Introduction to Parallel Computing

Vistas in Advanced Computing / Summer 2017

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CENTER FOR ADVANCED COMPUTING & DATA SYSTEMS

Overview

- Point-to-point taxonomy and available functions
- What is the status of a message?
- Non-blocking operations

What you've learned so far

- Six MPI functions are sufficient for programming a distributed system memory machine

```
MPI_Init(int *argc, char ***argv);
MPI_Finalize ();

MPI_Comm_rank (MPI_Comm comm, int *rank);
MPI_Comm_size (MPI_Comm comm, int *size);

MPI_Send (void *buf, int count, MPI_Datatype dat,
          int dest, int tag, MPI_Comm comm);
MPI_Recv (void *buf, int count, MPI_Datatype dat,
          int source, int tag,  MPI_Comm comm,
          MPI_Status *status);
```

Point-to-point operations

- Data exchange between two processes
  - both processes are actively participating in the data exchange ➔ two-sided communication
- Large set of functions defined in MPI-1 (50+)

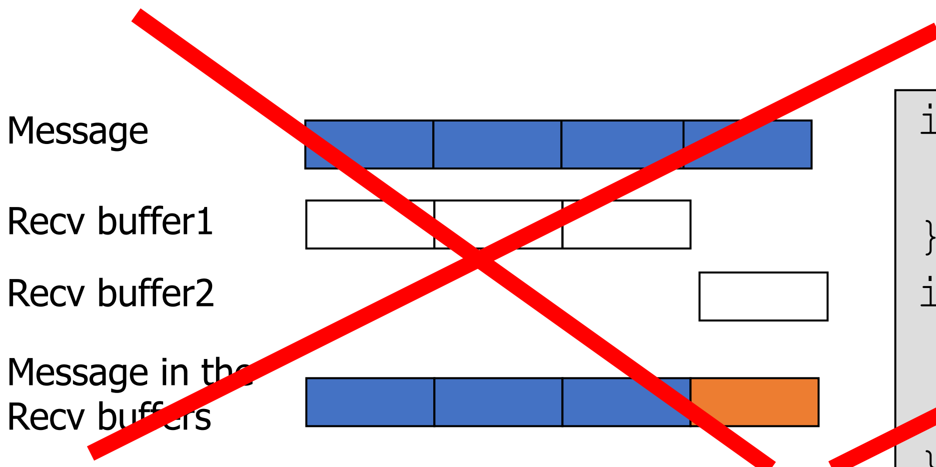
	Blocking	Non-blocking	Persistent
Standard	MPI_Send	MPI_Isend	MPI_Send_init
Buffered	MPI_Bsend	MPI_Ibsend	MPI_Bsend_init
Ready	MPI_Rsend	MPI_Irsend	MPI_Rsend_init
Synchronous	MPI_Ssend	MPI_Issend	MPI_Ssend_init

A message contains of…

- the data which is to be sent from the sender to the receiver, described by
  - the beginning of the buffer
  - a data-type
  - the number of elements of the data-type
- the message header (message envelope)
  - rank of the sender process
  - rank of the receiver process
  - the communicator
  - a tag

Rules for point-to-point operations

- **Reliability**: MPI guarantees, that no message gets lost
- **Non-overtaking rule**: MPI guarantees, that two messages posted from process A to process B arrive in the same order as posted
- **Message-based paradigm**: MPI specifies, that a single message cannot be received with more than one Recv operation (in contrary to sockets!)




```
if (rank == 0 ) {
  MPI_Send(buf, 4, …);
}
if ( rank == 1 ) {
  MPI_Recv(buf, 3, …);
  MPI_Recv(&(buf[3], 1, …);
}
```

Message matching (I)

- How does the receiver know, whether the message which he just received is the message for which he was waiting?
  - the sender of the arriving message has to match the sender of the expected message
  - the tag of the arriving message has to match the tag of the expected message
  - the communicator of the arriving message has to match the communicator of the expected message

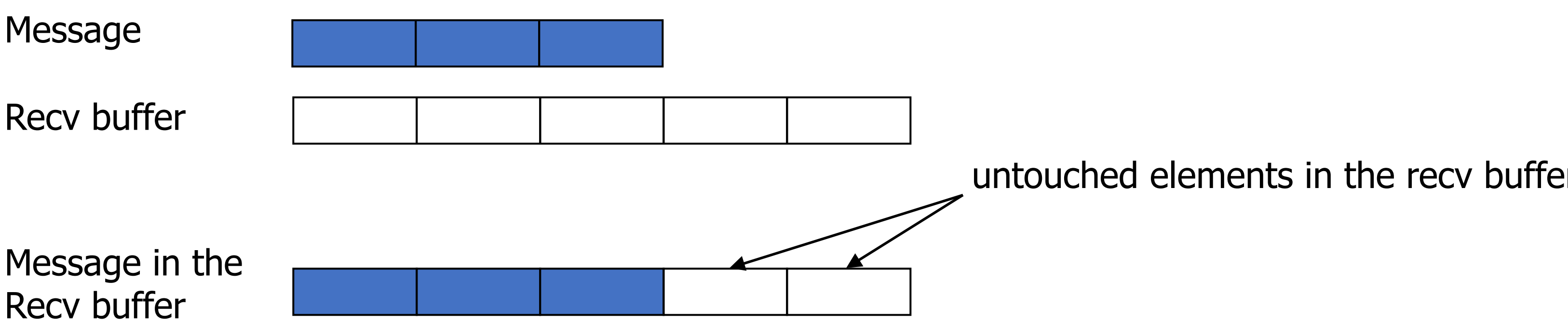
Message matching (II)

