Avoiding deadlock:
Non blocking communication

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1

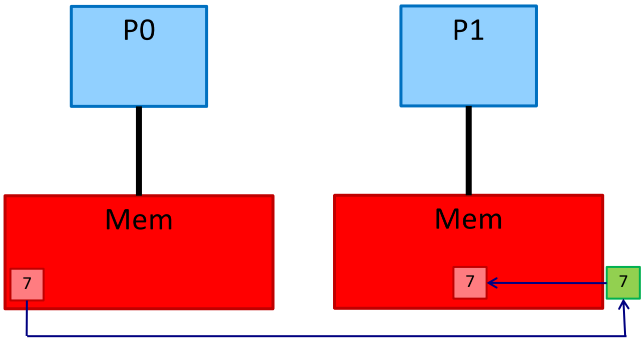
Overview

- Eager vs. rendezvous protocol
- Deadlock
- Non-blocking communication
- Performance implications from non-blocking communication

2

Small messages: Eager protocol

- Eager sending:
- When send is issued, data transferred to buffer on receiver
- There it gets buffered until matching receive is posted
- After receive is posted, copied into process memory

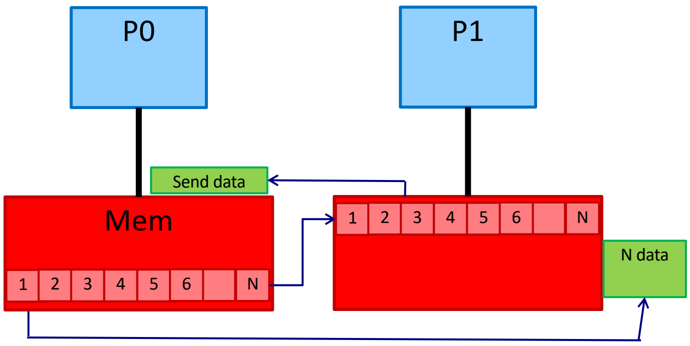


- Eager sending is not suitable for large messages:
- Receiver or Sender: not enough buffer memory to hold transferred data

3

Large messages: Rendezvous protocol

- When send is issued, meta-data transferred, e.g. N integers to come
- Matching receive is posted
  - Memory on receiver available (arg. of recv)
  - Data request is sent to sender

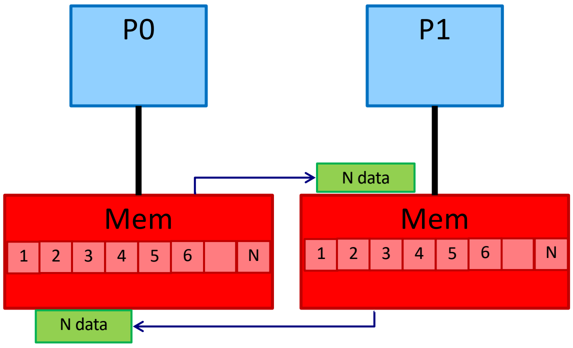


- Sender sends actual data
  - Sender must not overwrite send buffer until copied
  - Sender will wait forever if no matching receive is posted

4

Deadlock

- Both tasks use a send operations which goes “*rendezvous*”
- Both tasks **wait for ever** for the request to send data
- **`MPI_Send`** can not return, buffer can not be overwritten
- You have to assume that any **`MPI_Send`** waits for the receive
  - Different system in future
  - Future use more data



5

Synchronous send

In C:

```
int MPI_Ssend(void* buf, int count, MPI_Datatype
  datatype, int dest, int tag, MPI_Comm comm)
```

In Fortran 90:

```
MPI_SSEND(BUF, COUNT, DATATYPE, DEST, TAG, &
   COMM, IERROR)
```

In Python:

```
comm.ssend(obj, dest=dest, tag=tag)
```

- Same arguments as MPI_Send
- Call returns only **after** receive has been posted
- Always uses **rendezvous** or similar protocol
- **Useful for testing for deadlock problem in a code**

6

Non-blocking communication (overview)

