

Collective Communications

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Collective Communication

- Communications involving a group of processes.
- Called by all processes in a communicator.
- Examples:
 - Barrier synchronisation.
 - Broadcast, scatter, gather.
 - Global sum, global maximum, etc.

Characteristics of Collective Comms

- Collective action over a communicator.
- All processes must communicate.
- Synchronisation may or may not occur.
- Standard collective operations are blocking.
 - non-blocking versions recently introduced into MPI 3.0
 - may be useful in some situations but not yet commonly employed
 - obvious extension of blocking version: extra request parameter
- No tags.
- Receive buffers must be exactly the right size.

Barrier Synchronisation

- C:

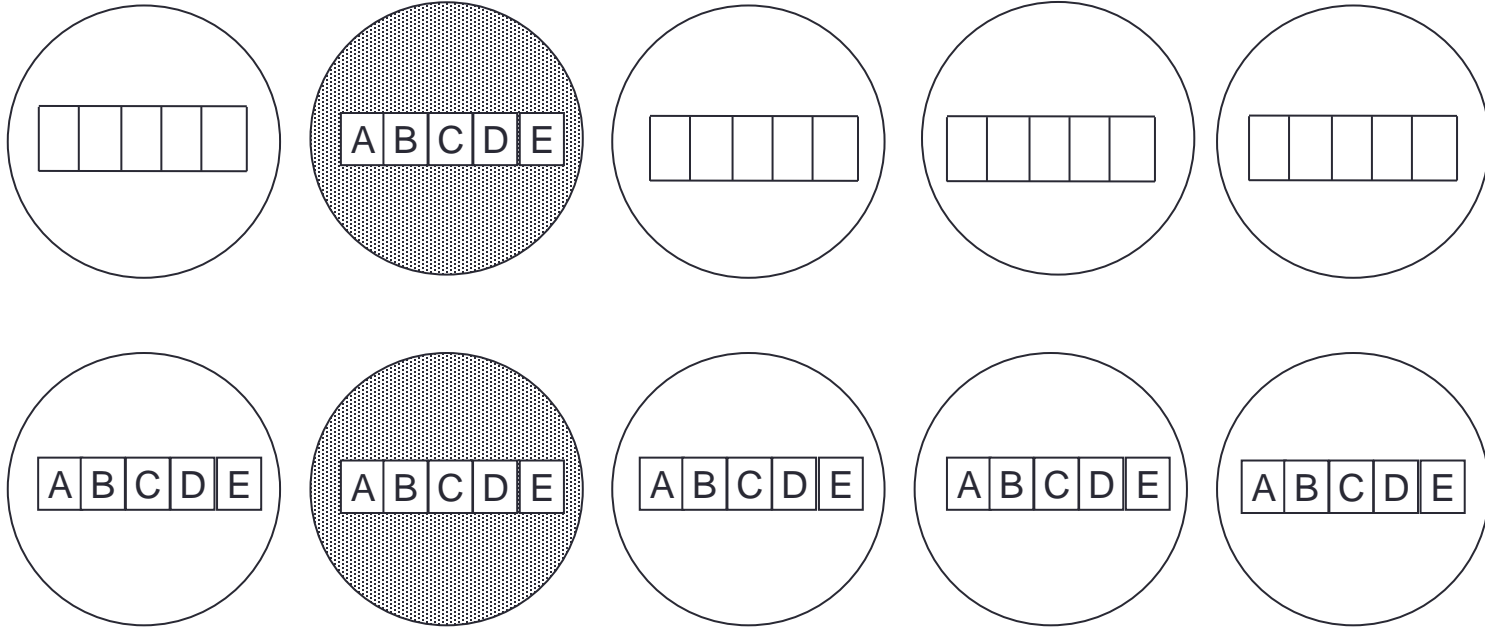
```
int MPI_Barrier (MPI_Comm comm)
```

- Fortran:

```
MPI_BARRIER (COMM, IERROR)
```

```
INTEGER COMM, IERROR
```

Broadcast



Broadcast

- C:

```
int MPI_Bcast (void *buffer, int count,  
              MPI_Datatype datatype, int root,  
              MPI_Comm comm)
```

