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CPSC 524 Assignment #2

### Info

To build and run my solution, run the two scripts

```
$ bash build.sh
```

and

```
$ bash run.sh
```

This builds the three task files, then runs all three. The modules I used are:

- 1) Base/yale\_hpc**
- 2) Langs/Intel/15**
- 3) MPI/OpenMPI/1.8.6-intel15**

The output of my **env** command is the following:

```
MKLRROOT=/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/mkl
MANPATH=/opt/moab/share/man:/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-
intel15/share/man:/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.
164/man/en_US:/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/
debugger/gdb/intel64/share/man:/home/apps/fas/Langs/Intel/2015_update2/compo
ser_xe_2015.2.164/debugger/gdb/intel64_mic/share/man:/usr/share/man:/opt/moa
b/share/man:
GDB_HOST=/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/debug
ger/gdb/intel64_mic/bin/gdb-ia-mic
HOSTNAME=compute-33-1.local
INTEL_LICENSE_FILE=/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2
.164/licenses:/opt/intel/licenses:/home/apps/fas/Licenses/intel_site.lic
IPPROOT=/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/ipp
SHELL=/bin/bash
TERM=xterm
HISTSIZE=1000
SSH_CLIENT=10.191.63.252 46290 22
GDBSERVER_MIC=/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/
debugger/gdb/target/mic/bin/gdbserver
```

PERL5LIB=/opt/moab/lib/perl5:/opt/moab/lib/perl5

LIBRARY\_PATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-intel15/lib:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/./compiler/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/compiler/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mkl/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/tbb/lib/intel64/gcc4.4

FPATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-intel15/include:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mkl/include

OLDPWD=/lustre/home/client/fas/cpsc424/thp8

QTDIR=/usr/lib64/qt-3.3

QTINC=/usr/lib64/qt-3.3/include

SSH\_TTY=/dev/pts/2

MIC\_LD\_LIBRARY\_PATH=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mpirt/lib/mic:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/lib/mic:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/compiler/lib/mic:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mkl/lib/mic:/opt/intel/mic/coi/device-linux-release/lib:/opt/intel/mic/myo/lib:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/tbb/lib/mic

ANT\_HOME=/opt/rocks

USER=thp8

LD\_LIBRARY\_PATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-intel15/lib:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mpirt/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/./compiler/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/ipp/tools/intel64/perfsys:/opt/intel/mic/coi/host-linux-release/lib:/opt/intel/mic/myo/lib:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/compiler/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mkl/lib/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/tbb/lib/intel64/gcc4.4:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/ipt/intel64/lib

ROCKS\_ROOT=/opt/rocks

MIC\_LIBRARY\_PATH=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/compiler/lib/mic:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.

2.164/mpirt/lib/mic:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.  
2.164/tbb/lib/mic

CPATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-  
intel15/include:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.16  
4/ipp/include:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/  
mkl/include:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/tb  
b/include

NLSPATH=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/compil  
er/lib/intel64/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/2015\_update2/compos  
er\_xe\_2015.2.164/ipp/lib/intel64/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/2  
015\_update2/composer\_xe\_2015.2.164/mkl/lib/intel64/locale/%l\_%t/%N:/home/apps  
/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/gdb/intel64\_mic  
/share/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_20  
15.2.164/debugger/gdb/intel64/share/locale/%l\_%t/%N

YHPC\_COMPILER=Intel

OMPI\_MCA\_orte\_precondition\_transports=f20cd2d28f432704-15e3f8c3bb8e89d6

PATH=/opt/roab/bin:/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-  
intel15/bin:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/bi  
n/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mpir  
t/bin/intel64:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/  
debugger/gdb/intel64\_mic/bin:/home/apps/fas/Langs/Intel/2015\_update2/composer  
\_xe\_2015.2.164/debugger/gdb/intel64/bin:/home/apps/fas/Modules:/usr/lib64/qt-  
3.3/bin:/opt/roab/bin:/usr/local/bin:/bin:/usr/bin:/usr/java/latest/bin:/opt/  
rocks/bin:/opt/rocks/sbin:/home/apps/bin:/usr/local/sbin:/usr/sbin:/sbin:/hom  
e/fas/cpsc424/thp8/bin

