CMSC 818
Message Passing with PVM and MPI

Alan Sussman

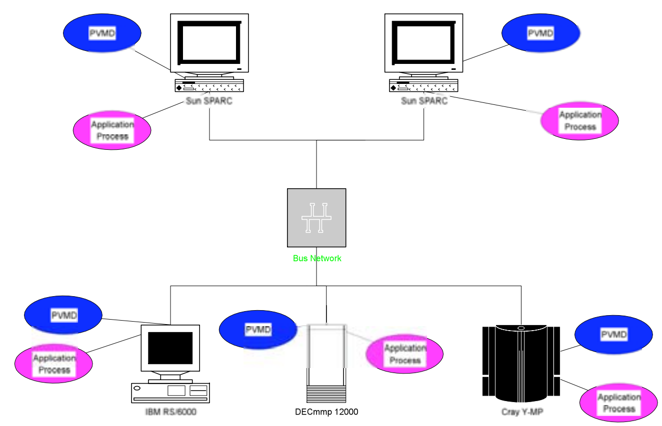
Message passing

- For distributed memory parallelism
  – no shared address space between processes/threads
- Harder to program correctly than shared memory (debatable), but scales better
  – all communication between processes is explicit, including any synchronization operations
- Typically two-sided communication
  – both ends (sender/receiver) have to perform an action/call
  – but one-sided variants exist in some systems (e.g., Cray shmem put/get, MPI one-sided comm)
- Both point-to-point and collective operations
  – collective is not the same as synchronized

PVM

- Provide a simple, free, portable parallel environment
- Run on (almost) everything
  – Parallel Hardware: SMP, MPPs, Vector Machines
  – Network of Workstations: ATM, Ethernet,
    • UNIX machines and PCs running Win32 API
  – Works on a heterogeneous collection of machines
    • handles type conversion as needed
- Provides two things
  – message passing library
    • point-to-point messages
    • synchronization: barriers, reductions
  – OS support
    • process creation (pvm_spawn)

PVM Environment (UNIX)



- One PVMD per machine
  – all processes communicate through pvmd (by default)
- Any number of application processes per node

PVM Message Passing

- All messages have tags
  - an integer to identify the message
  - defined by the user
- Messages are constructed, then sent
  - pvm_pk{int,char,float}(*var, count, stride)
  - pvm_unpk{int,char,float} to unpack
- All processes are named based on task ids (tids)
  - local/remote processes are the same
- Primary message passing functions
  - pvm_send(tid, tag)
  - pvm_recv(tid, tag)

PVM Process Control

- Creating a process
  - pvm_spawn(task, argv, flag, where, ntask, tids)
  - task is name of program to start
  - flag and where provide control of where tasks are started
  - ntask determines how many copies are started
  - program must be installed on each target machine
  - returns number of tasks actually started
- Ending a task
  - pvm_exit
  - does not exit the process, just the PVM machine
- Info functions
  - pvm_mytid() - get the process task id

PVM Group Operations

- Group is the unit of communication
  - a collection of one or more processes
  - processes join group with pvm_joingroup("<group name>")
  - each process in the group has a unique id
    - pvm_gettid("<group name>")
- Barrier
  - can involve a subset of the processes in the group
  - pvm_barrier("<group name>", count)
- Reduction Operations
  - pvm_reduce(void (*func)(), void *data, int count, int datatype, int msgtag, char *group, int rootinst)
    - result is returned to rootinst node
    - does not block
  - pre-defined funcs: PvmMin, PvmMax,PvmSum,PvmProduct

PVM Performance Issues

- Messages have to go through PVMD
  - can use *direct route* option to prevent this problem
- Packing messages
  - semantics imply a copy
  - extra function call to pack messages
- Heterogeneous Support
  - information is sent in machine independent format
  - has a short circuit option for known homogenous comm.
    - passes data in native format then

Sample PVM Program

```
int main(int argc, char **argv) {
    int myGroupNum;
    int friendTid;
    int mytid;
    int tids[2];
    int message[MESSAGESIZE];
    int c,i,okSpawn;

    /* Initialize process and spawn if necessary */
    myGroupNum=pvm_joingroup("ping-pong");
    mytid=pvm_mytid();
    if (myGroupNum==0)  { /* I am the first process */
        pvm_catchout(stdout);
        okSpawn=pvm_spawn(MYNAME,argv,0,"",1,&friendTid);
        if (okSpawn!=1) {
            printf("Can't spawn a copy of myself!\n");
            pvm_exit();
            exit(1);
        }
        tids[0]=mytid;
        tids[1]=friendTid;
    } else { /*I am the second process */
        friendTid=pvm_parent();
        tids[0]=friendTid;
        tids[1]=mytid;
    }
    pvm_barrier("ping-pong",2);

    if (myGroupNum==0) {
        /* Initialize the message */
        for (i=0 ; i<MESSAGESIZE ; i++) {
            message[i]='1';
        }  }
    /* Now start passing the message back and forth */
    for (i=0 ; i<ITERATIONS ; i++) {
        if (myGroupNum==0) {
            pvm_initsend(PvmDataDefault);
            pvm_pkint(message,MESSAGESIZE,1);
            pvm_send(friendTid,i);
            pvm_recv(friendTid,i);
            pvm_upkint(message,MESSAGESIZE,1);
        }
        else {
            pvm_recv(friendTid,i);
            pvm_upkint(message,MESSAGESIZE,1);
            pvm_initsend(PvmDataDefault);
            pvm_pkint(message,MESSAGESIZE,1);
            pvm_send(friendTid,i);
        }
    }
    pvm_exit();
    exit(0);
}
```


