Symmetric Computing

Lucas A. Wilson

Texas Advanced Computing Center
Symmetric Computing

Run MPI tasks on both MIC and host

• Also called “heterogeneous computing”

• Two executables are required:
  – CPU
  – MIC

• Currently only works with Intel MPI

• MVAPICH2 support coming
**Definition of a Node**

A “node” contains a host component and a MIC component:

- **Host** – refers to the Sandy Bridge component
- **MIC** – refers to one or two Intel Xeon Phi coprocessor cards

<table>
<thead>
<tr>
<th>NODE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host</strong></td>
<td></td>
</tr>
<tr>
<td>2x Intel 2.7 GHz E5-2680</td>
<td></td>
</tr>
<tr>
<td>16 cores</td>
<td></td>
</tr>
<tr>
<td><strong>MIC</strong></td>
<td></td>
</tr>
<tr>
<td>1-2 Intel Xeon PHI SE10P</td>
<td></td>
</tr>
<tr>
<td>61 cores / 244 HW threads</td>
<td></td>
</tr>
</tbody>
</table>
Environment variables for MIC

By default, environment variables are “inherited” by all MPI tasks

Since the MIC has a different architecture, several environment variables must be modified

- **OMP_NUM_THREADS** – # of threads on MIC
- **LD_LIBRARY_PATH** – must point to MIC libraries
- **I_MPI_PIN_MODE** – controls the placement of tasks
- **KMP_AFFINITY** – controls thread binding
Symmetric run on 1 Node

mpiexec.hydra \ 
–n 16 –host localhost ./host.exe \ 
–env OMP_NUM_THREADS 30 \n(env LD_LIBRARY_PATH $MIC_LD_LIBRARY_PATH \n(env I_MPI_PIN_MODE mpd \n(env KMP_AFFINITY balanced \n–n 4 –host mic0 ./mic.exe

16 tasks on host

4 tasks on mic0

Environment variables for MIC tasks
Steps to create a symmetric run

1. Compile a host executable and a MIC executable:
   – mpicc -openmp -o my_exe.cpu my_code.c
   – mpicc -openmp -mmic -o my_exe.mic my_code.c

2. Determine the appropriate number of tasks and threads for both MIC and host:
   – 16 tasks/host – 1 thread/MPI task
   – 4 tasks/MIC – 30 threads/MPI task
Steps to create a symmetric run

3. Create a batch script to distribute the job

```bash
#!/bin/bash
#--------------------------------------------------------
# symmetric.slurm
# Generic symmetric script – MPI + OpenMP
#--------------------------------------------------------
#SBATCH -J symmetric       #Job name
#SBATCH -o symmetric.%j.out #stdout; %j expands to jobid
#SBATCH -e symmetric.%j.err #stderr; skip to combine
#SBATCH -p development     #queue
#SBATCH -N 2               #Number of nodes
#SBATCH -n 32              #Total number of MPI tasks
#SBATCH -t 00:30:00        #max time
#SBATCH -A TG-01234        #necessary if multiple projects

export MIC_PPN=4
export MIC_OMP_NUM_THREADS=30

ibrun.symm -m ./my_exe.mic -c ./my_exe.cpu
```
Steps to create a symmetric run

1. Compile a host executable and a MIC executable
2. Determine the appropriate number of tasks and threads for both MIC and host
3. Create the batch script
4. Submit the batch script
   - `sbatch symmetric.slurm`
Symmetric launcher – ibrun.symm

Usage:

`ibrun.symm -m ./<mic_executable> -c ./<cpu_executable>`

- Analog of ibrun for symmetric execution
- # of MIC tasks and threads are controlled by env variables

MIC_PPN=<# of MPI tasks/MIC card>
MIC_OMP_NUM_THREADS=<# of OMP threads/MIC MPI task>
MIC_MY_NSLOTS=<Total # of MIC MPI tasks>
Symmetric launcher

- # of host tasks determined by batch script (same as regular ibrun)
- ibrun.symm does not support –o and –n flags
- Command line arguments may be passed within quotes

ibrun.symm –m "./my_exe.mic args" –c "./my_exe.cpu args"
Symmetric launcher

• If the executables require redirection or complicated command lines, a simple shell script may be used:

<table>
<thead>
<tr>
<th><code>run_mic.sh</code></th>
<th><code>run_cpu.sh</code></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>#!/bin/sh</code></td>
<td><code>#!/bin/bash</code></td>
</tr>
<tr>
<td><code>a.out.mic &lt;args&gt; &lt; inputfile</code></td>
<td><code>a.out.host &lt;args&gt; &lt; inputfile</code></td>
</tr>
</tbody>
</table>

`ibrun.symm -m ./run_mic.sh -c run_cpu.sh`

Note: The bash, csh, and tcsh shells are not available on MIC. So, the MIC script must begin with “`#!/bin/sh`”
Symmetric Launcher Example

... 
#SBATCH -N 4 -n 32
export OMP_NUM_THREADS=2
export MIC_OMP_NUM_THREADS=60
export MIC_PPN=2

The MPI tasks will be allocated in consecutive order by node (CPU tasks first, then MIC tasks). For example, the task allocation described by the above script snippet will be:

<table>
<thead>
<tr>
<th>NODE</th>
<th>Host Tasks</th>
<th>MIC Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>NODE 1</td>
<td>8 tasks (0-7)</td>
<td>2 tasks (8-9)</td>
</tr>
<tr>
<td>NODE 2</td>
<td>8 tasks (10-17)</td>
<td>2 tasks (18-19)</td>
</tr>
<tr>
<td>NODE 3</td>
<td>8 tasks (20-27)</td>
<td>2 tasks (28-29)</td>
</tr>
<tr>
<td>NODE 4</td>
<td>8 tasks (30-37)</td>
<td>2 tasks (38-39)</td>
</tr>
</tbody>
</table>
Task Binding

When using IMPI, process binding may be controlled with the following environment variable:

- \texttt{I_MPI_PIN\_MODE=<pinmode>}

<table>
<thead>
<tr>
<th>\texttt{pinmode}</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{mpd}</td>
<td>mpd daemon pins MPI processes at startup (Best performance for MIC)</td>
</tr>
<tr>
<td>\texttt{pm}</td>
<td>Hydra launcher pins MPI processes at startup (Doesn’t appear to work on MIC)</td>
</tr>
<tr>
<td>\texttt{lib}</td>
<td>MPI library pins processes BUT this does not guarantee colocation of CPU and memory (Default)</td>
</tr>
</tbody>
</table>

\texttt{I\_MPI\_PIN\_MODE=mpd} (default for ibrun.symm)
Task Binding

You can also lay out tasks across the local cores

- Explicitly: `I_MPI_PIN_PROCESSOR_LIST=<proclist>`
  - `export I_MPI_PIN_PROCESSOR_LIST=1-7,9-15`
- Grouped: `I_MPI_PIN_PROCESSOR_LIST=<map>`

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bunch</td>
<td>The processes are mapped as closely as possible on the socket</td>
</tr>
<tr>
<td>scatter</td>
<td>The processes are mapped as remotely as possible to avoid sharing common resources: caches, cores</td>
</tr>
<tr>
<td>spread</td>
<td>The processes are mapped consecutively with the possibility to not share common resources</td>
</tr>
</tbody>
</table>
Task Binding

Be careful when using MIC and host
• MIC – 244 H/W threads and 1 socket
• Host – 16 cores and 2 sockets

To set I_MPI_PROCESSOR_LIST for MIC simply use the MIC prefix, e.g.

```bash
export MIC_I_MPI_PROCESSOR_LIST=1,61,121,181
```
Thread Placement

Thread placement may be controlled with the following environment variable

- **KMP_AFFINITY=**<type>

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>compact</td>
<td>pack threads close to each other</td>
<td><img src="" alt="compact Diagram" /></td>
</tr>
<tr>
<td>scatter</td>
<td>Round-Robin threads to cores</td>
<td><img src="" alt="scatter Diagram" /></td>
</tr>
<tr>
<td>balanced</td>
<td>keep OMP thread ids consecutive (MIC only)</td>
<td><img src="" alt="balanced Diagram" /></td>
</tr>
<tr>
<td>explicit</td>
<td>use the proclist modifier to pin threads</td>
<td><img src="" alt="explicit Diagram" /></td>
</tr>
<tr>
<td>none</td>
<td>does not pin threads</td>
<td><img src="" alt="none Diagram" /></td>
</tr>
</tbody>
</table>
Balance

- How to balance the code?

<table>
<thead>
<tr>
<th></th>
<th>Sandy Bridge</th>
<th>Xeon Phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>32 GB</td>
<td>8 GB</td>
</tr>
<tr>
<td>Cores</td>
<td>16</td>
<td>61</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>2.7 GHz</td>
<td>1.1 GHz</td>
</tr>
<tr>
<td>Memory Bandwidth</td>
<td>51.2 GB/s(x2)</td>
<td>352 GB/s</td>
</tr>
<tr>
<td>Vector Length</td>
<td>4 DP words</td>
<td>8 DP words</td>
</tr>
</tbody>
</table>
Example: Memory balance
Balance memory use and performance by using a different # of tasks/threads on host and MIC

Host
16 tasks/1 thread/task
2GB/task

Xeon PHI
4 tasks/60 threads/task
2GB/task
Balance

Example: Performance balance
Balance performance by tuning the # of tasks and threads on host and MIC

Host
16 tasks/1 thread/task
2GB/task

Xeon PHI
4 tasks/30 threads/task
2GB/task
MPI with Offload Sections

ADVANTAGES
• Offload Sections may easily be added to MPI/OpenMP codes with directives
• Intel compiler will automatically detect and compile offloaded sections

CAVEATS
• However, there may be no MPI calls within offload sections
• Each host task will spawn an offload section
Exercises

• Exercise 1
  – Run natively on the MIC using mpiexec.hydra

• Exercise 2
  – Run in a symmetric mode using MIC and host

• Exercise 3
  – Run an MPI code with offload
Lucas A. Wilson
lwilson@tacc.utexas.edu

For more information:
www.tacc.utexas.edu