MAIL=/var/spool/mail/thp8

YHPC\_COMPILER\_MINOR=164

TBBROOT=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/tbb

C\_INCLUDE\_PATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-intel15/include

PWD=/lustre/home/client/fas/cpsc424/thp8/as2

F90=ifort

JAVA\_HOME=/usr/java/latest

YHPC\_COMPILER\_MAJOR=2

\_LMFILES\_=/home/apps/fas/Modules/Base/yale\_hpc:/home/apps/fas/Modules/Langs/I  
ntel/15:/home/apps/fas/Modules/MPI/OpenMPI/1.8.6-intel15

LANG=en\_US.iso885915

DOMAIN=omega

GDB\_CROSS=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/gdb/intel64\_mic/bin/gdb-mic  
MOABHOMEDIR=/opt/moab  
MODULEPATH=/home/apps/fas/Modules  
KDEDIRS=/usr  
LOADEDMODULES=Base/yale\_hpc:Langs/Intel/15:MPI/OpenMPI/1.8.6-intel15  
YHPC\_COMPILER\_RELEASE=2015  
F77=ifort  
HISTCONTROL=ignoredups  
SSH\_ASKPASS=/usr/libexec/openssh/gnome-ssh-askpass  
CXX=icpc  
MPM\_LAUNCHER=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/mpm/bin/start\_mpm.sh  
INTEL\_PYTHONHOME=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/python/intel64/  
HOME=/home/fas/cpsc424/thp8  
SHLVL=2  
FC=ifort  
LOGNAME=thp8  
CVS\_RSH=ssh  
QTLIB=/usr/lib64/qt-3.3/lib  
SSH\_CONNECTION=10.191.63.252 46290 10.191.12.33 22  
MODULESHOME=/usr/share/Modules  
LESSOPEN=||/usr/bin/lesspipe.sh %s  
arch=intel64  
INFOPATH=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/gdb/intel64/share/info/:/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/debugger/gdb/intel64\_mic/share/info/  
CC=icc  
INCLUDE=/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/mkl/include  
G\_BROKEN\_FILENAMES=1

```
MPI_PATH=/usr/local/cluster/hpc/MPI/OpenMPI/1.8.6-intel15
BASH_FUNC_module()=( ) { eval ` /usr/bin/modulecmd bash $*`
}
_=/bin/env
```

A sample output of my three programs (task1, task2, task3) is the following:

**task1:**

```
/lustre/home/client/fas/cpsc424/thp8
/lustre/home/client/fas/cpsc424/thp8/as2
compute-32-14
compute-32-14
compute-32-13
compute-32-13
```

Message printed by master: Total elapsed time is 0.000055 seconds.

From process 1: I worked for 4 seconds after receiving the following message:

Hello, from process 0.

From process 3: I worked for 8 seconds after receiving the following message:

Hello, from process 0.

From process 2: I worked for 12 seconds after receiving the following message:

Hello, from process 0.

```
real    0m16.837s
user    0m2.230s
sys     0m0.223s
```

Message printed by master: Total elapsed time is 0.000052 seconds.

From process 3: I worked for 4 seconds after receiving the following message:

Hello, from process 0.

From process 1: I worked for 8 seconds after receiving the following message:

Hello, from process 0.

From process 2: I worked for 12 seconds after receiving the following message:

    Hello, from process 0.

real    0m13.430s

user    0m2.228s

sys     0m0.191s

Message printed by master: Total elapsed time is 0.000054 seconds.

From process 2: I worked for 4 seconds after receiving the following message:

    Hello, from process 0.

From process 3: I worked for 8 seconds after receiving the following message:

    Hello, from process 0.