- What happens if the length of the arriving message does not match the length of the expected message?
  - the length of the message is not used for matching
  - if the received message is shorter than the expected message, no problems
  - the received message is longer than the expected message
    - an error code (`MPI_ERR_TRUNC`) will be returned
    - or your application will be aborted
    - or your application will deadlock
    - or your application writes a core-dump

Message matching (III)

- Example 1: correct example

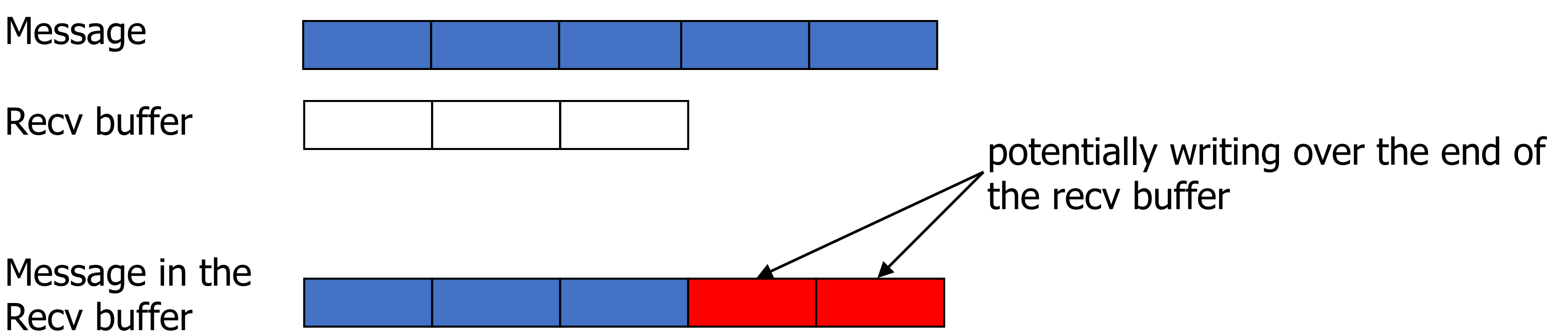
```
if (rank == 0 ) {
  MPI_Send(buf, 3, MPI_INT, 1, 1, MPI_COMM_WORLD);
}
else if ( rank == 1 ) {
  MPI_Recv(buf, 5, MPI_INT, 0, 1, MPI_COMM_WORLD,
           &status);
}
```



Message matching (IV)

- Example 2: erroneous example

```
if (rank == 0 ) {
  MPI_Send(buf, 5, MPI_INT, 1, 1, MPI_COMM_WORLD);
}
else if ( rank == 1 ) {
  MPI_Recv(buf, 3, MPI_INT, 0, 1, MPI_COMM_WORLD,
           &status);
}
```



Deadlock (I)

- **Question**: how can two processes safely exchange data at the same time?
- Possibility 1

<u>Process 0</u> <u>Process 1</u>

Process 0	Process 1
`MPI_Send(buf,…)` `MPI_Recv(buf,…)`	`MPI_Send(buf,…)` `MPI_Recv(buf,…)`

  - can deadlock, depending on the message length and the capability of the hardware/MPI library to buffer messages

Deadlock (II)

- Possibility 2: re-order MPI functions on one process

Process 0

```
MPI_Recv(rbuf,…);
MPI_Send(buf,…);
```

Process 1

```
MPI_Send(buf,…);
MPI_Recv(rbuf,…);
```

- Other possibilities:
  - asynchronous communication – shown later
  - use buffered send (MPI_Bsend) – not shown here
  - use MPI_Sendrecv – not shown here

