Seismic Code

- Given echo data, compute under sea map
- Computation model
  - designed for a collection of workstations
  - uses variation of RPC model
  - workers are given an independent trace to compute
    - requires little communication
    - supports load balancing (1,000 traces is typical)
- Performance
  - max mfops = $O((F * nz * B^*)^{1/2})$
  - F - single processor MFLOPS
  - nz - linear dimension of input array
  - B^* - effective communication bandwidth
    - $B^* = B/(1 + BL/w) \approx B/7$ for Ethernet (10msec lat., w=1400)
  - real limit to performance was latency **not** bandwidth

Database Applications

- Too much data to fit in memory (or sometimes disk)
  - data mining applications (K-Mart has a 4-5TB database)
  - imaging applications (NASA has a site with 0.25 petabytes)
    - use a fork lift to load tapes by the pallet
- Sources of parallelism
  - within a large transaction
  - among multiple transactions
- Join operation
  - form a single table from two tables based on a common field
  - try to split join attribute in disjoint buckets
    - if know data distribution is uniform its easy
    - if not, try hashing

Speedup in Join parallelism

- Books claims a speed up of $1/p^2$ is possible
  - split each relation into p buckets
    - each bucket is a disjoint subset of the joint attribute
  - each processor only has to consider N/p tuples per relation
    - join is $O(n^2)$ so each processor does $O((N/p)^2)$ work
    - so spedup is $O(N^2/p^2)/O(N^2) = O(1/p^2)$
- **this is a lie!**
    - could split into 1/p buckets on one processor
    - time would then be $O(p * (N/p)^2) = O(N^2/p)$
    - so speedup is $O(N^2/p^2)/O(N^2/p) = O(1/p)$
      - Amdahls law is not violated

Parallel Search (TSP)

- may appear to be faster than 1/n
  - but this is not really the case either
- Algorithm
  - compute a path on a processor
    - if our path is shorter than the shortest one, send it to the others.
    - stop searching a path when it is longer than the shortest.
  - before computing next path, check for word of a new min path
  - stop when all paths have been explored.
- Why it appears to be faster than 1/n speedup
  - we found the a path that was shorter sooner
  - however, the reason for this is a different search order!

Ensuring a fair speedup

- T_{serial} = faster of
  - best known serial algorithm
  - simulation of parallel computation
    - use parallel algorithm
    - run all processes on one processor
  - parallel algorithm run on one processor
- If it appears to be super-linear
  - check for memory hierarchy
    - increased cache or real memory may be reason
  - verify order operations is the same in parallel and serial cases

Quantitative Speedup

- Consider master-worker
  - one master and n worker processes
  - communication time increases as a linear function of n