From process 1: I worked for 12 seconds after receiving the following message:

    Hello, from process 0.

real    0m13.432s

user    0m2.173s

sys     0m0.192s

## **task2:**

compute-32-12

compute-32-12

compute-32-11

compute-32-11

Message from process 1: Hello master, from process 1 after working 4 seconds.

Message from process 2: Hello master, from process 2 after working 12 seconds.

Message from process 3: Hello master, from process 3 after working 8 seconds.

Message printed by master: Total elapsed time is 18.000380 seconds.

real 0m19.510s

user 0m11.148s

sys 0m0.211s

Message from process 1: Hello master, from process 1 after working 12 seconds.

Message from process 2: Hello master, from process 2 after working 8 seconds.

Message from process 3: Hello master, from process 3 after working 4 seconds.

Message printed by master: Total elapsed time is 21.000689 seconds.

real 0m22.423s

user 0m14.115s

sys 0m0.200s

Message from process 1: Hello master, from process 1 after working 4 seconds.

Message from process 2: Hello master, from process 2 after working 8 seconds.

Message from process 3: Hello master, from process 3 after working 12 seconds.

Message printed by master: Total elapsed time is 15.000380 seconds.

real 0m16.418s

user 0m8.137s

sys 0m0.202s

### **task3:**

Message from process 1: Hello master, from process 1 after working 4 seconds.

Message from process 2: Hello master, from process 2 after working 12 seconds.

Message from process 3: Hello master, from process 3 after working 8 seconds.

Message printed by master: Total elapsed time is 15.001325 seconds.

real 0m18.439s

user 0m8.112s

sys 0m0.257s

Message from process 1: Hello master, from process 1 after working 12 seconds.

Message from process 2: Hello master, from process 2 after working 4 seconds.

Message from process 3: Hello master, from process 3 after working 8 seconds.

Message printed by master: Total elapsed time is 15.000327 seconds.

real 0m16.437s

user 0m8.068s

sys 0m0.190s

Message from process 1: Hello master, from process 1 after working 8 seconds.

Message from process 2: Hello master, from process 2 after working 12 seconds.

Message from process 3: Hello master, from process 3 after working 4 seconds.

Message printed by master: Total elapsed time is 15.000332 seconds.

real 0m16.425s

user 0m8.108s

sys 0m0.186s

### **Design choices and questions**

My design of parts 1 and 2 are fairly straightforward. For part 2, I removed the line in which the workers print out their "I worked for ... seconds," and replaced it with an MPI completion message to the master. I modified master so that rather than exiting after sending all its messages, it waits for each process to finish its job (by waiting for a completion message) and does three seconds of "processing work." This is done in process rank order, which means that master waits for the first process, then the second, etc. This means that if the processes finish in reverse order (three, two, one), the master process will wait until process one finishes to begin processing the responses, which takes an additional nine seconds in total. This explains the difference in times across several trials. I.e., if the processes finish in ascending order (one, two three), the master process can process the first response while the second working is finishing its job. Thus, only three additional seconds of processing time block the master worker from returning (the processing of the first two responses is done while other workers are still finishing).



The reason that the elapsed times are more reasonable in task2 is that the master worker is waiting for all the jobs to finish (complete) rather than just return. In task1, master sends its messages and returns, before waiting for any workers to complete. Thus, the task as a whole does not finish until the last worker is done, but the master process only prints the time required to send all the messages.

My implementation of task3 relies on a separate “msg” data structure, which includes a completion message and a rank id. Rather than waiting for completion messages in ascending order, the master worker first waits for any worker to finish, logs the “msg” along with the rank of the completion message, processes the response, then waits for the next worker to complete. Once all workers are done, the master uses the logged completion ranks to print out the completion messages in the proper order. Thus, the responses of the first two workers to complete can be processed while waiting for the slowest worker’s response, and thus consecutive runs of the program will always take about 15 seconds (the time for all three workers to complete plus an additional three seconds of processing time).