Example

- Implementation of a ring using Send/Recv
  - Rank 0 starts the ring

```
MPI_Comm_rank (comm, &rank);
MPI_Comm_size (comm, &size);

if (rank == 0 ) {
  MPI_Send(buf, 1, MPI_INT, rank+1, 1,comm);
  MPI_Recv(buf, 1, MPI_INT, size-1, 1,comm,&status);
}
else if ( rank == size-1 ) {
  MPI_Recv(buf, 1, MPI_INT, rank-1, 1,comm,&status);
  MPI_Send(buf, 1, MPI_INT, 0,      1,comm);
}
else {
  MPI_Recv(buf, 1, MPI_INT, rank-1, 1,comm,&status);
  MPI_Send(buf, 1, MPI_INT, rank+1, 1,comm);
}
```

Wildcards

- **Question:** can I use wildcards for the arguments in Send/Recv?
- **Answer:**
  - for Send: no
  - for Recv:
    - tag: yes, `MPI_ANY_TAG`
    - source: yes, `MPI_ANY_SOURCE`
    - communicator: no

Status of a message (I)

- the MPI status contains directly accessible information
  - who sent the message
  - what was the tag
  - what is the error-code of the message
- … and indirectly accessible information through function calls
  - how long is the message
  - has the message bin cancelled

Status of a message (II) – usage in C

```
MPI_Status status;

MPI_Recv ( buf, cnt, MPI_INT, …, &status);

/*directly access source, tag, and error */
src = status.MPI_SOURCE;
tag = status.MPI_TAG;
err = status.MPI_ERROR;

/*determine message length and whether it has been
  cancelled */
MPI_Get_count (status, MPI_INT, &rcnt);
MPI_Test_cancelled (status, &flag);
```

Status of a message (IV)

- If you are not interested in the status, you can pass
  - `MPI_STATUS_NULL`
  - `MPI_STATUSES_NULL`

to MPI_Recv and all other MPI functions, which return a status

Non-blocking operations (I)

- A regular `MPI_Send` returns, when '… the data is safely stored away'
- A regular `MPI_Recv` returns, when the data is fully available in the receive-buffer
- Non-blocking operations initiate the Send and Receive operations, but do not wait for its completion.
- Functions, which check or wait for completion of an initiated communication have to be called explicitly
- Since the functions initiating communication return *immediately,* all MPI-functions have an *I* prefix (e.g. `MPI_Isend` or `MPI_Irecv`).

Non-blocking operations (II)

```
MPI_Isend (void *buf, int cnt, MPI_Datatype dat,
           int dest, int tag, MPI_Comm comm,
           MPI_Request *req);
MPI_Irecv (void *buf, int cnt, MPI_Datatype dat,
           int src, int tag, MPI_Comm comm,
           MPI_Request *req);
```

Non-blocking operations (III)

- After initiating a non-blocking communication, it is not allowed to touch (=modify) the communication buffer until completion
  - you can not make any assumptions about when the message will really be transferred
- All *Immediate* functions take an additional argument, a *request*
- a request uniquely identifies an ongoing communication, and has to be used, if you want to check/wait for the completion of a posted communication

Completion functions (I)

```
MPI_Wait      (MPI_Request *req, MPI_Status *stat);
MPI_Waitall   (int cnt, MPI_Request *reqs,
               MPI_Status  *stats);
MPI_Waitany   (int cnt, MPI_Request *reqs, int *index,
               MPI_Status *stat);
MPI_Waitsome (int cnt, MPI_Request *reqs, int *outcnt,
              int *indices, MPI_Status *stats);
```

- Functions waiting for completion
  - `MPI_Wait` – wait for one communication to finish
  - `MPI_Waitall` – wait for all comm. of a list to finish
  - `MPI_Waitany` – wait for one comm. of a list to finish
  - `MPI_Waitsome` – wait for at least one comm. of a list
- Content of the status not defined for Send operations

Completion functions (II)

```
MPI_Test      (MPI_Request *req, int *flag,
               MPI_Status *stat);
MPI_Testall   (int cnt, MPI_Request *reqs, int *flag,
               MPI_Status  *stats);
MPI_Testany   (int cnt, MPI_Request *reqs, int *index,
               int *flag, MPI_Status *stat);
MPI_Testsome (int cnt, MPI_Request *reqs, int *outcnt,
              int *indices, int *flag, MPI_Status *stats);
```

- Test-functions verify, whether a communication is complete
  - `MPI_Test` – check, whether a comm. has finished
  - `MPI_Testall` – check, whether all comm. of a list finished
  - `MPI_Testany` – check, whether one of a list of comm. finished
  - `MPI_Testsome` – check, how many of a list of comm. finished

Deadlock problem revisited

- **Question**: how can two processes safely exchange data at the same time?
- Possibility 3: usage of non-blocking operations

Process 0

```
MPI_Irecv(rbuf,…, &req);
MPI_Send (buf,…);
MPI_Wait (req, &status);
```

Process 1

```
MPI_Irecv(rbuf,…,&req);
MPI_Send (buf,…);
MPI_Wait (req, &status);
```

- note:
  - you have to use 2 separate buffers!
  - many different ways for formulating this scenario
  - identical code for both processes