MPI—Message Passing Interface

Goals

- Portable application-level interface
- Support efficient communication across a wide variety of machines
- Support heterogeneous computing environments
- Provide a reliable communication interface

History

- Defined by a large consortium (60 individuals, 40 organizations)
- First standard presented in 1992
- Widely adopted
  - Many implementations, including vendor-specific implementations
  - Widely used
- MPI2
  - Extensions proposed starting in 1995

MPI—Message Passing Interface

History (cont)

- MPI 2.0 (1997)
  - Adds many features
    - Process management
    - One-sided communication
    - Parallel I/O
  - Rarely implemented or used

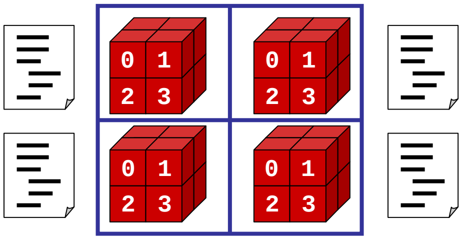
The Basic Model

Distributed memory

- Each process sees a local address space
- Processes send messages to communicate with other processes

SPMD code

- Write one piece of code that executes on each processor

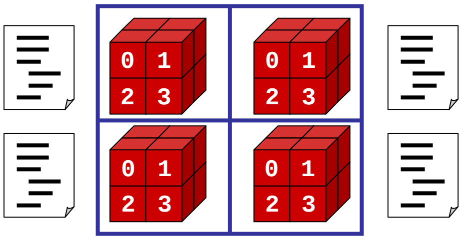


4 processes

Basic Model (cont)

SPMD code

- Write one piece of code that executes on each processor



Local View (4 processes)

SPMD vs. SIMD?

- SIMD is a hardware execution model
- Each instruction executes in lock step
- SPMD is a software execution model– each process executes independently

Execution Models

SPMD execution

- Execute the same binary on each processor
- Can mimic MIMD execution by using control flow that depends on a process’ rank

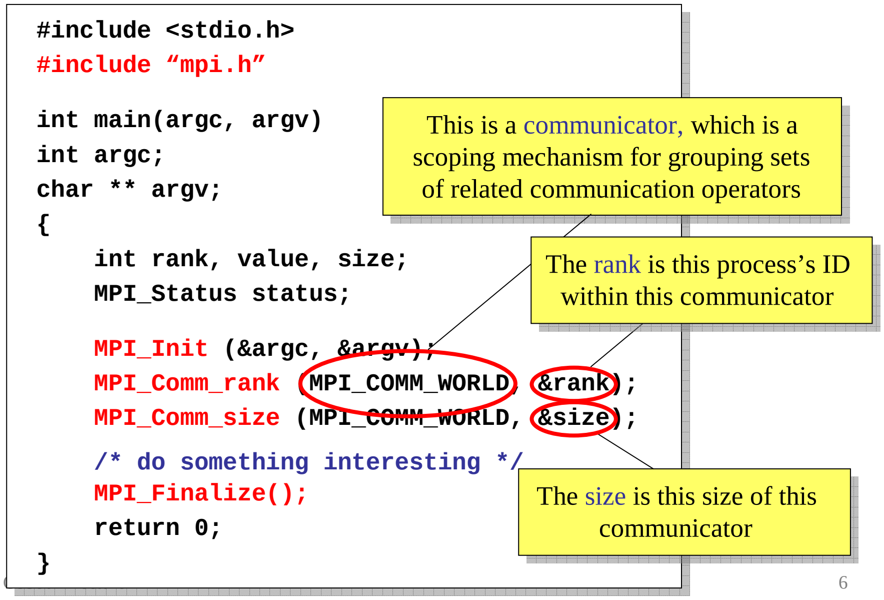
MIMD execution

- Execute different binary on different processors

How do SPMD and MIMD differ?

- Fundamentally, no difference
- MIMD supports heterogeneous processors
- MIMD has lower control flow overhead
- MIMD has smaller code size
- MIMD code may be easier for a compiler to analyze (?)

