Hybrid Computing Lab

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Introduction to Parallel Computing
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Based on material developed by Kent Milfeld, TACC
What you will learn

• Using numactl in execution of **serial**, **MPI** and a 4x# (4 tasks each with # threads) hybrid code

• Communications in **Hybrid codes**
  – Communication between nodes with threaded MPI calls.
    • MPI calls from serial region
    • MPI calls from master thread in a parallel region
    • MPI calls from all threads in a parallel region
Hybrid Computing – Ranger

• Untar the file numahybrid.tar
  – cd         (Start in your home directory.)
  – tar xvf ~train200/numahybrid.tar (extract files)
  – cd numahybrid
numactl_serial – Ranger

The memory intensive daxpy code is run on four different sockets using local, interleave and off-socket-memory policies. The commands below make the daxpy executable and run it with numa control commands. See the job script and the table on the next page for the numa options. Run the job and report the times and relative performance.

• **Execute:**
  – cd numactl_serial (change directory to numactl_serial)
  – module unload mvapich; module swap pgi intel; module load mvapich
  – make
  – qsub job (submits job)
• From the job output fill in the table.

<table>
<thead>
<tr>
<th>Command</th>
<th>Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>numactl –l -C 0</td>
<td></td>
</tr>
<tr>
<td>numactl –l -C 1</td>
<td></td>
</tr>
<tr>
<td>numactl –l -C 2</td>
<td></td>
</tr>
<tr>
<td>numactl –l -C 3</td>
<td></td>
</tr>
<tr>
<td>numactl –i all –C 0</td>
<td></td>
</tr>
<tr>
<td>numactl –i all –C 1</td>
<td></td>
</tr>
<tr>
<td>numactl –i all –C 2</td>
<td></td>
</tr>
<tr>
<td>numactl –i all –C 3</td>
<td></td>
</tr>
<tr>
<td>Numactl –m 3 –C 0</td>
<td></td>
</tr>
</tbody>
</table>

Rank the performance of **local, interleave, and off-Socket-memory** policies.

1.)
2.)
3.)

From best to poorest performance.
The memory intensive mpi_daxpy code is run on four sockets simultaneously using local, interleave and tacc_affinity policies. The commands below make the mpi_daxpy executable and run it with numa control commands. See the job script and the table on the next page for the numa options. Run the job and report the times and relative performance.

- Execute:
  - cd numactl_mpi (change directory to numactl_mpi)
  - if you have done this already, don’t do it again:
    - module unload mvapich; module swap pgi intel; module load mvapich
  - make
  - qsub job (submits job)
Numactl_mpi – Ranger

• From the job output fill in the table.

<table>
<thead>
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</tr>
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<tbody>
<tr>
<td>numactl –l</td>
<td></td>
</tr>
<tr>
<td>numactl –i all</td>
<td></td>
</tr>
<tr>
<td>numactl tacc_affinity</td>
<td></td>
</tr>
</tbody>
</table>

Rank the performance of local, interleave, and tacc_affinity memory policies.
1.)
2.)
3.)
From best to poorest performance.
The daxpy code is run as 4 tasks in a node (4x1) and 4 tasks with 4 threads in a node (4x4). Cd down to directories numactl_4x1 and numactl_4x4, respectively, and follow the instructions below.

• Execute:
  – cd numactl_4x1 or _4x4 (change directory to numactl_mpi)
  – if you have done this already, don’t do it again:
    module unload mvapich; module swap pgi intel; module load mvapich
  – make
  – qsub job       (submits job)
Numactl_4x1, Numactl_4x4 – Ranger

- From the job output fill in the table.

<table>
<thead>
<tr>
<th>Command (4x1)</th>
<th>Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;no numactl&gt;</td>
<td></td>
</tr>
<tr>
<td>numactl -l</td>
<td></td>
</tr>
<tr>
<td>numactl -i all</td>
<td></td>
</tr>
<tr>
<td>numactl tacc_affinity</td>
<td></td>
</tr>
</tbody>
</table>

Rank the 4x1 performance of.
1.)
2.)
3.)
From best to poorest performance.

<table>
<thead>
<tr>
<th>Command (4x4)</th>
<th>Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;no numactl&gt;</td>
<td></td>
</tr>
<tr>
<td>numactl -l</td>
<td></td>
</tr>
<tr>
<td>numactl -i all</td>
<td></td>
</tr>
<tr>
<td>numactl tacc_affinity</td>
<td></td>
</tr>
</tbody>
</table>

Rank the 4x4 performance of.
1.)
2.)
3.)
From best to poorest performance
Communications in Hybrid codes

• The tmpi (threaded mpi) code, performs various types of communication (point-2-point and broadcast) within a hybrid code. Check to make sure the code performs the operations correctly, compare the cost of sending a single large message in the serial region, and 16 small messages in the parallel region (both mvapich and openmpi MPIs are used.)