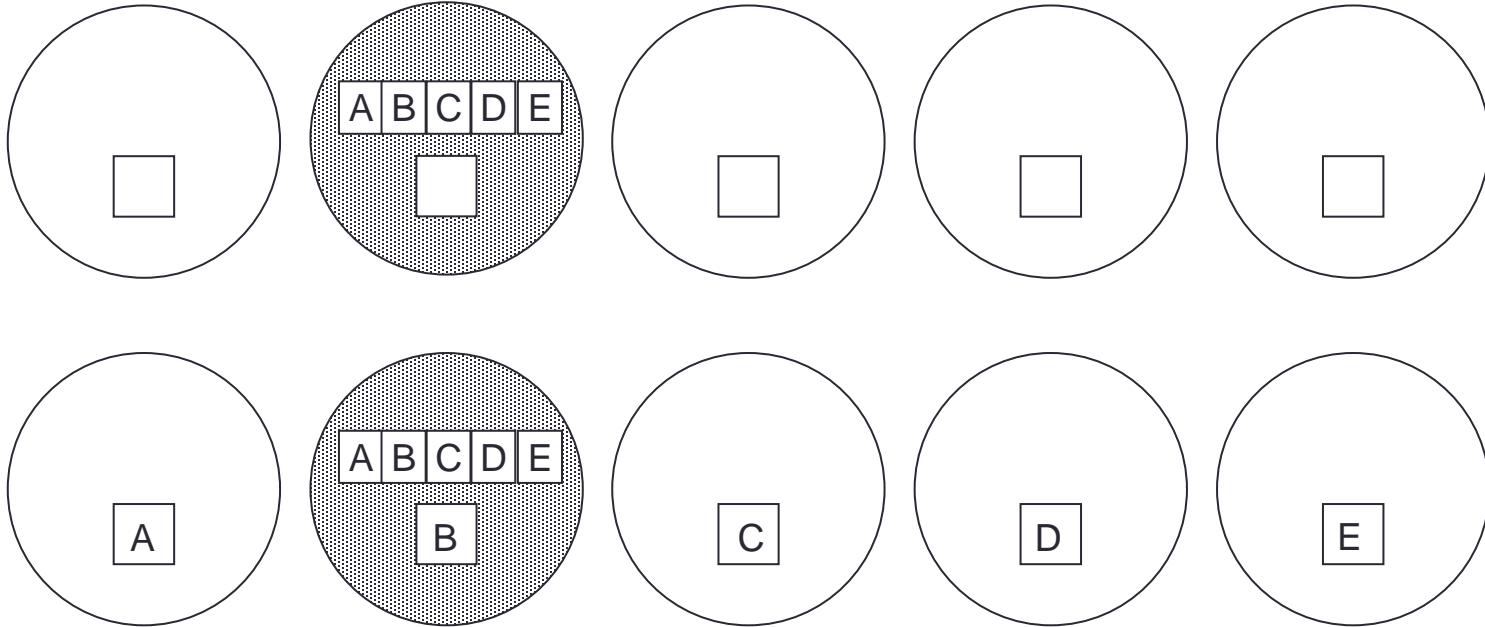
- Fortran:

```
MPI_BCAST (BUFFER, COUNT, DATATYPE, ROOT,  
          COMM, IERROR)
```

```
<type> BUFFER(*)
```

```
INTEGER COUNT, DATATYPE, ROOT, COMM, IERROR
```

Scatter



Scatter

- C:

