Collective Communications

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

- 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.

- C:

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

- Fortran:

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

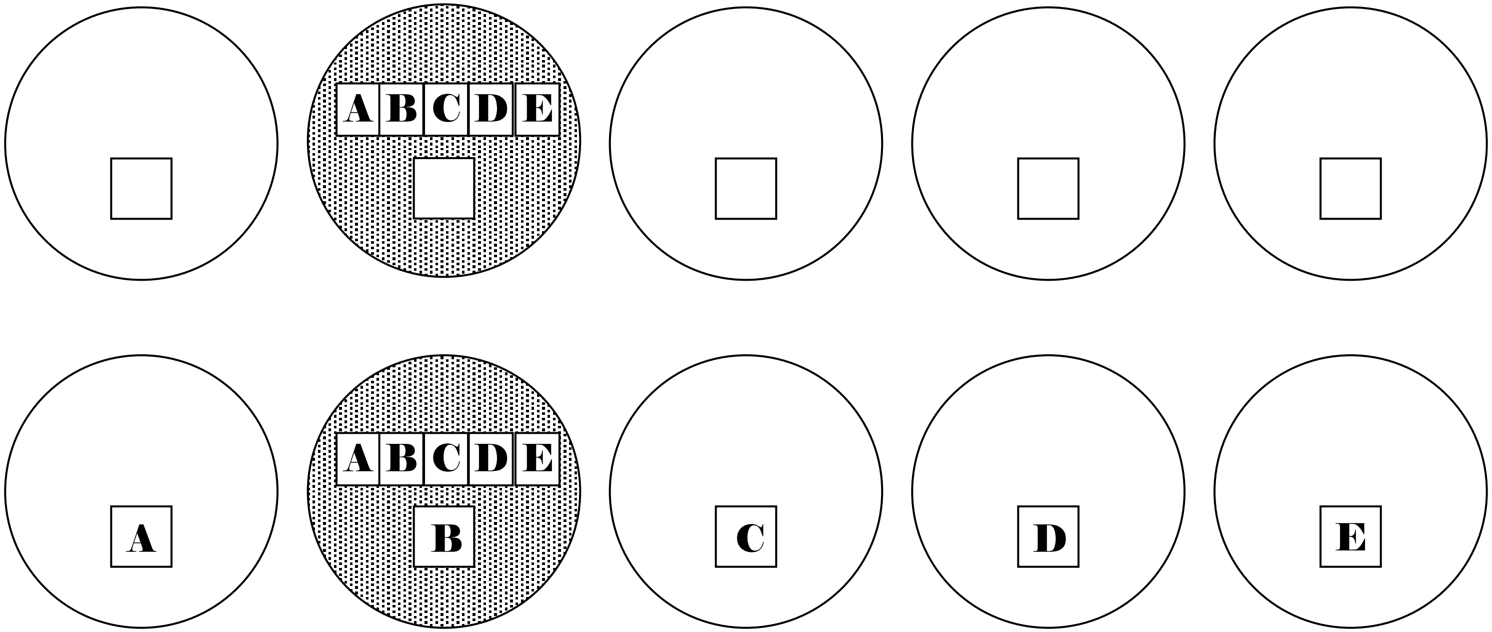
- C:

```
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
```


A
B
C
D
E
A
B
C
D
E
A
B
C
D
E

Scatter

- C:

