Introduction to MPI Programming

Rocks-A-Palooza II Lab Session

SDSC

Modes of Parallel Computing

- SIMD - Single Instruction Multiple Data

  processors are “lock-stepped”: each processor executes single instruction in synchronism on different data
- SPMD - Single Program Multiple Data

  processors run asynchronously a personal copy of a program
- MIMD - Multiple Instruction Multiple Data

  processors run asynchronously: each processor has its own data and its own instructions
  - MPMD - Multiple Program Multiple Data

MPI in Parallel Computing

- MPI addresses message-passing mode of parallel computation
  - Processes have separate address spaces
  - Processes communicate via sending and receiving messages
- MPI is designed mainly for SPMD/MIMD (or distributed memory parallel supercomputer)
  - Each process is run on a separate node
  - Communication is over high-performance switch
  - Paragon, IBM SP2, Meiko CS-2, Thinking Machines CM-5, NCube-2, and Cray T3D
- MPI can support shared memory programming model
  - Multiple processes can read/write to the same memory location
  - SGI Onyx, Challenge, Power Challenge, Power Challenge Array, IBM SMP, Convex Exemplar, and the Sequent Symmetry
- MPI exploits Network Of Workstations (heterogeneous)
  - Sun, DEC, Hewlett-Packard, SGI, IBM, Intel and Pentium (various Linux OS)

What is MPI?

- Message Passing application programmer Interface
  - Designed to provide access to parallel hardware
    - Clusters
    - Heterogeneous networks
    - Parallel computers
  - Provides for development of parallel libraries
  - Message passing
    - Point-to-point message passing operations
    - Collective (global) operations
  - Additional services
    - Environmental inquiry
    - Basic timing info for measuring application performance
    - Profiling interface for external performance monitoring

MPI advantages

- Mature and well understood
  - Backed by widely-supported formal standard (1992)
  - Porting is “easy”
- Efficiently matches the hardware
  - Vendor and public implementations available
- User interface:
  - Efficient and simple (vs. PVM)
  - Buffer handling
  - Allow high-level abstractions
- Performance

MPI disadvantages

- MPI 2.0 includes many features beyond message passing

- Execution control environment depends on implementation

MPI features

- Thread safety
- Point-to-point communication
  - Modes of communication

    standard | synchronous | ready | buffered

  - Structured buffers
  - Derived datatypes
- Collective communication
  - Native built-in and user-defined collective operations
  - Data movement routines
- Profiling
  - Users can intercept MPI calls and call their own tools

Communication modes

- standard
  - *send* has no guarantee that corresponding *receive* routine has started
- synchronous
  - *send* and *receive* can start before each other but complete together
- ready
  - used for accessing fast protocols
  - user guarantees that matching *receive* was posted
  - use with care!
- buffered
  - *send* may start and return before matching *receive*
  - buffer space must be provided

Communication modes (cont'd)

- All routines are
  - Blocking - return when they are locally complete
    - Send does not complete until buffer is empty
    - Receive does not complete until buffer is full
    - Completion depends on
      - size of message
      - amount of system buffering
  - Non-blocking - returns immediately and allows next statement to execute
    - Use to overlap communication and computation when time to send data between processes is large
    - Immediately returns "request handle" that can be used for querying and waited on,
    - Completion detected by MPI_Wait() or MPI_Test()

Point-to-point vs. collective

- point-to-point, blocking MPI_Send/MPI_Recv

  MPI_Send(start, count, datatype, dest, tag, comm)

  MPI_Recv(start, count, datatype, source, tag, comm, status)
  - simple but inefficient
  - most work is done by process 0:
    - Get data and send it to other processes (they idle)
    - May be compute
    - Collect output from the processes
- collective operations to/from all

  MPI_Bcast(start, count, datatype, root, comm)

  MPI_Reduce(start, result, count, datatype, operation, root, comm)
  - called by all processes
  - simple, compact, more efficient
  - must have the same size for “count”and “datatype”
  - “result” has significance only on node 0

