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

- C:

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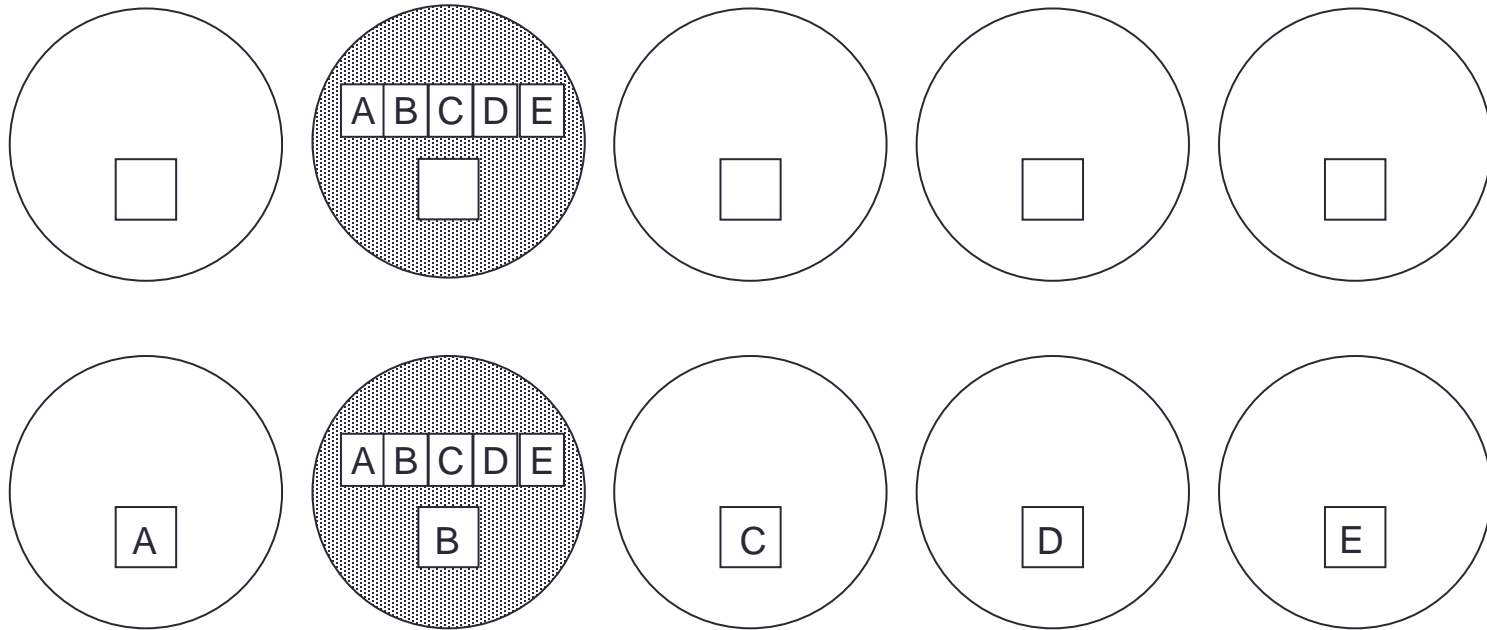
- Fortran:

```
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)
```
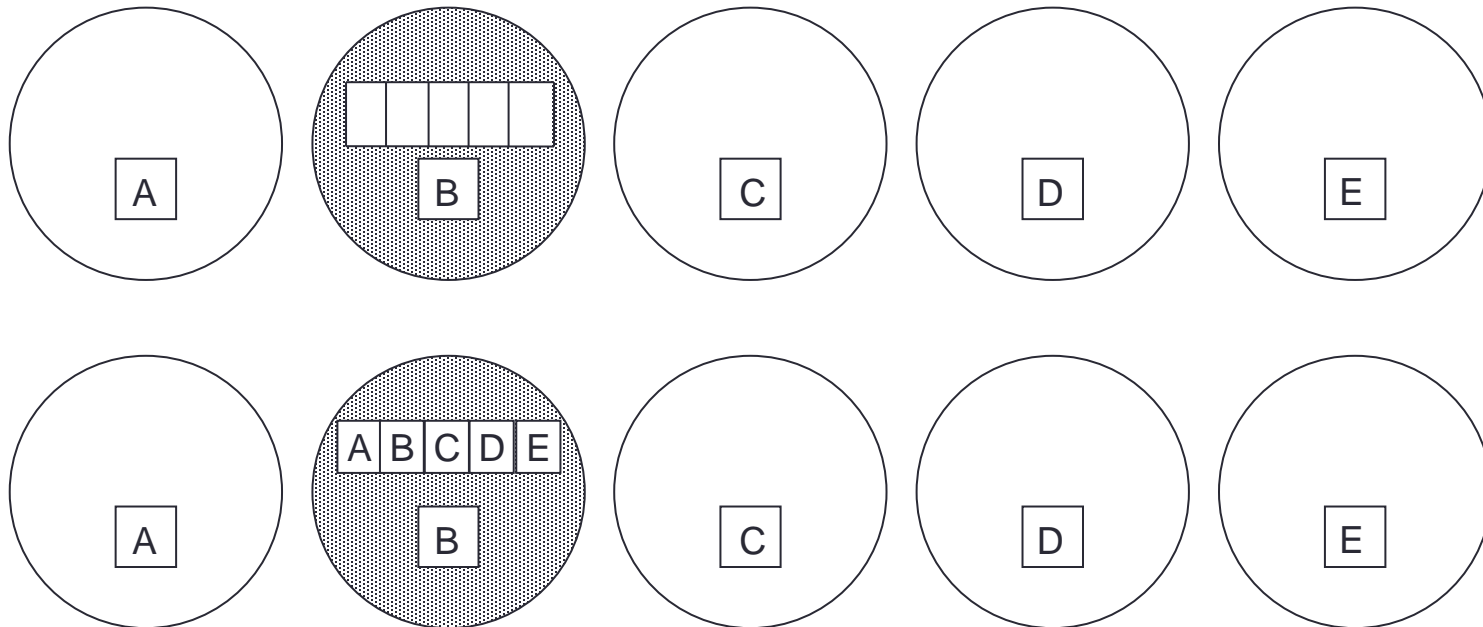
- Fortran:

```
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

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Predefined Reduction Operations

MPI Name	Function
MPI_MAX	Maximum
MPI_MIN	Minimum
MPI_SUM	Sum
MPI_PROD	Product
MPI_LAND	Logical AND
MPI_BAND	Bitwise AND
MPI_LOR	Logical OR
MPI_BOR	Bitwise OR
MPI_LXOR	Logical Exclusive OR
MPI_BXOR	Bitwise Exclusive OR
MPI_MAXLOC	Maximum and location
MPI_MINLOC	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)
```
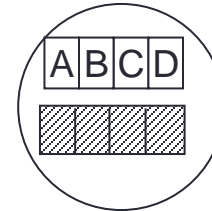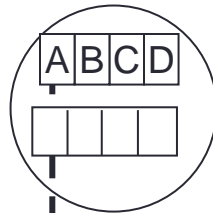
- Fortran:

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

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

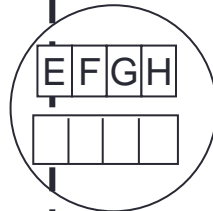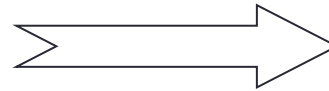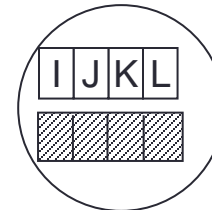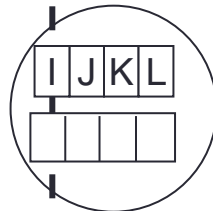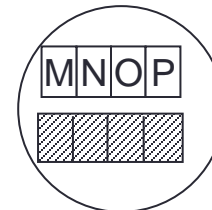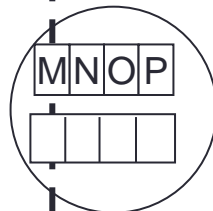# MPI_REDUCE

Rank

0

Root

1

2

3

AoEoIoM

MPI_REDUCE

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 o must act as

```
for (i = 1 to len)
    inoutvec(i) = inoutvec(i)  o  invec(i)
```

- Operator o 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
```
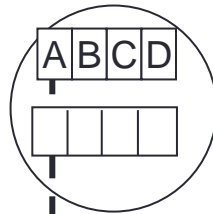
Variants of MPI_REDUCE

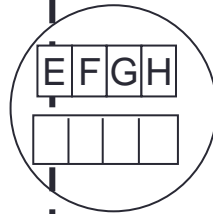- **MPI_Allreduce** no root process
- **MPI_Reduce_scatter** result is scattered
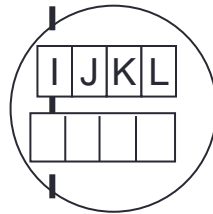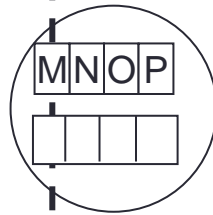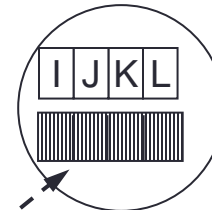- **MPI_Scan** "parallel prefix"

MPI_ALLREDUCE

Rank

0

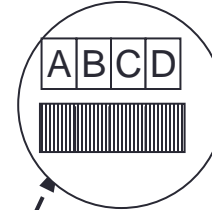1   MPI_ALLREDUCE

2

3

AoEoIoM

21

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)