- Avoid deadlock by using non-blocking send and/or receive
- Non-blocking calls return directly, in general:
  - Not safe to overwrite a send buffer
  - Receive buffer does not contain data
- Additional calls: **`MPI_Wait`**, **`MPI_Test`**, **`MPI_Waitall`** to check communication has finished

- A "checker" has to be called, otherwise
  - **nasty memory** or **resource** leak
  - code may behave **non-deterministic**

7

No deadlock by non-blocking receive

1. Both tasks issue non-blocking receive
   - Receive buffer becomes available
   - Program continues executing
2. Both tasks post send "rendezvous" operations
   - Since receive buffers available, send transfers data & returns
3. Both tasks check on receive (e.g. **`MPI_Wait`**):
   - Ensures data has arrived in receive buffer
   - Checking operation required – it completes operation
4. Continue with calculation and use received data

- **Rem:** The non-blocking call continues work, when program is doing other work

8

Non-blocking receive in C

```
int MPI_Irecv(void* buf, int count, MPI_Datatype
  datatype, int source, int tag, MPI_Comm comm,
  MPI_Request *request)
```

- `buf:` address of receive buffer (output)
- `count:` number of elements to be received
- `datatype:` date type of buffer (explained further down)
- `source:` rank of sender (data origin)
- `tag:` message tag (needs to match the send!)
- `comm:` communicator
- `request:` request handle (output), pass into “checker”

9

Non-blocking receive in Fortran 90

```
MPI_IRECV(BUF, COUNT, DATATYPE, SOURCE, TAG,&
   COMM, REQUEST, IERROR)
<TYPE>:: BUF
INTEGER:: COUNT, DATATYPE, SOURCE, TAG,&
   COMM, REQUEST, IERROR
```

- `BUF:` address of receive buffer (output)
- `COUNT:` number of elements to be received
- `DATATYPE:` date type of buffer (explained further down)
- `SOURCE:` rank of sender (data origin)
- `TAG:` message tag (needs to match the send!)
- `COMM:` communicator
- `REQUEST:` request handle (output), pass into checker

10

Non-blocking receive in Python

```
req = comm.irecv(source=source, tag=tag)
```

- `source`: rank of sender (data origin)
- `tag`: message tag (needs to match the send!)

- A `Request` object is returned
- Python object is returned by the `wait` method of `Request` object

- Example:

```
req = comm.irecv(source=0, tag=0)
obj = req.wait()
```

11

Remarks on `irecv` and large data

- Default buffer size of irecv: 32768 bytes
- For larger received message:
  - Supply buffer
  - Increase buffer size
    - Environment variable: **`MPI4PY_RC_IRECV_BUFSZ`**
    - Runtime configuration option: **`mpi4py.rc.irecv_bufsz`**
- Example for **`mpi4py.rc.irecv_bufsz`**:

```
import mpi4py
mpi4py.rc.irecv_bufsz = 1048576
from mpi4py import MPI
```

12

Non-blocking receive in Python (large data)

```
req = comm.irecv(buf, source=source, tag=tag)
```

- When recieving large data via `irecv`, you may see the “message truncated” error.
- In such case a buffer will be needed by `irecv`

- Example:

```
# 1 MB buffer; make it larger if needed
buf = bytearray(1<<20)
req = comm.irecv(buf, source=0, tag=0)
obj = req.wait()
```

13

Non-blocking send in C: MPI_Isend

```
int MPI_Isend(void* buf, int count, MPI_Datatype
  datatype, int dest, int tag, MPI_Comm comm,
  MPI_Request *request)
```

- `buf:` address of send buffer
- `count:` number of elements to be send
- `datatype:` date type of buffer (explained further down)
- `dest:` rank of receiver
- `tag:` message tag (put **0** if you don’t need)
- `comm:` communicator
- `request:` request handle (output), pass into checker

14

Non-blocking send Fortran 90: MPI_ISEND

```
MPI_ISEND(BUF, COUNT, DATATYPE, DEST, TAG, &
   COMM, REQUEST, IERROR)
```

```
<TYPE>::   BUF
INTEGER:: COUNT, DATATYPE, DEST, TAG, COMM
INTEGER:: REQUEST, IERROR
```