MPI complexity

- MPI extensive functionality is provided by many (125+) functions
- Do I Need them all ?
  - No need to learn them all to use MPI
  - Can use just 6 basic functions

    MPI_Init
    MPI_Comm_size
    MPI_Comm_rank
    MPI_Send / **MPI_Recv** or **MPI_Bcast** / **MPI_Reduce**
    MPI_Finalize
  - Flexibility: use more functions as required

To be or not to be MPI user

- Use if:
  - Your data do not fit data parallel model
  - Need portable parallel program
  - Writing parallel library
- Don't use if:
  - Don't need any parallelism
  - Can use libraries
  - Can use fortran

Writing MPI programs

- provide basic MPI definitions and types

  #include “mpi.h”
- start MPI

  MPI_Init(&argc, &argv);
- provide local non-MPI routines
- exit MPI

  MPI_Finalize();

see /opt/mpich/gnu/examples
/opt/mpich/gnu/share/examples

Compiling MPI programs

- From a command line:
  - mpicc -o prog prog.c
- Use profiling options (specific to mpich)
  - **-mpilog** Generate log files of MPI calls
  - **-mpitrace** Trace execution of MPI calls
  - **-mpianim** Real-time animation of MPI (not available on all systems)
  - **--help** Find list of available options
- Use makefile!
  - get Makefile.in template and create Makefile