  $T_p = TCOMP_p + TCOMM_p$

  $TCOMP_p = T_s/P$

  $1/S_p = T_p/T_s = 1/P + TCOMM_p/T_s$

  $TCOMM_p$ is $P * TCOMM_1$

  $1/S_p = 1/p + p * TCOMM_1/T_s = 1/P + P/r_1$

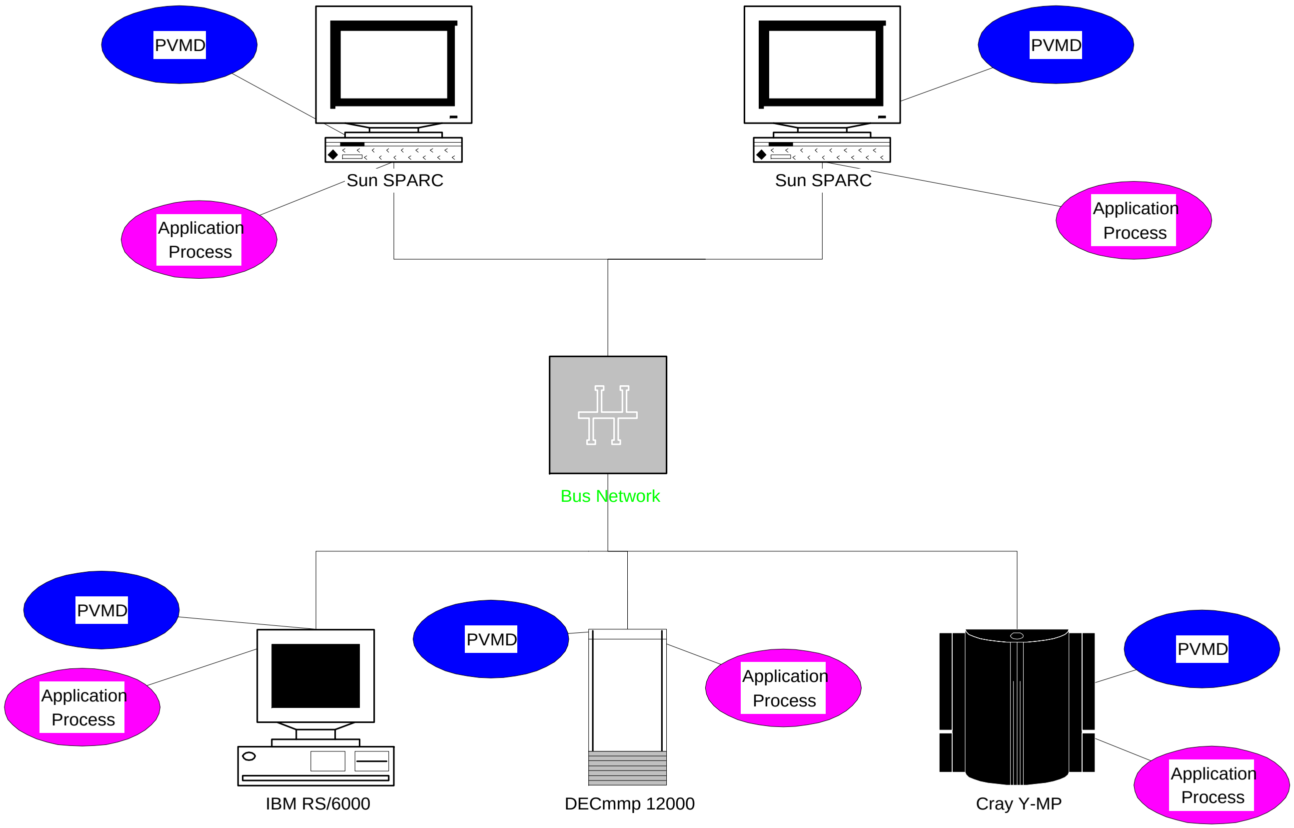
  where $r_1 = T_s/TCOMM_1$

  $d(1/S_p)/dP = 0 \text{ --> } P_{opt} = r_1^{1/2}$ and $S_{opt} = 0.5\ r_1^{1/2}$
- For hierarchy of masters
  - $TCOMM_p = (1+\log P)TCOMM_1$
  - $P_{opt} = r_1$ and $S_{opt} = r_1/(1 + \log r_1)$

PVM

- Provide a simple, free, portable parallel environment
- Run on everything
  - Parallel Hardware: SMP, MPPs, Vector Machines
  - Network of Workstations: ATM, Ethernet,
    - UNIX machines and PCs running Win*
  - Works on a heterogenous 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 proccess 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)
  - flag and where provide control of where tasks are started
  - ntask controls how many copies are started
  - program must be installed on target machine
- 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
- Heterogenous 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);

    /* Main Loop Body */
    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++) {
            pvm_initsend(PvmDataDefault);
            pvm_pkint(message,MESSAGESIZE,1);
            pvm_send(tid,msgid);

            pvm_recv(tid,msgid);
            pvm_upkint(message,MESSAGESIZE,1);
        }
    } else {
            pvm_recv(tid,msgid);
            pvm_upkint(message,MESSAGESIZE,1);
            pvm_initsend(PvmDataDefault);
            pvm_pkint(message,MESSAGESIZE,1);
            pvm_send(tid,msgid);
    }
    pvm_exit();
    exit(0);
}
```

MPI

- Goals:
  - Standardize previous message passing:
    - PVM, P4, NX
  - Support copy free message passing
  - Portable to many platforms
- Features:
  - point-to-point messaging
  - group communications
  - profiling interface: every function has a name shifted version
- Buffering
  - 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 recv.

MPI Communicators

- Provide a named set of processes for communication
- All processes within a communicator can be named
  - 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 will MPI_COMM_WORLD

Non-Blocking Functions

- Two Parts
  - post the operation
  - wait for results
- Also includes a poll option
  - checks if the operation has finished
- Semantics
  - must not alter buffer while operation is pending

MPI Misc.

- MPI Types
  - All messages are typed
    - base 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
- What's not in MPI-1
  - process creation
  - I/O
  - one sided communication