Message Passing Interface

DPHPC15

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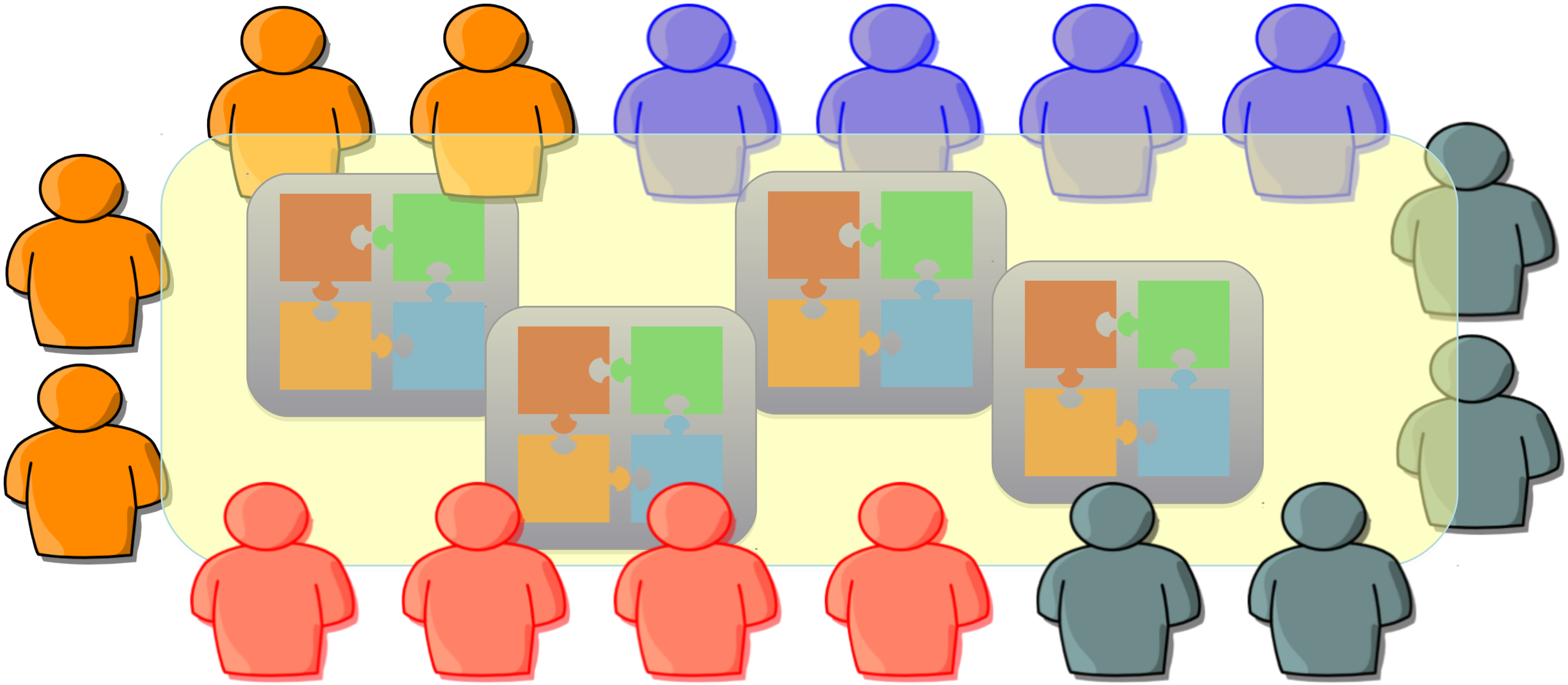
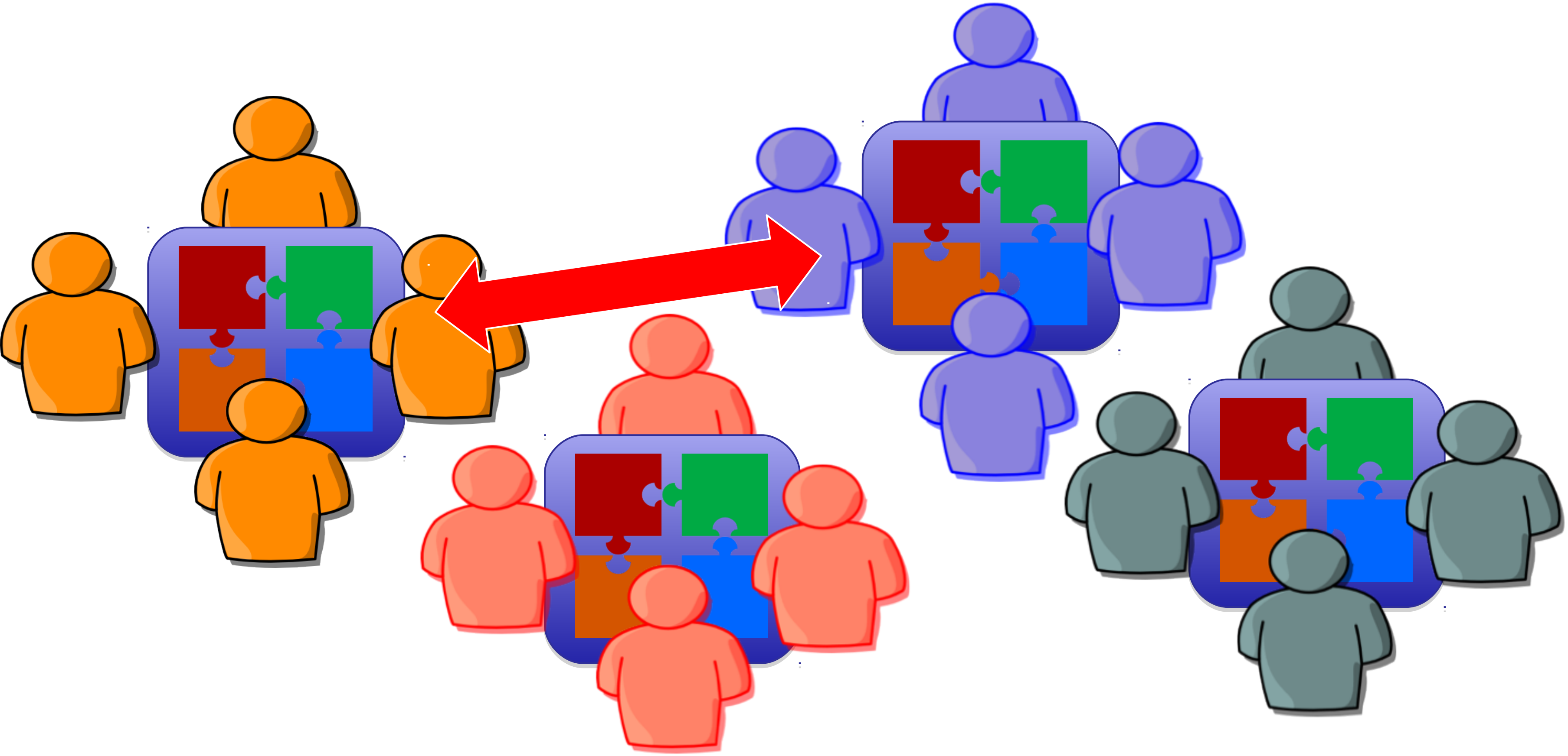
DSM (Distributed Shared Memory)



