Lecture 6

Programming Using the Message-Passing Paradigm III

MPI: the Message Passing Interface; Overlapping, Multicast

Ceng505 *Parallel Computing* at November 01, 2010

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Contents

Overlapping Communication with Computation

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- that can perform the transmission of messages without interrupting the CPUs.

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  - or a process that has started a non-blocking receive operation may want to use the data.

Non-Blocking Communication Operations II

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int MPI_Isend(void *buf, int count, MPI_Datatype datatype,
    int dest, int tag, MPI_Comm comm, MPI_Request *request)
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- **MPI_Isend** and **MPI_Irecv** functions **allocate a request object** and return a pointer to it in the *request* variable.

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- **MPI_Isend** and **MPI_Irecv** functions **allocate a request object** and return a pointer to it in the *request* variable.
- This *request* object is used as an argument in the **MPI_Test** and **MPI_Wait** functions to identify the operation whose status we want to query or to wait for its completion.

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- but the status information associated with the receive operation is returned by the **MPI_Test** and **MPI_Wait** functions.

```
int MPI_Test(MPI_Request *request, int *flag, MPI_Status *status)
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Non-Blocking Communication Operations III

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- **MPI_Test** tests whether or not the non-blocking send or receive operation identified by its *request* has finished.

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- **MPI_Test** tests whether or not the non-blocking send or receive operation identified by its *request* has finished.
- It returns flag = true (non-zero value in C) if it is completed.

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- It returns flag = true (non-zero value in C) if it is completed.
- The *request* object pointed to by *request* is deallocated and *request* is set to *MPI_REQUEST_NULL*.
- Also the *status* object is set to contain information about the operation.

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- For the cases that the programmer wants to explicitly deallocate a *request* object, MPI provides the following function.

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int MPI_Request_free(MPI_Request *request)
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- Note that the deallocation of the request object does not have any effect on the associated non-blocking send or receive operation.
- That is, if it has not yet completed it will proceed until its completion.

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- Hence, one must be careful before explicitly *deallocating a request object*,
- since without it, we cannot check whether or not the non-blocking operation has completed.
- A non-blocking communication operation can be matched with a corresponding blocking operation.
- For example, a process can send a message using a non-blocking send operation and this message can be received by the other process using a blocking receive operation.

Non-Blocking Communication Operations VI

- *Avoiding Deadlocks;* by using non-blocking communication operations we can remove most of the deadlocks associated with their blocking counterparts.

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- For example, the following piece of code is not safe.

```
int a[10], b[10], myrank;
MPI_Status status;
...
MPI_Comm_rank(MPI_COMM_WORLD, &myrank);
if (myrank == 0) {
  MPI_Send(a, 10, MPI_INT, 1, 1, MPI_COMM_WORLD);
  MPI_Send(b, 10, MPI_INT, 1, 2, MPI_COMM_WORLD);
}
else if (myrank == 1) {
  MPI_Recv(b, 10, MPI_INT, 0, 2, &status,
                                MPI_COMM_WORLD);
  MPI_Recv(a, 10, MPI_INT, 0, 1, &status,
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Non-Blocking Communication Operations VI

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}
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```

- However, if we replace <u>either the send or receive</u> operations with their non-blocking counterparts, then the code will be safe, and will correctly run on any MPI implementation.

