Introduction to Parallel Programming with MPI

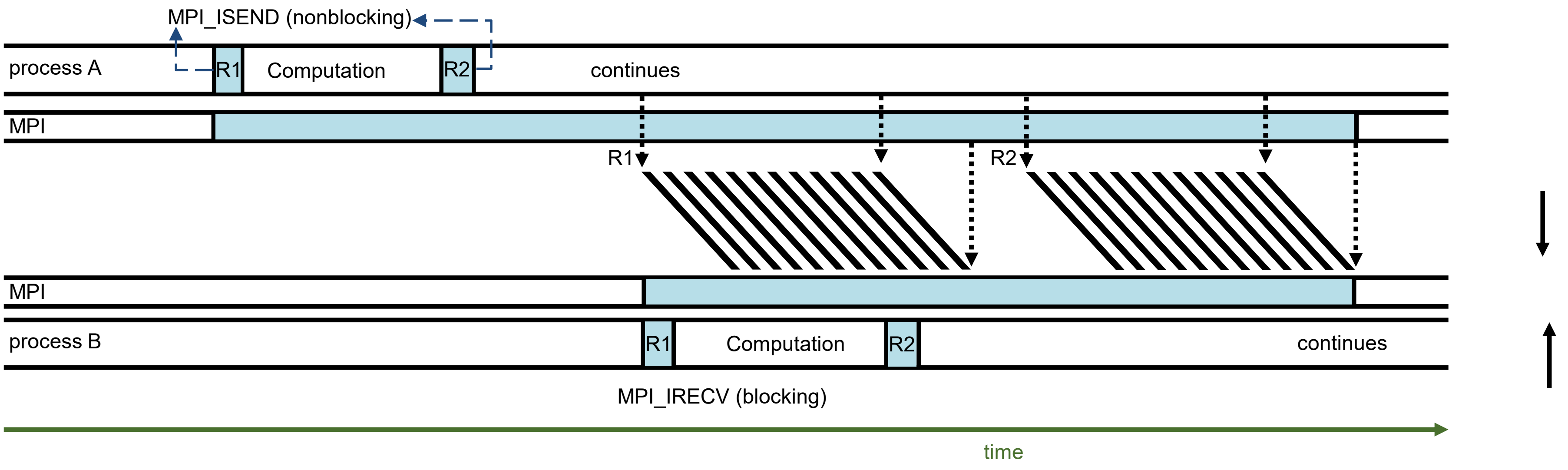
Dr. Alireza Ghasemi, Dr. Georg Hager

Erlangen National High Performance Computing Center

MPI Point-to-Point Communication: Nonblocking

Nonblocking point-to-point communication

- Call to a nonblocking send/recv procedure returns straight away. It avoids synchronization so that the following opportunities can be exploited:
  - Avoiding certain deadlocks
  - Truly bidirectional commun.
  - Avoid idle time:
    - Overlapping commun. and comput.



Standard nonblocking send/receive

- ```
  MPI_Isend(sendbuf, count, datatype, dest,   tag,
            comm, MPI_Request * request);
  
  MPI_Irecv(recvbuf, count, datatype, source, tag,
            comm, MPI_Request * request);
  ```

  request: pointer to variable of type **MPI_Request**,
  will be associated with the corresponding operation
- **Do not reuse sendbuf/recvbuf before MPI_Isend/MPI_Irecv has been completed**
  - Return of call does not imply completion
- **MPI_Irecv** has no status argument
  - obtained later during completion via **MPI_Wait*/MPI_Test***
  ```

Nonblocking send and receive variants

- Completion
  - Return of `MPI_I*` call does not imply completion
  - Check for completion via `MPI_Wait* / MPI_Test*`
  - Semantics identical to blocking call after successful completion

nonblocking MPI function	blocking MPI function	type	completes when
`MPI_Isend`	`MPI_Send`	synchronous or buffered	depends on type
`MPI_Ibsend`	`MPI_Bsend`	buffered	buffer has been copied
`MPI_Issend`	`MPI_Ssend`	synchronous	remote starts receive
`MPI_Irecv`	`MPI_Recv`	--	message was received

Test for completion

Two test modes:

- Blocking
  - `MPI_Wait*`: Wait until the communication has been completed and buffer can safely be reused
- Nonblocking
  - `MPI_Test*`: Return true (false) if the communication has (not) completed

Despite the naming, the modes both pertain to nonblocking point-to-point communication!

Test for completion – single request

- Test one communication handle for completion:

```
MPI_Wait(MPI_Request * request,
         MPI_Status * status);
MPI_Test(MPI_Request * request, int * flag,
         MPI_Status * status);
```

request: request handle of type **MPI_Request**

status: status object of type **MPI_Status** (cf. **MPI_Recv**)

flag: variable of type **int** to test for success

Use of wait/test

MPI_Wait

```
MPI_Request request;
MPI_Status status;


MPI_Isend(
   send_buffer, count, MPI_CHAR,
   dst, 0, MPI_COMM_WORLD, &request);



// do some work…
// do not use send_buffer

MPI_Wait(&request, &status);

// use send_buffer
```

MPI_Test

```
MPI_Request request;
MPI_Status status;
int flag;

