Distributed Computing and Introduction to High Performance Computing

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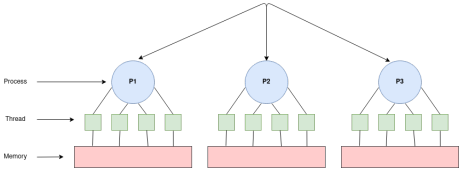
Outline of this lecture

- Distributed Memory Architectures
- The MPI Library
- My first example using MPI

Distributed Memory Architecture

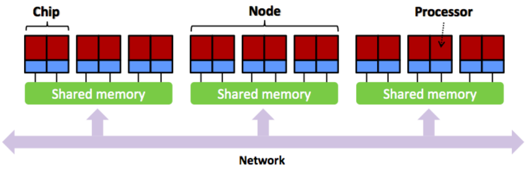
Distributed Memory Multiprocessors



- Each processor has a local memory
  - Physically separated memory address space
- Processors must communicate to access non-local data
  - Message communication (message passing)
  - ➠ Message passing architecture
  - Processor interconnection network
- Parallel applications must be partitioned across
  - Processors: execution units
  - Memory: data partitioning
- Scalable architecture
  - Small incremental cost to add hardware (cost of node)

Distributed Memory Architecture

The Message-Passing Model



- Nodes are complete computer systems
  - Including I/O
- Nodes communicate via interconnection network
  - Standard networks
  - Specialized networks
- Network interfaces
  - Communication integration
- Easier to build

Performance Metrics: Latency and Bandwidth

- Bandwidth
  - Need high bandwidth in communication
  - Match limits in network, memory, and processor
  - Network interface speed vs. network bisection bandwidth
- Latency
  - Performance affected since processor may have to wait
  - Harder to overlap communication and computation
  - Overhead to communicate is a problem in many machines
- Latency hiding
  - Increases programming system load
  - Examples: communication/computation overlaps, prefetch

Distributed Memory Architecture

Advantages of Distributed Memory Architectures

- The hardware can be simpler (especially versus NUMA) and is more scalable
- Communication is explicit and simpler to understand
- Explicit communication focuses attention on costly aspect of parallel computation
- Synchronization is naturally associated with sending messages, reducing the possibility for errors introduced by incorrect synchronization
- Easier to use sender-initiated communication, which may have some advantages in performance

Distributed Memory Architecture

MPI (Message Passing Interface)

- A standard message passing specification for the vendors to implement
- 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 run a different piece of data MIMD (Multiple Instructions Multiple Data)

The MPI library

Rank and size

- One can access to the number of processes managed by a given communicator using the `MPI_COMM_SIZE()` function
- You can get the rank of a process, within a communicator, by calling `MPI_COMM_RANK()` function

```python
from mpi4py import MPI

#Communicator, Rank and size
COMM = MPI.COMM_WORLD
SIZE = COMM.Get_size()
RANK = COMM.Get_rank()

print("I am the proccess {RANK} among {SIZE}".format(RANK = RANK, SIZE = SIZE))
```

```
$ mpirun -n 4 python ranksize.py

I am the proccess 0 among 8
I am the proccess 1 among 8
I am the proccess 2 among 8
I am the proccess 3 among 8
```