Non-Blocking Communication Operations VII

- Safe with non-blocking communication operations;

```
int a[10], b[10], myrank;
MPI_Status status;
MPI_Request requests[2];
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if (myrank == 0) {
  MPI_Send(a, 10, MPI_INT, 1, 1, MPI_COMM_WORLD);
  MPI_Send(b, 10, MPI_INT, 1, 2, MPI_COMM_WORLD);
}
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- This example also illustrates that the non-blocking operations started by any process can finish in any order depending on the transmission or reception of the corresponding messages.

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```

- This example also illustrates that the non-blocking operations started by any process can finish in any order depending on the transmission or reception of the corresponding messages.
- For example, the second receive operation will finish before the first does.

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Collective Communication and Computation Operations I

- MPI provides an extensive set of functions for performing commonly used collective communication operations.
- All of the collective communication functions provided by MPI take as an argument a communicator that defines the group of processes that participate in the collective operation.
- All the processes that belong to this communicator **participate** in the operation,
- and *all of them must call* the collective communication function.

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- The parallel program should be written such that it behaves correctly even if a global synchronization is performed before and after the collective call.

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- The parallel program should be written such that it behaves correctly even if a global synchronization is performed before and after the collective call.
- **Barrier;** the barrier synchronization operation is performed in MPI using the **MPI_Barrier** function.

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- The call to **MPI_Barrier** *returns only after all* the processes in the group have called this function.

Broadcast I

- **Broadcast;** the <u>one-to-all</u> broadcast operation is performed in MPI using the **MPI_Bcast** function.

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- The data that is broadcast consist of *count* entries of type *datatype*.
- The data received by each process is stored in the buffer *buf*.
- Since the operations are virtually synchronous, they do not require tags.

Broadcast II

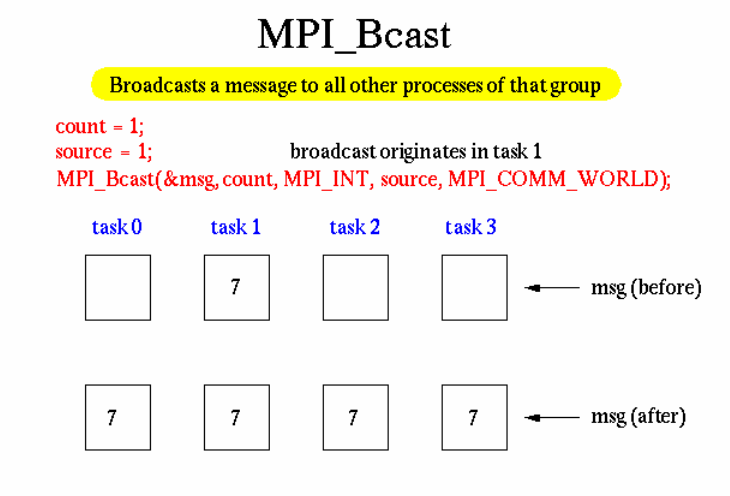

Figure: Diagram for Broadcast.

Reduction I

- **Reduction**; the all-to-one reduction operation is performed in MPI using the **MPI_Reduce** function.

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int MPI_Reduce(void *sendbuf, void *recvbuf, int count,
        MPI_Datatype datatype, MPI_Op op, int target,
        MPI_Comm comm)
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  - returns the combined values in the buffer *recvbuf* of the process with rank *target*.

Reduction I

- **Reduction**; the all-to-one reduction operation is performed in MPI using the **MPI_Reduce** function.