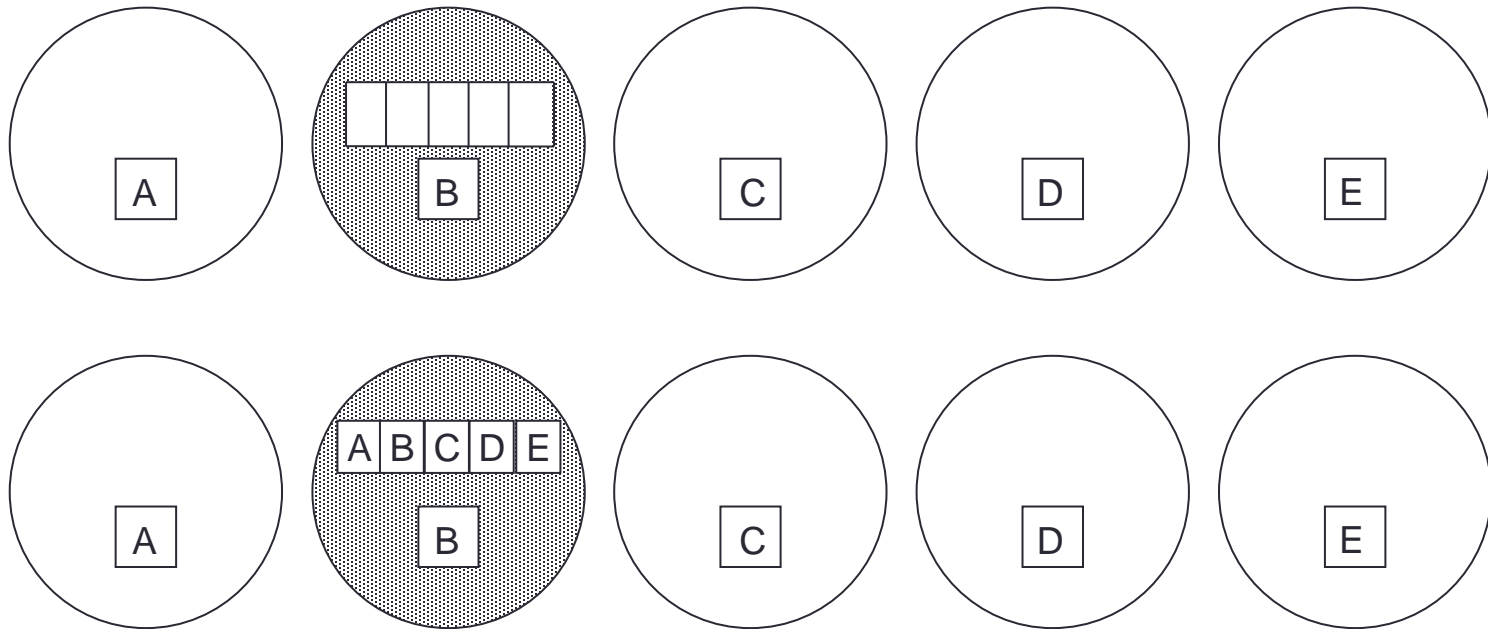
```
int MPI_Scatter(void *sendbuf,  
               int sendcount, MPI_Datatype sendtype,  
               void *recvbuf, int recvcount,  
               MPI_Datatype recvtype, int root,  
               MPI_Comm comm)
```

- Fortran:

```
MPI_SCATTER(SENDBUF, SENDCOUNT, SENDTYPE,  
            RECVBUF, RECVCOUNT, RECVTYPE,  
            ROOT, COMM, IERROR)
```

```
<type> SENDBUF, RECVBUF  
INTEGER SENDCOUNT, SENDTYPE, RECVCOUNT  
INTEGER RECVTYPE, ROOT, COMM, IERROR
```

Gather



Gather

- C:

```
int MPI_Gather(void *sendbuf, int sendcount,  
              MPI_Datatype sendtype, void *recvbuf,  
              int recvcount, MPI_Datatype recvtype,  
              int root, MPI_Comm comm)
```

- Fortran:

```
MPI_GATHER (SENDBUF, SENDCOUNT, SENDTYPE,  
            RECVBUF, RECVCOUNT, RECVTYPE,  
            ROOT, COMM, IERROR)
```

```
<type> SENDBUF, RECVBUF  
INTEGER SENDCOUNT, SENDTYPE, RECVCOUNT  
INTEGER RECVTYPE, ROOT, COMM, IERROR
```

