並列言語 XcalableACC を用いた格子 QCD の性能評価

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XcalableACC

Overview

XcalableACC (XACC) is a directive-based language extension of C and Fortran for accelerated cluster systems.

- High productivity by directives
- High performance by direct communication between accelerators

Components

- XcalableMP (XMP) for distributed-memory parallelism

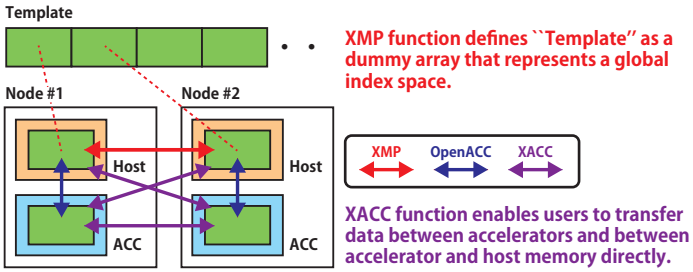
XcalableMP XMP is a directive-based language extension of C and Fortran for cluster systems

- OpenACC for offloading works for accelerators

OpenACC DIRECTIVES FOR ACCELERATORS OpenACC is another directive-based language extension for heterogeneous CPU/Accelerator systems

- XACC extensions for communication of data on accelerators

Memory Model



Omni XcalableACC Compiler

- *http://omni-compiler.org*
- Developed by RIKEN AICS and Center for Computational Sciences in University of Tsukuba

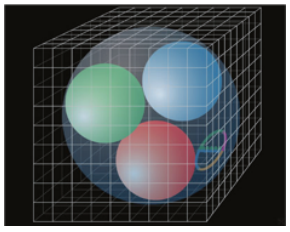
Evaluation using Lattice QCD

What is Lattice QCD ?

- Solve the quantum chromodynamics (QCD) theory of quarks and gluons

$$D_{x,y} = \delta_{x,y} - \kappa \sum_{\mu=1}^{4} \{(1-\gamma_\mu)U_\mu(x)\delta_{x+\hat{\mu},y} + (1+\gamma_\mu)U_\mu^\dagger(x-\hat{\mu})\delta_{x-\hat{\mu},y})\}$$

- The four-dimensional space-time continuum is replaced by a four-dimensional hypercubic lattice
- We have used the Lattice QCD mini-application developed by Hideo Matsufuru (KEK)
- The Lattice QCD mini-application uses a part of the Bridge++, which is a real world application (http://bridge.kek.jp/Lattice-code/)
- Typical stencil application



A part of code

A programmer only adds XMP and OpenACC directives into the sequential Lattice QCD code.

```
QCDSpinor_t v[NT][NZ][NY][NX];    // Quark
QCDMatrix_t u[4][NT][NZ][NY][NX]; // Gluon
...
#pragma xmp align v[i][j][*][*] with t(j,i)
#pragma xmp align u[*][i][j][*][*] with t(j,i)
#pragma xmp shadow v[1:1][1:1][0][0]
#pragma xmp shadow u[0][1:0][1:0][0][0]
...
#pragma xmp reflect (v) width(/periodic/1:1,/periodic/1:1,0,0) acc
#pragma xmp reflect (u) width(0,/periodic/1:0,/periodic/1:0,0,0) acc
...
#pragma acc data present(v, u, ⋯)
#pragma acc parallel loop collapse(4) ⋯
#pragma xmp loop (iz,it) on t(iz,it)
 for(it = 0; it < NT; it++){
  for(iz = 0; iz < NZ; iz++){
   for(iy = 0; iy < NY; iy++){
    for(ix = 0; ix < NX; ix++){
     …
```

Define XMP distributed arrays

Exchange halo region

Parallelize loop

OpenACC directive parallelizes the loop statement parallelized by XMP directive

Evaluation

http://ccs.tsukuba.ac.jp/eng/research-activities/projects/ha-pacs/

- Ivy Bridge E5-2680v2, 10Cores x 2 Sockets
- DDR3 128GB (59.7GB/s x 2, NUMA)
- NVIDIA K20X (D.P. 1.31TFlops) x 4 GPUs
- GDDR5 6GB (250GB/s)
- InfiniBand 4xQDR x 2rails, 8GB/s
- MVAPICH2-GDR 2.1a, gcc-4.4.7, etc..

Productivity

	Serial	MPI+OpenACC	XcalableACC	
SLOC(*)	900	1,134	1,019	10% down
Delta SLOC(**)	-	292	123	58% down
Added	-	234	119	
Deleted	-	0	0	
Modified	-	58	4	

(*) Source Lines of Code

(**) How is a source code changed from the serial code

Performance (Problem Size: 32x32x32x32)