Distributed Computing and Introduction to High Performance Computing

Imad Kissami[1]

[1]Mohammed VI Polytechnic University, Benguerir, Morocco

Outline of this lecture

Communication Modes

- Standard Send
- Synchronous Send
- Buffered send

Communication Modes

General concepts

Blocking call

- A call is blocking if the memory space used for the communication can be reused immediately after the exit of the call
- The data sent can be modified after the call.
- The data received can be read after the call.

Point-to-Point Send Modes

Mode	Blocking	Non-blocking
Standard Send	`MPI_SEND()`	`MPI_ISEND()`
Synchronous Send	`MPI_SSEND()`	`MPI_ISSEND()`
Buffered send	`MPI_BSEND()`	`MPI_IBSEND()`
Receive	`MPI_RECV()`	`MPI_IRECV()`

Table: Point-to-Point Send Modes

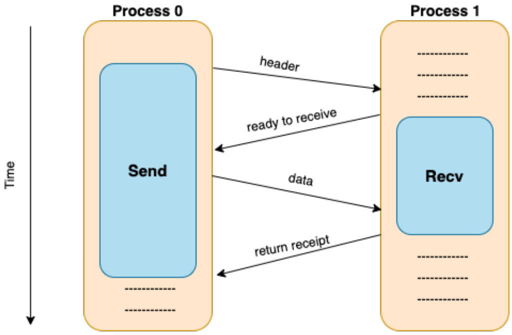
Communication Modes

Synchronous sends

- A synchronous send involves a synchronization between the involved processes. A send cannot start until its receive is posted. There can be no communication before the two processes are ready to communicate.

Rendezvous Protocol

- The rendezvous protocol is generally the protocol used for synchronous sends (implementation-dependent). The return receipt is optional.



Communication Modes

Interface of : MPI_SSEND()

```
MPI_SSEND(values, count, msgtype, dest, tag, comm, code)

type(*), intent(in) :: values
integer, intent(in) :: count, msgtype, dest, tag, comm

integer, intent(out) :: code
```

- Advantages of synchronous mode
  - Low resource consumption (no buffer)
  - Rapid if the receiver is ready (no copying in a buffer)
  - Knowledge of receipt through synchronization
- Disadvantages of synchronous mode
  - Waiting time if the receiver is not there/not ready
  - Risk of deadlocks

```
COMM.Ssend(self, data, int dest, int tag=0)
#or
COMM.ssend(self, data, int dest, int tag=0)
```

Communication Modes

Deadlock example

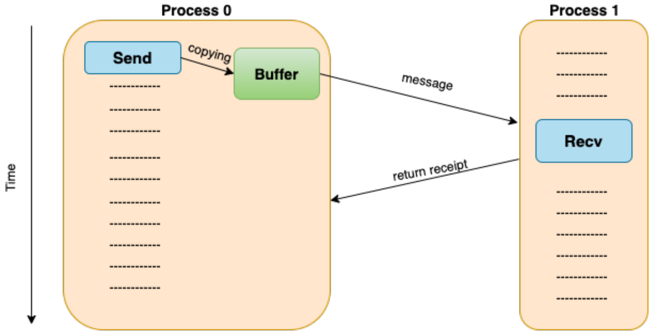
In the following example, there is a deadlock because we are in synchronous mode. The two processes are blocked on the MPI_SSEND() call because they are waiting for the MPI_RECV() of the other process. However, the MPI_RECV() call can only be made after the unblocking of the MPI_SSEND() call.

```python
from mpi4py import MPI

COMM = MPI.COMM_WORLD
RANK = COMM.Get_rank()

tag = 99

sendbuf = 1000
COMM.ssend(sendbuf, dest=1, tag=tag)

recvbuf = COMM.recv(source=1, tag=tag)
print("I, process 1, I received ",recvbuf," from the process 2.")
```

```
mpirun -n 2 python ssendrecv.py
```

Communication Modes

- **Buffered sends**
  A buffered send implies the copying of data into an intermediate memory space. There is then no coupling between the two processes of communication. Therefore, the return of this type of send does not mean that the receive has occurred.
- **Protocol with user buffer on the sender side**
  In this approach, the buffer is on the sender side and is managed explicitly by the application. A buffer managed by MPI can exist on the receiver side. Many variants are possible. The return receipt is optional.