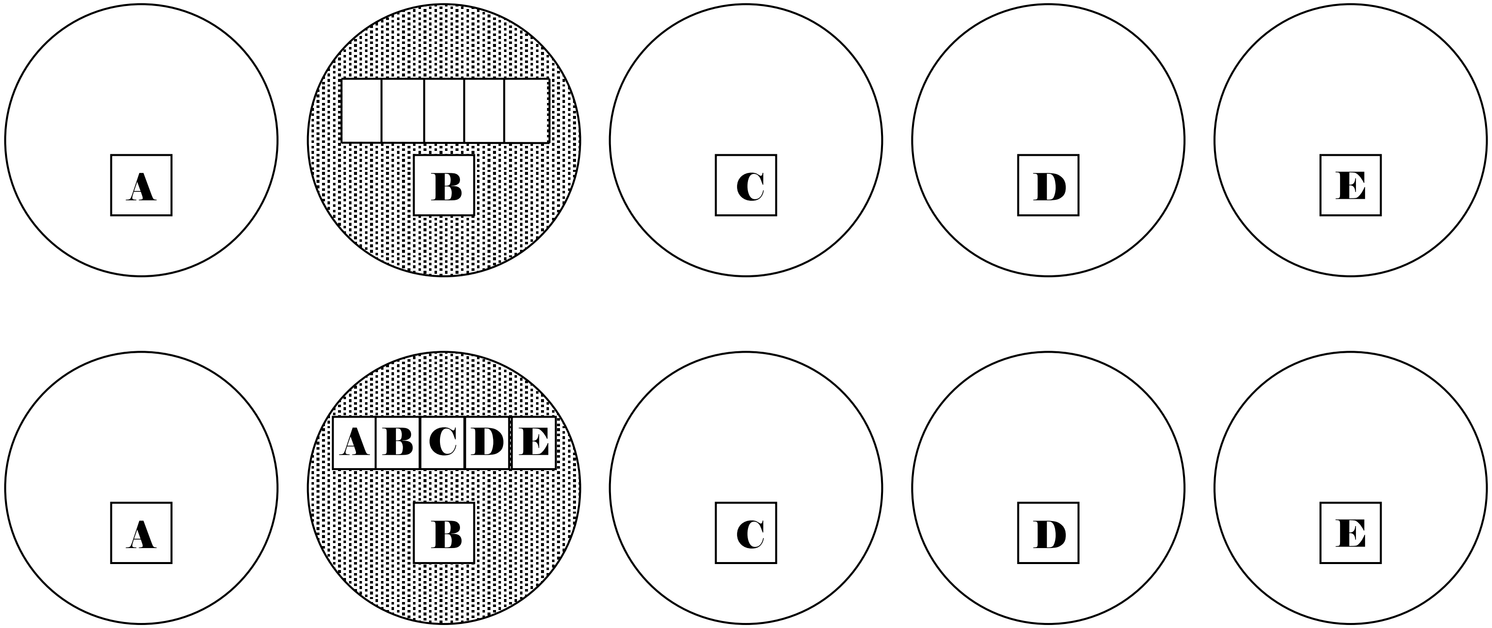
```
int MPI_Scatter(void *sendbuf,
    int sendcount, MPI_Datatype sendtype,
    void *recvbuf, int recvcount,
    MPI_Datatype recvtype, int root,
    MPI_Comm comm)
```