```
int MPI_Reduce(void *sendbuf, void *recvbuf, int count,
        MPI_Datatype datatype, MPI_Op op, int target,
        MPI_Comm comm)
```

  - combines the elements stored in the buffer *sendbuf* of each process in the group,
  - using the operation specified in *op*,
  - returns the combined values in the buffer *recvbuf* of the process with rank *target*.

- Both the *sendbuf* and *recvbuf* must have the same number of *count* items of type *datatype*.

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  - using the operation specified in *op*,
  - returns the combined values in the buffer *recvbuf* of the process with rank *target*.

- Both the *sendbuf* and *recvbuf* must have the same number of *count* items of type *datatype*.
- When *count* is more than one, then the combine operation is applied element-wise on each entry of the sequence.
- Note that all processes must provide a *recvbuf* array, even if they are not the *target* of the reduction operation.

Reduction II

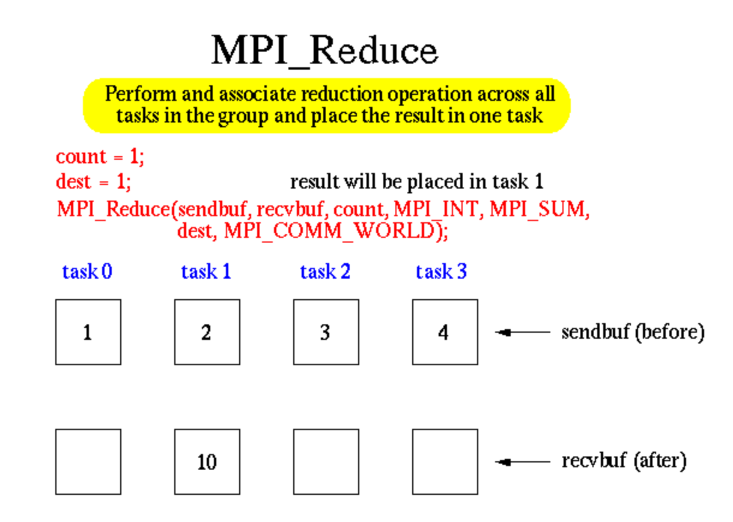

Figure: Diagram for Reduce.

Reduction III

- MPI provides a list of predefined operations that can be used to combine the elements stored in *sendbuf* (See Table 1).

Table: Predefined reduction operations.

Operation	Meaning	Datatypes
MPI_MAX	Maximum	C integers and floating point
MPI_MIN	Minimum	C integers and floating point
MPI_SUM	Sum	C integers and floating point
MPI_PROD	Product	C integers and floating point
MPI_LAND	Logical AND	C integers
MPI_BAND	Bit-wise AND	C integers and byte
MPI_LOR	Logical OR	C integers
MPI_BOR	Bit-wise OR	C integers and byte
MPI_LXOR	Logical XOR	C integers
MPI_BXOR	Bit-wise XOR	C integers and byte
MPI_MAXLOC	max-min value-location	Data-pairs
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- MPI also allows programmers to define their own operations.

Gather I

- **Gather**; the all-to-one gather operation is performed in MPI using the **MPI_Gather** function.

```
int MPI_Gather(void *sendbuf, int sendcount,
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- As a result, the *target* process receives a total of *p* buffers (*p* is the number of processors in the communication *comm*).

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- Each process, including the *target* process, sends the data stored in the array *sendbuf* to the *target* process.
- As a result, the *target* process receives a total of *p* buffers (*p* is the number of processors in the communication *comm*).
- The data is stored in the array *recvbuf* of the target process, in a rank order.
- That is, the data from process with rank *i* are stored in the *recvbuf* starting at location *i * sendcount* (assuming that the array *recvbuf* is of the same type as *recvdatatype*).

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- The argument *recvcount* specifies the number of elements received by each process and not the total number of elements it receives.
- So, *recvcount* must be the same as *sendcount* and their datatypes must be matching.

Gather III

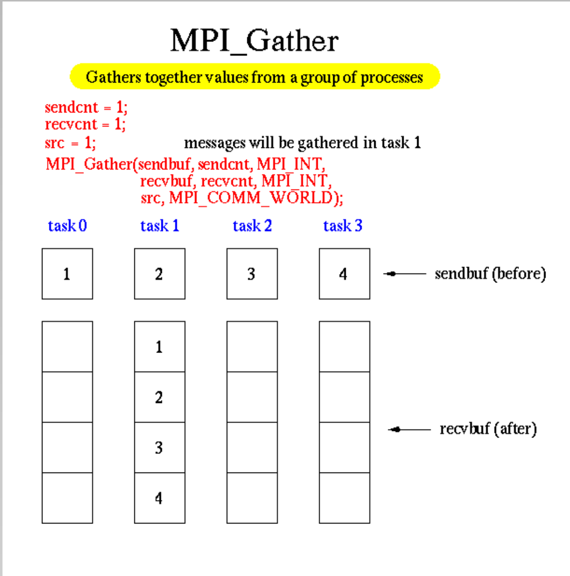

Figure: Diagram for Gather.