Global Reduction Operations

- Used to compute a result involving data distributed over a group of processes.
- Examples:
 - global sum or product
 - global maximum or minimum
 - global user-defined operation

Predefined Reduction Operations

MPI Name	Function
<code>MPI_MAX</code>	Maximum
<code>MPI_MIN</code>	Minimum
<code>MPI_SUM</code>	Sum
<code>MPI_PROD</code>	Product
<code>MPI_LAND</code>	Logical AND
<code>MPI_BAND</code>	Bitwise AND
<code>MPI_LOR</code>	Logical OR
<code>MPI_BOR</code>	Bitwise OR
<code>MPI_LXOR</code>	Logical Exclusive OR
<code>MPI_BXOR</code>	Bitwise Exclusive OR
<code>MPI_MAXLOC</code>	Maximum and location
<code>MPI_MINLOC</code>	Minimum and location

MPI_Reduce

- C:

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

- Fortran:

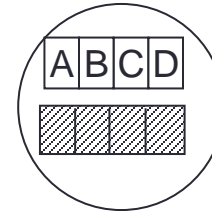
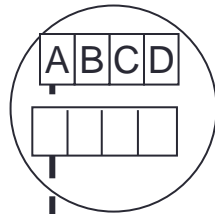
```
MPI_REDUCE (SENDBUF, RECVBUF, COUNT,  
           DATATYPE, OP, ROOT, COMM, IERROR)
```

```
<type>    SENDBUF, RECVBUF  
INTEGER   SENDCOUNT, SENDTYPE, RECVCOUNT  
INTEGER   RECVTYPE, ROOT, COMM, IERROR
```

MPI_REDUCE

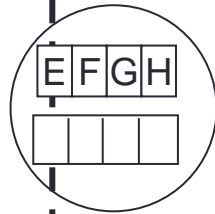
Rank

0

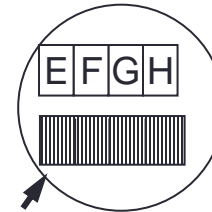


1

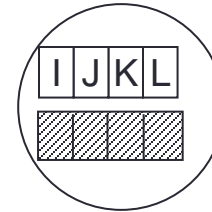
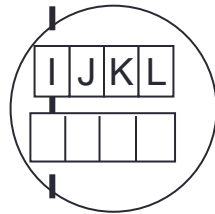
Root



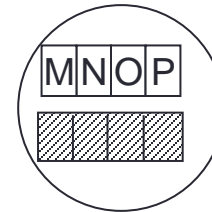
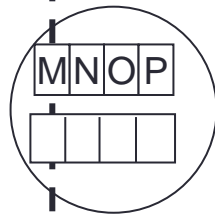
MPI_REDUCE



2



3



AoEoloM

Example of Global Reduction

Integer global sum

- C:

```
MPI_Reduce(&x, &result, 1, MPI_INT,  
           MPI_SUM, 0, MPI_COMM_WORLD)
```

- Fortran:

```
CALL MPI_REDUCE(x, result, 1, MPI_INTEGER,  
               MPI_SUM, 0,  
               MPI_COMM_WORLD, IERROR)
```

- Sum of all the **x** values is placed in **result**.
- The result is only placed there on process 0.