Communication Modes

Interface of : MPI_BSEND()

- **Buffered sends**
  The buffers have to be managed manually (with calls to MPI_BUFFER_ATTACH() and MPI_BUFFER_DETACH()). Message header size needs to be taken into account when allocating buffers (by adding the constant MPI_BSEND_OVERHEAD() for each message occurrence).
- **Interfaces**

```
MPI_BUFFER_ATTACH (buf, typesize, code)
MPI_BSEND (values, count, msgtype, dest, tag, comm, code)
MPI_BUFFER_DETACH (buf, typesize, code)

TYPE(*), intent(in) :: values
integer, intent(in) :: count, msgtype, dest, tag, comm
integer, intent(out) :: code
TYPE(*) :: buf

integer :: typesize
```

```
COMM.Bsend(self, data, int dest, int tag=0)
#or
COMM.bsend(self, data, int dest, int tag=0)
```

Communication Modes

- Advantages of buffered mode
  - No need to wait for the receiver (copying in a buffer)
  - No risk of deadlocks
- Disadvantages of buffered mode
  - Uses more resources (memory use by buffers with saturation risk)
  - The send buffers in the MPI_BSEND() or MPI_IBSEND() calls have to be managed manually (often difficult to choose a suitable size)
  - Slightly slower than the synchronous sends if the receiver is ready
  - No knowledge of receipt (send-receive decoupling)
  - Risk of wasted memory space if buffers are too oversized
  - Application crashes if buffer is too small
  - There are often hidden buffers managed by the MPI implementation on the sender side and/or on the receiver side (and consuming memory resources)

Communication Modes

Interface of : MPI_SEND()

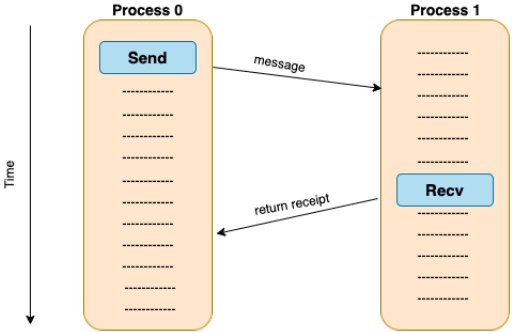
- **Standard sends**
  A standard send is made by calling the MPI_SEND() subroutine. In most implementations, the mode is buffered (eager) for small messages but is synchronous for larger messages.
- **Interfaces**

```
MPI_SEND(values, count, msgtype, dest, tag, comm, code)

TYPE(*), intent(in) :: values
integer, intent(in) :: count, msgtype, dest, tag, comm

integer, intent(out) :: codee
```

```
COMM.Send(self, data, int dest, int tag=0)
#or
COMM.send(self, data, int dest, int tag=0)
```

Communication Modes

- **The eager protocol**
  The eager protocol is often used for standard sends of small-size messages. It can also be used for sends with MPI_BSEND() for small messages (implementation-dependent) and by bypassing the user buffer on the sender side. In this approach, the buffer is on the receiver side. The return receipt is optional.



Communication Modes

- Advantages of standard mode
  - Often the most efficient (because the constructor chose the best parameters and algorithms)
  - The most portable for performance
- Disadvantages of standard mode
  - Little control over the mode actually used (often accessible via environment variables)
  - Risk of deadlocks depending on the mode used
  - Behavior can vary according to the architecture and problem size

Communication Modes

- **Example :**

```
if RANK == 2:
    sendbuf = 1000
    COMM.send(sendbuf, dest=1, tag=tag)

if RANK == 5
    recvbuf = COMM.recv(source=2, tag=tag)
    print("I, process 5, I received ",recvbuf," from the process 2.")
```

```
mpirun -n 6 python bsendrecv.py

I, process 5, I received 1000 from the process 2.
```

Communication Modes

Non blocking communication

- **Presentation**

  The overlap of communications by computations is a method which allows executing communications operations in the background while the program continues to operate.

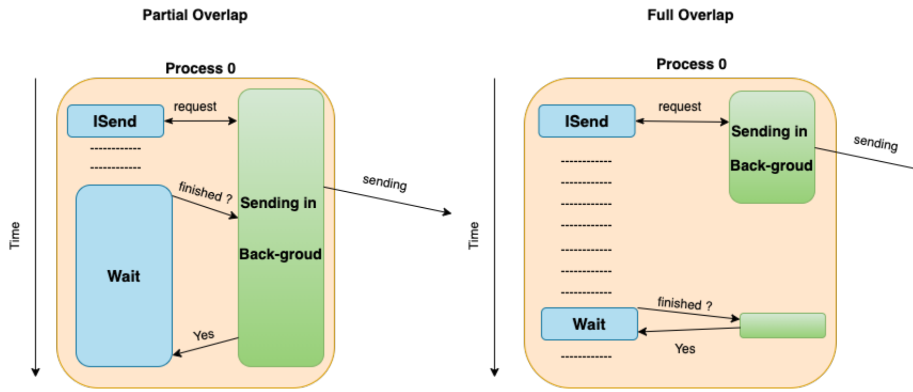
  On Ada, the latency of a communication internode is 1.5 µs, or 4000 processor cycles.

  - It is thus possible, if the hardware and software architecture allows it, to hide all or part of communications costs.
  - The computation-communication overlap can be seen as an additional level of parallelism.
  - This approach is used in MPI by using nonblocking subroutines (i.e.MPI_ISEND(), MPI_IRECV() and MPI_WAIT()).