Gather IV

- MPI also provides the **MPI_Allgather** function in which the data are *gathered to all the processes and not only at the target process*.

```
int MPI_Allgather(void *sendbuf, int sendcount,
        MPI_Datatype senddatatype, void *recvbuf, int recvcount,
        MPI_Datatype recvdatatype, MPI_Comm comm)
```


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int MPI_Allgather(void *sendbuf, int sendcount,
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```

- The meanings of the various parameters are similar to those for **MPI_Gather**;

Gather IV

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```

- The meanings of the various parameters are similar to those for **MPI_Gather**;
- however, each process must now supply a *recvbuf* array that will store the gathered data.

Gather V

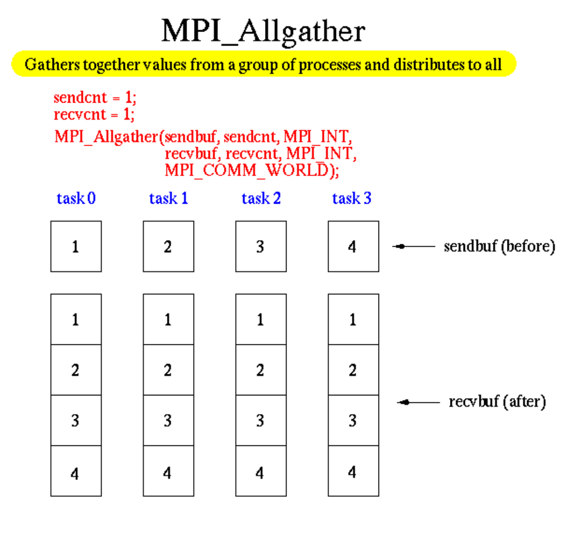

Figure: Diagram for All_Gather.

Gather VI

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- MPI refers to these operations as the vector variants.

```
int MPI_Gatherv(void *sendbuf, int sendcount,
        MPI_Datatype senddatatype, void *recvbuf,
        int *recvcounts, int *displs,
        MPI_Datatype recvdatatype, int target, MPI_Comm comm)

int MPI_Allgatherv(void *sendbuf, int sendcount,
        MPI_Datatype senddatatype, void *recvbuf,
        int *recvcounts, int *displs, MPI_Datatype recvdatatype,
        MPI_Comm comm)
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        MPI_Datatype recvdatatype, int target, MPI_Comm comm)

int MPI_Allgatherv(void *sendbuf, int sendcount,
        MPI_Datatype senddatatype, void *recvbuf,
        int *recvcounts, int *displs, MPI_Datatype recvdatatype,
        MPI_Comm comm)
```

- These functions allow a different number of data elements to be sent by each process by replacing the *recvcount* parameter with the array *recvcounts*.

Scatter

- **Scatter**; the one-to-all scatter operation is performed in MPI using the **MPI_Scatter** function.

```
int MPI_Scatter(void *sendbuf, int sendcount,
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- Similarly to the gather operation, MPI provides a vector variant of the scatter operation, called **MPI_Scatterv**, that allows different amounts of data to be sent to different processes.

Scatter II

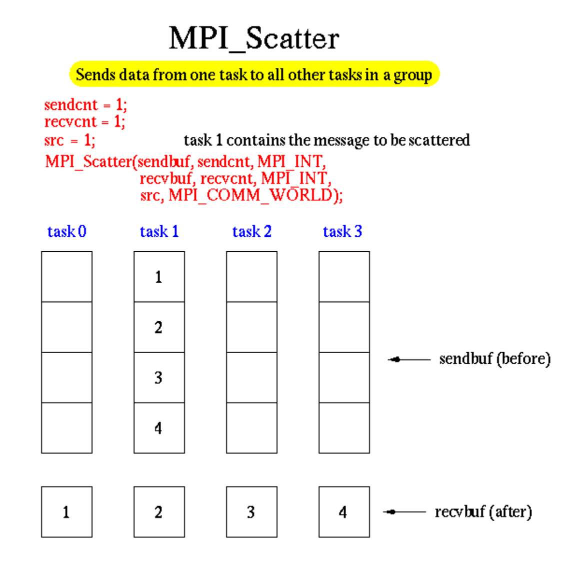

Figure: Diagram for Scatter.

All-to-All I

- **Alltoall**; the all-to-all communication operation is performed in MPI by using the **MPI_Alltoall** function.