Message Passing



MPI (Message Passing Interface)

A message passing specification implemented by different vendors (Cray-, IBM-, Intel-, Microsoft-MPI) and groups (Open MPI, MPICH)

Context: distributed memory parallel computers

- Each processor has its own memory and cannot access the memory of other processors
- Any data to be shared must be explicitly transmitted from one to another

Most message passing programs use the *single program multiple data (SPMD)* model

- Each processor executes the same set of instructions
- Parallelization is achieved by letting each processor operation a different piece of data
- MIMD (Multiple Instructions Multiple Data)

SPMD example

```
main(int argc, char **argv){
    if(process is assigned Master role){
        /* Assign work and coordinate workers and collect results */
        MasterRoutine(/*arguments*/);
    } else {  /* it is worker process */
        /* interact with master and other workers. Do the work and
    send results to the master*/
        WorkerRoutine(/*arguments*/);
    }
}
```

Why MPI?

- Small
  - Many programs can be written with only 6 basic functions
- Large
  - MPI’s extensive functionality from many functions
- Scalable
  - Point-to-point communication
- Flexible
  - Don’t need to rewrite parallel programs across platforms

What we need to know...

Basic functions

Function	Description
int MPI_Init(int *argc, char **argv)	Initialize MPI
int MPI_Finalize()	Exit MPI
int MPI_Comm_size(MPI_Comm comm, int *size)	Determine number of processes within a comm
int MPI_Comm_rank(MPI_Comm comm, int *rank)	Determine process rank within a comm
int MPI_Send(void *buf, int count, MPI_Datatype datatype, int dest, int tag, MPI_Comm comm)	Send a message
int MPI_Recv(void *buf, int count, MPI_Datatype datatype, int src, int tag, MPI_Comm comm, MPI_Status *status)	Receive a message

Communicator

- An identifier associated with a group of processes
  - Each process has a unique rank within a specific communicator from 0 to (#processes-1)
  - Always required when initiating a communication by calling an MPI function
- Default: MPI_COMM_WORLD
  - Contains all processes
- Several communicators can co-exist
  - A process can belong to different communicators at the same time

Hello World

```
#include "mpi.h”
int main( int argc, char *argv[] ) {
    int nproc, rank;
    MPI_Init (&argc,&argv); /* Initialize MPI */

    MPI_Comm_size(MPI_COMM_WORLD,&nproc); /* Get Comm Size*/
    MPI_Comm_rank(MPI_COMM_WORLD,&rank); /* Get rank */

    printf(“Hello World from process %d\n”, rank);

    MPI_Finalize(); /* Finalize */
    return 0;
}
```

How to compile…

Need to tell the compiler where to find the MPI include files and how to link to the MPI libraries.

Fortunately, most MPI implementations come with scripts that take care of these issues:

- mpicc mpi_code.c –o a.out

Two widely used (and free) MPI implementations

- MPICH (http://www-unix.mcs.anl.gov/mpi/mpich)
- OPENMPI (http://www.openmpi.org)

Blocking Message Passing

- The call waits until the data transfer is done
  - The sending process waits until all data are transferred to the system buffer
  - The receiving process waits until all data are transferred from the system buffer to the receive buffer
  - Buffers can be freely reused

Blocking Message Send

```
MPI_Send (void *buf, int count, MPI_Datatype dtype, int dest, int tag,
    MPI_Comm comm);
```

Blocking Message Send

Standard (MPI_Send)	The sending process returns when the system can buffer the message or when the message is received and the buffer is ready for reuse.
Buffered (MPI_Bsend)	The sending process returns when the message is buffered in an application-supplied buffer.
Synchronous (MPI_Ssend)	The sending process returns only if a matching receive is posted and the receiving process has started to receive the message.
Ready (MPI_Rsend)	The message is sent as soon as possible.

Blocking Message Receive

MPI_Recv (void *buf, int count, MPI_Datatype dtype, int source, int tag,
MPI_Comm comm, MPI_Status *status);

Example (from http://mpi.deino.net/mpi_functions/index.htm)

```
…
if (rank == 0) {
    for (i=0; i<10; i++)  buffer[i] = i;
    MPI_Send(buffer, 10, MPI_INT, 1, 123, MPI_COMM_WORLD);
} else if (rank == 1) {
    for (i=0; i<10; i++)  buffer[i] = -1;
    MPI_Recv(buffer, 10, MPI_INT, 0, 123, MPI_COMM_WORLD, &status);
    for (i=0; i<10; i++)
       if (buffer[i] != i)
         printf("Error: buffer[%d] = %d but is expected to be %d\n", i, buffer[i], i);
 }
…
```