- 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



- 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
```

- 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
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

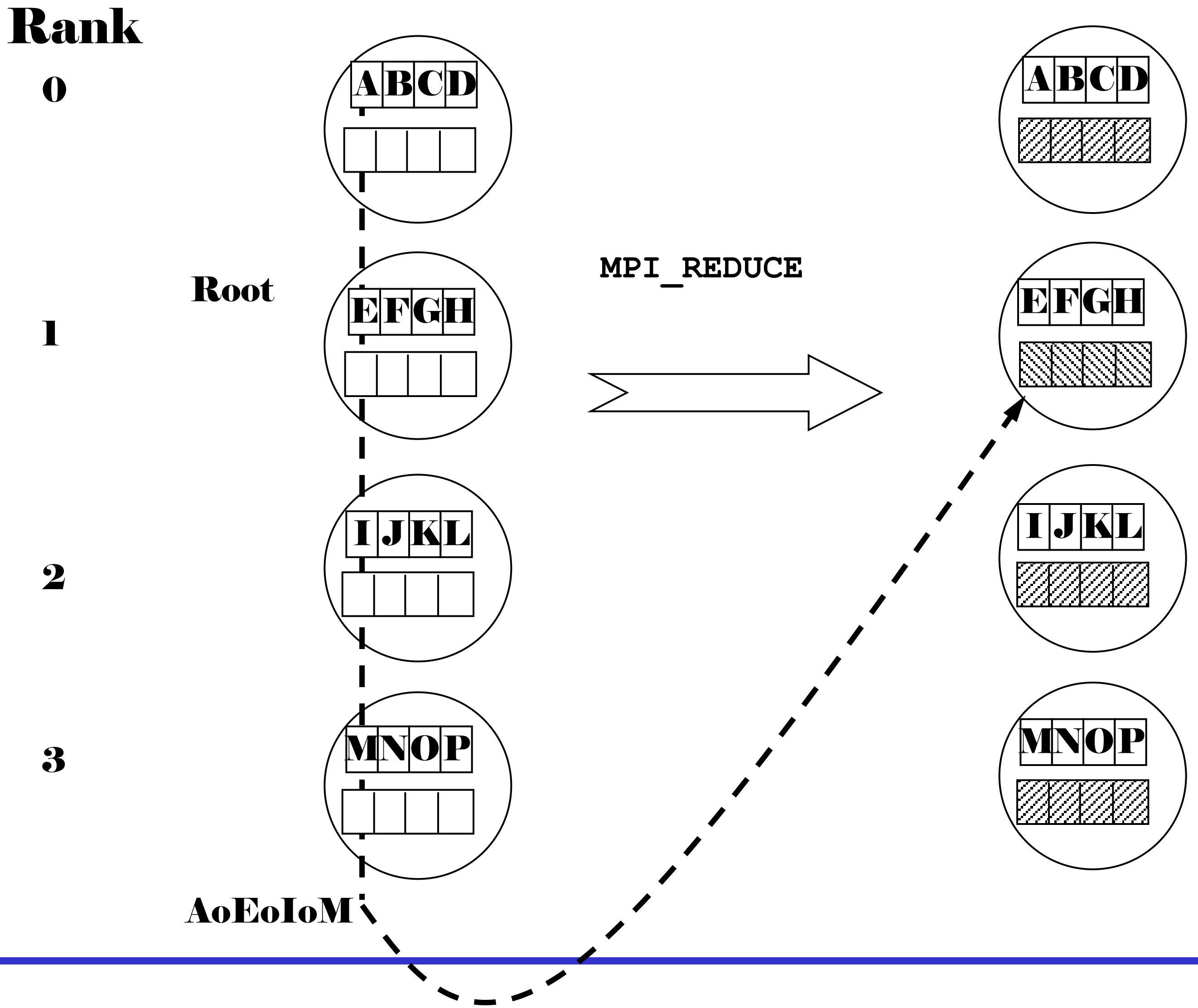
- C:

```
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
```


Rank
0
1
2
3
Root
ABCD
EFGH
IJKL
MNOP
AoEoIoM
MPI_REDUCE
ABCD
EFGH
IJKL
MNOP

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 processor 0.

- Reducing using an arbitrary operator, $\circ$
- 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
```

- Operator function for ○ must act as:

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

- Operator ○ need not commute but must be associative.

