Intro to MPI

Parallel Computer Memory Architectures

- **There are three possible parallel computers' memory architectures:**

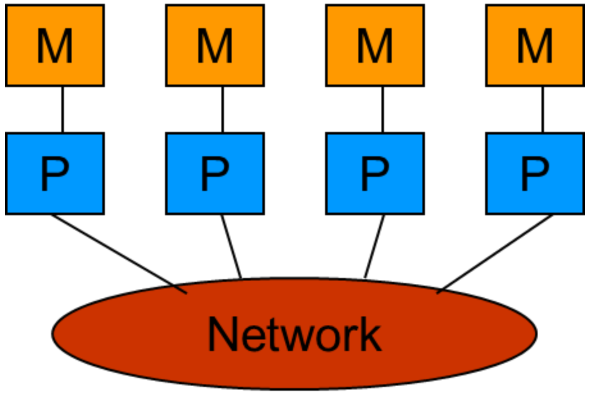
1. **Shared memory**
    - ***Uniform Memory Access (UMA)***
    - ***Non-Uniform Memory Access (NUMA)***

2. **Distributed memory**

3. **Hybrid Distributed Shared memory**

Distributed Memory Parallel Architecture

- **Distributed memory**
- In contrast to shared memory parallelism, in distributed memory parallelism, processes each keep their own private memories, separate from the memories of other processes.
- In order for one process to access data from the memory of another process, the data must be communicated, commonly by a technique known as message passing, in which the data is packaged up and sent over a network.
- **In this architecture, the programmers have explicit control over data distribution and communication. Synchronization between tasks is programmer's responsibility.**
- One standard of message passing is the Message Passing Interface (MPI), which defines a set of functions that can be used inside of C, C++ or Fortran codes for passing messages.



MPI (Message Passing Interface)

- **The Message-Passing Interface (MPI)**
  - supports a **Distributed memory programming model**
  - can be executed on **distributed, shared or hybrid hardware** platforms
  - is a **message passing library** standard, is a **specification** for the developers and users of message passing libraries
  - supports **distributed parallelism**, is used for developing **message passing programs.**
  - supports **Explicit parallelism** as programmers have explicit control over data distribution and communication and is responsible for identifying parallelism and implementing parallel applications. **Synchronization** between tasks is **programmer's** responsibility**.**
  - consists of a **header file**, a **library of routines** and a **runtime environment**.

MPI (Message Passing Interface)

Advantages of message-passing model

- **Portability- Programs need a** little or no modification while porting to a different platform.
- Provides the programmer with **explicit control** over the location of data in the memory.
- Can be used on a **wider range** of problems **than OpenMP..**
- Runs on **distributed, shared or hybrid hardware** platforms

Disadvantage of message-passing model

- **Extra effort** required by the Programmer to **convert program serial to parallel version.**
- **Explicit parallelism** makes **debugging difficult**, given the placement of memory and the ordering of communication requires additional details from the programmer.

MPI API

- MPI is actually just an **Application Programming Interface (API).**
- An **API specifies** what a call to each routine should look like, and how each routine should behave.
- An **API does not** specify how each routine should be implemented, and sometimes is intentionally vague about certain aspects of a routine's behavior.
- Each **platform** has its **own MPI implementation**.

Minimal Set of MPI Routines

- **`MPI_Init`**
  - starts up the MPI runtime environment at the beginning of a run.
- **`MPI_Finalize`**
  - shuts down the MPI runtime environment at the end of a run.
- **`MPI_Comm_size`**
  - gets the number of processes in a run, N_p (typically called just after **`MPI_Init`**).
- **`MPI_Comm_rank`**
  - gets the process ID that the current process uses, which is between 0 and N_p-1 inclusive (typically called just after **`MPI_Init`**).

Minimal Set of MPI Routines

- `MPI_Send`
  - sends a message from the current process to some other process (the **destination**).
- `MPI_Recv`
  - receives a message on the current process from some other process (the **source**).
- `MPI_Bcast`
  - **broadcasts** a message from one process to all of the others.
- `MPI_Reduce`
  - performs a **reduction** (for example, sum, maximum) of a variable on all processes, sending the result to a single process.