MPI

- Goals:
  - Standardize previous message passing:
    - PVM, P4, NX (Intel), MPL (IBM), …
  - Support copy-free message passing
  - Portable to many platforms – defines an API, not an implementation
- Features:
  - point-to-point messaging
  - group/collective communications
  - profiling interface: every function has a name-shifted version
- Buffering (in standard mode)
  - no guarantee that there are buffers
  - possible that send will block until receive is called
- Delivery Order
  - two sends from same process to same dest. will arrive in order
  - no guarantee of fairness between processes on receive

MPI Communicators

- Provide a named set of processes for communication
  - plus a *context* – system allocated unique tag
- All processes within a communicator can be named
  - a communicator is a group of processes and a context
  - numbered from 0…n-1
- Allows libraries to be constructed
  - application creates communicators
  - library uses it
  - prevents problems with posting wildcard receives
    - adds a communicator scope to each receive
- All programs start with MPI_COMM_WORLD
  - Functions for creating communicators from other communicators (split, duplicate, etc.)
  - Functions for finding out about processes within communicator (size, my_rank, …)

Non-Blocking Point-to-point Functions

- Two Parts
  - post the operation
  - wait for results
- Also includes a poll/test option
  - checks if the operation has finished
- Semantics
  - must not alter buffer while operation is pending (wait returns or test returns true)
  - and data not valid for a receive until operation completes

Collective Communication

- Communicator specifies process group to participate
- Various operations, that may be optimized in an MPI implementation
  - Barrier synchronization
  - Broadcast
  - Gather/scatter (with one destination, or all in group)
  - Reduction operations – predefined and user-defined
    - Also with one destination or all in group
  - Scan – prefix reductions
- Collective operations may or may not synchronize
  - Up to the implementation, so application can't make assumptions

MPI Calls

- Include <mpi.h> in your C/C++ program
- First call MPI_Init(&argc, &argv)
- MPI_Comm_rank(MPI_COMM_WORLD, &myrank)
  - myrank is set to id of this process (in range 0 to P-1)
- MPI_Wtime()
  - Returns wall time
- At the end, call MPI_Finalize()
  - No MPI calls allowed after this

MPI Communication

- Parameters of various calls (in later example)
  - var – a variable
  - num – number of elements in the variable to use
  - type {MPI_INT, MPI_REAL, MPI_BYTE, …}
  - root – rank of process at root of collective operation
  - src/dest – rank of source/destination process
  - status - variable of type MPI_Status;
- Calls (all return a code – check for MPI_Success)
  - MPI_Send(var, num, type, dest, tag, MPI_COMM_WORLD)
  - MPI_Recv(var, num, type, src, MPI_ANY_TAG, MPI_COMM_WORLD, &status)
  - MPI_Bcast(var, num, type, root, MPI_COMM_WORLD)
  - MPI_Barrier(MPI_COMM_WORLD)

MPI Misc.

- MPI Types
  - All messages are typed
    - base/primitive types are pre-defined:
      - int, double, real, {unsigned}{short, char, long}
    - can construct user-defined types
      - includes non-contiguous data types
- Processor Topologies
  - Allows construction of Cartesian & arbitrary graphs
  - May allow some systems to run faster
- Language bindings for C, Fortran, C++, …
- What's not in MPI-1
  - process creation
  - I/O
  - one sided communication

Sample MPI Program

```
#include "mpi.h"
int main(int argc, char **argv) {
    int myrank, friendRank;
    char message[MESSAGESIZE];
    int i, tag=MSG_TAG;
    MPI_Status status;

    /* Initialize, no spawning necessary */
    MPI_Init(&argc, &argv);
    MPI_Comm_rank(MPI_COMM_WORLD,&myrank);
    if (myrank==0)  { /* I am the first process */
        friendRank = 1;
    }
    else { /*I am the second process */
        friendRank=0;
    }
    MPI_Barrier(MPI_COMM_WORLD);
    if (myrank==0) {
        /* Initialize the message */
        for (i=0 ; i<MESSAGESIZE ; i++) {
            message[i]='1';
        }
    }

/* Now start passing the message back and forth */
    for (i=0 ; i<ITERATIONS ; i++) {
        if (myrank==0) {
            MPI_send(message, MESSAGESIZE,
MPI_CHAR, friendRank, tag,
MPI_COMM_WORLD);
            MPI_Recv(message, MESSAGESIZE,
MPI_CHAR, friendRank, tag,
MPI_COMM_WORLD, &status);
        }
        else {
            MPI_Recv(message, MESSAGESIZE,
MPI_CHAR, friendRank,tag,
MPI_COMM_WORLD, &status);
            MPI_send(message, MESSAGESIZE,
MPI_CHAR, friendRank, tag,
MPI_COMM_WORLD);
        }
    }
    MPI_Finalize();
    exit(0);
}
```


For more details

- PVM – http://www.csm.ornl.gov/pvm/pvm_home.html
  - current version is 3.4.6, available for download from netlib
  - book from MIT Press is *PVM: Parallel Virtual Machine A Users' Guide and Tutorial for Networked Parallel Computing*
- MPI – http://www.mpi-forum.org
  - includes both 1.1 and 2.2 documentation (API)
  - books from MIT Press include *Using MPI* and *MPI: The Complete Reference*
  - multiple public domain implementations available
    - mpich2 – Argonne National Lab - http://www.mcs.anl.gov/research/projects/mpich2/
    - OpenMPI (formerly LAM) – http://www.open-mpi.org
  - vendor implementations available too (IBM, Cray, Sun, …)
  - for UMIACS Linux cluster info, see http://www.umiacs.umd.edu/research/parallel/ - start with Class guide link – you'll be using the bug cluster