Non-blocking Message Passing

- Returns immediately after the data transferred is initiated
- Allows to overlap computation with communication
- Need to be careful though
  - When send and receive buffers are updated before the transfer is over, the result will be wrong

Non-blocking Message Passing

MPI_Isend (void *buf, int count, MPI_Datatype dtype, int dest, int tag,
MPI_Comm comm, MPI_Request *req);

MPI_Irecv (void *buf, int count, MPI_Datatype dtype, int source, int tag,
MPI_Comm comm, MPI_Request *req);

MPI_Wait(MPI_Request *req, MPI_Status *status);

req — Specifies the request used by a completion routine when called by the application to complete the send operation.

Blocking	MPI_Send	MPI_Bsend	MPI_Ssend	MPI_Rsend	MPI_Recv
Non-blocking	MPI_Isend	MPI_Ibsend	MPI_Issend	MPI_Irsend	MPI_Irecv

Non-blocking Message Passing

```
…
right = (rank + 1) % nproc;
left = rank - 1;
if (left < 0)        left = nproc – 1;
MPI_Irecv(buffer, 10, MPI_INT, left, 123, MPI_COMM_WORLD, &request);
MPI_Isend(buffer2, 10, MPI_INT, right, 123, MPI_COMM_WORLD,
    &request2);
MPI_Wait(&request, &status);
MPI_Wait(&request2, &status);
…
```

How to execute MPI codes?

The implementation supplies scripts to launch the MPI parallel calculation

- mpirun –np #proc a.out
- mpiexec –n #proc a.out

A copy of the same program runs on each processor core within its own process (private address space)

Communication

- through the network interconnect
- through the shared memory on SMP machines

Collective communications

A single call handles the communication between all the processes in a communicator

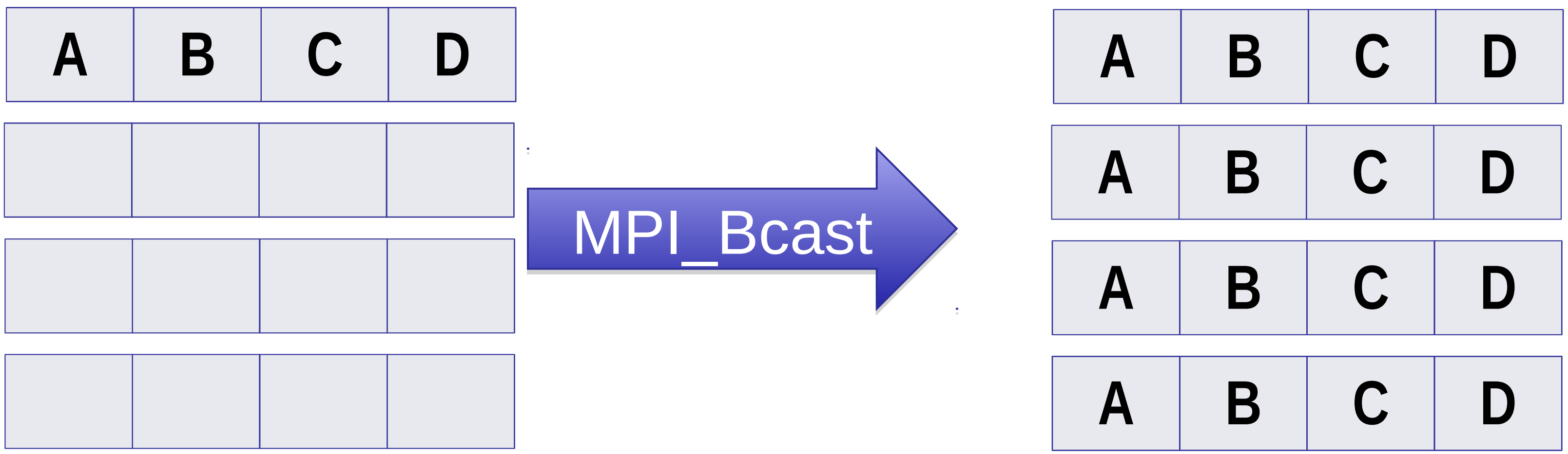
There are 3 types of collective communications