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

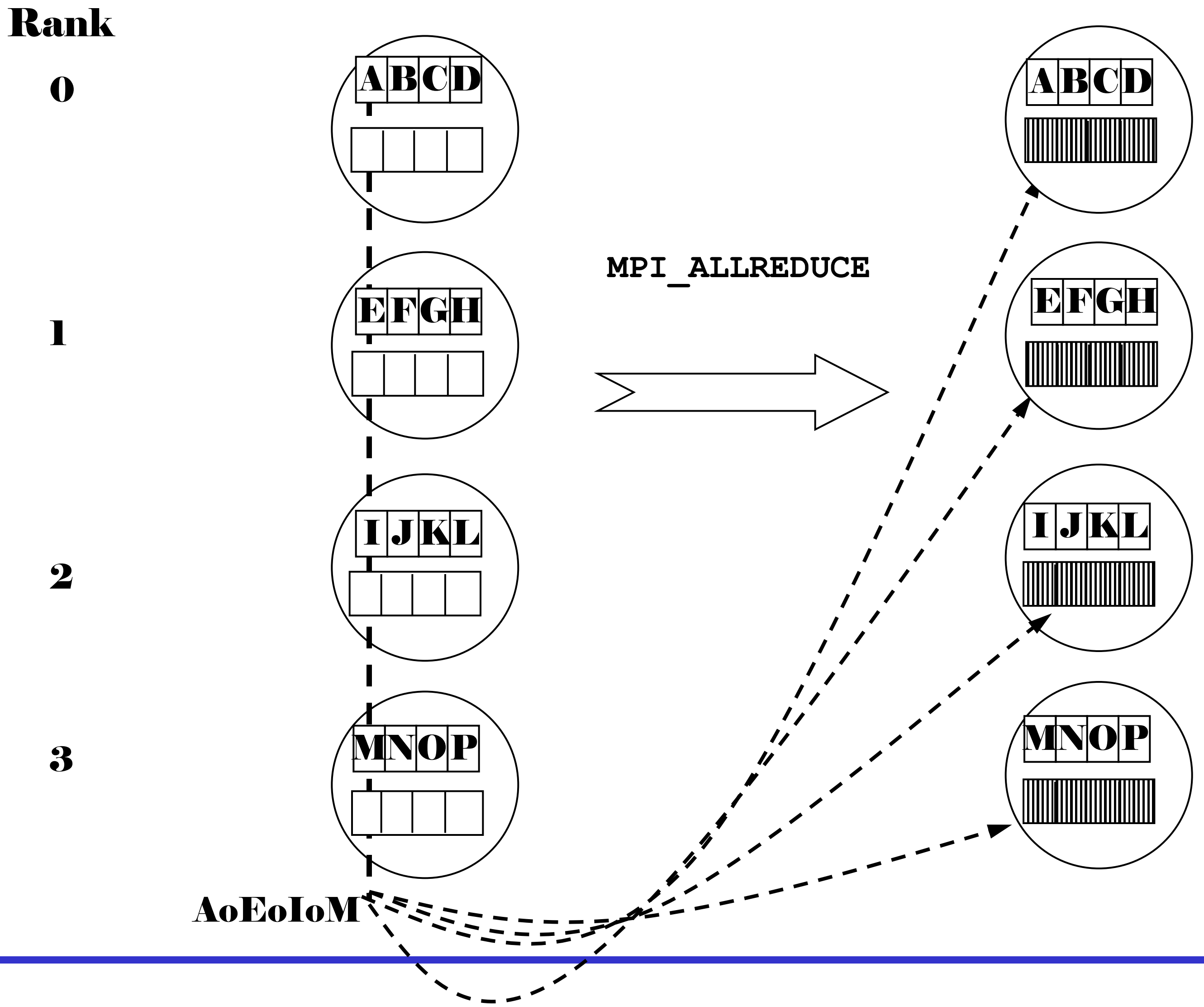
```
int MPI_Op_create(MPI_User_function *my_op,
                  int commute, MPI_Op *op)
```

- Fortran:

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

EXTERNAL MY_OP
LOGICAL COMMUTE
INTEGER OP, IERROR
```

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


Rank
0
1
2
3
A B C D
E F G H
I J K L
M N O P
MPI_ALLREDUCE
AoEoIoM

Integer global sum

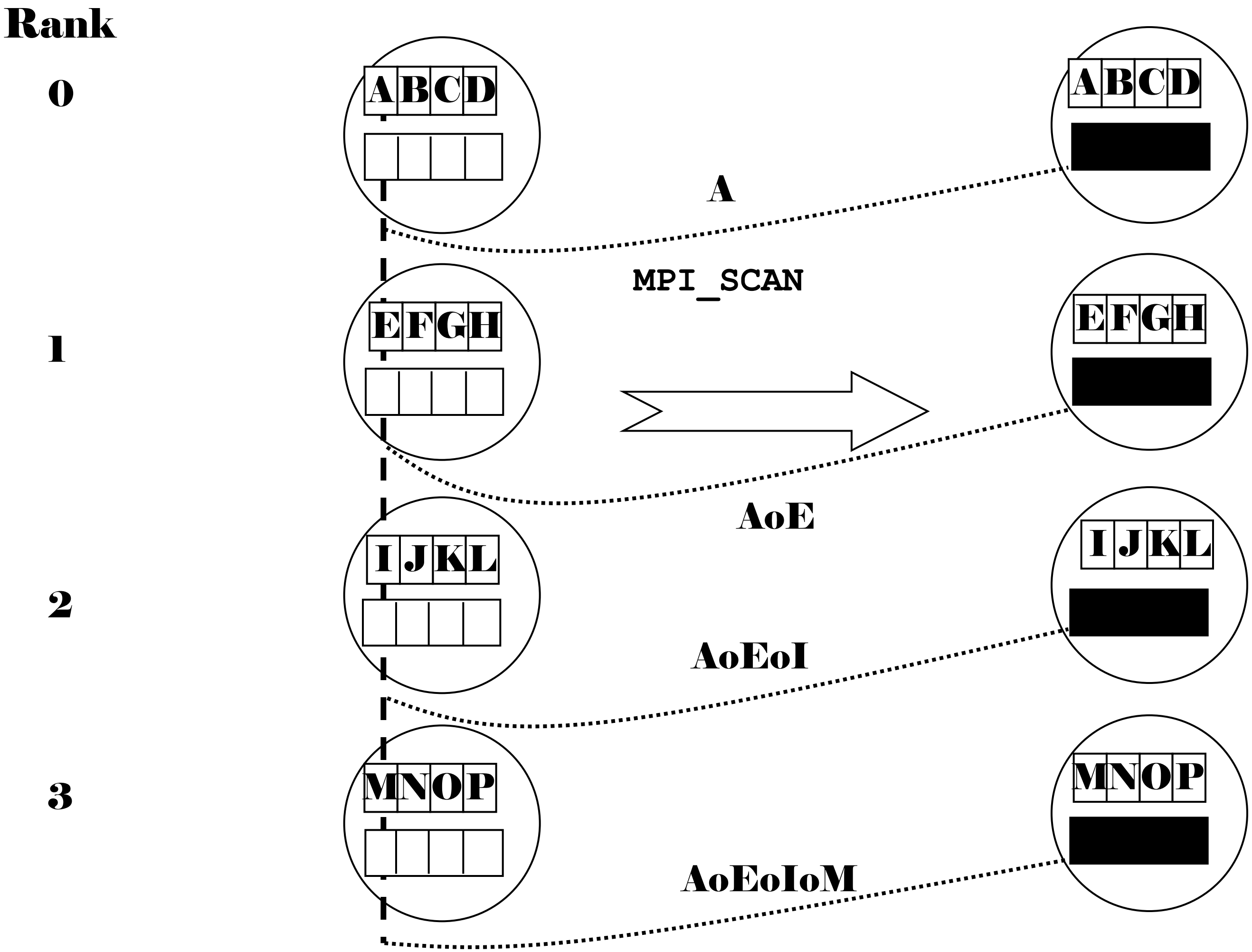
- C:

```
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)
```

MPI_SCAN


Rank
0
1
2
3
ABCD
EFGH
IJKL
MNOP
A
MPI_SCAN
AoE
AoEoI
AoEoIoM
ABCD
EFGH
IJKL
MNOP

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)
```

- 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