- `BUF:` address of send buffer
- `COUNT:` number of elements to be send
- `DATATYPE:` date type of buffer (explained further down)
- `DEST:` rank of receiver
- `TAG:` message tag (put **0** if you don't need)
- `COMM:` communicator
- `REQUEST:` request handle (output), pass into checker

15

Non-blocking send in Python: isend

```
req = comm.isend(obj, dest=dest, tag=tag)
```

- `obj:` the Python object to be sent
- `dest:` rank of receiver
- `tag:` message tag (optional; default is 0)

- A `Request` object is returned
- The `Request` object has the `wait` method

- Example:

```
req = comm.isend(data, dest=0, tag=0)
req.wait()
```

16

Waiting on non-blocking communication

- In C:

```
int MPI_Wait(MPI_Request *request, MPI_Status *status)
```

- In Fortran 90:

```
MPI_WAIT(REQUEST, STATUS, IERROR)
    INTEGER:: REQUEST, STATUS(MPI_STATUS_SIZE)
    INTEGER:: IERROR
```

- **request**: handle from `MPI_Irecv` or `MPI_Isend`
- **status**: status info from complete operation (recv)
- In Python:

```
req.wait()
```

- Call waits (blocks) until communication has finished

17

Example in C

```
int b, a=17;
MPI_Request s_req, r_req;
MPI_Status  cstat;

MPI_Irecv(&b, 1, MPI_INT, npr, 0, myc, &r_req);
MPI_Isend(&a, 1, MPI_INT, npr, 0, myc, &s_req);

/* don't touch a or b here, can do other work */

MPI_Wait(&s_req, &cstat);
a = 9;     /* now safe to change a */
MPI_Wait(&r_req, &cstat);
b = 2*b;  /* b can now be used */
```

18

Example in Fortran 90

```
integer:: b, a=17
integer:: s_req, r_req, ierror
integer, dimension(MPI_STATUS_SIZE) :: cstat

MPI_Irecv(b, 1, MPI_INTEGER, npr, 0, myc, &
  r_req, ierror)
MPI_Isend(a, 1, MPI_INTEGER, npr, 0, myc, &
  s_req, ierror)
! don't touch a or b here, can do other work
MPI_Wait(s_req, cstat, ierror)
a = 9      ! now safe to change a
MPI_Wait(r_req, cstat, ierror)
b = 2*b    ! b can now be used
```

19

Example in Python

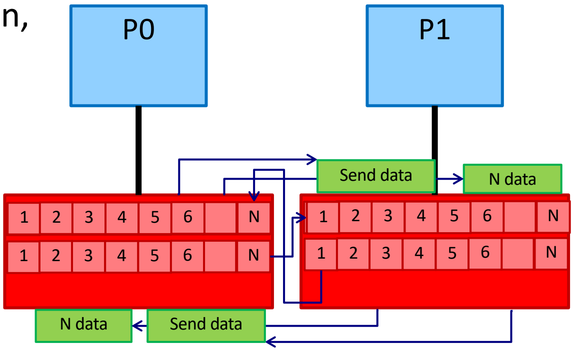
```
from mpi4py import MPI

comm = MPI.COMM_WORLD
a = 17
# for large messages supply irecv with a buffer
r_req = comm.irecv(source=0, tag=myc)
s_req = comm.isend(a, dest=0, tag=myc)
# don't touch a, can do other work
s_req.wait()
a = 9
b = r_req.wait()
b = 2*b
```

20

Example: resolving deadlock: MPI_Isend

- Both tasks use an **`MPI_Isend`** operation
- **`Isend`** publishes the send operation, e.g. transfers meta data
- **`MPI_Isend`** calls return
- <u>Don't modify sendbuffer yet!!</u>
- Both task post **`MPI_Recv`**
  - Publish recv-buffers
  - Match of send & recv
  - Request data transfer
  - Receives data
- Tasks **<u>must</u>** call **`MPI_Wait`**
  - Finalises the **`Isend`** and frees resources