- Data movement (e.g. MPI_Bcast)
- Reduction (e.g. MPI_Reduce)
- Synchronization (e.g. MPI_Barrier)

Broadcast

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

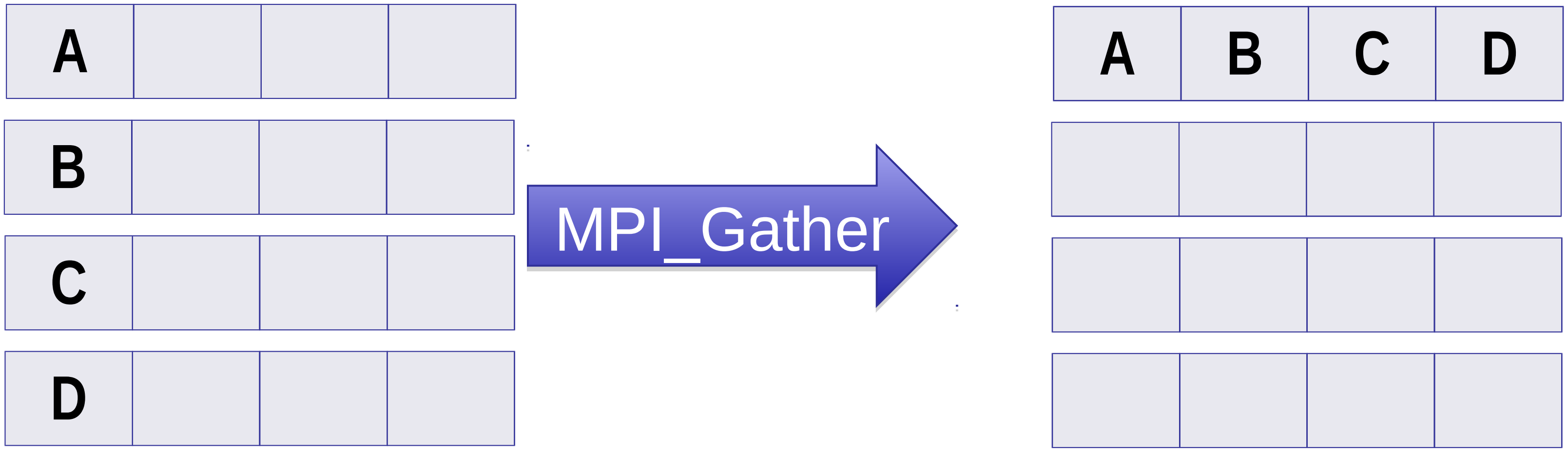
- One process (root) sends data to all the other processes in the same communicator
- Must be called by all the processes with the same arguments



Gather

int MPI_Gather(void *sendbuf, int sendcnt, MPI_Datatype sendtype, void *recvbuf, int recvcnt, MPI_Datatype recvtype, int root, MPI_Comm comm)