```
int MPI_Alltoall(void *sendbuf, int sendcount,
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- MPI also provides a vector variant of the all-to-all personalized communication operation called **MPI_Alltoallv** that allows different amounts of data to be sent.

All-to-All II

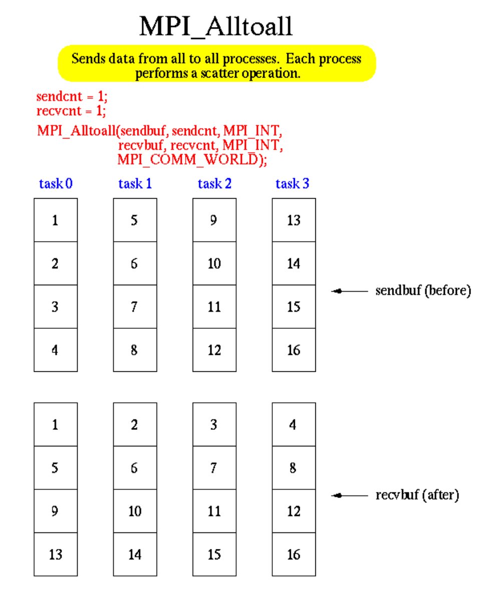

Figure: Diagram for Alltoall.

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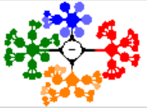
- The function takes *color* and *key* as input parameters in addition to the communicator, and partitions the group of processes in the communicator *comm* into disjoint subgroups.



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- The function takes *color* and *key* as input parameters in addition to the communicator, and partitions the group of processes in the communicator *comm* into disjoint subgroups.
- Each subgroup contains all processes that have supplied the same value for the *color* parameter.
- Within each subgroup, the processes are ranked in the order defined by the value of the *key* parameter.

Groups and Communicators II

- Figure 7 shows an example of splitting a communicator using the MPI_Comm_split function.

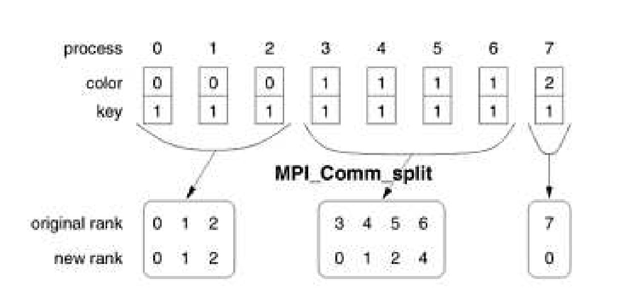
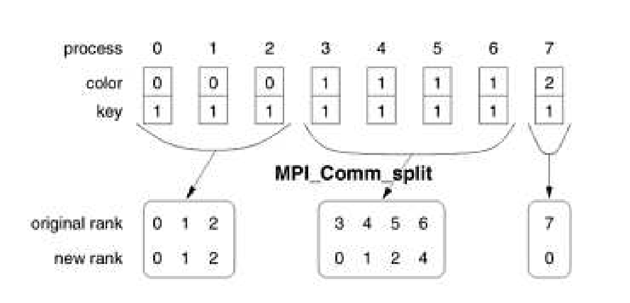


Figure: Using MPI_Comm_split to split a group of processes in a communicator into subgroups.

Groups and Communicators II

- Figure 7 shows an example of splitting a communicator using the MPI_Comm_split function.
- If each process called MPI_Comm_split using the values of parameters *color* and *key* as shown in Fig 7, then three communicators will be created, containing processes 0, 1, 2, 3, 4, 5, 6, and 7, respectively.



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