPI_Send (buf,count, datatype, dest, tag, comm, ierror)
Receive a message	int MPI_Recv (void *buf,int count, MPI_Datatype datatype, int source, int tag, MPI_Comm comm, MPI_Status *status)	<type> buf(*) integer count, datatype, source,tag integer comm, status, ierror call MPI_Recv (buf,count, datatype, source, tag, comm, status, ierror)

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Standard input

Standard input is only accessible to the root process (rank=0)

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mpi_bcast

```
program test_broadcast
  implicit none
  include 'mpif.h'

  integer :: i, num
  integer :: nproc, rank, ierr

  call mpi_init(ierr)
  call mpi_comm_size(mpi_comm_world,nproc,ierr)
  call mpi_comm_rank(mpi_comm_world,rank, ierr)

  if(rank==0) then
    num=1
  endif

  call mpi_bcast(num,1,mpi_int,0,mpi_comm_world,ierr)

  num = num + rank

  write(*,"(a,i4,a,i4)") 'result in process id:',rank,' is', num

  call mpi_finalize(ierr)
end program test_broadcast
```

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Problem - 1

```
program test_mpi
  implicit none

  integer :: i, N, sum

  N = 100

  sum=0
  do i = 1, N
    sum = sum + i
  enddo

  write(*,"(a,i5,2x,a,i7)") "Sum of first ",N," numbers is: ", sum
end program test_mpi
```

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Problem - 1

```
program test_mpi
  implicit none
  include 'mpif.h'

  integer :: i, N, sum, final_sum

  integer :: ierr, nproc, rank

  call mpi_init(ierr)
  call mpi_comm_size(mpi_comm_world,nproc,ierr)
  call mpi_comm_rank(mpi_comm_world,rank, ierr)

  N = 100
  sum=0

  do i = 1+rank, N, nproc
    sum = sum + i
  enddo

  write(*,"(a,i5,2x,a,i7)") "Sum of first ",N," numbers is: ", sum

  call mpi_finalize(ierr)

end program test_mpi
```

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Problem - 1

```
program test_mpi
implicit none
include 'mpif.h'

integer :: i, N, sum, final_sum, stride, first, last

integer :: ierr, nproc, rank

call mpi_init(ierr)
call mpi_comm_size(mpi_comm_world,nproc,ierr)
call mpi_comm_rank(mpi_comm_world,rank, ierr)

N = 100
sum=0

stride = (N)/nproc

first = stride*rank+1
last = (rank+1)*stride

if(rank==nproc-1) then
    last=N
endif

write(*,"(a9,i4,a12,i8,a12,i8)") 'process: ',rank,&
    & ' starts at: ',first,' ends at: ',last

do i = first, last
    sum = sum + i
enddo

write(*,"(a,i5,2x,a,i7)") "Sum of first ",N,&
    & " numbers is: ", sum

call mpi_finalize(ierr)

end program test_mpi
```

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Problem – 1

```
program test_mpi
implicit none
include 'mpif.h'

integer :: i, N, sum, final_sum, stride, first, last

integer :: ierr, nproc, rank

call mpi_init(ierr)
call mpi_comm_size(mpi_comm_world,nproc,ierr)
call mpi_comm_rank(mpi_comm_world,rank, ierr)

N = 100
sum=0

stride = (N)/nproc

first = stride*rank+1
last = (rank+1)*stride

if(rank==nproc-1) then
  last=N
endif

write(*,"(a9,i4,a12,i8,a12,i8)") 'process: ',rank,&
& ' starts at: ',first,' ends at: ',last

do i = first, last
  sum = sum + i
enddo

write(*,"(a,i5,2x,a,i7)") "Sum of first ",N,&
& " numbers is: ", sum

call mpi_finalize(ierr)

end program test_mpi
```

```
$ mpirun -np 3 ./a.out
process:    0 starts at:      1 ends at:      33
process:    2 starts at:     67 ends at:     100
Sum of first 100 numbers is:  2839
process:    1 starts at:     34 ends at:      66
Sum of first 100 numbers is:  1650
Sum of first 100 numbers is:   561
$
```

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Problem - 1

```
program test_mpi
  implicit none
  include 'mpif.h'

  integer :: i, N, sum, final_sum, stride, first, last

  integer :: ierr, nproc, rank

  call mpi_init(ierr)
  call mpi_comm_size(mpi_comm_world,nproc,ierr)
  call mpi_comm_rank(mpi_comm_world,rank, ierr)

  N = 100
  sum=0

  stride = (N + nproc - 1)/nproc

  first = stride*rank+1
  last = min(N, (rank+1)*stride)

  write(*,"(a9,i4,a12,i8,a12,i8)") 'process: ',rank,&
    & ' starts at: ',first,' ends at: ',last

  do i = first, last
    sum = sum + i
  enddo

  write(*,"(a,i5,2x,a,i7)") "Sum of first ",N,&
    & " numbers is: ", sum

  call mpi_finalize(ierr)
end program test_mpi
```

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Problem - 1

```
program test_mpi
  implicit none
  include 'mpif.h'

  integer :: i, N, sum, final_sum, stride, first, last

  integer :: ierr, nproc, rank

  call mpi_init(ierr)
  call mpi_comm_size(mpi_comm_world,nproc,ierr)
  call mpi_comm_rank(mpi_comm_world,rank, ierr)

  N = 100
  sum=0

  stride = (N + nproc - 1)/nproc

  first = stride*rank+1
  last = min(N, (rank+1)*stride)

  write(*,"(a9,i4,a12,i8,a12,i8)")
    & ' starts at: ',first,' end

  do i = first, last
    sum = sum + i
  enddo

  write(*,"(a,i5,2x,a,i7)") "Sum of
    & " numbers is: ", sum

  call mpi_finalize(ierr)

end program test_mpi
```

```
$ mpirun -np 4 ./a.out
process:    0 starts at:      1 ends at:      25
Sum of first 100 numbers is:    325
process:    3 starts at:     76 ends at:    100
Sum of first 100 numbers is:   2200
process:    1 starts at:     26 ends at:     50
Sum of first 100 numbers is:    950
process:    2 starts at:     51 ends at:     75
Sum of first 100 numbers is:   1575
```

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Hands-on

1. Use MPI_Reduce function in the program given in the previous slide and print the result in the root process
2. Write a MPI Fortran program to read five numbers from standard input and write the output to terminal.
3. Write a program to generate 1000 random numbers in each process, in the range [0, 1] in process 0, in the range [1,2] in process 1, in the range [2,3] in process 2, and so on. And, find average, max and min values (over all the numbers)

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Reading material

- Check the website given below for a well-written hands-on tutorial on MPI
<https://mpitutorial.com/tutorials/>
- Peter Pacheco, "Parallel Programming with MPI"