MPI_Isend(
   send_buffer, count, MPI_CHAR,
   dst, 0, MPI_COMM_WORLD, &request);

do {
    // do some work…
    // do not use send_buffer
    MPI_Test(&request, &flag, &status);
} while (!flag);

// use send_buffer
```

Wait for completion – all requests in a list

- MPI can handle multiple communication requests
- Wait/Test for completion of multiple requests:

```
MPI_Waitall(int count, MPI_Request requests[],
                       MPI_Status statuses[]);

MPI_Testall(int count, MPI_Request requests[],
            int *flag, MPI_Status statuses[]);
```

- Waits for/Tests if all provided requests have been completed

Use of `MPI_Waitall`

```
MPI_Request requests[2];
MPI_Status  statuses[2];

MPI_Isend(send_buffer, …, &(requests[0]));
MPI_Irecv(recv_buffer, …, &(requests[1]));

// do some work…

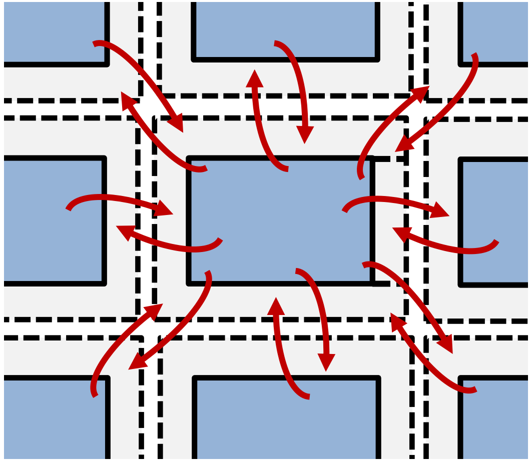
MPI_Waitall(2, requests, statuses)
// Isend & Irecv have been completed
```

Arrays of requests and statuses

number of elements in the arrays

Ghost cell exchange with nonblocking MPI

Ghost cell exchange with nonblocking send/recv with all neighbors at once



Possible implementation:

1. Update cells that need the halo
2. Copy new data into contiguous send buffers
3. Start nonblocking receives/sends from/to corresponding neighbors
4. Update local cells that do not need halo cells for boundary conditions ("bulk update")
5. Wait with MPI_Waitall for all obtained requests to complete
6. Copy received halo data into ghost cells

Opportunity to overlap communication (steps 3-5) with bulk update (MPI implementation permitting)

Wait for completion – one or several requests out of a list

Wait for/Test if exactly one request among many has been completed

```
MPI_Waitany(int count, MPI_Request requests[],
            int * idx, MPI_Status * status);

MPI_Testany(int count, MPI_Request requests[],
            int * idx, int * flag,
            MPI_Status * status);
```

Wait for/Test if at least one request among many has been completed

```
MPI_Waitsome(int incount, MPI_Request requests[], int * outcount,
             int indices[], MPI_Status statuses[]);

MPI_Testsome(int incount, MPI_Request requests[], int * outcount,
             int indices[], MPI_Status statuses[]);
```

Use of `MPI_Testany`

```
MPI_Request requests[2];
MPI_Status  status;
int finished = 0;

MPI_Isend(send_buffer, …, &(requests[0]));
MPI_Irecv(recv_buffer, …, &(requests[1]));
do {
   // do some work…
   MPI_Testany(2, requests, &idx, &flag, &status);
   if (flag) { ++finished; }
} while (finished < 2);
```

- completed requests are automatically set to `MPI_REQUEST_NULL`
- completed requests: `requests[idx]`

Pitfalls with nonblocking MPI and compiler optimizations

- Fortran:
```
MPI_IRECV(recvbuf, ..., request, ierror)
MPI_WAIT(request, status, ierror)
write (*,*) recvbuf
```
- may be compiled as
```
MPI_IRECV(recvbuf, ..., request, ierror)
registerA = recvbuf
MPI_WAIT(request, status, ierror)
write (*,*) registerA
```

MPI might modify recvbuf after MPI_IRECV returns, but the compiler has no idea about this

- i.e., old data is written instead of received data!
- Workarounds:
  - `recvbuf` may be allocated in a common block, or
  - calling `MPI_GET_ADDRESS(recvbuf, iaddr_dummy, ierror)` after `MPI_WAIT`
  - `asynchronous attribute`

Nonblocking point-to-point communication

- Standard nonblocking send/recv **`MPI_Isend()`**/**`MPI_Irecv()`**
  - Return of call does not imply completion of operation
  - Use **`MPI_Wait*()`** / **`MPI_Test*()`** to check for completion using request handles
- All outstanding requests must be completed!
- Potentials
  - Overlapping of communication with work (not guaranteed by MPI standard)
  - Overlapping send and receive
  - Avoiding synchronization and reducing idle times
- Caveat: Compiler does not know about asynchronous modification of data

Quiz:

1. Every nonblocking send or receive requires a subsequent MPI_Wait* or MPI_Test* call?
    a) Correct b) Incorrect

2. Can MPI_Isend be matched with blocking receive (MPI_Recv)?
    a) Yes b) No

3. Which one is not a potential use case of nonblocking point-to-point communication in MPI?
    a) Overlapping send and receive
    b) Avoiding every possible idle times
    c) Overlapping of communication with work