• Execute:
  cd threaded_mpi
  if you have done this already, don’t do it again:
    module unload mvapich; module swap pgi intel; module load mvapich
    ./build.sh

• This builds tmpi.mvapich1 and tmpi.openmp
#!/bin/tcsh
# use bash shell
#$ -V # inherit submission environment
#$ -cwd # use submission directory
#$ -N threadedmpi # jobname (threadedmpi)
#$ -j y # stdout/err combined
#$ -o $JOB_NAME.o$JOB_ID # output name jobname.ojobid
#$ -pe 1way 32 # 1 task/node, 32 cores total
#$ -q development # queue name !! can use normal
#$ -l h_rt=00:10:00 # request 10 minutes
## -M <myemail_addr> # Mail address !! your own mail
## -m be # send email at begin/end of job}
#$ -A 20090528HPC # your account
set echo # echo cmds, use "set -x" in sh

setenv MY_NSLOTS 2
setenv OMP_NUM_THREADS 16
ibrun ./tmpi < input

If # of tasks is not a multiple of 16, set value here.

This will give you 10 exclusive minutes of 2 nodes ( =32/16) 1 task per node (1-way) and a total of 2 tasks in the development queue. 16 threads (OMP_NUM_THREADS 16) are launched on each node.
MPI/OpenMP Ranger

• Submit the batch job:

```bash
% qsub job ...
Welcome to TACC's Ranger System, an NSF Teragrid Resource
  --> Submitting 2 tasks...
  --> Submitting 1 tasks/host...
  --> Submitting exclusive job to 2 hosts...
...
Your job 18073 ("threadedmpi") has been submitted

% qstat
job-ID prior name       user     state submit/start at   queue slots
--------------------------------------------------------------------------------
18075 0.00001 threadedmp milfeld r 01/17/2008 22:48:54 normal@i104-408 32

% showq
...
```
include "mpif.h"
...

call MPI_Init_thread(MPI_THREAD_MULTIPLE, iprovided, ierr)
call MPI_Comm_size(MPI_COMM_WORLD, nranks, ierr)
call MPI_Comm_rank(MPI_COMM_WORLD, irank, ierr)

if(irank == 0) then
    call mpi_send(as,n,MPI_REAL8, 1,9,MPI_COMM_WORLD, ierr)
    call mpi_recv(as,n,MPI_REAL8, 1,1,MPI_COMM_WORLD, istatus,ierr)
else if (irank == 1) then
    call mpi_recv(as,n,MPI_REAL8, 0,9,MPI_COMM_WORLD, istatus,ierr)
    call mpi_send(as,n,MPI_REAL8, 0,1,MPI_COMM_WORLD, ierr)
endif

if(irank .eq. 0) read(*,'(i5)') iread1
call MPI_Bcast(iread1,1,MPI_INTEGER, 0,iwcomm, ierr)
$OMP PARALLEL private(i,ithread,nthreads, icp1, icp2, icpd)

ithread = OMP_GET_THREAD_NUM()

if(ithread == 0) then
    if(irank .eq. 0) read(*,'(i5)') iread2
    call MPI_Bcast(iread2,1,MPI_INTEGER, 0,iwcomm, ierr)
end if
Multi-threaded communication

```
!$OMP DO ordered
do i = 1,nthreads
!$OMP ordered
    if(irank == 0) then
        call mpi_send(as,ns,MPI_REAL8, 1,ithread,MPI_COMM_WORLD, ierr)
call mpi_recv(as,ns,MPI_REAL8, 1,ithread,MPI_COMM_WORLD, istatus,ierr)
    else if (irank == 1) then
        call mpi_recv(as,ns,MPI_REAL8, 0,ithread,MPI_COMM_WORLD, istatus,ierr)
call mpi_send(as,ns,MPI_REAL8, 0,ithread,MPI_COMM_WORLD,ierr)
    endif
!$OMP end ordered
end do
if(irank == 0 .and. ithread == 0) then
    call mpi_send(as,n,MPI_REAL8, 1,ithread,MPI_COMM_WORLD, ierr)
call mpi_recv(ar,n,MPI_REAL8, 1,ithread,MPI_COMM_WORLD, istatus,ierr)
else if (irank == 1 .and. ithread == 0) then
    call mpi_recv(ar,n,MPI_REAL8, 0,ithread,MPI_COMM_WORLD, istatus,ierr)
call mpi_send(as,n,MPI_REAL8, 0,ithread,MPI_COMM_WORLD, ierr)
endif
!$OMP barrier
!$OMP END PARALLEL
call mpi_finalize(ierr)
```

End of Parallel
End of MPI
Hybrid Communication Cost (Output from tmpi):

Mvapich1
Serial Region Ping Pong  (words:secs) 400000:  0.00509
Serial Region Broadcast  (sec)              0.00002
Parallel Region Broadcast (sec)             0.00001
Parallel region messages:
  One Large message  size:secs 400000 tot time:  0.00555
  16 Small messages  size:secs 25000 tot time:  0.00548

  individual times:  0.00042  0.00033  0.00038  0.00033  0.00033  0.00033
                    0.00033  0.00033  0.00034  0.00033  0.00033  0.00033
                    0.00033  0.00033  0.00033  0.00033  0.00033
                    0.00033  0.00033

OpenMPI
Serial Region Ping Pong  (words:secs) 400000:  0.00501
Serial Region Broadcast  (sec)              0.00005
Parallel Region Broadcast (sec)             0.00001
Parallel region messages:
  One Large message  size:secs 400000 tot time:  0.00553
  16 Small messages  size:secs 25000 tot time:  0.13446

  individual times:  0.12864  0.00038  0.00038  0.00039  0.00038  0.00065  0.00036
                    0.00036  0.00038  0.00034  0.00038  0.00037  0.00036  0.00037
                    0.00036  0.00036