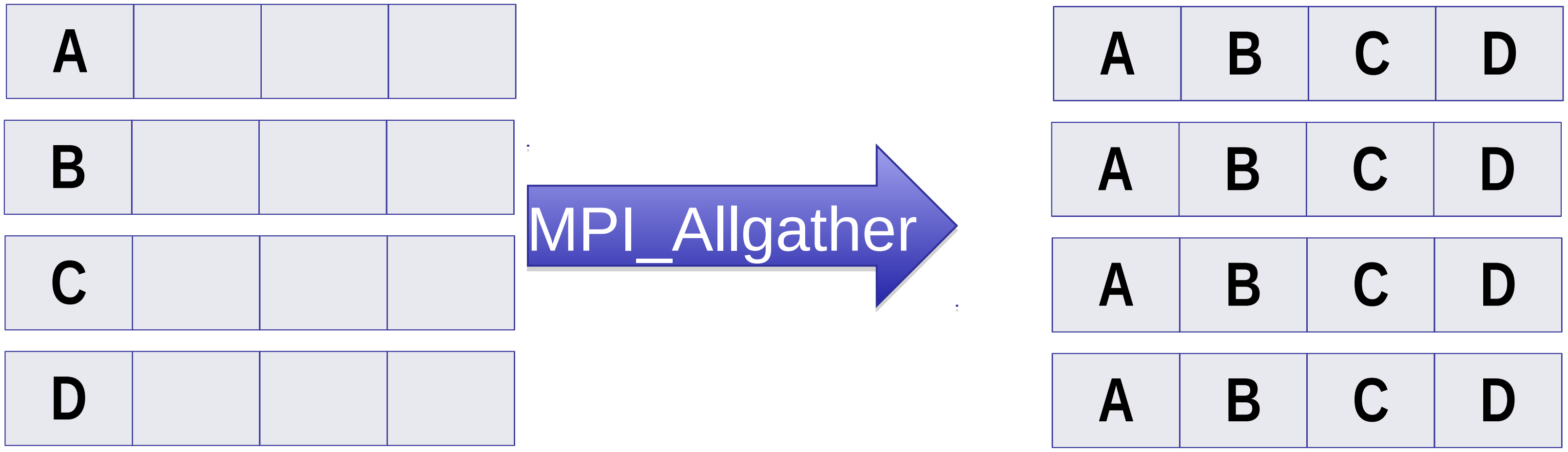
- One process (root) collects data to all the other processes in the same communicator
- Must be called by all the processes with the same arguments



Gather to All

int MPI_Allgather(void *sendbuf, int sendcnt, MPI_Datatype sendtype, void *recvbuf, int recvcnt, MPI_Datatype recvtype, MPI_Comm comm)

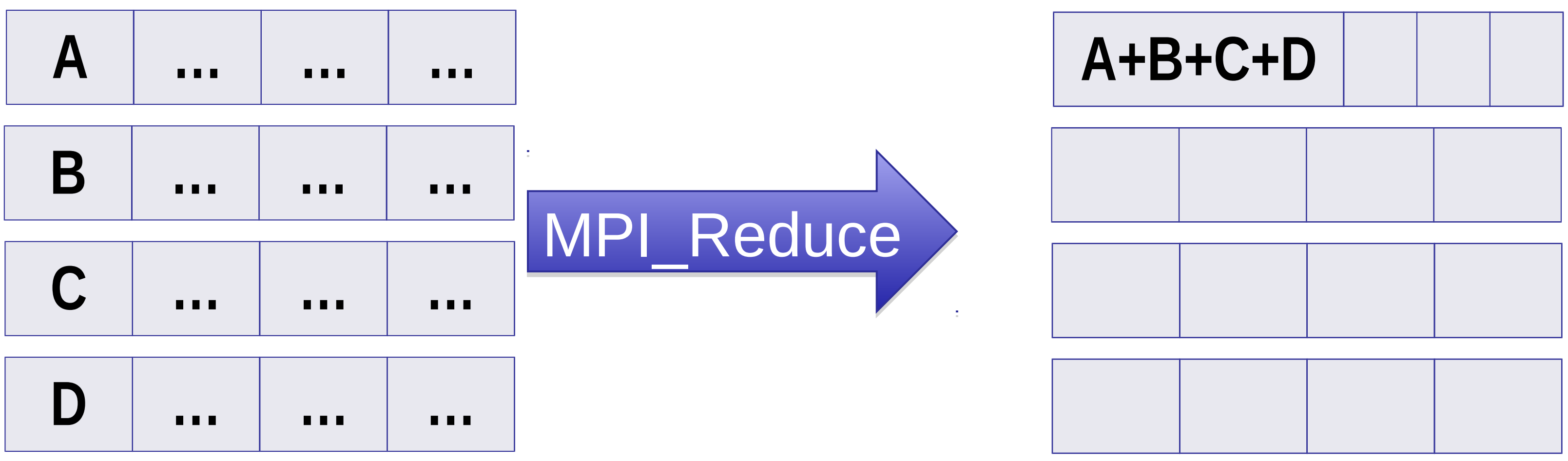
- All the processes collects data to all the other processes in the same communicator
- Must be called by all the processes with the same arguments