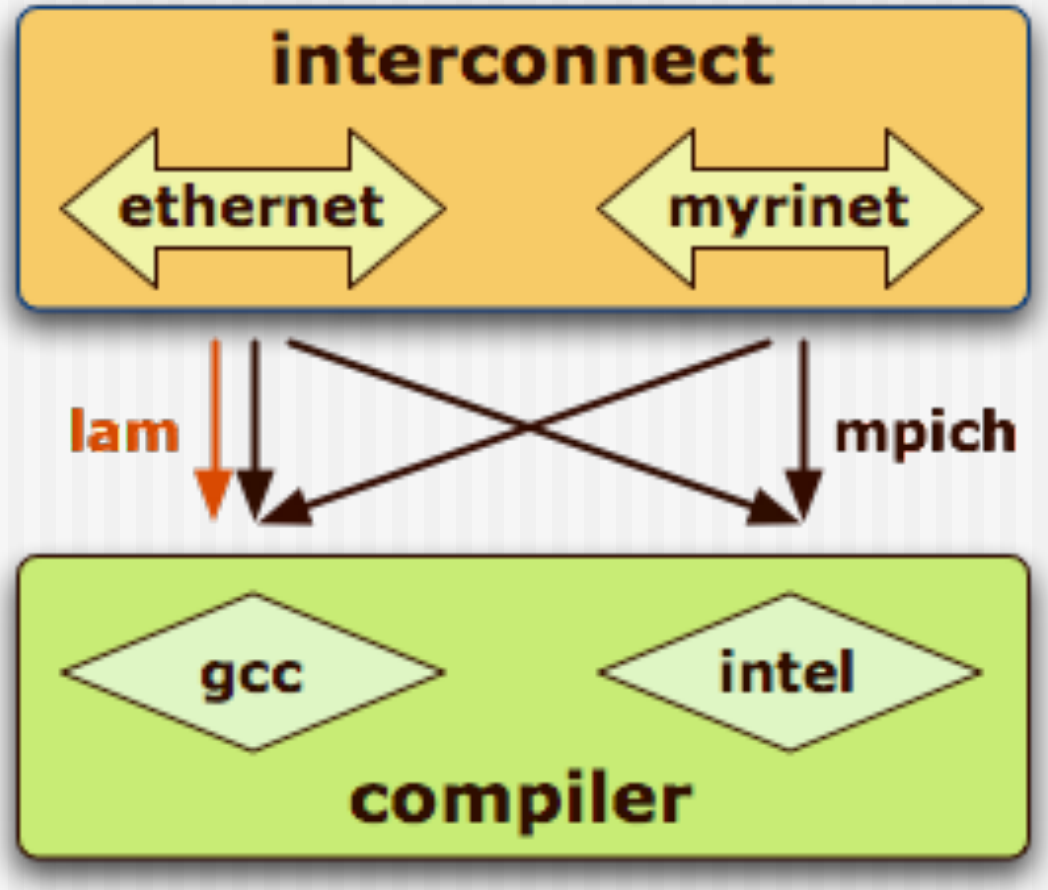
    mpireconfig Makefile
  - compile

    make progName

Running MPI program

- Depends on your implementation of MPI
  - For mpich:
    - mpirun -np2 foo # run MPI program
  - For lam:
    - lamboot -v lamhosts # starts LAM
    - mpirun -v -np 2 foo # run MPI program
    - lamclean -v # rm all user processes
    - mpirun … # run another program
    - lamclean …
    - lamhalt # stop LAM

Common MPI flavors on Rocks



MPI flavors path

/opt + MPI flavor + interconnect + compiler + bin/ + executable

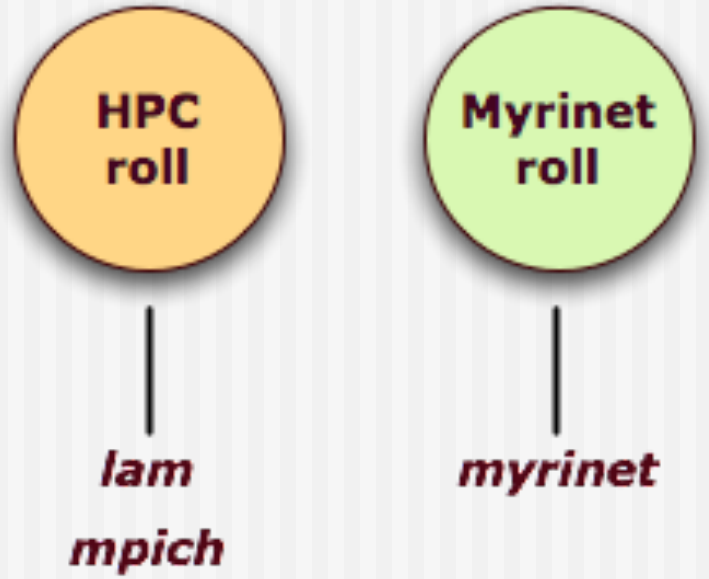
- MPICH + Ethernet + GNU
  /opt/mpich/ethernet/gnu/bin/…
- MPICH + Myrinet + GNU
  /opt/mpich/myrinet/gnu/bin/…
- MPICH + Ethernet + INTEL
  /opt/mpich/ethernet/intel/bin/…
- MPICH + Myrinet + INTEL
  /opt/mpich/myrinet/intel/bin/…

- LAM + Ethernet + GNU
  /opt/lam/ethernet/gnu/bin/…
- LAM + Myrinet + GNU
  /opt/lam/myrinet/gnu/bin/…
- LAM + Ethernet + INTEL
  /opt/lam/ethernet/intel/bin/…
- LAM + Myrinet + INTEL
  /opt/lam/myrinet/intel/bin/…

C: mpicc
F77: mpif77

C++: mpiCC
F90: mpif90

What provides MPI



Example 1: LAM hello

Execute all commands as a regular user

1. Start ssh agent for key management

   $ ssh-agent $SHELL
2. Add your keys

   $ ssh-add

   (at prompt give your ssh passphrase)
3. Make sure you have right mpicc:

   $ which mpicc

   (output must be /opt/lam/gnu/bin/mpicc)
4. Create program source hello.c (see next page)

hello.c

```
#include "mpi.h"
#include <stdio.h>
int main(int argc ,char *argv[])
{
    int myrank;
    MPI_Init(&argc, &argv);
    MPI_Comm_rank(MPI_COMM_WORLD, &myrank);
    fprintf(stdout, "Hello World, I am process  %d\n", myrank);
    MPI_Finalize();
    return 0;
}
```