MPI Example: Initialization and Cleanup



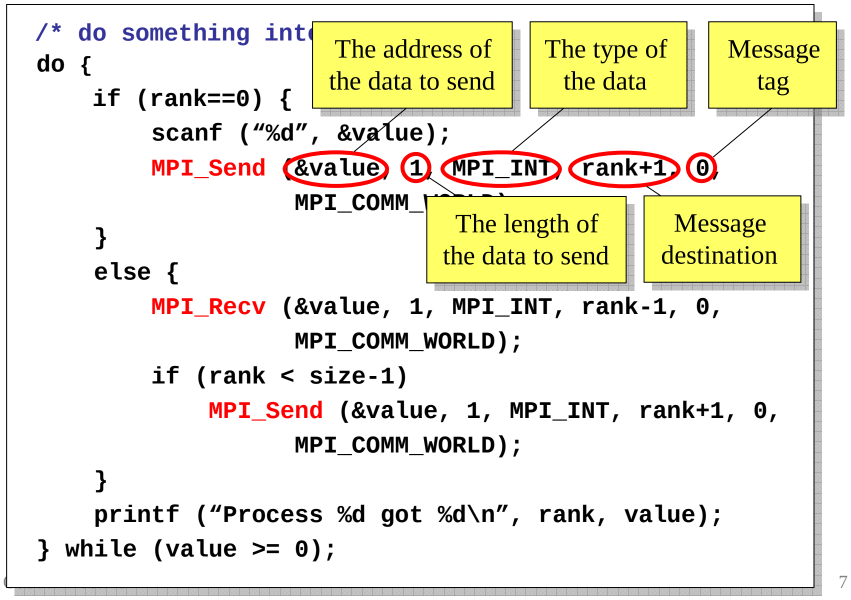
```
#include <stdio.h>
#include “mpi.h”

int main(argc, argv)
int argc;
char ** argv;
{
    int rank, value, size;
    MPI_Status status;

    MPI_Init (&argc, &argv);
    MPI_Comm_rank (MPI_COMM_WORLD, &rank);
    MPI_Comm_size (MPI_COMM_WORLD, &size);

    /* do something interesting */
    MPI_Finalize();
    return 0;
}
```

This is a communicator, which is a scoping mechanism for grouping sets of related communication operators

The rank is this process’s ID within this communicator

The size is this size of this communicator

MPI Example: Point-to-Point Communication



```
/* do something int
do {
    if (rank==0) {
        scanf ("%d", &value);
        MPI_Send (&value, 1, MPI_INT, rank+1, 0,
                  MPI_COMM_
    }
    else {
        MPI_Recv (&value, 1, MPI_INT, rank-1, 0,
                  MPI_COMM_WORLD);
        if (rank < size-1)
            MPI_Send (&value, 1, MPI_INT, rank+1, 0,
                  MPI_COMM_WORLD);
    }
    printf ("Process %d got %d\n", rank, value);
} while (value >= 0);
```

The address of the data to send

The type of the data

Message tag

The length of the data to send

Message destination

Point-to-Point Communication

MPI_Send

- Blocking send– blocks until the message buffer is safe to reuse

MPI_Recv

- Blocking receive—blocks until the message buffer is safe to reuse

Will the following code lead to deadlock?

```
/* Assume two processes */
MPI_Send (&value, 1, MPI_INT, 1-rank, 0, MPI_COMM_WORLD);
MPI_Recv (&value, 1, MPI_INT, 1-rank, 0, MPI_COMM_WORLD);
```

MPI Example: Point-to-Point Communication (cont)

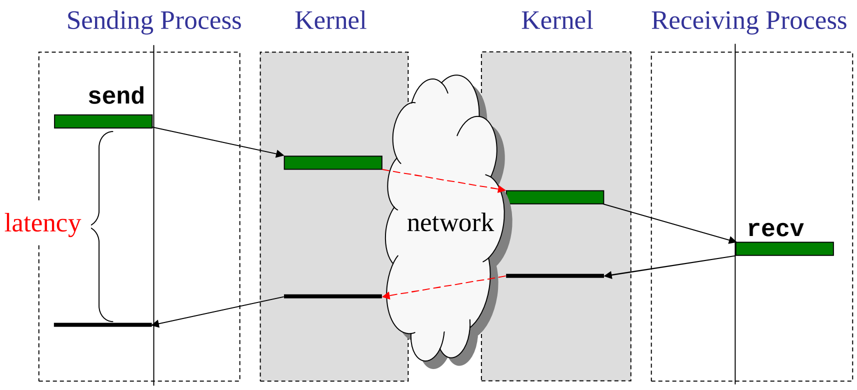
```
/* do something interesting */
do {
    if (rank==0) {
        scanf (“%d”, &value);
        MPI_Send (&value, 1, MPI_INT, rank+1, 0,
                  MPI_COMM_WORLD);
    }
    else {
        MPI_Recv (&value, 1, MPI_INT, rank-1, 0,
                  MPI_COMM_WORLD);
        if (rank < size-1)
            MPI_Send (&value, 1, MPI_INT, rank+1, 0,
                  MPI_COMM_WORLD);
    }
    printf (“Process %d got %d\n”, rank, value);
} while (value >= 0);
```

What does this code do?