```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] );
```
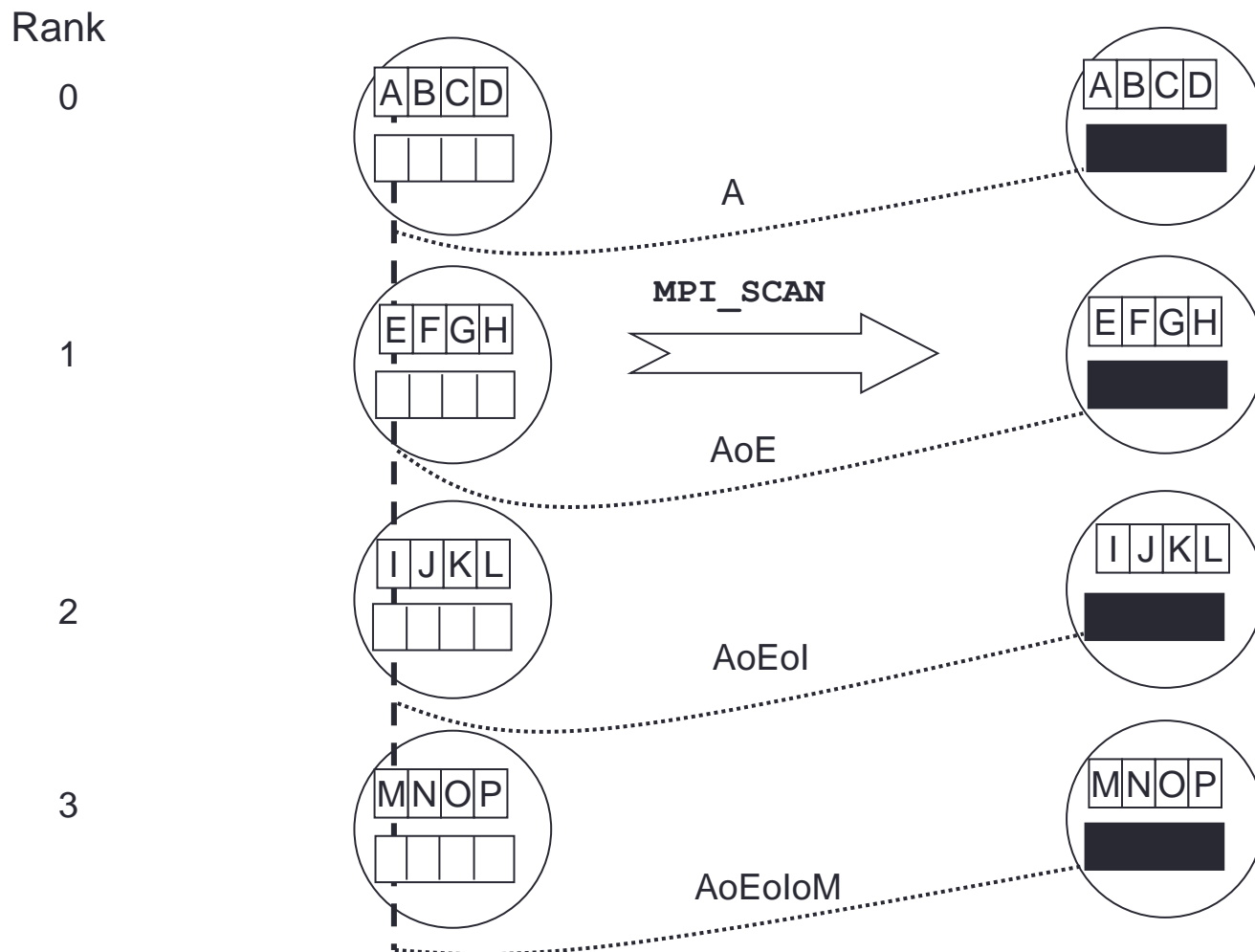
MPI_SCAN

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