- **Non blocking communication**

  A nonblocking call returns very quickly but it does not authorize the immediate re-use of the memory space which was used in the communication. It is necessary to make sure that the communication is fully completed (with MPI_WAIT(), for example) before using it again.

Communication Modes



Communication Modes

- Advantages of non blocking mode
  - Possibility of hiding all or part of communications costs (if the architecture allows it)
  - No risk of deadlock
- Disadvantages of non blocking mode
  - Greater additional costs (several calls for one single send or receive, request management)
  - Higher complexity and more complicated maintenance
  - Less efficient on some machines (for example with transfer starting only at the MPI_WAIT() call)
  - Risk of performance loss on the computational kernels (for example, differentiated management between the area near the border of a domain and the interior area, resulting in less efficient use of memory caches)
  - Limited to point-to-point communications (it is extended to collective communications in MPI 3.0)

Communication Modes

Interface of : MPI_ISEND(), MPI_ISSEND(), MPI_IBSEND(), MPI_IRECV()

```
MPI_ISEND(values, count, datatype, dest, tag, comm, req, code)
MPI_ISSEND(values, count, datatype, dest, tag, comm, req, code)
MPI_IBSEND(values, count, datatype, dest, tag, comm, req, code)

TYPE(*), intent(in) :: values

integer, intent(in) ::count, datatype, dest, tag, comm
integer, intent(out) :: req, code
```

```
MPI_IRECV(values, count, msgtype, source, tag, comm, req, code)

TYPE(*), intent(in) :: values
integer, intent(in) :: count, msgtype, source, tag, comm

integer, intent(out) :: req, code
```

```
COMM.Isend(self, data, int dest, int tag=0)
COMM.Issend(self, data, int dest, int tag=0)
COMM.Ibsend(self, data, int dest, int tag=0)


data = COMM.Irecv(self, source, int tag=0)
#or
Comm.IRecv(self, buf, int source, int tag=0, Status status=None)
```

Communication Modes

Interface of : MPI_WAIT()

MPI_WAIT() wait for the end of a communication, MPI_TEST() is the nonblocking version.

```
MPI_WAIT(req, statut, code)
MPI_TEST(req, flag, statut, code)

integer, intent(inout) :: req
integer, dimension(MPI_STATUS_SIZE), intent(out) :: statut
integer, intent(out) :: code

logical, intent(out) :: flag
```

```
req = COMM.Isend(self, data, int dest, int tag=0)
req.Wait(self, Status status=None)
req.Test(self, Status status=None)
```

Communication Modes

Interface of : MPI_WAIT()

MPI_WAITALL() (MPI_TESTALL()) await the end of all communications.

```
MPI_WAITALL(taille, reqs, statuts, code)
MPI_TESTALL(taille, reqs, statuts, flag, code)

integer, intent(in) :: count
integer, dimension(count) :: reqs
integer, dimension(MPI_STATUS_SIZE,count), intent(out) :: statuts
integer, intent(out) :: code

logical, intent(out) :: flag
```

```
req = COMM.Isend(self, data, int dest, int tag=0)
req.Waitall(type cls, requests, statuses=None)
req.Test(type cls, requests, statuses=None)
```

Communication Modes

- **Request management**
  - After a call to a blocking wait function (MPI_WAIT(), MPI_WAITALL(),...), the request argument is set to MPI_REQUEST_NULL.
  - The same for a nonblocking wait when the flag is set to true.
  - A wait call with a MPI_REQUEST_NULL request does nothing.
- Example :

```python
data = np.ones(1)

if RANK == 2:
    data = np.random.random_sample(1)
    print("I, process 2, I send", data[0], "to process 5")
    req = COMM.Isend(data, dest=5)
    req.Wait()
    req.Test()

if RANK == 5:
    req = COMM.Irecv(data, source=2)
    req.Wait()
    print("I, process 5, I received ",data[0]," from the process 2.")
```

```
mpirun -n 6 python isendirecv.py

I, process 2, I send 0.7493708552194022 to process 5
I, process 5, I received  0.7493708552194022  from the process 2.
```

Communication Modes

Number of received elements

```
MPI_RECV(buf,count,datatype,source,tag,comm,msgstatus,code)

<type>:: buf
integer :: count, datatype
integer :: source, tag, comm, code

integer, dimension(MPI_STATUS_SIZE) :: msgstatus
```

- In MPI_RECV() or MPI_IRECV() call, the count argument in the standard is the number of elements in the buffer buf.
- This number must be greater than the number of elements to be received.
- When it is possible, for increased clarity, it is adviced to put the number of elements to be received.
- We can obtain the number of elements received with MPI_GET_COUNT() and the msgstatus argument returned by the MPI_RECV() or MPI_WAIT() call.

```
MPI_GET_COUNT(msgstatus,msgtype,count,code)

integer, INTENT(IN) :: msgtype
integer, INTENT(OUT) :: count, code

integer, dimension(MPI_STATUS_SIZE), INTENT(IN) :: msgstatus
```