21

Resolved deadlock with **`MPI_Isend`** in C

```
MPI_Isend(p_send_buf, n, MPI_INT, neigh, 1,comm, &req);

p_recv_buf = (int*)malloc(n * sizeof(int));

MPI_Recv(p_recv_buf, n, MPI_INT, neigh, 1, comm,&stat);

MPI_Wait(&req, &stat);    // wait required

for (int i=0; i<n; i++)
   p_send_buf[i] = p_recv_buf[i];

free(p_recv_buf);
```

22

Resolved deadlock with **MPI_Isend** in Python

```
req = comm.isend(buffer, dest=neigh, tag=1)

recv_buf = comm.recv(source=neigh, tag=1)

req.wait()        # wait required

buffer = copy.deepcopy(recv_buf)
```

- Doesn't have any buffer issues, since using **recv** and not **irecv**

23

Non-blocking communication and performance

- Non blocking communication can be used to **hide communication** time:
  - Issue communication calls early
  - Do other work, not associated with the communication buffers
  - Delay the Wait/Test for the communication calls until data is needed
  - Particular useful on modern RDMA hardware (communication not done by processor)
- Pre-posting non-blocking receives can reduce data traffic
  - Data goes directly into application buffer instead of buffer in MPI library

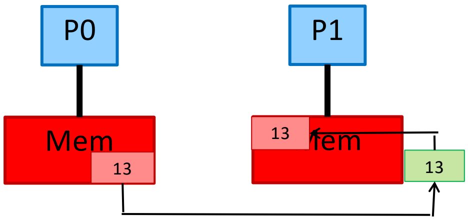
25

Late receive

- If receive not posted, data needs storing somewhere

Program on P0:	Program on P1:

`a = 13`
`send(a,1)`
	`somework(c)`
	`morework(c)`
	`recv(b,0)`
	`c = c * b`



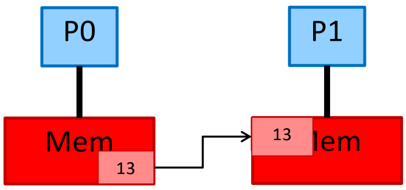
26

Pre-post receive

- If non-blocking receive pre-posted, can go directly into application space

Program on P0:	Program on P1:

`a = 13`
`send(a,1)`
	`irecv(b,0,r)`
	`somework(c)`
	`morework(c)`
	`wait(r)`
	`c = c * b`



27

Summary

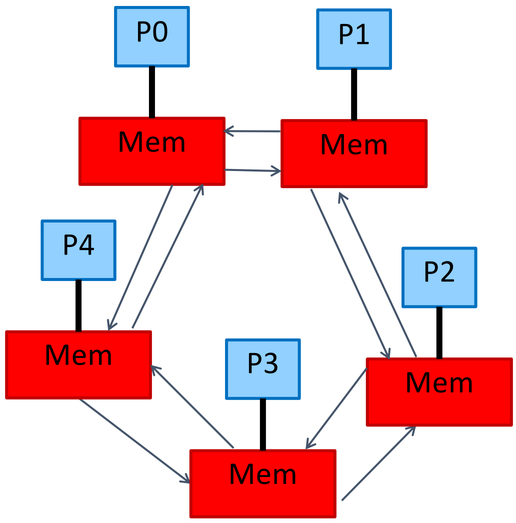
- Explained the danger of deadlock in p-2-p communication
- Non-blocking communication
  - to avoid deadlock
  - to overlap communication and calculation
  - preposted receives: performance boost on certain architectures
- **Important:** Every non-blocking call (`MPI_Isend, MPI_Irecv, …`) **requires** a matching `MPI_Wait` or a true `MPI_Test`

28

Exercise

Messages around a ring

- Each processor should
  - Initialise 2 integer arrays
    - set one to rank number
    - other to 1000x rank number
  - Send one up and down
  - Receive from neighbours
  - Sum up received data in separate (up/down) sums
  - Pass the received data on, to continue in the direction they came
- Checks after final exchange:
  - Last receive (up & down) equal 1x and 1000x own rank
  - The two sums equal: ½n(n-1) and 500n(n-1)



30