Round Trip Message Latency

Latency

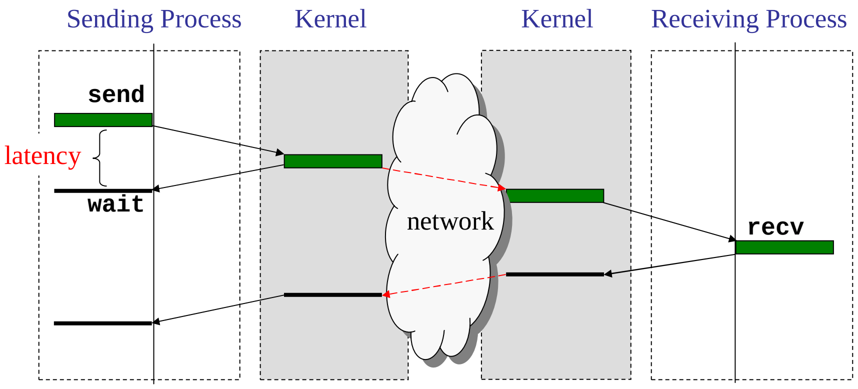
– Much copying and synchronization



Cost of Blocking Communication

Implications

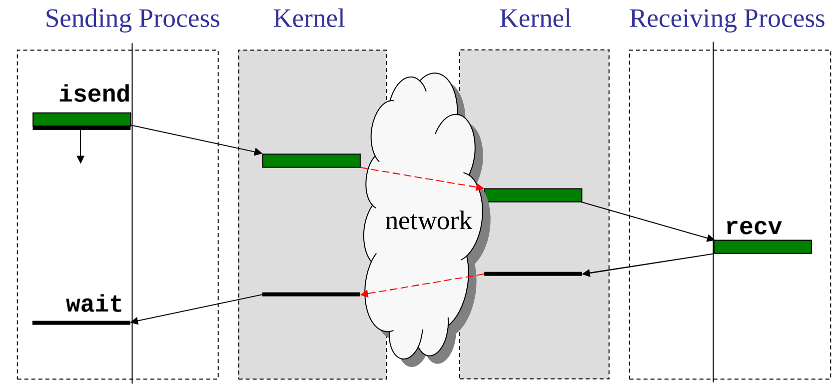
- Lower latency– e.g. `MPI_Send()`returns when data has been copied to the kernel

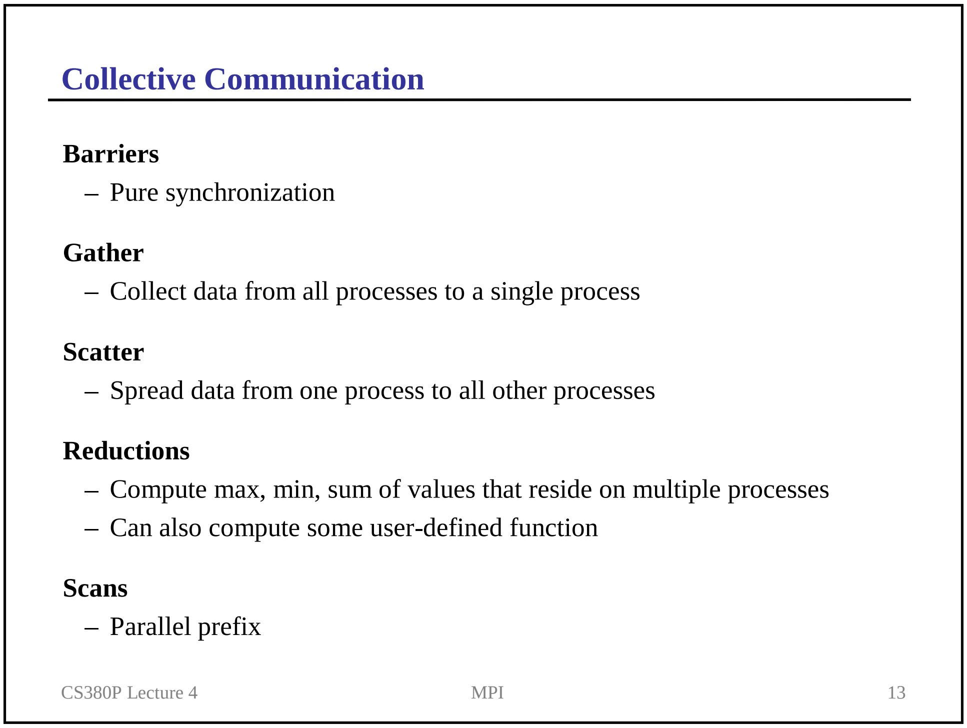


Cost of Non-Blocking Communication

Implications

- Lower latency
- Buffer might be overwritten before being copied to the kernel





Collective Communication

Barriers

- Pure synchronization

Gather

- Collect data from all processes to a single process

Scatter

- Spread data from one process to all other processes

Reductions

- Compute max, min, sum of values that reside on multiple processes
- Can also compute some user-defined function

Scans

- Parallel prefix