MPI Program Structure (C)

```
#include <stdio.h>
#include "mpi.h"
 [other includes]

int main (int argc, char* argv[])
{ /* main */
  int my_rank, num_procs, mpi_error_code;
   [other declarations]
  mpi_error_code =
    MPI_Init(&argc, &argv);          /* Start up MPI  */
  mpi_error_code =
    MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
  mpi_error_code =
    MPI_Comm_size(MPI_COMM_WORLD, &num_procs);
   [actual work goes here]
  mpi_error_code = MPI_Finalize(); /* Shut down MPI */
} /* main */
```

MPI is MPMD

MPI is Multiple Program, Multiple data (MPMD) model:

- each processor runs independently of the others with independent programs and data, and a different instruction sequences on different data sets are executed simultaneously on a set of processors.
- To make job of programmer easy and achieve scalability most of the message passing programs are written using single program multiple data (SPMD) approach.

Processes can use:

- **point-to-point communication** operations to send a message from one named process to another.
- **collective communication** operations to collectively perform commonly used global operations such as **summation** and **broadcast**.

MPI DataTypes

C		Fortran	
char	MPI_CHAR	CHARACTER	MPI_CHARACTER
int	MPI_INT	INTEGER	MPI_INTEGER
float	MPI_FLOAT	REAL	MPI_REAL
double	MPI_DOUBLE	DOUBLE PRECISION	MPI_DOUBLE_PRECISION

- MPI supports several other data types, but most are variations of these, and probably these are all you'll use.

Communicators

- An MPI communicator is a collection of processes that can send messages to each other.
- `MPI_COMM_WORLD` is the default communicator; it contains all of the processes. It's probably the only one you'll need.
- Some libraries create special library-only communicators, which can simplify keeping track of message tags.

Broadcasting

- What happens if one process has data that everyone else needs to know?

  For example, what if the server process needs to send an input value to the others?

```
MPI_Bcast(length, 1, MPI_INTEGER,
  source, MPI_COMM_WORLD);
```

- Note that `MPI_Bcast` doesn't use a tag, and that the call is the same for both the sender and all of the receivers.
- All processes have to call `MPI_Bcast` at the same time; everyone waits until everyone is done.

Reduction

- A **reduction** converts an array to a scalar: for example sum, product, minimum value, maximum value, Boolean AND, Boolean OR, etc.

- Reductions are so common, and so important, that MPI has two routines to handle them:
  - **`MPI_Reduce`**: sends result to a single specified process
  - **`MPI_Allreduce`**: sends result to all processes (and therefore takes longer)

Non-blocking Communication

- MPI allows a process to start a send, then go on and do work while the **message is in transit**.
- This is called **non-blocking** or **immediate** communication.
- Here, “immediate” refers to the fact that the call to the MPI routine returns immediately rather than waiting for the communication to complete.

Immediate Send

```
mpi_error_code =
    MPI_Isend(array, size, MPI_FLOAT,
        destination, tag, communicator, request);
```

- Likewise:

```
mpi_error_code =
    MPI_Irecv(array, size, MPI_FLOAT,
        source, tag, communicator, request);
```

- This call starts the send/receive, but the send/receive won't be complete until:

```
MPI_Wait(request, status);
```

Communication Hiding

- In between the call to **`MPI_Isend/Irecv`** and the call to **`MPI_Wait`**, both processes can **do work!**
- If that work takes at least as much time as the communication, then the cost of the communication is effectively zero, since the communication won't affect how much work gets done.
- This is called **communication hiding**.

Acknowlegements

Adapted from:

- **Basic MPI Tutorial at** http://www.shodor.org/refdesk/Resources/Tutorials/BasicMPI/
- **Supercomputing in Plain English, Shared Memory Multithreading** Slides by Henry Neeman.

Thank You!