Reduction

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

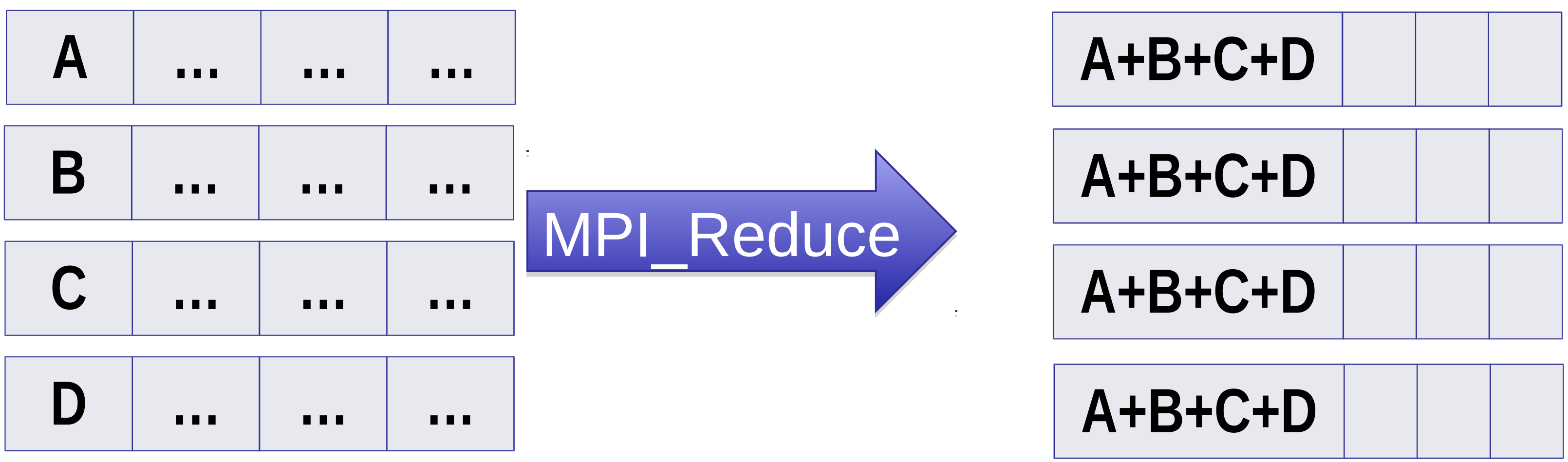
- One process (root) collects data to all the other processes in the same communicator, and performs an operation on the data
- MPI_SUM, MPI_MIN, MPI_MAX, MPI_PROD, logical AND, OR, XOR, and a few more
- MPI_Op_create(): User defined operator



Reduction to All

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

- All the processes collect data to all the other processes in the same communicator, and perform an operation on the data
- MPI_SUM, MPI_MIN, MPI_MAX, MPI_PROD, logical AND, OR, XOR, and a few more
- MPI_Op_create(): User defined operator



Synchronization

int MPI_Barrier(MPI_Comm comm)

```
#include "mpi.h"
#include <stdio.h>
int main(int argc, char *argv[]) {
    int rank, nprocs;
    MPI_Init(&argc,&argv);
    MPI_Comm_size(MPI_COMM_WORLD,&nprocs);
    MPI_Comm_rank(MPI_COMM_WORLD,&rank);
    MPI_Barrier(MPI_COMM_WORLD);
    printf("Hello, world.  I am %d of %d\n", rank, nprocs);
    MPI_Finalize();
    return 0;
}
```

Homework

Find an iterative method to calculate Pi (if you cannot find one read http://en.wikipedia.org/wiki/Monte_Carlo_method)

Write a sequential version in C

Write a parallel version using MPI (based on seq. Code)