Example 1 (cont'd)

5. compile
   $ mpicc -o hello hello.c
6. create machines file with IP's of two nodes. Use your numbers here!
   198.202.156.1
   198.202.156.2
7. start LAM
   $ lamboot -v machines
8. run your program
   $ mpirun -np 2 -v hello
9. clean after the run
   $ lamclean -v
10. stop LAM
   $ lamhalt

Example1 output

$ ssh-agent $SHELL	
$ ssh-add	Enter passphrase for /home/nadya/.ssh/id_rsa: Identity added: /home/nadya/.ssh/id_rsa (/home/nadya/.ssh/id_rsa)
$ which mpicc	/opt/lam/gnu/bin/mpicc
$ mpicc -o hello hello.c	
$ lamboot -v machines	LAM 7.1.1/MPI 2 C++/ROMIO - Indiana University n-1<27213> ssi:boot:base:linear: booting n0 (rocks-155.sdsc.edu) n-1<27213> ssi:boot:base:linear: booting n1 (10.255.255.254) n-1<27213> ssi:boot:base:linear: finished
$ mpirun -np 2 -v hello	27245 hello running on n0 (o) 7791 hello running on n1 Hello World, I am process 0 Hello World, I am process 1
$ lamclean -v	killing processes, done closing files, done sweeping traces, done cleaning up registered objects, done sweeping messages, done
$ lamhalt	LAM 7.1.1/MPI 2 C++/ROMIO - Indiana University

Example 2: mpich cpi

1. set your ssh keys as in example 1 (if not done already)
   $ ssh-agent $SHELL
   $ ssh-add
2. copy example files to your working directory
   $ cp /opt/mpich/gnu/examples/*.c .
   $ cp /opt/mpich/gnu/examples/Makefile.in .
3. create Makefile
   $ mpireconfig Makefile
4. make sure you have right mpicc
   $ which mpicc
   If output lists path /opt/lam… update the path:
   $ export PATH=$/opt/mpich/gnu/bin:$PATH
5. compile your program
   $ make cpi
6. run
   $ mpirun -np 2 -machinefile machines cpi

or $ mpirun -nolocal -np 2 -machinefile machines cpi

Example 2 details

- If using frontend and compute nodes in machines file use

  mpirun -np 2 -machinefile machines cpi
- If using only compute nodes in machine file use

  mpirun -nolocal -np 2 -machinefile machines cpi

  - -nolocal - don't start job on frontend
  - -np 2 - start job on 2 nodes
  - -machinefile machines - nodes are specified in machinesfile
  - cpi - start program cpi

More examples

- See CPU benchmark lab
  - how to run linpack
- Additional examples in
  - /opt/mpich/gnu/examples
  - /opt/mpich/gnu/share/examples

Cleanup when an MPI Program Crashes

- MPICH in Rocks uses shared memory segments to pass messages between processes on the same node
- When an MPICH program crashes, it doesn't properly cleanup these shared memory segments
- After a program crash, run:

  $ cluster-fork sh /opt/mpich/gnu/sbin/cleanipcs

- NOTE: this removes all shared memory segments for your user id
  - If you have other live MPI programs running, this will remove their shared memory segments too and cause that program to fail

Online resources

MPI standard:

www-unix.mcs.anl.gov/mpi

Local Area Multicomputer MPI (LAM MPI):

www.osc.edu/lam.html

MPICH:

www.mcs.anl.gov/mpi/mpich

Aggregate Function MPI (AFMPI):

garage.ecn.purdue.edu/~papers

Lam tutorial

www.lam-mpi.org/tutorials/one-step/lam.php

Glossary

MPI - message passing interface

PVM - parallel virtual machine

LAM - local area multicomputer

P4 - 3rd generation parallel programming library, includes message-passing and shared-memory components

Chameleon - high-performance portability package for message passing on parallel supercomputers

Zipcode - portable system for writing of scalable libraries

ADI - abstract device architecture

Glossary (cont'd)

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SPMD - Single Program Multiple Data

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