User-Defined Reduction Operators

- Reducing using an arbitrary operator, o
- C - function of type `MPI_User_Function`:

```
void my_op (void *invec, void *inoutvec, int *len,  
            MPI_Datatype *datatype)
```
- Fortran - external subprogram of type

```
SUBROUTINE MY_OP (INVEC (*), INOUTVEC (*), LEN,  
                 DATATYPE)  
  
<type>    INVEC (LEN), INOUTVEC (LEN)  
INTEGER  LEN, DATATYPE
```

Reduction Operator Functions

- Operator function for \circ must act as

```
for (i = 1 to len)
```

```
    inoutvec(i) = inoutvec(i)  $\circ$  invec(i)
```

- Operator \circ need not commute, but must be associative

Registering User-Defined Operator

- Operator handles have type `MPI_Op` or `INTEGER`

- C:

```
int MPI_Op_create(MPI_User_function *my_op,  
                 int commute, MPI_Op *op)
```

- Fortran:

```
MPI_OP_CREATE (MY_OP, COMMUTE, OP, IERROR)
```

```
EXTERNAL MY_OP
```

```
LOGICAL COMMUTE
```

```
INTEGER OP, IERROR
```

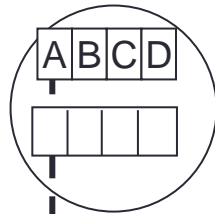
Variants of MPI_REDUCE

- `MPI_Allreduce` no root process
- `MPI_Reduce_scatter` result is scattered
- `MPI_Scan` “parallel prefix”

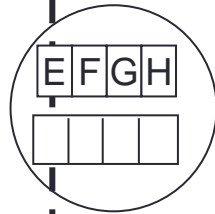
MPI_ALLREDUCE

Rank

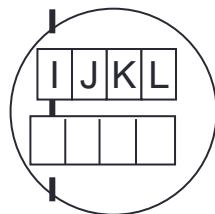
0



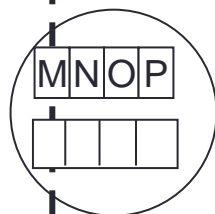
1



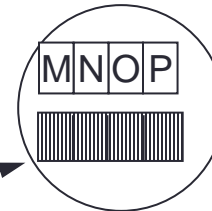
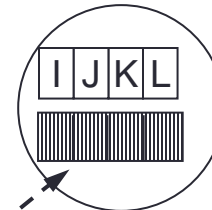
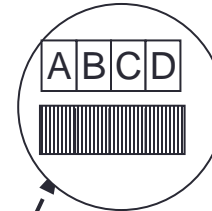
2



3



MPI_ALLREDUCE



AoEoloM

MPI_ALLREDUCE

Integer global sum

- C:

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

- Fortran:

```
MPI_ALLREDUCE (SENDBUF, RECVBUF, COUNT,  
              DATATYPE, OP, COMM, IERROR)
```

Allreduce example

Integer global sum

- C:

```
MPI_Allreduce(&x, &result, 1, MPI_INT,  
             MPI_SUM, MPI_COMM_WORLD)
```

- Fortran:

```
CALL MPI_ALLREDUCE(x, result, 1, MPI_INTEGER,  
                 MPI_SUM,  
                 MPI_COMM_WORLD, IERROR)
```

- Sum of all the **x** values is placed in **result**.
- The result is stored on every process

Vector reductions (Fortran)

```
double precision, dimension(3) :: localdata, globaldata

localdata(1) = pressure
localdata(2) = temperature
localdata(3) = rainfall

call mpi_allreduce(localdata, globaldata, 3,          &
                  MPI_DOUBLE_PRECISION, MPI_SUM,    &
                  MPI_COMM_WORLD, ierr)

write(*,*) "global P, T and R = ", globaldata(:)
```


Vector reductions (C)

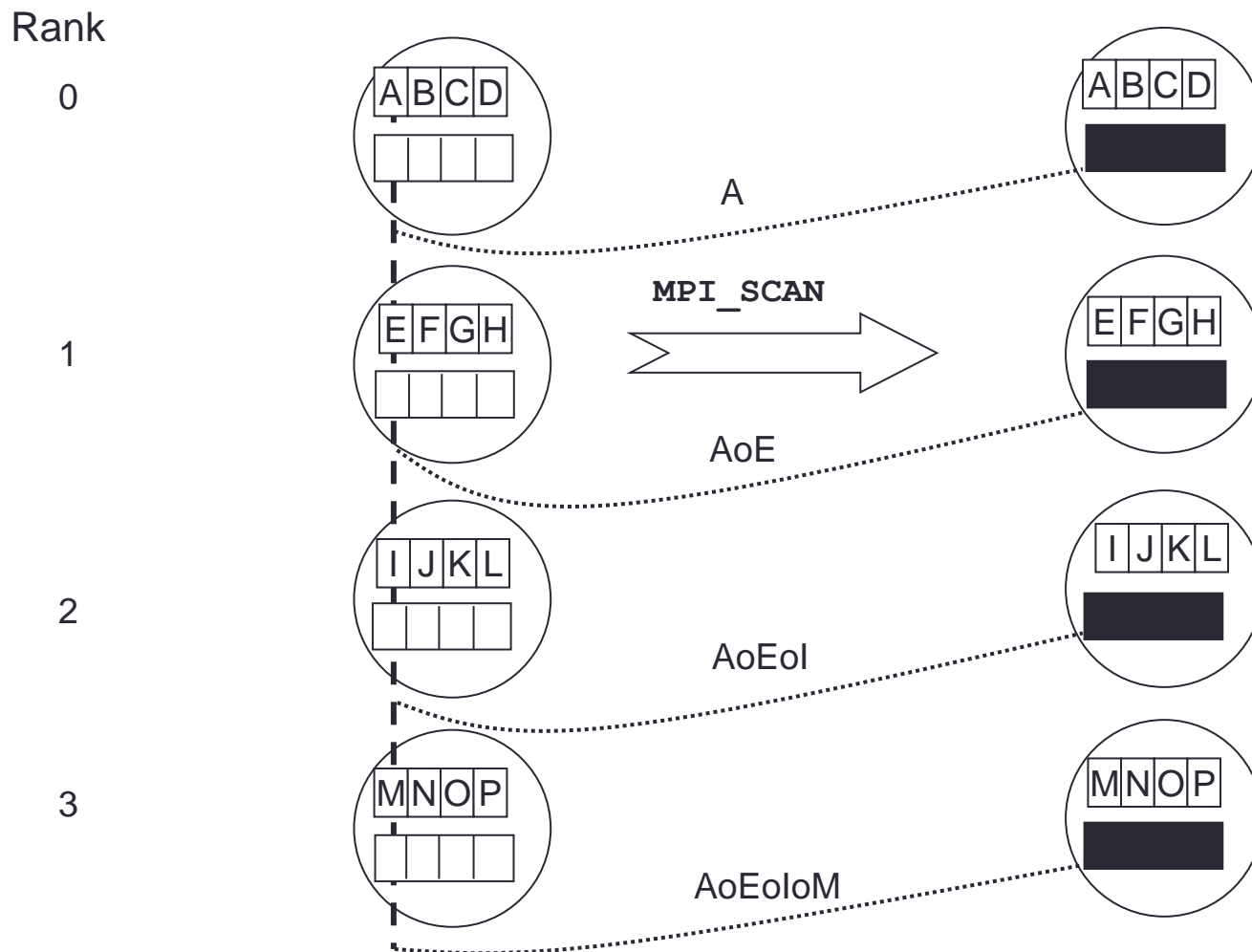
```
double localdata[3], globaldata[3];

localdata[0] = pressure;
localdata[1] = temperature;
localdata[2] = rainfall;

mpi_allreduce(localdata, globaldata, 3,
              MPI_DOUBLE, MPI_SUM, MPI_COMM_WORLD);

printf("global P, T and R = %f, %f, %f\n",
       globaldata[0], globaldata[1], globaldata[2] );
```

MPI_SCAN



MPI_SCAN

Integer partial sum

- C:

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

- Fortran:

```
MPI_SCAN(SENDBUF, RECVBUF, COUNT,  
        DATATYPE, OP, COMM, IERROR)
```

Exercise

- See Exercise 5 on the sheet
- Rewrite the pass-around-the-ring program to use MPI global reduction to perform its global sums.
- Then rewrite it so that each process computes a partial sum